BIOMASS AND BIOENERGY CONFERENCE

Proceedings of the Biomass and Bioenergy Conference 2018

April 10th-12th, 2018
Sorocaba, SP -Brazil

Realization

GRUPO DE PESQUISA Biomassa Bioenergia

ufscar

Title: Proceedings of the Biomass and Bioenergy Conference – BBC Brazil 2018
FÁBIO MINORU YAMAJI and FRANCIANE ANDRADE DE PÁDUA

Address: Parque Tecnológico de Sorocaba
Itavuvu Avenue, 11.777, Sorocaba - SP, Brazil
Sorocaba, April 12th, 2018.

ABOUT THE EVENT

The **Biomass and Bioenergy Conference** reunited the world's leading biomass and bioenergy references to present and discuss perspectives, solutions and their impacts in Brazil and the world. The aim of the conference was to promote the meeting of professionals, researchers, research centers, companies and universities to talk about the use and application of biomass in all its forms and its importance in society, encouraging scientific research and development through lectures and presentations.
*The authors take full responsibility for the content of the works presented in this proceeding.

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PROGRAM

LECTURES	SPEAKERS - INSTITUTION
Bioenergy in Brazil: Sustainability Matters	**Prof. Dr. Heitor Cantarella** FAPESP - Brazil
A Combined Restoration and Certifications Strategy for Sustainable Bioenergy	**Prof. Dr. Florian Kraxner** International Institute for Applied Systems Analysis - Austria
Biomass quality in grasses for biofuel production: challenges and potential	**Dra. Cynthia Maria Borges Damasceno** EMBRAPA - Brazil
Forest production for fuel in southeast Asia	**Prof. Dr. Hiroyuki Yamamoto** Nagoya University - Japan
Biomass to bioenergy in Argentina: different projects, common challenges	**Profa. Dra. María Eugenia Castelao Caruana** Universidad de Buenos Aires – Argentina
Biomass uses as an energy source - focus on the northeast region of Brazil	**Profa. Dra. Rosimeire Cavalcante dos Santos** Federal University of Rio Grande do Norte - Brazil
The sugarcane chain as a supplier of electric bioenergy	**Prof. Dr. Octavio Antonio Valsechi** Federal University of São Carlos - Brazil
Characterization of the Combustion Behavior of Solid Biofuels	**Prof. Dr. Hans-Joachim Gehrmann** Karlsruher Institute of Technology - Germany
Biomass Accumulation in the forests with high pressure of fuelwood extraction in Chiapas, México	**Prof. Dr. Deb Raj Aryal** Conacyt- Universidad Autónoma de Chiapas - Mexico
Wood resources utilization in the context of the bioeconomy	**Prof. Dr. Jan Parobek** Technical University in Zvolen - Slovakia
Technological Advanced in Solid Biofuel	**Prof. Dr. Electo Eduardo Silva Lora** Federal University of Itajubá - Brazil
Biomass Pyrolysis Products for the Environment	**Profa. Dra. Naoko Ellis** University British Columbia - Canada

SHORT COURSES

TITLE	SPEAKERS - INSTITUTION
Characterization of biofuels for energy purposes	**Prof. M.Sc. Jorge Luis Dias dos Santos** IPT - Brazil
Privatization in Electricity Sector: Experience in Argentina	**Prof. Dr. Andrés Di Pelino** Universidad de Buenos Aires - Argentina
Reseacher Training and Writing High Impact Article	**Prof. Dr. Valtencir Zucolotto** USP - Brazil

AWARDS

BEST WORK PRIZE

BIOMASS ACCUMULATION IN THE FORESTS WITH HIGH PRESSURE OF FUELWOOD EXTRACTION IN CHIAPAS, MÉXICO - CONACYT- UNIVERSIDAD AUTÓNOMA DE CHIAPAS
Deb Raj Aryal, Roldan Ruiz Corzo, Alonso López Cruz, Carlos Vázquez Sanabria, Heriberto Gómez Castro, Francisco Guevara Hernández, René Pinto Ruiz, José Apolonio Venegas, Alejandro Ley de Coss, Isaí Euán Chi, Danilo Morales Ruiz

First Place (Oral)

HYDROTREATMENT OF BIO-OIL FOR FUEL AND CHEMICALS PRODUCTION - KARLSRUHE INSTITUTE OF TECHNOLOGY
Júlia Santos, Caroline Carriel Schmitt, Chiara Boscagli, Klaus Raffelt, Michael Rapp, Nicolaus Dahmen

Second Place (Oral)

DETERMINATION OF THE PHYSICAL-CHEMICAL PROPERTIES OF SOLID WASTE FOR USE IN THE PYROLYSIS PROCESS - UNICAMP
Adriana Garcia, Juliana Araujo da Silva, Jorge Luis Dias dos Santos, Carina Ferrari Braga, Marcelo Aparecido Mendonça, Maria Alvina Krahenbuhl

Third Place (Oral)

CONSUMPTION AND CHARACTERIZATION OF THE FORESTRY BIOMASS UTILIZED IN THE TOBACCO CURE PROCESS - FEDERAL UNIVERSITY OF SANTA MARIA
Carline Andréa Welter, Jorge Antonio de Farias, Rafael da Silva Rech, Cristiane Pedrazzi, Dimas Agostinho da Silva, Débora da Silva Teixeira

First Place (Poster)

ESTIMATES OF ENERGY PROPERTIES OF TORREFIED PELLETS BY COLORIMETRIC PARAMETERS - FEDERAL UNIVERSITY OF VIÇOSA
Mateus Alves de Magalhães, Carlos Miguel Simões da Silva, Angélica de Cássia Oliveira Carneiro, Benedito Rocha Vital, Déborah Nava Soratto, Humberto Fauller de Siqueira, Márcia Silva de Jesus

Second Place (Poster)

TERMOGRAVIMETRIC CHARACTERIZATION OF BIOMASS IMPREGNATED WITH BIODEGRADABLE IONIC LIQUID – FEDERAL INSTITUTE OF BAHIA
José Airton de M. Carneiro-Junior, Giulyane F. de Oliveira, Carine Tondo Alves, Silvio A. B. Vieira de Melo, Miguel A. Iglesias Duro, Ednildo Andrade Torres

Third Place (Poster)

DATA MINING, METHODOLOGY ANALYSIS AND METRICS STANDARD FOR SELECTION, COMPARISON AND ENVIRONMENTAL TECHNO-ECONOMIC IMPROVEMENT OF LIGNOCELLULOSIC BIOMASS CONVERSION – FEDERAL UNIVERSITY OF RIO DE JANEIRO

Goulart, A. K., Seidl, P. R., Leite, L. F, Orleans, L. F, Almeida, L

SUMMARY

ABSTRACTS

THEME: ALGAE

MICROALGAE GROWTH USING CHEESE WHEY AS A SUBSTRATE

Amanda Silva Resende[1], Alex Pereira Silva[2], Enio Nazaré de Oliveira Junior[2]
[1] Universidade Federal de São João Del-rei
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Abstract
Microalgae have been widely used as raw material in many processes due to a range of products resultants from its metabolism and the need to find substitutes to the usual biomass sources. The microalgae growth has advantages which make it a potential solution to energy and environmental problems. The applicatin of these microorganisms in effluent treatament process has been used once is possible to associate the production of microalgae biomass to effluent contaminants removal. Many species of microalgae are able to grow well in wastewater because they can be cultivated under mixotrophic conditions. Mixotrophy is a trophic culture method in which microalgae can drive both photoautotrophy and heterotrophy utilizing both inorganic and organic carbon (C) sources that provide higher biomass and lipid productivities than cultivation under photoautotrophic conditions. The aim of this study was to investigate the effect of organic carbon source, the cheese whey, industrial dairy waste, on the growth of *Chlorella Sorokiniana* and *Chlorella Vulgaris*. The microalgae cultivation was made in economic photobioreactors using transparent PET bottles with a fluorescent lamp at a luminosity of 3,2 Klux at an ambient temperature. Firstly, the inoculum was growth in a culture medium until the stationary phase, in 13-day, then, it was possible to infer the biomass by the optical density measured in a spectrophotometer at 600 nm, resulting in 1,083 AU to *Chlorella Sorokiniana* and 0,805 AU to *Chlorella Vulgaris*, After 13-day culture, was added 25% (v/v) of cheese whey in inoculum, then the both species returned to the log phase and they were cultivated for more 17 days until reached the stationary phase, so, the optical density was read again at 600 nm and the results showed 2,301 AU to *Chlorella Sorokiniana* and 2,421 AU to *Chlorella Vulgaris*. Therefore, it was possible to conclude that both microalgae species grow in the presence of cheese whey. It is known that despite the enormous potential of microalgae, there are still technological limitations that increase the cost of large-scale production of algal biomass, making these products and processes uncompetitive in the market. Thus, the cheese whey, industrial dairy waste, is a low-cost alternative culture medium, besides that the culture of microalgae in industrial dairy waste improves the final quality of effluent, then, it will be economic and the environmental advantageous.

Keywords: microalgae; biomass; cheese whey

Acknowledgments: This work acknowledges the Universidade Federal de São João del Rei Campus Alto Paraopeba.

THEME: BIODIESEL

HYDROESTERIFICATION OF WASTE COOKING OIL IN SUBCRITICAL WATER AND SUPERCRITICAL ETHANOL FOR BIODIESEL PRODUCTION

Walter Rodolfo Quiroga Pérez[1], Liliana Guzmán Beckmann[1]
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Abstract
This study was aimed to find the best operation conditions for the hydroesterification (hydrolysis and esterification in two steps) of waste cooking oil by using subcritical water and supercritical ethanol without catalyst. Waste cooking oil was obtained from a local business, then it was filtered to a mesh 40 and characterized. Hydrolysis was carried out at 250, 275 and 300 °C for 20, 40 and 60 minutes with a volume ratio 1:1, stirring rate of 500 rpm and at vapor pressure of water. The conversion was calculated by the percentage of free fatty acids [FFA] which were measured by potentiometric titration, the maximum value was greater than 98% after 40 minutes at 300 °C. [FFA] were esterified with supercritical ethanol under reactions conditions at 250, 300 and 350 °C at 10 MPa for 10, 20 and 30 minutes with a molar ratio of ethanol to FFA of 10:1 and stirring rate of 500 rpm. At 350 °C and 10 minutes the esterification of [FFA] in supercritical ethanol gave a conversion greater than 95%, and it was calculated as a function of percentage of FFA. 1 L of biodiesel was produced under these conditions and then it was characterized.

Keywords: hydroesterification, hydrolysis, esterification, subcritical water, supercritical ethanol, biodiesel

Acknowledgments: This work acknowledges Departamento de Ingeniería Química of Escuela Politécnica Nacional, specially to Liliana Guzman for all her supporting during the project

CHARACTERIZATION OF BIODIESEL BLENDS FOR ATOMIZATION IN AN EFFERVESCENT INJECTOR

Otávio Mendes da Siva[1], Bruna Monise Delfino[1], Cláudia Gonçalves de Azevedo [1]

[1] Universidade Estadual Paulista "Júlio de Mesquita Filho" – UNESP – Campus de Rosana

Abstract

Growing concerns about the shortage and cost of non-renewable energy source as well as environmental issues arouse the interest of the scientific and industrial community for the utilization of biofuels, in special, ethanol and biodiesel, such as mixing these with gasoline and diesel for industrial applications. Therefore, it is of great interest to investigate the use of renewable energy sources, such biofuels and of theses fuels with conventional fuels in order to reduce costs, increase the operation efficiency and reduce the emission of pollutants. Combustion of liquid fuels depends on efficient atomization to increase the surface area of the fuel and thus achieve high rates of mixing and evaporation. In order to promote combustion with maximum efficiency and minimum emission of pollutants, an injector must provide a fuel spray that evaporates and disperses rapidly to produce a homogeneous mixture of vaporized fuel and air. Since a significant portion of the industrial combustors operate with liquid fuels and the injector is a fundamental part in combustion systems using such fuels, the present work aims to characterized an effervescent injector for the atomization of fuel mixtures. A theoretical study of an effervescent injector will be realized to atomize different blends composed of biofuels (commercial hydrated ethanol and soybean and bovine tallow biodiesel) and fossil fuels (commercial S500 diesel) with different proportions. The physicochemical properties of the fuel mixtures were determined, and theoretically the characteristics and quality of the spray generated using the Lund et al. (1993) equation to calculate the SMD (Sauter mean diameter) and the Lefebvre, 1988 and Wang et al., 1989 equation to calculate the discharge coefficient for different injection conditions. For all the cases it was verified that for a constant air mass flow rate the SMD exhibits a tendency to decrease with the increase of the ALR and the discharge coefficients decrease as occurs an increase in the ALR.

Keywords: Spray, effervescent injector, SMD, discharge coefficient

CHARACTERIZATION OF SOYBEAN CULTIVARS OIL

Maghnom Henrique MELO[1], Luiz Cláudio GARCIA[2], Maria Elena PAYRET ARRÚA[3], Pedro Henrique WEIRICH NETO[2], Eduardo Lebarbenchon de MIRANDA[1].

1 State University of Ponta Grossa, Academic of Bioenergy.
2 State University of Ponta Grossa, Department of Soil Science and Agricultural Engineering.
3 State University of Ponta Grossa, Department of Chemistry.

Abstract
Concerned about the emission of polluting gases and the probable global warming, Brazil has recently adopted politics of the using biodiesel in mixture with petrodiesel. For the production of biodiesel, the main raw material used is soybean oil. One of the largest producers and exporters of soybeans is Brazil, that cultivates countless genotypes under different edaphoclimatic conditions. Unfortunately, the development of this culture has always considered quantitative aspects. Aiming to change this scenario, the objective was to qualify the oil of the 12 soybean cultivars aiming for biodiesel production. The oil content and protein content of the grains were evaluted. The acidity index and saponification index of oil were evaluated. The cultivars were sown in December 2016 in field condition (-25.093056, -50.063327 UTM), in soil with medium texture, climate, according to Köppen, Cfb. The design used was randomized blocks with three replicates. The oil content of the grains presented difference, staying between 150 and 200 g kg^{-1} of the total grain mass. The acidity index varied between treatments, for example, the cultivar 5959 presented high values (15 mg KOH g^{-1} of oil), relative to cultivar 2606 (1,7 mg KOH g^{-1} of oil). The higher the acidity index of an oil, the higher the acidity of the biodiesel obtained, and it may even render unviable biodiesel. Therefore, it is expected to contribute scientifically to the technological discussion on the qualification of soybean cultivars in order to better the exploitation of the oil in the biofuels chain.

Keywords: biodiesel; oil content; acidity index.

THEME: BIOENERGY - ECONOMY, MARKET AND POLICY

A COMBINED RESTORATION AND CERTIFICATION STRATEGY FOR SUSTAINABLE BIOENERGY

Florian Kraxner[1], Ping Yowargana[1], Sylvain Leduc[1], Piera Patrizio[1], Dmitry Schepaschenko[1], Sabine Fuss[2], Anatoly Shvidenko[1], Charlotte Kottusch[1], Sennai Mesfun[1], Andrey Krasovskii[1], Bintang Yuwono[1], Andree Ekadinata[1], Linda See[1]

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Abstract

Land is central to people's livelihood and basic needs. The world has high potential of degraded land that can be restored to serve the enhancement of human well-being. However, people have different understanding of degradation which leads to lack of coordinated and impactful actions that are required to realize the potential of degraded land. Clear, inclusive and operational definitions of degradation are required in order to assess needs and benefits of forest and landscape restoration. This presentation shows the latest results of the RETORE+ project, a five-year partnership that aims at addressing Food-Land-Energy nexus related to restoration or utilization of degraded/marginal land in Indonesia and Brazil. In Indonesia, participatory mapping campaigns will be combined with land-use and supply chain modelling. The aim will be to identify specific areas with scenarios for restoration and sustainable utilization and their implications on production (including on bioenergy), biodiversity, greenhouse gas (GHG) emissions and social impacts (e.g. land tenure rights). In Brazil, the project will enhance established land monitoring and modelling capabilities and support Brazil's contribution to meeting the "Bonn Challenge". Renewable energy types, i.e. bioenergy, are picking up in their contributions to the total energy supply in tropical countries and are often listed as an important component for reaching the Nationally Determined Contributions (NDCs) to reaching the ambitious climate mitigation targets under the Paris Agreement. A major RESTORE+ tool for assessing bioenergy potentials is IIASA's spatially explicit renewable energy systems optimization model BeWhere. Engineering-type modeling can help identifying the potential for using degraded, abandoned and marginal land for energy feedstock production. By doing so, different ecosystems services than the sole maximization of carbon sequestration can be proposed as restoration option. However, a major challenge remains in assuring the sustainability of feedstock production in the tropics. Otherwise suitable tools such as the independent certification of forest management and plantations is usually to costly and hence rarely applied in Indonesia or Brazil.This presentation shows the unique opportunity to combine restoration efforts and related funding with energy feedstock production and biomass certification in order to ensure the sustainability of such systems. First results indicate that multiple ecosystems benefits can be generated under the proposed strategy.

Keywords: restoration; bioenergy; food-land-energy nexus; energy modeling; certification;

Acknowledgments: IIASA's Tropical Futures Initiative (TFI, www.iiasa.ac.at/tropics); IIASA-led "RESTORE+: Addressing Landscape Restoration on Degraded Land in Indonesia and Brazil" project (www.restoreplus.org);

ANATOMICAL DIFFERENTIATION OF CHARCOAL OF *Swietenia macrophylla* KING AND *Eucalyptus* sp. FOR IDENTIFICATION PURPOSES

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Abstract
The anatomical characteristics of the wood are maintained after the carbonization, so bythe cell's characterization that make up the wood, it is possible to identify the charcoal, what make possible the anatomical characterization of the charcoal from illegally cut tree species, with the possibility of being applied as a tool for monitoring. In this context, the objective of this academic work was to provide a subsidy for the identification of charcoal of the*Swietenia macrophylla*specie, that is in danger of extinction, and differentiate it from a hybrid's charcoal of *Eucalyptus grandis x Eucalyptus urophylla* planted in Amazon. The *S.macrophylla*wood was collected in reforestation planting located in the urban area of Marabá city in the state of Pará and the hybrid *E. grandis* x *E. urophylla* from the commercial plantation of Siderúrgica Norte Brasil SA (SINOBRAS) installed in the city of São Bento do Tocantins-TO. Five individuals were selected per specie, so samples were removed by non-destructive method of the stalk at 1.30 meters from the soil. For the of charcoal production, the material were wrapped in aluminum foil and carbonized in a muffle furnace with a final temperature of 450 °C and a heating rate of 1.66 °C. The charcoal anatomical description followed the recommendations commonly used for wood anatomy. After carbonization *S macrophylla* specie presented solitary vessels and multiple radial without obstruction, averageof 12 vessels number mm^{-2} and tangential diameter of 115μm, the wide rays with 3-5 cells per series and average of 8 rays per millimeter, the marginal typeof axial parenchyma, well as the stratification of rays, thecharacteristic of species, have been preserved. For *E. grandis* x *E. urophylla* hybrids vessels predominantly solitary (90% or more) in diagonal and/or radial pattern and tangential diameter of 88μm, rays predominantly uniseriate with average of 20 rays per millimeter, presence of tyloses and axial parenchyma paratracheal vasicentric and unilateral type were maintained even after carbonization. Based on the results, the possibility of taxonomic determination from carbonized material was confirmed, *S. macrophylla* charcoal differs anatomically from *Eucalyptus* sp. ones, useful characteristics for this species distinction were presented and will be relevant as a tool for the monitoring of charcoal trade in Amazon.

Keywords: anthracology; comparative anatomy; amazon

Acknowledgments: Empresa Brasileira de Pesquisa Agropecuária Amazônia Oriental

CUMULATIVE MERCHANTABLE STEM VOLUME EQUATIONS FOR POPLAR (*Populus* spp.) PLANTATIONS ON FARMLAND IN SWEDEN

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Abstract

In Sweden there is an increasing interest in the use of poplar, mainly as a future bioenergy supplier. Effective management of poplar plantations for high yield production would be facilitated by equations providing better predictions of commercial stem volume than currently available equations. Two equations were developed for estimation of commercial stem volume for poplar trees (*Populus.* Spp.) The commercial stem volume can, with these equations, be estimated for either any given top diameter or any bole length, in contrast to traditional volume equations that give one estimate, only, for the whole tree.The independent variables used in the equations are diameter at breast height (DBH), total stem height (H) for both equations and given top diameter (d), for (Eq. 1) and given bole length (h) for (Eq. 2). Data for fitting the equations were collected from 107 poplar trees growing at 39 stands in central and southern Sweden (lat. 55–60° N). The mean age of the stands was 17 years (range 7–30), the mean density 980 stems·ha^{-1} (190–3 404), and the mean diameter at breast height (outside bark) 24.2 cm (range 12.1–40.8). The stands were growing on former farmland and all stands were located on sites with clay sediments, with textures ranging from light to medium clay. The management of the stands varied; some had not been thinned at all, while the others had been moderate to heavy thinned. To verify the tested equations, performance of accuracy and precision in the cumulative stem volume predictions at five points along the stem were closely analysed, as well as an overall performance for the whole tree. Statistics used for evaluation of the equations show that the commercial volume equation based on any given top diameter (Eq. 1) performed better than the equation based on any given bole length (Eq. 2) with R^2 of 0.992 and 0.990 respectively, Absolute Bias 0.046 and 0.051 (m^3) respectively and Root Mean Square Error (RMSE) of 0.0663 and 0.0717 respectively. The commercial stem volume equations developed in the study is likely to be beneficial for optimising the efficiency and profitability of poplar plantation management when having trees with larger diameters within the plantations that can be harvested for additional timber assortments other than bioenergy.

Keywords: forest management; forest production; commercial volume equations; bioenergy

Acknowledgments: This work acknowledges all the people that has carried out the time consuming and hard work to collect the field data for this study, especially to mention is Mr Jonas Johansson and Mr Lars Hedman.

ESTIMATION AND SIMULATION OF THE MAXIMUM PRICE OF RENEWABLE FUEL FOR FUEL OIL REPLACEMENT

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Abstract
Forest biomass has been gaining representativeness in the Brazilian energy sector each year, due to its renewable production potential and the numerous products generated for the purpose of replacing fuel oil. Thus, the objective of this study was to estimate the energy parameters of fuels commonly used for energy production and to calculate the maximum price to be paid for each type of fuel analyzed. Initially, the characterization of fuels (pellets, wood chip, firewood with 0.45, 0.50, and 0.55 $g.cm^{-3}$, and fuel oil) was carried out based on the available literature, collecting data basic density, moisture content and higher calorific value. The estimation of the parameters for the calculation of the maximum price was made by obtaining the net heating value of each fuel, being possible to obtain the energy density of each fuel. The simulation of the maximum price was made based on the energy equivalence between the fuels, obtaining the maximum price to be paid for each fuel in relation to the fuel oil. Was considered a change in the price of fuel oil between R$ 1200,00 and R$ 1300,00.m^{-3}. It was observed that renewable fuels have a lower energy density than fuel oil due to the low density of the solid product in relation to the liquid and the low heating value resulting from the presence of hydroxyl groups in the molecular structure of renewable fuels. Pellets are the fuels that allow to pay a higher price among the renewables, due to its high density and lower moisture content, the price being between R$ 339,89 and R$ 368,22.m^{-3}. It is concluded that renewable fuels have the potential of replacing fuel oil for energy purposes, due to economic and mainly environmental factors. Pellets are the renewable fuels with better energy characteristics compared to the others.

Keywords: renewable energy source, energy of wood, marketplace.

FREE OR CAPTIVE CONSUMER? A CASE STUDY FOR A SUGARCANE MILLS

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Abstract
The free market environment is becoming more viable in the face of the compulsory increase in the energy tariff of energy distribution concessionaires, and the consumer must verify the viability of the transfer to this market. The study develop the analysis of the migration of a thermoelectric plant from fuel to sugarcane bagasse from consumption in the environment regulated to the free environment. The plant is called IACO and is located in the city of Paraíso das Águas - State of Mato Grosso do Sul. It is framed as an autoproducer of electricity, producing during the harvest period and consuming during the off-season. The methodology adopted will be based on the calculation of the consumption and demand with the values applied in the environment regulated by the local utility Energisa MS and in the free environment by the transmission tariffs and energy values at the Settlement Price of the Differences - SPD. The consumption data were collected by the mass memory and load curve provided by the distribution concessionaire. In the end, was proposed a free environment for the energy consumption of the IACO, showing the technical and economic feasibility of this migration.
Keywords: Energy saving, free energy market, sugarcane mills

MARKET OF WOOD PELLETS

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Abstract
Due to incentive politics to the reduction of the emission of the greenhouse gasses the world market of wood pellets grew in the last years, moving the world trade of this product. In 2005 the world production of pellets was of 5 million tons; in 2016 the production was of 28 million tons. To supply the needs of provisioning for pellets in Europe, new projects are appearing in Brazil in the last years. In this sense, in the present work a bibliographical revision was accomplished with the objective of elaborating a diagnosis of the tendency and opportunities of the world market of pellets. Through this study it can be verified that the consumption of this biofuel is divided in two sections: residential and industrial. The consumption in the European Union, in 2015, was of 20,3 million tons and with growth expectations in the demand of both sections. North America is the largest exporter of the product, being United Kingdom the largest receiver of the North American pellets. In South Korea and Japan an incipient consuming market of wood pellets exists, which are being used in substitution to the vegetable coal for generation of energy. Brazil possesses great potential of growth of this section mainly due to annual increment of the species pinus and eucalyptus and to extensive available areas for development of energy forests. In conclusion, there are challenges to overcome for increase the national production, related of the increasement of the national market and standardization of the national wood pellets to facilitate the use, exportation and increase the number of investments in the sector.

Keywords: Bioenergie, Biomass, World Market.

PRODUCTION MODELS FOR BIOENERGY-POPLAR PLANTATIONS ON FARMLAND IN SWEDEN

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Abstract
Interest in utilizing trees for bioenergy production has increased drastically in recent decades. Poplars (*Populus* spp.) are an exotic group of species in Sweden. Hybrid poplar plantations with short rotation (≤ 20 years) established on farmland in south and central Sweden, have shown promising production and been in focus as a future potential bio-fuel feedstock. Results from 20-year-old poplar plantations show a total production of up to 300 t d.w. ha^{-1}. Mean annual volume production is on average around 20-25 m^3. Taper, biomass- and volume models were developed for individual poplar trees. One model was developed for biomass estimations of individual stumps (incl. roots) and another for biomass estimation of 2nd generation coppiced poplars. We have finally studied the properties of false heartwood of poplar stems. All models fitting data comes from harvested plantations in Sweden.1) Biomass and Volume models for individual Poplar trees: The developed biomass equation uses dbh (diameter at breast height, 1.3 m above ground) as independent variable and estimates the stem, twigs and leaf fractions separately or together. One equation with dbh (D) and total height (H) as independent variables were constructed for stem volume estimation (V) and compared with a number of published equations. 2) Biomass models for Poplar stumps and 2nd generation coppices: There are two ways to manage the remaining stumps after harvest: 1) Excavation, or 2) Management of sprouts established on stumps. Models for estimation of individual stumps and coppice biomass were developed. Biomass production of 1000 excavated stumps could be 45-50 t d.w. ha^{-1}. The stump was 74% on average of the total stump-root biomass. Roots (50 mm) made up the remaining 26%. Biomass of 7-year-old coppices on 1000 stumps could be 30-35 t d.w. ha^{-1}. 3) Taper model for individual Poplar trees: Taper models estimate diameter (d) using DBH, corresponding height (h) and total height (H) as independent variables and are useful for estimating properties of different assortments with mini diameter restrictions. The objective was to develop a simple taper equation with good ability to predict diameter at a given height and compare it with common published taper equations. 4) Models for prediction of false heartwood properties in Poplar stems: All of the sampled stems contained false heartwood. At 0 – 50 % of stem height, all sampled trees were discolored and at 90 % of stem height, 33 % were discolored. The percentage of false heartwood area by stem area was highest at 1 % and 10 % of stem height (26.6 % and 24.7 % respectively). Equations were constructed describing the correlation between diameter at breast height and the diameter of false heartwood at different stem heights aimed for stems to be used for construction. However, most of the fast-growing poplars in Sweden is expected to be harvested as biofuel.

Keywords: populus; bioenergy; forest production, volume and biomass models

Acknowledgments: This work acknowledges all the people that has carried out the time consuming and hard work to collect the field data for this study, especially to mention is Mr. Jonas Johansson and Mr. Lars Hedman.

SOFTWARE THAT ASSISTS THE ANALYSIS OF THE ECONOMIC VIABILITY OF THE INSTALLATION OF BIODIGESTERS IN RURAL PROPERTIES DESTINED FOR MILKING

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Abstract
In Brazil, energy consumption is increasing on a large scale while the number of energy demand grows slowly and small percentages each year. Although with a large number of options for energy growth such as solar, wind and biogas. The rural properties destined to the creation of pigs and cattle for the milking have enormous energetic potential, since they are the most propitious to the implantation of the biodigestor, due to the quantity of waste that these animals produce and the facility in collecting them, since they are created in confinement most of the time. Since the greatest obstacle for such properties to implant the biodigestor is related to knowledge, since there are not always qualified people, or even financial resources on the part of the owners to do this analysis and when analyzing the initial price of the implantation, they may end up creating a barrier , without being aware that this investment will return in a short time. With this in mind, the objective of this study is to present an efficient mathematical model that can be used in several rural farms destined to the bovinocultura and, together, software that facilitates and makes accessible the analysis of the viability of the implantation of the biodigester. Thus, any rural producer will be able to know if the implantation of the biodigester is economically viable in its property. The model consists of determining the total income and the total cost with the implantation of the biodigester, returning the net income that the property will have. For this it is necessary to calculate the number of cattle heads, necessary in the property to maximize the income with the use of the biodigester. The final result is a set of information needed to analyze the biodigester's implementation. For the validation of the proposed model, we used data from the São Joaquim farm, located in the city of Araçatuba. This model was implemented in Java using the simplex method. The software will be made available so that the interested parties can verify the feasibility of the implantation of a system of generation of energy from the biogas. Based on the simulations, the validation of the proposed mathematical model can be verified, since the cost with the implementation compared to the net income shows the viability of the project under the economic-financial approach. However, when considering the environmental benefit provided by the project the favorable decision of the enterprise is reinforced.

Keywords: energy generation; biogas; sustainability

Acknowledgments: Os autores agradecem a Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP), pelo apoio financeiro. Processo: 2013/25526-5

STUDY OF THE ECONOMIC IMPACT CAUSED BY THE USE OF URBAN WASTE IN THE GENERATION OF ENERGY

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Abstract
The urban solidwaste appears today as a relevant modern urban environmental problem, one of the most important trouble for the human communities. It's very difficult to manage the final destination due the expressive volume of waste accumulated every year. This work proposes the use of urban solid waste as an alternative source of energy generation, transforming it into biogas, other fuels or biomass, since energy issues are a critical point into world economies, due to the increasing energy consumption and the difficulty of to meet this demand. This work aims to show the political, economic and environmental advantages the use of urban waste as base material for its energy matrix. Using the study of environmental laws looking for opportunities for increase of the energy matrix with the use of biomass, and how this would impact the economy of a certain region, will be used as bed test for simulation the municipality of Rosana - SP, where occurs the energy UNESP engineering course. The increasing demand for energy and the difficulty of expanding current energy sources will leads the search for new energy resources. In order to achieve these objectives, we will seek an evaluation of the methodologies and tools that have helped us in the search for the economic and technical advantages for the energy processing and transformation of solid waste into commodities or energy. We will also look for a solution for implementation of the method in small cities, which is one of the lines of research for the sustainability of small communities and rural areas on planet earth.

Keywords: economic impact, rsu, urban solid waste

Acknowledgments: Unesp

SUGARCANE BAGASSE LOW HEAT VALUE INFLUENCES ON THE THERMAL EFFICIENCY OF A THERMAL POWER PLANT

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Abstract

A thermal power plant is a station where electric power is generated by a thermal source. This source can be obtained from non-renewable fuel burn, such as coal, or renewable fuel burn, such as biomass. Nowadays, there is a need of developing technologies that reuse the biomass, such as the sugarcane bagasse left from the sugar-ethanol plants and grains left from the oil industry. According to Miranda et al. (2009), the state of Goiás (GO) produces around 50 MW in the sugar-ethanol sector and the great challenge for the power generation development is the improvement of the power efficiency so that the system can consume fewer natural resources and obtain higher amount of generated energy. Considering those facts and based on a thermal power plant case from Morrinhos–GO, its thermal efficiency behavior is analyzed through graphs in relation to the output temperature and pressure in the turbine and it's proposed a thermal efficiency improvement. Both graphs are obtained varying the bagasse low heat value (LHV) through a drying process. In order to analyze and calculate this problem, it is developed a numerical implementation routine (programming) based on the equations from the Rankine cycle energy balance, in which the thermal power plant operates. The graphs point out that the boiler output temperature or pressure increase, consequently, the turbine input as well, which is caused by LHV range. As a result, the thermal efficiency improves and there is a better performance. It also provides an increasing amount of vapor and higher work in the turbine. As a result, there is an addition to the net work and, once again, a thermal efficiency improvement so the bioenergy is generated in a more sustainable way.

Keywords: Bioenergy, Sugarcane, Thermal Power Plant.

THE IMPORTANCE OF FIREWOOD FOR THE TOBACCO FARMERS IN THE WATERSHED OF RIO PARDO, SOUTH OF BRAZIL

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Abstract
The region of the Vale do Rio Pardo has its agriculture rooted in the tobacco farming, mostly on small properties. The tobacco production is present in the region for over 60 years and it was a great responsible for the regional development. The constant concern regarding environmental issues has led the tobacco industry to invest in programs of reforestation, preservation of water resources, soil conservation, reduction of pesticides use, environmental education, among others. In this context, this study aimed to identify the volume of firewood consumed, the price paid for the firewood and the main species used in the tobacco cure process in the Rio Pardo Watershed. Therefore, it was interviewed 180 tobacco farmers in 12 municipalities located in Rio Pardo Watershed, the sampling intensity varied according to the number of producers per municipality. The 180 sampled units were sufficient considering a 95% level of confidence. The major contribution of this study and the proposed objectives was that around 53.6% of the farmers purchase firewood, and *Eucalyptus* spp. are the main species used as raw material for energy production by the tobacco producers. Natural forest corresponds to 6.51% of the firewood used in tobacco curing process. The firewood has a significant importance in the cultivation of tobacco, being the high price of this input one of the primary concerns among the farmers. The average cost of the firewood was R$ 49.83/m^{st} generating a total consumption of firewood purchased of 76002.06 stere meters, thus a cost of approximately R$ 3,780,000.00 for all the studied area.

Keywords: Firewood traceability, Production costs, Energy self-sufficiency.

THE ROLE OF BIOENERGY COUPLED WITH CARBON CAPTURE AND STORAGE IN INDONESIA’S DEEP DECARBONIZATION PATHWAYS

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Abstract

In an attempt to contribute to the global climate target by limiting the increase in global average temperatures by the middle of century to 2˚C, Indonesia has pledged to pursue development using low-carbon strategies. A deep dive in carbon emissions will be required by mid-century to achieve the stringent world target. This will be a huge challenge for Indonesia, where economic development and social inclusion are still the most prominent challenge. Infrastructure and energy access are the main challenge in developing Indonesia economy, low-cost fossil fuels have been a great deal for Indonesia past development. The past trajectory should not follows, and it is required for Indonesia to overhaul the energy system whilst considering socio-economic challenges.Energy is the second largest greenhouse gas (GHG)-emitting sector in Indonesia, and it is expected to significantly contribute to emissions level reduction target. With the high rate of economic growth projected for the following years, an increase in energy supply is expected for fulfilling the fast-growing demand of energy. Main sectors in the economic development phase of industrialization, namely: electricity generation, manufacturing industries, and transportation are expecting a large growth of energy demand in the future.A deep dive in carbon emissions is achievable with three Pillars of Decarbonization within the energy sector consist of energy efficiency improvements, decarbonization of electricity, and electrification of end-users(Siagian, 2015). Special features in decarbonizing Indonesia electricity is by utilizing renewables and bioenergy, as well as implementing Carbon Capture and Storage (CCS) technology. Negative emissions technology such as combining bioenergy with Carbon Capture and Storage (BECCS) will have a substantial role in transforming Indonesia energy system by reducing electricity generation related and transportation fuels emissions, both in respect to the implementation of pre- and post- combustion BECCS technologies. This work will be further developed under IIASA’s RESTORE+ project.

Keywords: deep decarbonization; negative emissions technology; bioenergy; carbon capture and storage;

Acknowledgments: Biomass and Bioenergy Lab at UFSCar, Sorocoba; BeWhere IIASA; Center of Excellence on CCS/CCUS Indonesia, Institut Teknologi Bandung (ITB); TFI, www.iiasa.ac.at/tropics; RESTORE+, www.restoreplus.org

URBAN WASTE ENERGY CONVERSION IN SMALL CITIES STRATEGIC STUDY FOR DEVELOPMENT

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Abstract
The urban solid waste generation it's increasing each year with a significant rate. This effect causes several reserved areas of controlled landfills, consequently also increase the soil degradation and groundwater pollution. The reuse of these residues in the production of fuels has been one of the alternatives that aims to reduce the generation of solid waste in order to reduct the environmental impact that this generation causes. With the use of Urban Solid Waste (RSU) it is possible to enter in the carbon credit market, which becomes a political / economic advantage. The use of RSU is a viable option in the context of energy generation since the energy consumption is already increasing more thanr the current sources of energy generation are read to use. Thus, aiming at analyzing the current energy market and the political / economic impact of the use of MSW, as a raw material for energy and fuel generation, this paper aims to analyze the entire environmental context of the RSU and the current energy demand. as a solution to small towns and rural areas anywhere in the world, and one of the advantages of using them is not to be affected by the weather conditions.

Keywords: urban solid waste; political; carbon credit

USE OF THE INAJÁ STIPE (*Attalea maripa* [AUBL.] MART.) FOR THE GENERATION OF BIOENERGY

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Abstract
Management palm trees may have a great potential to merge the sustainable resource uses as well as to improve the community quality of life. Some researches demonstrate that some palm can achieve an economic viability, i.e. for energy service, due to the large relative abundance distribution, and high rate of reproduction, thus emphasizing their role in the regeneration of degraded areas and forest succession. Rural communities use palm trees for food, thatched roofs, handicrafts, and others. However, in the Amazon region there is a large number of palm trees that have not yet been economically used or are being underutilized. Among them, *Attalea Maripa* (Aubl.) Mart., known as Inajá, that occurs all over the Brazilian North Region. In this context, the objective of this study was to evaluate the bioenergetic aptitude of the Inajá stipe. The samples were collected in five locals in the northeast of Pará State: Cametá (CA), Abaetetuba (AB), São João de Pirabas (SJP), São Caetano de Odivelas (SCO) and Capitão Poço (CP). In each area, 25 matrices were identified and evaluated. The breast circumference (CAP) and the stipe length (AE) were collected for physical, chemical and energetic analysis, and a composite sample was collected from three random stipes from each zone. The analyzes were in accordance with the Brazilian recommended standards: ABNT 11940 (1983) for physics, ABNT 8112 (1986) for chemical analysis, and ABNT 8633 (1983) for energetic analysis. Regarding CAP, we obtained an average of 132.43 cm (CV = 27.81%), and AE had an average of 314.89 cm (CV = 30.67%). These variations may be explained by the different bioclimatic conditions in each region where the populations are located, as well as the different ages of each palm tree. The average values of the physical variables, moisture content and basic density were 50.09% and 0.34 $g.cm^{-3}$, respectively. In this way, it is recommended to perform a drying process, and it may be outdoors for the equilibrium moisture content with the region. The chemical tests indicated an average volatile matter of 82.46%, with an ash content of 0.83% and a fixed carbon of 16.76%. As for the energy analysis, the higher calorific value was, on average, 4586.25 $kcal.kg^{-1}$. The results indicate that the Inajá stipe can be suitable for energetic uses, and it can also be used as firewood by the familiar farmers of the Amazon rainforest, but also any other way that requires energy as heat generation.
Keywords: Biomass energy, calorific power, renewable source.

WOOD RESOURCES UTILIZATION IN THE CONTEXT OF THE BIOECONOMY

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Abstract
New biotechnologies offer new possibilities to utilise forest biomass. These result in increasing demand for wood and have an impact on the existing wood resources and wood flows. The objective of this research is to identify and quantify actual material and energy wood flows to determine the main uses of wood in the context of bioeconomy in Slovakia. The research presents a comprehensive model of wood flows between the resources and utilisation of wood in different primary wood consuming sectors. The wood resources balance model covers all possible applications of wood in various forms, including flows of wood material and wood residues for industrial and energy purposes. To develop a balance model collection of data through the empirical research was carried out. Considering the cascade use of wood we were able to calculate respective cascade coefficients and determine the final level of wood consumption in different end-use sectors using wood as a material and as a source of energy production. It follows for the results that sawmilling industry consumed 30%, wood based panels industry 13%, pulp and paper industry 17%, energy sector 40% of the total domestic wood consumption. Taking into account wood cascading principles through repeated utilisation of wood residues and energy flows the total use of wood increased 1.46 times.

Keywords: bioeconomy, wood flow analysis, wood resources balance, wood cascading

Acknowledgments: Slovak Research and Development Agency (APVV-14-0869) and the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic (VEGA 1/0473/16)

THEME: BIOGAS

BIOGAS PRODUCTION SIMULATION OF DOMESTIC ORGANIC WASTE FROM ROSANA, SP – BRAZIL

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Abstract:
The present work has the purpose of verifying the potential of electric energy generation by anaerobic digestion of domestic organic wastes collected in the city of Rosana, SP - Brasil, producing an average of about 1732 kg/day, contributing with a significant amount of greenhouse gases (CH_4, CO_2, N_2, H_2S, NH_3) where methane (CH_4) is 21 times more aggressive than carbon dioxide (CO_2), despite this, is a gas with great energetic potential. Thus, anaerobic digestion becomes a viable alternative to reduce methane pollution. The methane production was calculated with a first order rate model and numerical simulation was performed with the open source package Scilab 6.0 ©. The amount of organic waste generated per day in Rosana, considering the total solids of 41% and 64% volatile solids, is capable of supplying 144.2 m³ of methane gas, equivalent to 206.2 kWh/day. This energy can supply the demand for approximately 24 rural residences in Rosana and the biodigestion surplus can be used as fertilizer.

Keywords: biogas; organic waste; first order rate model; scialb.

Acknowledgments: Grupo Bio-Joule.

ECONOMIC ANALYSIS OF ELECTRIC POWER PRODUCTION THROUGH BIOGAS PRODUCED WITH ANIMAL WASTE IN THE MUNICIPALITY OF ROSANA.

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Abstract
Brazil stands out worldwide because it is one of the countries that most use renewable energies in its energy matrix. Furthermore, due to its geoclimatic conditions, Brazil has a high diversity of natural resources that can be used as energy vectors. One of the largest sources of energy available in Brazil is biomass. Biomass is designated as any organic matter, plant matter or animal matter, which has potential to be used in energy production, so biomass can be used in biodigestors for the biogas production. Biogas is a combustible gas produced from the anaerobic digestion of organic matter which ca produce electricyty through the use of generator sets. The objective of this work is to realize the economic viability of the implantation of a modified first order rate Canadian biodigestor and a generator set in a rural property, based on the data of the Integrated Solid Waste Management Plan of the Municipality of Rosana-SP, organic matter of swine, bovine and buffaloes. The results show that the investment in the generation of electricity from biogas of the residues of swine, bovine and buffaloes of the Municipality of Rosana is viable.

Keywords: biogas; economic analysis; biodigesters

Acknowledgments: Biojoule Research Group

INTEGRATION OF BIOETHANOL AND BIODIESEL PRODUCTION FROM BIOGAS: ENVIRONMENTAL ASPECTS AND DISTRIBUTED ENERGY GENERATION

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Abstract
Brazil stands out as one of the largest producers of bioethanol and biodiesel, meeting the great demand in the country mainly in the transport sector. However, along with the production of such biofuels there is the generation of large volumes of waste as vinasse and glycerin. The objective of this study is to determine the theoretical energy potential generated by the anaerobic digestion (AD) of vinasse and anaerobic co-digestion (AcoD) of glycerin and vinasse, in order to meet the population's demands of cities where the plants of biofuels are located and reduce the concentration of carbon dioxide in the atmosphere. In this article, we present the literature review that gives information about the energy generation potential of vinasse and glycerin and we selected an autonomous bioethanol plant and a biodiesel plant, located in the cities of Santa Bárbara do Oeste (SP) and Sumaré (SP), in Brazil, to determine the proposed potential energy. The results showed that the bioethanol plant generates a large volume of 180,000 m³ month^{-1} of vinasse, presenting has a high potential for the production of biogas and energy which when converted into the biological process of AD. Due to the large volumes, part of the vinasse generated of 11,880 m³ month^{-1} by the bioethanol plant could be made available to the biodiesel plant aiming at co-DA with glycerin. The biodiesel plant generates a smaller volume of glycerin when compared to the vinasse, however, the mixture in an ideal proportion, obtained in the present study, proved to be an excellent alternative for energy generation because of the high concentration of organic matter present and better biogas yield. We observed that vinasse and glycerin, being substrates for the biological process in question, are viable for biogas production, generating 1,597,140 m³ of month^{-1} in AD and 243,777 m³ of month^{-1} in AcoD rich in methane, and subsequently 10,975,694.4 MJ (3,048,804 kWh) month^{-1} and 1,675,263.3 MJ (465,351 kWh) month^{-1} in electric energy to meet a portion of the population considered. In the environmental aspect, we estimate that by taking advantage of the aforementioned wastes in the generation of energy there we would have a reduction of carbon in the atmosphere. We concluded that both vinasse and glycerin are promising as an alternative for the integration of the bioethanol and biodiesel plant in the generation of energy from the anaerobic biological process.

Keywords: biomass; vinasse; glycerin; bioenergy

Acknowledgments: The authors would like to thank Capes (Coordination for the Improvement of Higher Education Personnel) for the financial support.

POTENTIAL OF ELECTRIC ENERGY GENERETE WITH BIOGAS FROM ANIMAL WASTE IN ROSANA, SP

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Abstract
Brazil's agricultural production generates waste that can be used as a renewable source of energy. One way to use the energy content of this waste is to turn it into biogas. Biogas is a gas generated by the anaerobic fermentation of organic matter of vegetable or animal origin. The biogas composition varies according to the type of biomass used in the process and may contain up to 70% methane gas, which is a highly combustible gas and has a high calorific value, although it has a greater impact on the greenhouse effect when compared with carbon dioxide. Based on the Integrated Solid Waste Management Plan of the Municipality of Rosana / SP, this work calculated the potential for the production of electricity generated with biogas, produced with a modified Canadian biodigester fed with bovine, porcine and buffalo waste. For this purpose, the first order rate model was used and all numerical simulation was performed in the programming language C. For cattle, considering volatile solids equal to 83% and total solids 14%, the amount of methane gas produced was 9.18×10^{-3} m^3/ day / generating head was 1.3×10^{-2} m^3 kWh. For swine, considering 77% volatile solids and 13% total solids, the amount of methane gas produced was 1.3×10^{-2} m^3 / day / head generating 1.8×10^{-2} kWh. For buffaloes, considering volatile solids of 77% and total solids of 18%, the amount of methane gas produced was 2.7×10^{-2} m^3 / day / head generating 3.9×10^{-2} kWh. These results, together with the low cost of construction of a biodigester, are important for the economic viability of the use of animal waste in a small rural property.

Keywords: bioenergy, biomass, waste

VINASSE ENERGY POTENTIAL IN THE PARANAÍBA RIVER BASIN

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Abstract
Approximately 70% of the Brazilian electricity matrix is composed of energy from hydroelectric plants. After the energy crisis of 2001, Brazilian government has adopted the thermoelectric as an alternative to meet the high energy demands which, in addition to being polluting and consequently against the environmental commitments signed at COP21, provides a high cost energy. In this way, Brazil is faced with a panorama of uncertainties regarding the guarantee of energy supply, making it necessary to develop new sustainable energy sources. Although Brazil is the largest producer of sugarcane in the world, the energy potential of this crop is still underestimated, given the lack of governmental incentive. Vinasse is a liquid waste with high polluting potential, which is produced in a large volume. Due to its great potential for biogas generation and hence, electric power generation the present work aims to analyze the energy and electric potential of vinasse generated in expansion area, more precisely in the Paranaíba River Basin (946,600 ha of planted area) under rainfed and with 80% supplementation of actual evapotranspiration - ETa through irrigation scenarios. It was observed that the average electric energy generation was 2.41 and 5.20 TWh, respectively, confirming an expected increase. Compared to the generation of the Itaipu plant, which produced 89 TWh in 2015, the energy generated by the vinasse produced in both scenarios in the assessed basin is not so significant. However, if all volume of vinasse produced throughout Brazil is considered, approximately 9 and 4 times more respectively when considering the harvest of 2016/2017, its use may become significant for the Brazilian electric matrix. In addition, vinasse is a waste that requires care as to its final destination, generating costs for the mills. In this way, its use for generating electricity not only reduces economic spending, but also can generate income through the supply of electricity to the grid.

Keywords: vinasse; ethanol; sugarcane.

Acknowledgments: The authors would like to thank CAPES (Coordination for the Improvement of Higher Education Personnel) for the financial support during the development of this study.

THEME: CHARCOAL

APPARENT DENSITY AND MECHANICAL STRENGTH OF CHARCOAL FROM RESIDUES OF *Piptadenia suaveolens* (MIQ.) AT DIFFERENT FINAL TEMPERATURE CARBONIZATION

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Abstract
The density of wood is an important property for the charcoal production, since the higher its density, the higher will be the mechanical strength of the charcoal produced. On other hand, it is important to emphasized that the specie has potential for the energy sector, once its present accelerated growth in the native forest. In this way, samples from the branch of the second bifurcation of three trees of *Piptadenia suaveolens (Miq.)* from native forest were obtained, and each analysis was performed in triplicate. The specimens were carbonized at three final carbonization temperature: 450, 600 and 750 ° C, with the heating rate of 1.67 ° C.min^{-1} and residence time of 30 minutes. For the strength of the charcoal, a universal mechanical test machine was performed, and after that the apparent density of the charcoal was determined following the norms recommended by the ASTM. Statistical analysis was performed in Software R using the Tukey test with a 0.05% error rate. The mechanical strength varied statistically, with 10.38MPa at 450 ° C and 19.87MPa at 750 ° C. For density, it did not present statistical differences, having average near to 0,433g / cm³. In view of these results, it is concluded that the residues of the studied species, which are mostly discarded, presents similar mechanical values, and sometimes even higher than Eucalyptus for the literature. According to the literature, the increase in resistance from 500 ° C is directly related to the release of volatiles associated with the modification of the quantity, size and shape of the porosity in the material, resulting in an increase of apparent relative density.

Keywords: energy of biomass; modulus of elasticity; physical properties

CHARCOAL PRODUCTION IN THE ARGENTINE DRY CHACO: WHERE, HOW AND WHO?

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Abstract
Charcoal production has been widespread in the past and is still common where poor societies and dry forests coexist. For the Dry Chaco in South America, one of the largest remaining dry forests of the world, we describe the geographical distribution, type of production systems, environmental and social context and output of charcoal based on remote sensing (charcoal kiln detection); together with existing environmental (forest cover/biomass), social (population density, poverty), and infrastructure (roads) data. While most of the region has low kiln densities (1 kiln every 1000 km^2), foci of higher production were found in the north of Santiago del Estero and the west of Chaco provinces (1 kiln every 5 km^2). Individual or small groups (up to three units) prevail over the regions (58.2% of all kiln sites), frequently associated with a forest land cover. Large groups of kilns (≥ 12 units, 15.5% of all kilns) were associated with land cleared for cultivation. For a subset of kiln sites for which forest biomass data was available, we found that typical kiln sites (1–3 kilns) had half of the average biomass of the region within a radius of 125 m. Although charcoal production in the whole region has been stable for 50 years, a strong redistribution from richer to poorer provinces has taken place. At the county level, kiln density and charcoal production records showed a linear association that suggests an average output of 11 tons of charcoal per year per kiln. Comparing counties with high vs. low charcoal production with similarly high forest cover, the first had higher population density and poverty levels. Today small scale charcoal production by poor rural people represents the only significant use of forests products that provides some market incentive for their preservation. However this situation is associated with marginal social conditions, inefficient production, and forest degradation. Developing charcoal production under environmentally and socially virtuous conditions should be seen as a unique opportunity and an urgent challenge in the face of the fast deforestation of dry forests.

Keywords: charcoal kilns; dry forests; biomass; bioenergy; forest development

Acknowledgments: the Science and Technology UNSE PIDES Project 23/B144 and 23/B145 and the FCF-UNSE and UNSE.

CLONAL SELECTION OF *Corymbia* sp. FOR ENERGY AND CHARCOAL PRODUCTION

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Abstract

Forestry biomass has become increasingly interesting due to the rising concern about non-renewable energy matrices. This biomass still has another advantage, it can fix carbon during its growth. Brazil is known for its high forest productivity, making this country interesting in the context of renewable energies. The hybrid species of *Corymbia torelliana* and *Corymbia citriodora* are known for their high density but have gained space in the scenario because they present significant advantages in terms of growth, ease in vegetative propagation, tolerance to diseases, insects and cold. The aim of this study is to select genetic materials of hybrids of *Corymbia torelliana* and *Corymbia citriodora* for energy and charcoal production. Eight genetic materials were evaluated at the age of seven, hybrids of the species *Corymbia torelliana* x *Corymbia citriodora,* from a forestry company. The wood properties, specific gravity, higher calorific value and wood energy density were measured. For charcoal, yield, apparent density, higher calorific value, fixed carbon yield and energy density were measured. The wood data was subjected to a Scott Knott test and the charcoal data was subjected to principal component analysis. Wood energy density observed in this work ranged from 993.58 to 1133.85 $MJ.m^{-3}$. Energy density is important when the wood is utilized to produce energy. It combines the specific gravity and the high hatting value. The results show that the genetic materials V and III have greater energetic potential and III, VI and VIII have potential to produce charcoal.

Keywords: forestry biomass, multivariate analysis, Scott-Knott test, energy density.

DETERMINATION OF THE ENERGETIC PROPERTIES OF CHARCOAL FROM TWO AMAZONIAN SPECIES

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Abstract
Brazil stood out positively in the ranking of production and consumption of charcoal, in which it has an excellent application for the production of pig iron and also alloys of iron and silicon metal. In the energy sector, charcoal needs mechanical strength to withstand the load of iron ore in the blast furnaces, in addition, the charcoal yield as well as its apparent density are essential variables in the energetic scope. In this study, wood of breu (*Protium apiculatum*) and acariquarana (*Rinorea guianensis*) of the second cutting cycle of the FLONA- Tapajós forest management are mentioned, which are among those with the highest diametric growth, frequency and abundance of the new floristic composition and, consequently, for energy plantations. Therefore, the objective of this work was to evaluate the gravimetric yield, apparent density, MOR and MOE of charcoal originated from the mentioned species. The wood of the base of three trees was unfolded in samples with dimensions 20x20x40mm³ (tangential x radial x axial). After that, they were send to a kiln (100°C ± 2) in order to obtain the dry mass value and then to the muffle type electric using a heating rate of 1.7 $^{o}C.min^{-1}$ and with the final temperature of 400 ºC, remainning at this temperature for 60 minutes. After the carbonization, the tests of gravimetric yield, apparent density and parallel compression to the fibers were carried out. Later, the samples were submitted to mechanical tests on a universal machine EMIC. The mean values obtained for apparent density were 0.382 and 0.663 g.cm-3 to *Protium apiculatum* and *Rinorea guianensis*, respectively, presenting significantly statistical differences between them. For gravimetric yield, MOR and MOE, statistical differences were not found, where the means were close to 38%, 15 MPa and 840 MPa respectively. It is concluded that both species have potential for energy production.

Keywords: mechanical strength; amazon; gravimetric yield.

EFFECT OF FOREST PRODUCTIVITY AND PERMEABILITY OF EUCALYPTUS GENOTYPES ON THE DRYING SPEED OF WOOD FOR CHARCOAL

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Abstract
Drying of wood is a determining factor in most uses, such as the production of charcoal, as it directly influences gravimetric yield, fines generation, carbonization time, among others. However, the genetic improvement of *Eucalyptus* in Brazil, in general, is focused mainly on the volumetric production of wood and not on the quality of the wood, and this can have impacting consequences from drying to the product generated. In this context, the objective of this work was to evaluate the effect of the Annual Average Increase and permeability of the wood of different clones of *Eucalyptus* sp. in the drying speed of the log wood for the production of charcoal. Six commercial clones of *Eucalyptus* sp., at the age of nine years, were used from a clonal test located in the city of Ubá-MG. The experiment was installed according to DIC using three diameter classes, with and without bark, with two replicates each. The wood logs were placed in a structure 60 cm from the floor to avoid direct contact with the same. The initial moisture of the wood was determined and monitoring of the drying was carried out biweekly by successive weighing of the wood until the 154th day of observation. For the determination of the longitudinal permeability of the wood to the gaseous flow, a DIC experiment was set up for the six clones and three diameter classes. The sapwood permeabilities were determined for the 3 diameter classes and the heartwood for 2 diameter classes. The heartwood/sapwood ratio, wood density in the base-top and radial directions, the morphology of the pores and fibers in the base-top direction and the structural chemical composition were also determined. For the drying data, exponential models were adjusted to explain the behavior of moisture loss; and the comparison between the treatments was performed by the model identity test. The other data were submitted to analysis of variance, and when differences were established between them, the Tukey test was applied at a level of 5% of significance. It was concluded that the IMA and, consequently, the diameter directly affects the drying time of the wood in log, that is, the genotypes that present the larger diameters require more time to dry, in addition, it was verified that the permeability of the wood also affected the total drying time. More permeable woods dry faster when compared to logs of similar diameters. Genetic materials that presented lower humidity over time, i.e., drying faster were clones 1213, 57 and GG100, respectively.

Keywords: charcoal; heartwood; permeability

Acknowledgments: Clonar; Fapemig, CNPq, SIF, G6

EFFECT OF THE FINAL TEMPERATURE OF CARBONIZATIONS IN THE ENERGETIC PROPERTIES OF THE CHARCOAL OF THE WOOD FROM *Bixa arborea* HUBER

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Abstract
In the course of the carbonization, the wood undergoes a transformation process in which its components and behavior are modified. It is known that the quality of the charcoal suffer a great influence of the properties of the wood as well its production process. Thus, the objective of this study was to analyze the effect of the final carbonization temperature on the values of volatile materials, ash, fixed carbon and higher calorific value of *Bixa arborea* Huber. Three trees from the second cutting cycle of the Tapajós National Forest were used for this purpose. The carbonizations were performed in the muffle type electric furnace at final temperatures of 300 °C, 400 °C and 500 °C, remaining at the final temperature for 30 minutes using the heating rate of 1.67 ° $C.min^{-1}$. For each tree, three carbonizations were performed for each temperature, totalizing nine carbonizations. After the carbonization, the material was submitted to analysis of immediate chemical composition following the American standard ASTM D-1762-84. The higher calorific value was determined by the equation proposed by Demirba (1997). The results were analyzed through the RStudio software, in which the Shapiro-Wilk tests for normality and Bartlett's were applied for the homogeneity of variances and submitted to the analysis of variance followed by the Tukey test for differentiation of medium treatments at the level of 95% probability. The results showed statistical difference between the three treatments. The fixed carbono, ash content and the higher calorific value of the charcoal increased with the increase of the carbonization temperature, where the minumum value was 61%; 1,3% and 6037 Kcal/Kg, as well the maximum value was 82%; 2,7 and 6900 Kcal/Kg respectively. Contrary behavior occurred for volatile material content, which under the same conditions reduced its value from 41.2% to 17.77%. For the best energetic use of the species, it's recommended to use 500ºC as final carbonization temperature.

Keywords: amazon species; wood of the second cutting cycle; immediate analysis

ENERGETIC VIABILITY OF *Eucalyptus* sp. FOR USE IN THE PRODUCTION OF CHARCOAL BY PYROLYSIS

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Abstract
Eucalyptus bark is a waste generated in large volume and has been used as a source of energy (direct burning) by industries. This work tries to use the*Eucalyptus spp*. bark as a source of raw material for the production of charcoal and to study the influence of pyrolysis temperatures on the properties of the final product. Charcoal was produced at different temperatures: 300 °C, 400 °C and 500 °C, and determined their properties by proximate analysis, higher heating value (HHV) and thermogravimetry analysis (TGA). It was observed that higher pyrolysis temperature resulted in increase of the fixed carbon content and HHV. In the thermogravimetry and derivative thermogravimetry (TG/DTG) curves it was possible to determine the differences in the thermal stability of the three types of charcoal. It can be concluded that the charcoal of the Eucalyptus bark is an alternative for the energy reutilization of this residue and also can be used as charcoal for heating or domestic use.

Keywords: tga, biomass energy, wood residue, solid biofuel.

Acknowledgments: This work acknowledges the CAPES and the research group Biomass and Bioenergy at UFSCar – Sorocaba.

EVALUATION OF THE GRAVIMETRIC YIELD OF CHARCOAL FROM *Tachigali crhysophylla* IN DIFFERENTS MAXIMUM CARBONIZATION TEMPERATURES

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Abstract
Charcoal presents advantages in relation to mineral coal as a smaller production of CO_2, originating from renewable sources, as well very small proportion of ash content, sulfur and phosphorus. In the steel industry, this biofuel is a bioreactor in the production of pig iron, iron alloys, steel and other derivatives of iron ore, besides that, it's used in ceramics and in homes for food cooking, for example. In the energy sector, residues, such as branches, from native forests, during the forest harvest, as well those from the timber industry are considered alternatives to no-renowned fuels. In the energy process, factors such as maximum temperatures can influence the charcoal yield during carbonization. Therefore, objective of this research is to evaluate the gravimetric yield from tachi charcoal (*Tachigali crhysophylla*) in differents maximum carbonization temperatures. The collected material was originated from three trees of an forest management plan at Floresta Nacional do Tapajós, where disks was taken from one meter after the second bifurcation. After, was a confectioned sample in 2x2x4cm (tangential x radial x axial). Carbonization occurred with a heating rate of 1.7ºC.min^{-1} and residence time 30 minutes, using differents maximum carbonization temperatures with 300ºC, 400ºC and 500ºC, in which were composed of 12 samples for each temperature. Statistical analysis with Kruskal-Wallis test at a level of 5% of significance, through software "R" v.3.3.3. The average values of the results of the gravimetric charcoal yield were 44.81% (300ºC), 36.83% (400ºC) and 36.26% (500ºC), where their coefficients of variation consisted of 2.62%, (300ºC), 2.61% (400ºC) and 3.28% (500°C). In this way, there was a significant superiority with temperature of 300ºC in relation to the others, meanwhile, the maximum temperatures of 400ºC and 500ºC did not present significant differences in themselves. The chemical structures of wood such as cellulose, hemicellulose and lignin have different thermal degradation peaks during carbonization. Therefore, this results are consistent with the literature, where the higher the temperature, the greater the degradation of these chemical compounds and thus, being released through volatile materials. It's concluded that the charcoal of *Tachigali crhysophylla* presents better yield with temperature of 300ºC.

Keywords: tachi; charcoal; steel industry; waste; amazonian species

Acknowledgments: Wood Tecnology Laboratory from UFOPA, Santarem-PA, for the infrastructure made available for this research.

GRAVIMETRIC PERFORMANCE IN CAATINGA NATIVE SPECIES CHARCOAL

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Abstract
This work aims to evaluate the gravimetric yield of charcoal from native Caatinga forest species marketed as a source of energy under a forest management plan. Sampling was carried out in the State of Rio Grande do Norte, in the municipalities of Campo Grande (geographic microregion of the Midwest), Cruzeta (Seridó region) and Touros (Agreste region). The number of species was determined by the importance value index (IVI) calculated based on the forest inventory data of the study areas. For this study it was decided to analyze two species presents in the three areas, that are also used as energy source in Rio Grande do Norte stateFive trees of Jurema Branca (*Piptadenia stipulacea*) and five Marmeleiro trees (*Cróton sonderianus*) were then felled, among the three managed areas, totaling 10 trees sampled For the analyzes of the gravimetric yield in charcoal in duplicate, carbonizations were carried out in laboratory muffle under electric heating, with a total time of 6 hoursan average heating rate of 1.07 °C min-^{1}. The data were submitted to analysis of variance and, when differences were established between them, the Tukey test was applied, at 5% probability. It was concluded that the gravimetric charcoal yields were similar for the two species in the three different areas and the results obtained showed satisfactory rates for the conversion of wood to charcoal.

Keywords: Wood; Power supply; Carbonization; Charcoal.

INFLUENCE OF FINAL TEMPERATURE ON THE PHYSICAL AND ENERGETIC PROPERTIES OF CHARCOAL OF *Piptadenia suaveolens* (MIQ.)

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Abstract
Renewable energy sources include forest biomass, which can be used as an energy source through wood or charcoal. However, its application is not only related to the burning or combustion of random wood, since wood is a heterogeneous material that is influenced by several factors that affects its properties. Therefore, it is necessary to knowledge its technological characteristics, such as the final carbonization temperature, which presents influence in the charcoal quality. The objective of this study was to evaluate the influence of the final temperature on the physical and energetic properties of the charcoal of *Piptadenia suaveolens* (Miq.). For this purpose, material from the first log of three trees from native forest was collected, which were unfolded in test samples for later carbonization, and three treatments were applied in the carbonizations, with the final temperatures of 450 ° C, 600 ° C and 750 ° C, respectively. The carbonization process occurredin a muffle-type electric resistance furnace, and the heating rate of 1.67 ° C was applied. The analyzes were performed in triplicate by repetition, using ASTM D7582 - 15 standard for charcoal yield, percent volatile materials, ash and carbon fixed carbon. For higher calorific value, IKA C2000 calorimetric pump was utilized. Charcoal of the specie *P. suaveolens* obtained a gravimetric yield of 35, 30 and 29%, at temperatures of 450 ° C, 600 ° C and 750 ° C respectively, these three temperatures did not present difference from each other. The values of volatile materials, ash and fixed carbon at 450 ° C were 23.5, 2.3 and 74.2%, while at 600 ° C were 11.6, 0.9 and 87, 5%, and in the temperature of 750 ° C the values were 9.8, 0.9 and 89.3%, respectively. For the higher calorific value, the growth tendency was observed conforming the final temperature increase, to be quoted 7853, 8237 and 8081 Kcal / kg. It was verified that the specie *P. suaveolens* has high potential for the generation of energy in the form of charcoal. The low values of volatiles and ashes and, the high calorific value found in the charcoal of this specie can favor its use for the steel industry.

Keywords: energy of wood; high calorific value; apparent density.

MECHANICAL RESISTANCE OF CHARCOAL FROM *Swartzia laurifolia* IN DIFFERENT MAXIMUM CARBONIZATION TEMPERATURES

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Abstract
Charcoal is a highlight in the energy sector where it's considered an alternative in the use of waste produced from native forests and planted forests, during forest harvesting activities or in the process of unfolding in timber industries. The production of energy from residues of forest species in the Amazon is a reality and represents an important participation in the local economy, however, it's necessary to characterize the energy potential of the species and to find the best variables of the carbonization process in order to optimize production and quality of the final product. The study of the mechanical resistance of charcoal, especially of native species, still presents little information in the brazilian literature since there is no norm that regulates the tests. Thus, the objective of the research is to evaluate whether different maximum carbonization temperatures can influence the mechanical strength of *Swartzia laurifolia* charcoal. The wood used in the test comes from the area of certified forest management. After drying in air and acclimatization at 12% moisture, the material was unfolded in a test specimen of 2 x 2 x 4 cm³ (tangential x radial x longitudinal) and carbonized with a heating rate of 1.6 ° $C.min^{-1}$ and residence time of 30 minutes at the different maximum temperatures used being: 300 °C, 400 °C, 500 °C. The carbonized material was subjected to a compression test parallel to the fibers obtaining the values of maximum strength (MOR) and modulus of elasticity (MOE). All statistical analyzes were performed at 5% probability in software "R". Both MOR [12.49MPa (300 ºC), 9.26MPa (400 ºC) and 15.03MPa (500 ºC)] and the MOE [559.43MPa (300 ºC), 575.86MPa (400 ºC) and 433.27MPa (500 ºC)] in the parallel compression did not present differences between the treatments applied. The results of MOR differ from the literature that the higher the temperature, the lower the mechanical strength of the charcoal, this can be due to the amplitude of variation verified or the high density of the source material. It is concluded that charcoal from *Swartzia laurifolia* can be produced at higher temperatures (up to 500 ºC) in order to improve its energy characteristics, such as higher fixed carbon content and lower ash content, without compromising the final mechanical resistance that is important in transport and use processes.

Keywords: gombeira; mor; moe; coal-fired steelwords; amazon species

Acknowledgments: Wood Tecnology Laboratory from UFOPA, Santarem-PA, for the infrastructure made available for this research.

NATIVE SPECIES USABLE FOR THE PRODUCTION OF CHARCOAL; A CASE STUDY IN SOUTHEAST MEXICO

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Abstract

The illegal production of charcoal in Mexico is uncertain, the regularization of this commercial activity pricipally for rural communities is necessary for the conservation of forest resources. This study aimed to evaluate the availability of wood species for the production of charcoal within a sustainable context. This study was conducted in 31.6 ha^{-1} within dry tropical forest at Southeastern Mexico. We installed 21 rectangular plots of 10 x 60 m (1.26 ha^{-1}). Measurement, counting, and labeling of trees ofbetwen 2.5 - 7.5cm diameter at breast height (DBH, 1.3 m above ground level) were carried out in 100 m^2 nested plot,this diameter class was considered as regeneration trees, trees betwen 7.5 - 12.5 cm DBH in 200 m2 plot,these was considered as reserve trees, and trees of12.5cm DBH in 600 m^2 plot, these was considered as trees suitable for charcoal production or usable trees.All trees were identified, individually marked, and DBH and total height were measured.The biomass was then estimated employing allometric equations. We found 741 ind. ha^{-1}, of which 427 (57.7%) ind. ha^{-1} are usable. The species with greater presence and usable potential was Lysiloma latisiliquum with 150.8 ind.ha-1, 5.6 m^2 ha^{-1} of basal area (BA) and 32.8 Mg.ha^{-1} of biomass (BASS), followed by Bursera simaruba with 84.9 ind.ha-1, 2.89 m2 ha-1 of BA and 9.08 Mg.ha^{-1} of BASS, Metopium brownei with 37.3 ind.ha^{-1}, 1.7 m2 ha^{-1} of BA and 9.6 Mg.ha^{-1} of BASS. In the total study area (31.6 ha-^{1}) it was estimated 13,517.77 ind, 471.16 M^2 of BA and 2640.23 Mg. ha^{-1} of bass. It is important to mention that they are not considered usable species within the NOM-059-SEMARNAT-2010 of Mexico.

Keywords: charcoal, drytropical forest, bioenergy, biomass

Acknowledgments: CONACYT, ITChiná, UFSCar, Biomass & Bioenergy Laboratory

PHYSICAL, MECHANICAL AND ENERGETIC PROPERTIES OF *Tachigali chrysophylla* UNDER DIFFERENTS FINAL CARBONIZATION TEMPERATURES

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The correct use of wood waste generated by forest-based industries in the Amazon is a challenge and an opportunity. The charcoal production from this material is presented as viable alternative and that can generate income to the region. However, it is necessary to define the best parameters for the optimization of production, as the final temperature, a key factor. The aim here was to determine if the final temperature significantly affects the most relevant physical, mechanical and energetic properties to charcoal production from wood waste of *Tachigali chrysophylla* and if there is a better temperature. The material used in this study was collected in an area under forest management of the second cutting cycle in the Amazon. Branch waste of three individuals from *Tachigali chrysophylla* were cut in 20x20x40mm³ samples and carbonized at differents final temperatures: 300, 400 e 500ºC at 1,6°C.min-1. It were determined the apparent density, mechanical strength and modulus of elasticity at parallel compression, gravimetric yield and the high calorific value. The data were analyzed with $p<0,05$. The final temperature affected the charcoal properties evaluated. The temperature of 500ºC is indicated when it is aimed a charcoal with high mechanical strength at parallel compression and high calorific value. When the objective are higher apparent density and gravimetric yield in charcoal, the final temperature of 300ºC should be used.

Keywords: Amazonian waste; charcoal; apparent density; MOE; HCV.

PHYSICO-CHEMICAL PROPERTIES OF BAMBOO CHARCOALS FROM SPECIES *Bambusa vulgaris* Var *Vittatta*, *Dendrocalamus asper* AND *Phyllostachys pubescens*

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Abstract

In the current world, the search for sustainable fuels has become an extremely important factor for the development of energy generation in balance with the environment. In this context, biomass appears as one of the possible alternatives. Brazil has excellent climatic conditions and a vast territory for the production of forest biomass. Among the possible raw materials for the production of forest biomass, are the bamboo species, which have a high rate of growth and easy management. The objective of this work was to study in the laboratory, to determine the gravimetric yield, the upper calorific value and the percentages of fixed carbon, volatile and ashes of the charcoals of bamboo species: *Bambusa vulgaris var vittatta*, *Dendrocalamus asper and Phyllostachys pubescens.* For the carbonizetion process, initially small pieces of bamboo were obtained, the same were brought to the stove at 100°C for 24 hours, then the dried mass of bamboo was weighed and added in a carbonizer which was heated to 150°C for 45 minutes, then was heated to 180°C for 45 minutes and then was heated to 210°C for 30 minutes, the charcoal was cooling and after weighed for calculating the gravimetric yield. The samples were pulverized in a pot mill, the upper calorific value in a calorimeter was determined. The volatile, fixed carbon and ash contents were determined using the muffle furnace according to the Brazilian MB-15 method. The results obtained for the species *Bambusa vulgaris var vittatta*, *Dendrocalamus asper and Phyllostachys pubescens*, were respectively: gravimetric yield 44.08%, 42.77% and 47.09%; calorific value 28.806kJ/g, 29.075kJ/g and 28.489kJ/g; percentage of fixed carbon 62.1%, 66.09% and 57.8%; percentage of volatiles 35.89%, 30.92% and 40.4%; ash percentage 2.01%, 2.99% and 1.8%. It was observed that the *Dendrocalamus asper* species presented better results in the general context of the analyzes carried out because, despite presenting a slightly lower gravimetric yield and a little ash content, it presented the higher calorific value and fixed carbons content.

Keywords: Bamboo, Bioenergy, Carbonization, Sustainability.

PRODUCTION OF BIOCHAR WITH SUGARCANE STRAW (*Saccharum sp.*)

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Abstract
In the face of the growing sugarcane cultivation in Brazil together with the expansion of the mechanized harvest, thick layers of dry straw are deposited on the soil, making it difficult to regrow and the emergence of *Saccharum* sp. It is necessary to look for applications for sugarcane straw, which can be destined for the production of biochar. Biochar is all carbon-rich material obtained through the process of pyrolysis under limited supply of oxygen, acting as a soil conditioner and as a CO_2 sequester in the atmosphere. The aim of this work was to produce the biochar with sugarcane straw and to characterize it physicochemically. Pyrolysis was carried out in a muffle furnace at temperatures of 200 °C, 250 °C, 300 °C and 350 °C with a duration of approximately 2 hours, with 3 replications per treatment. Then carried out immediate analysis and the volatile content was determined according to ASTM E872-82, the ash content according to ASTM D1102-84, the fixed carbon and the gravimetric yield of biochar. Statistical analysis was performed using software R. The results obtained at the end of the analysis for fixed carbon were 24% at 200 °C, 34% at 250°C, 63% at 300°C and 64% to 350°C. In relation to the gravimetric yield of the biochar were obtained 85%, 67%, 30% and 28% for the respective temperatures. According to the statistical test, it was concluded that the treatment with 250°C proved to be the most efficient for biochar production.

Keywords: biomass; bioenergy; pyrolysis

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba.

QUALITY OF WOOD AND CHARCOAL FROM EUCALYPTUS CLONES FOR METALLURGICAL USE

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Abstract
Replacing the use of fossil reductants with charcoal in metallurgical industries has a great potential with respect to reducing CO_2 emissions and the contribution from this industry to the increasing greenhouse gas effect. Nevertheless, charcoals can be produced from different raw materials and under various process conditions, and have different properties influencing further applications. The objectives of the present work are to determine the properties of wood and charcoal from clones of *Eucalyptus urograndis* and assess impacts of charcoal features on CO_2 gasification reactivity. In addition, the CO_2 reactivity of metallurgical coke was also carried out for comparison purpose. Basic density, chemical composition and anatomy of wood were determined. Carbonizations in a laboratory kiln were done and the proximate and ultimate analysis, porosity, apparent density and friability of the charcoal produced were determined. The charcoal microstructure was studied using the SEM photomicrograph to trace the gas diffusion paths of CO_2 gas. The gasification reactivity was conducted using charcoal particles in a furnace setup at 850 °C, under CO_2 atmosphere. It was found that there is wood variability between the clones evaluated and strong correlations among wood and charcoal properties. All charcoals from Eucalyptus clones had higher reactivity in comparison to coke. The decrease in porosity, fiber wall fraction and increase apparent density in Eucalyptus wood char led to a slightly decreased CO_2 gasification reactivity. In this work, a strong correlation between charcoal reactivity and concentration of Potassium (K) was found.

Keywords: CO_2 gasification, reductant materials, charcoal

RECYCLING OF BIOMASS RESIDUES AS A COKE SUBSTITUTE IN IRON AND STEEL PRODUCTION

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Abstract
There is a production of around 43 million metric tons of steel per year in Germany and around 34 million metric tons per year in Brazil in 2015. Both countries belong to the ten largest steel manufacturers worldwide. Of these in total 77 million tons of steel are about 70% produced by the basic oxygen process, that is based on iron ore. In the production of pig iron in the blast furnace coke is needed, which is won by the coking of special coking coal. The coke is used as fuel and at the same time as a reducing agent for the iron oxide. The worldwide coke production is dominated by China. Currently, the price development has stabilized between U$ 200 and U$ 300 per ton. However, with an increasing demand for steel coke prices will rise again. Under these volatile market conditions for coke prices it appears mandatory for both, the German and Brazilian steelmakers, to search for alternatives for the use of coke. The goal of the BMBF-funded (BMBF – Federal Ministry of Education and research) project is the development of procedures and measures in order to use briquettes based on biomass residues as an alternative to coke in the steelmaking process. The process development includes not only pilot plant tests but also tests in an industrial scale in order to provide the economical connectivity. Biomass residues will be coked for use in blast furnaces in the steel industry and brought into particulate form. In principle such a procedure is investigated and established already. The innovation in these research project is an application oriented, "low-cost" coking process and the briquetting to high temperature process-capable components. The case results are expected to minimize the use of fossil coke consumption. This will lead to a significant improvement of the CO2 balance in the steelmaking process. Furthermore, it is expected to reduce the dependency on fossil imported coking coal or coke. This project contributes to improved bioeconomics in the basic materials industry and with no competition with food and feed production. The project is a binational project with research and industrial partners from Brazil and Germany. Brazilian research partners are UFMG and ULBRA, industrial partners are Gerdau S.A., Viena Siderurgica S/A and COAGRO Ltda. German research partners are TU Clausthal and the Hochschule Ruhr West, industrial partners are Fritz Winter foundry and RHM Rohstoff-Handelsgesellschaft mbH.

Keywords: charcoal, biomass residues, process optimization, material use of bagasse

Acknowledgments: We thank the Federal Ministry of Education and research of Germany for supporting this project

SOME MECHANICAL AND PHYSICAL PROPERTIES OF *Tachigali chrysophylla* CHARCOAL PRODUCED UNDER DIFFERENTS FINAL CARBONIZATION TEMPERATURES

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Abstract
The amount of waste generated by forest-based industries in the Amazon is a problem. The incorrect use of these wastes represents a great loss of material. This study aimed to determine the physical and mechanical properties of *Tachigali chrysophylla* charcoal produced at different final carbonization temperatures. The material used in this study is wood residues from an area under forest management of the second cutting cycle. Three individuals of *Tachigali chrysophylla* were collected, cut in 20x20x40mm³ samples and heating at different final carbonization temperatures: 300, 400 and 500 ° C, with 9 replicates in each treatment, using the heating rate of 1.6 °C.min^{-1}. The charcoal were submitted to mechanical tests (mechanical strength and modulus of elasticity at parallel compression) on universal machine EMIC and after that was determined the apparent density. For the evaluation of the experiment, a Tukey's mean comparison test at 5% probability level was performed in software R Studio to compare the three treatments. As a result, both the mechanical strength and the modulus of elasticity at parallel compression of the charcoal were significantly higher at the final temperature of 500 °C than the other two final temperatures. Also the apparent density was higher at 500ºC. The properties evaluated had higher values at the final carbonization temperature of 500ºC.

Keywords: amazon species; parallel compression of charcoal; charcoal apparent density

WOOD THERMAL PROFILE DURING THE PYROLYSIS PROCESS

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Abstract
The objective of this project was to obtain the temperature profile formed in the wood during the slow pyrolysis process. For this, small holes were opened into the wood using a drill, three thermocouples were inserted in the radial portion along the length of the wood and in the surface - center direction, whose objective is to follow the temperature gradient constructed throughout the material during the process. The experiment was carried out at the wood panels and energy laboratory - LAPEM, UFV. Three Eucalyptus wood logs, 35 cm long, 30% moisture and 8, 9 and 12 cm diameters, were used. The pyrolysis occurred in a muffle type electric oven. The final pyrolysis temperature was 400 °C. The gravimetric yield of the products was calculated after the pyrolysis process. It was observed the formation of thermal gradients in the wood throughout the process. The temperature difference between the surface and the center can reach up 200 °C, in the pyrolysis of the larger diameter wood. It was detected thermal heights formed in the wood at 100 °C, being more evident in the central portion. The thermal variation perceived in the wood can be explained by the presence of water, the consumption of energy for its evaporation automatically change the temperature gradients, in addition, as the wood is a porous material, the heat conductivity is poor, mainly in the carbonized zone. These phenomena influence the heat transfer during the pyrolysis process. The heating and drying stages are essential to increase the temperature that favors the process of decomposition and devolatilization of the wood. These steps occur more quickly on the surface. In the surface - to - center direction, the formation of temperature gradients generates transient thermal threshold due to the drying process. After the water was eliminated as a vapor, the temperature in the center of the material increases rapidly. Thus, a temperature gradient was formed between the surface and the center of the wood during the pyrolysis and the total time of the process will be higher in the larger diameter wood.

Keywords: Slow pyrolysis, biomass, charcoal, thermal transfer.

THEME: ETHANOL

EFFECTS OF CORN GRAIN STORAGE TIME ON ETHANOL PRODUCTION

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Abstract
The growing demand for ethanol fuel in Latin American countries has resulted in the search for new production technologies. In Brazil, corn was introduced as a new raw material in addition to sugarcane. This is processed in dedicated plants or with industrial park shared with the sugarcane. The main advantage of this technology is the possibility of storage of corn grains and processing in the sugarcane off-season. However, there is still a lack of information on the physiology of yeast in fermentation of stored grains. Thus, the aim of this study was to evaluate the storage effects of corn grains for 0, 30 and 75 days on ethanol fermentation. Initially, the corn hybrid 2B633PW grains were collected, crushed and sieved until granulometry of 1mm. These were stored in raffia bag in an environment protected from weather and pests. At the evaluation dates, the grains were immersed in water in the proportion of 200g/L and subjected to a cooking step for 60 minutes at 100 °C. Next, the sample was cooled to 80-90 °C, adding the Liquozyme Supra 2.2X enzyme (α-amylase), while stirring for 30 minutes. Then, the samples were sieved, adjusted to a temperature of 30-32 °C and a pH of 4.0-4.5. In 400 ml of the must, 10% (w/w) of the ThermoTolerant yeast (for corn) was added. At the beginning and end (Brix values less than 1%) of the fermentation, the cell viability, sprouting rate and sprout viability were quantified. In the wine, the alcohol content was evaluated and the fermentative efficiency was calculated. The experimental design was randomized with 3 treatments and 5 replicates and the data obtained were analyzed by the F test and the averages were compared according to the Tukey test (5%). As the storage time increased, the number of live yeast cells was lower, as was the reduction of the sprouting rate. However, there was an increase in alcohol content. There was no difference between treatments for fermentative efficiency. The conclusion is that the storage of corn grains by high periods negatively influences yeast in fermentation.

Keywords: ethanol; corn; fermentation.

EVALUATION OF RICE BRAN AS A SUPPLEMENT IN THE FERMENTATION PROCESS USING *Saccharomyces cerevisiae* FOR PRODUCTION OF BIOETHANOL

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Abstract

There is an increase in researches to create alternatives to fossil fuels, such as the production of bioethanol, through the use of biomass and agroindustrial lignocellulosic residues. The present work proposes the use of glucose and rice bran as source of carbon and energy, respectively, with the potential to enhance bioethanol production. Using different concentrations of cells (1 - 5 $g.L^{-1}$) and rice bran (2.5 - 7.5 $g.L^{-1}$) with *Saccharomyces cerevisiae*. The study was carried out with a factorial design 2^2, using the dry weight curve to monitor cell growth. The parameters substrate conversion factor in product, $Y_{p/s}$ ($g.g^{-1}$), and volumetric productivity, Q_p ($g.L^{-1}.h^{-1}$) were calculated. The nutrient source provided by rice bran affects the $Y_{p/s}$ response in the studied range in a quadratic form, but its linear form showed no significant effect ($\alpha = 0.05$). When it comes to means, the best results were obtained for 12 h (0.463 $g.g^{-1}$ and 1.149 $g.L^{-1}.h^{-1}$), and for fermentation medium 2 (0.440 $g.g^{-1}$ and 0.561 $g.L^{-1}.h^{-1}$). The medium with the highest concentration of ethanol also showed the lowest Monod's constant ($K_s = 4.434$ $g.L^{-1}$, $\mu_{max} = 0.0012$ h^{-1}), which demonstrates that this condition is conducive to the production of ethanol.

Keywords: Bioethanol, Rice Bran, *Saccharomyces cerevisiae*.

OTIMIZATION STUDIES ON OXALIC ACID PRETREATMENT OF CORN COB FOR PRODUCTION OF HEMICELLULOSIC HYDROLYSATE

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Abstract
The corn crop has different quality standards depending on the use of the crop. Good plant nutrition will ensure high levels of protein and energy of the grains in the corn cob. Corn cob is one of the residues coming from the maize processing, which represents approximately 18 kg (70% wet basis) after processing 100 kg of maize. Corn cob is a lignocellulosic material composed by cellulose, hemicellulose and lignin. The cellulose and hemicellulose fractions after corn cob pretreatment can be converted to fermentable sugars to produce bioethanol of second generation. The hemicellulosic and lignin fractions can be almost totally removed from corn cob by using a mild chemical pretreatment process as oxalic acid. Oxalic acid can catalyze the hydrolysis of hemicellulose and cellulose directly. It is one of the strongest organic acids known, but at the same time, oxalic acid is less toxic to yeasts and other microbes. The aim of this work was to study the corn cob oxalic acid pretreatment to produce a hemicellulosic hydrolysate with high amount of sugars and low amount of toxic compound, as acetic acid. The pretreatment condition was based on a 2^3 full factorial design augmented with star design (six axial points) and three replicates in the central point by using a response surface methodology. Standardized corn cob pellets (1.5 kg dry matter) contained 10% moisture were impregnated under vacuum with different concentrations of oxalic acid solution (0,05-0,20 g/g dry material) in a semi-pilot reactor for 20min at room temperature. The solid:liquid ratio during impregnation was 1:6. The residue took up 15% of the liquid, and excess oxalic acid solution was drained away. The impregnated corn cob pellets were treated at different temperatures (120-180°C) and reaction times (10-90 min). The pretreated corn cob pellets were then washed to extract sugars and the different hemicellulosic hydrolysates were stored at 4°C. The optimized corn cob pretreatment condition (temperature=165.3˚C, oxalic acid concentration of 0.09 g/g dry matter and reaction time of 17 min) obtained a hemicellulosic hydrolysate with high amount of xylose sugar (35.55 g/L) and low amount of toxic compounds as acetic acid (3.0 g/L). The corn cob hemicellulosic hydrolysate has a potential to be used as carbon source to produce bioethanol and other products by biotechnological route.

Keywords: oxeatment, response surface methodology, corn cob hemicelulosic hydrolysate

Acknowledgments: CNPq, Brazil. EdenIQ, Visalia, CA.

SUGARCANE AND ETHANOL WATER FOOTPRINT IN QUIRINÓPOLIS REGION UNDER DIFFERENT IRRIGATION SCENARIOS

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Abstract

Concern about replacing fossil fuels with bioenergy sources has been growing in recent years due to problems related to climate change. According to several studies, the burning of ethanol may reduce by 80% the emission of CO_2 in the atmosphere when compared to pure gasoline burning, contributing to the fulfillment of the commitments assumed by many countries to mitigate global warming. Brazil is the largest sugarcane producer and the second largest ethanol producer in the world. In this context, the expansion of sugarcane last decades has occurred mainly in the Center-West region of the country, which due to the water regime and the different soil types, may require irrigation. Since water resources and energy systems are intrinsically linked, especially in the case of bioenergy crops, the occupation of large areas associated with some agricultural practices raises concerns of possible impacts on local water resources. Therefore, this study aimed to quantify the relationship between water use and energy in Quirinópolis region, under different scenarios of water supplementation (rainfed, 20%, 50%, 80 % and 100% of actual evapotranspiration - ETa) by irrigation. For this purpose, the evapotranspiration demands and crop yields were estimated by the soil-plant-atmosphere system modeling enabling the water footprints estimations (sugarcane and ethanol). Our results showed that as the water supplementation increased, the ethanol water footprint decreased, going from the highest value of 56.86 under of rainfed to the lowest, of 20.40 $m^3\ GJ^{-1}$ under full irrigation. This is due to the increased productivity provided by irrigation. However, the supplementation of 20% by irrigation was reached the best efficiency in terms of water use since it provides the greatest reduction of the water footprint in relation to the rainfed when compared to the other irrigation scenarios. This is because moderate water stress is generally associated with increased water use efficiency. From this knowledge, the best irrigation strategy will depend on the region edaphoclimatic pattern and also by the available water resources. To improve this analysis, the economic impact of each scenario could be performed aiming reaching the best cost-benefit to be adopted in this study region.

Keywords: water footprint; ethanol; sugarcane.

Acknowledgments: The authors would like to thank CAPES (Coordination for the Improvement of Higher Education Personnel) for the financial support during the development of this study.

SWEET SORGHUM AND SUGARCANE AS RAW MATERIALS FOR ETHANOL PRODUCTION IN THE HARVEST BEGINNING

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Abstract
As a result of the growing demand for biofuels, especially ethanol, countries like Brazil, USA, India and Argentina have studied the sweet sorghum as a raw material. In Brazil, it is cultivated in sugarcane renovation areas during the summer and processed at the beginning of the next harvest. At that time, besides the sweet sorghum, there is the sugarcane that has not yet reached the maturation point, but may contain significant sugar contents. Thus, the aim of this study was to compare the sweet sorghum and the sugarcane available at the beginning of the harvest, as raw materials for the production of ethanol. The sweet sorghum was cultivated at the Experimental Farm of the Universidade do Sagrado Coração, Bauru-SP. Its planting was in January 2017 and the harvest was in May of the same year. The hybrids studied were BRS508 and BRS511. The sugarcane was obtained from agroindustrial units of the same region, being selected those that were in their cultivation fields of in the time of the sweet sorghum harvest. Thus, the varieties BRS867515 of 3rd, 4th and 5th cuts were used, as well as the SP80-1842 of 7th cut.For all crops studied, tons of stalks per hectare (TSH), Total Recoverable Sugars (TRS) and Liters of Ethanol produced per hectare were evaluated. The TSH of sweet sorghum was from 42 to 45 t/ha, and TRS from 103 to 111 kg/t. For the sugarcane, the TSH ranged from 39 to 82 t/ha, with TRS from 100 to 117 kg/t. Considering the production of ethanol, the levels of 2761 and 2903 L/ha were verified for sweet sorghum hybrids, and from 2700 to 5500 L/ha for the sugarcane varieties. Thus, the conclusion is that the sweet sorghum is competitive with some sugarcane varieties at the beginning of the harvest.

Keywords: bicolor sorghum; sugar-energy sector; bioenergy.

THEME: GASIFICATION AND PYROLYSIS

HYDROTREATMENT OF BIO-OIL FOR FUEL AND CHEMICALS PRODUCTION

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Abstract
Due to the growing interest of fuel and chemicals production from renewable resources, renewables alternatives have been developed in the last years. The fast pyrolysis can convert dry biomass into bio-oil, which can be further upgraded into fuels or platform chemicals. One of the upgrading options is the hydrotreatment, in which the oil is exposed to high hydrogen pressure, high temperature in the presence of a heterogeneous catalyst. In the present work, a beech wood bio-oil is upgraded at mild conditions applying a transition metal and noble metal catalysts. The performance of both catalysts will be compared in terms of degree of deoxygenation, activity, as well as the production of key components, in order to assign the most suitable catalyst for upgrading reactions and further upgrading optimization.

Keywords: upgrading, hydrotreatment, pyrolysis oil, bio-oil

PHYSICAL PROPERTIES OF *Eucalyptus* sp. SUBMITTED TO TORREFACTION IN PRESS

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Abstract
The main purpose of roasting is to concentrate the biomass energy in a product formed in a short time, low heating rates and moderate temperatures. The present study had as objective to evaluate the effect of the application of the thermal treatment - roasting - with different temperatures in wood pieces of *Eucalyptus* sp., which were, before the treatment, with a moisture content of 9%, for the improvement of its main physical properties. The material was subjected to laboratory roasting in a hydraulic press for 30 minutes, seven pieces at a time, comprising temperatures of 200, 220, 240, 260 and 280°C. Then, for the evaluation of the effect of the heat treatment on the physical properties, the material with and without treatment (control) was submitted to the analysis of basic density and hygroscopic equilibrium moisture. There was no influence of the roasting temperature on the basic density of the evaluated wood and the increase of the treatment temperatures significantly affected the equilibrium moisture of the material.

Keywords: thermal treatment, basic density, equilibrium moisture.

THERMOGRAVIMETRIC AND FTIR ANALYZES OF CORN COB PYROLYSIS

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Abstract
Charcoal has a large share in the Brazilian market. The production is carried out by pyrolysis of the biomass at different temperatures which can vary between 400 and 500°C. In this study the pyrolysis process of corn cob was investigated using thermogravimetric analysis (TGA) and infrared spectroscopy (FTIR). The samples after pyrolysis were compared with raw biomass to evaluate changes in fuel characteristics. In the DTG curves a reduction in the number of degradation peaks in the carbonized material was observed. A peak displacement was also observed for the higher temperatures. The FTIR spectra allowed identifying the aromatic ring of the lignin in the structure of the charcoals, indicating the presence of this compound even in the charcoals produced with a temperature of 500°C. It can be concluded that the temperature of 400°C was sufficient to completely degrade the hemicellulose and cellulose of the biomass, rendering the final product (charcoal) less reactive or thermally more resistant than the in natura corn cob.

Key words: Pyrolysis, thermal degradation, biomass, charcoal.

UPGRADING OF PYROLYSIS-OIL PRODUCED FROM SUGARCANE BIOREFINERY RESIDUES

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Abstract
The brazilian production of sugar and bioethanol from sugarcane generates high amounts of lignocellulosic residues, such as bagasse and straw.Through liquefaction processes, in particular fast pyrolysis, these residues can be converted into pyrolysis oil, for energy densification purpose. Due to its characteristics, including high viscosity and high oxygen content, the pyrolysis oil must be upgraded if fuel and chemical production are intended. The present work will approach the upgrading of pyrolysis oil produced from sugarcane bagasse and straw at the Phyton Unit, Karlsruhe-Germany. The heterogeneous-catalyzed hydrodeoxygenation reaction was performed in a batch reactor applying a nickel-based catalyst. Feed and upgraded products were characterized by a variety of analytical techniques, in order to evaluate the degree of deoxygenation, changes of the chemical composition, distribution of chemical compounds as well as molecular size distribution, in view of the growing interest in fuel and chemicals production using a renewable non-food biomass resource.

Keywords: sugarcane, upgrading, pyrolysis oil, hydrodeoxygenation

Acknowledgments: The authors would like to thank IPT, CTBE, KIT, BeMundus, CNPq, and Johnson Matthey.

THEME: SHORT ROTATION COPPICE

CARBON STOCKS IN DRY TROPICAL FOREST OF SOUTHERN MEXICO

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Abstract

The role of tropical secondary forests in carbon accumulation has been widely acknowledged, but the rates in carbon stocks still remain uncertain. The aim of this study was to analyze the carbon stocks per specie and diameter of semi-evergreen tropical forests. The study was carried in a secondary forest in eastern Yucatan Peninsula, Mexico. Measurement, counting, and labeling of trees ofbetwen 2.5 - 7.5cm diameter at breast height (DBH, 1.3 m above ground level) were carried out in 100 m^2 nested plot, trees betwen 7.5 - 12.5 cm DBH in 200 m^2 plot and trees of ≥ 12.5cm DBH in 600 m^2 plot. Three diameter classes were used (DBH 5 cm, 5 cmDBH9.9 cm, DBH≥10 cm). All trees were identified, individually marked, and DBH and total height were measured. The biomass was then estimated employing allometric equations. The factor of 0.47 was used to convert all live biomass pools to carbón. It was found 43.58 Mg C ha^{-1} (DBH 5 cm=0.12 Mg C ha^{-1}, 5 cmDBH9.9 cm= 1.95 Mg C ha^{-1} and DBH≥10 cm= 41.52 Mg C ha^{-1}) , varyngfrom 9.39 Mg C ha^{-1} to 103.83 Mg C ha^{-1} per plot. *Lysiloma latisiliquum* obtained the largest carbon stock (16.01 Mg C ha^{-1}) and *Acacia* spthe least (0.0058 Mg C ha^{-1}).

Keywords: tropical forest,

EVALUATION OF THE STATE AND DEVELOPMENT OF COPPICE FORESTS IN SLOVAKIA USING SELECTED INDICATORS

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Abstract
Two basic types of forest stands can be distinguished in Slovakia. The first type is the high forest (from the seed) and the second is represented by the coppice forest (from the stump sprout and/or root sucker). In the long term the coppice forest is less productive and less economic than the high forest. However, wood production, in particular for energy purposes, is achieved earlier and is more frequent than in the high forests. Management of the coppice forests is simple and these forests also resist very well to harmful agents. Taking into account all these aspects, coppice forests have a potential to contribute to the development of the bioeconomy. Their management, especially in the case of small private forest owners is justified in some natural conditions in Slovakia. On the other hand, the management of the coppice forests is limited by the reduction of soil quality resulting from the short and rapidly consecutive rotations. Therefore, their management is suitable mainly at nutrient-rich sites, provided fertilization shall be performed after 2-3 rotations. The aim of this analysis is to describe basic indicators of the state and development of the coppice forests in Slovakia, in particular, their area both on the forest and non-forest lands, tree species composition, growing stock and quality, as well as to outline the possibilities for the broader utilization of energy forest stands, in particular those established on abandoned agricultural lands. To carry out the above-mentioned analyses the following data sources were used: 1) forest management plans and 2) the mathematical and statistical methods of national inventory and forest monitoring. The area of coppice forests is one of the factors affecting the flows and utilisation of basic wood assortments. However, at the present, the impact of this factor in Slovakia is not large, as the current coppice forest area covers only 5.7%, approximately 110 thousand ha. Their share in the total forest area used to be higher in the past, but due to the systematic conversions of the coppice to high forest structures it was reduced during the period of the planned economy in 1950-1990. They are dominated by the main tree species such as black locust, Turkey oak and hornbeam.

Keywords: coppice; energy forest; wood flow; bioeconomy

Acknowledgments: This work acknowledges for the support of the Slovak Research and Development Agency (APVV-14-0869)

PHYSICAL PROPERTIES OF PINEWOOD SUBJECTED TO COMBINED IMPREGNATION-HEAT TREATMENTS

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Abstract
In the current scenario of the world forestry sector there is a great demand of the industries by the tree species that presents fast growing. They are used in buildings, manufature of furniture and frames and in rural áreas. Due to the high rate of exposure to humidity and the action of bad weather, these woods require treatments to increase their resistence against deterioration agents. The present study aimed to evaluate the dimensional changes and the apparent contact angle of *Pinus* sp. wood subjected to two-step impregnation-heat treatments. Five samples measuring 15x15x15mm were prepared for each treatment. The first step of the combined treatments was the wood impregnation with rosin-based thermoplastic adhesive using two methods: vacuum impregnation-immersion (VT) and hyperbaric vacuum-pressure at 6000bar (HBT) for 15min. The second step was the wood heat treatment at 180°C for 30min. The treated samples were oven-dried at 40°C and then immersed in water for 24 hours. Water absorption (WA), volumetric (αv), radial (αr) and tangential (αt) swellings were determined. The apparent contact angle (CA) of the samples was measured using a goniometer Biolin Scientific with the sessile drop method and water as solvent. The WA of treated wood (VT=33.42%; HBT=32.62%) was lower than in the control samples (91.16%). The impregnation of the rosin followed by heat treatment reduced about 3 times the wood ability to retain water. The HBT presented the highest level of tangential swelling, but it did not present significant difference between the control samples and the VT. Thus, the control samples had a higher WA rate but a proportional swelling to the treated wood, denoting the efficiency of the thermoplastic resin to prevent the interaction with water. The CA was stable over the time after the combined treatments, while the CA of the control wood samples decreased significantly. Therefore, both the combined treatments VT and HBT reduced the degree of hygroscopic water absorption. In general, the surface of treated wood became more hydrophobic with higher contact angles. On the other hand, the surface of treated wood became more hydrophobic with higher contact angles.

Keywords: heat treatment, resin, hygroscopicity, hydrophobicity.

Acknowledgments: This work was supported by Santander Universidades, FAPERGS, CAPES and CICECO-Aveiro Institute of Materials, POCI-01-0145-FEDER-007679 (FCT Ref. UID/CTM/50011/2013).

THEME: SOLID FUEL

ANALYSIS OF THE ENERGY OF BIOMASS BLENDS DESNIFICATION OF STRAIN OF CASSAVA, STRAW AND BAGASSE OF SUGARCANE

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Abstract
Brazil has important advantages in agroforestry activities that generate an abundant amount of solid waste. In addition to being the largest producer of sugarcane, it also becomes one of the largest cassava and waste producers in the world production. The present work aims to analyze the energetic densification of the mixture of straw, bagasse and manioc strain through the preparation of briquettes, and by means of the immediate chemical analysis, to infer which of the blends is the most adequate energetically. Blends were prepared in proportions of 1/6 of Cassava Strain + 2/3 of Sugarcane Bagasse + 1/6 of Sugarcane Straw and the second sample of 1/6 of Strain + 1 / 6 Bagasse + 2/3 of Straw, analyzing the volumetric expansion of the same. Subsequently, the volatile, ash test and fixed carbon test were performed. To prepare the briquettes, a hydraulic press with 30 tons was used and the volumetric expansion was verified in a period of 72 hours. In the immediate chemical analysis the volatile content was verified, obtaining in the first mixture 92.01%, and ash content obtaining 5.03%; with results for second mix volatile content of 88.73% and ash content of 4.51%. Obtaining as fixed carbon in the first sample 2.96% and for the second sample 7.06%; the volumetric variation for the first sample was 7.13% while the volumetric variation of the second was 10.11%. With the data obtained, it can be concluded that the sample that had the best energy performance is the first one, because obtained a high content of volatiles, low ash content and in comparison the second sample the volumetric expansion was low.

Keywords: energy, bioenergy, briquette

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba.

BIOMASS ACCUMULATION IN THE FORESTS WITH HIGH PRESSURE OF FUELWOOD EXTRACTION IN CHIAPAS, MEXICO

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Abstract

The role of tropical forest in mitigating atmospheric CO_2 has widely been acknowledged but the carbon capture and retention capacity of such ecosystems has been changed greatly due to increasing anthropogenic pressures. Expansion of agricultural and pasturelands, selective logging and unmanaged extraction of fuelwood are the common perturbations to forest ecosystems in rural areas of Mexico. In Mexico, about 28 million people cook with firewood, of these, 19 million people use this energy as a unique fuel for cooking and about 8 million use it in combination with LP gas. Chiapas is one of the states in southern Mexico where native forest ecosystems suffer greatly from such anthropogenic pressures. The hypothesis of this study was that the forests with higher pressure of fuelwood extraction accumulate lesser aboveground biomass compared to the forest with low fuelwood pressure. The study was carried out in four localities of the Frailesca region in Chiapas, a southern state of Mexico. Two of them with better access but with higher perturbation to the adjacent forests and the other two with lower pressure on the nearby forest ecosystems. Pine and Oak forests are the predominant forest types in the region. Sixteen plots of 400 m^2 area were established to measure the biomass stocks of the trees with ≥7.5 cm DBH. Published allometric equations were used to quantify the biomass stocks using DBH, tree height and wood density. The average aboveground biomass (AGB) stocks of pine forest with lower anthropogenic pressure was 213.4 Mg ha^{-1} and that of oak forest was 189.5 Mg ha^{-1}. But the AGB stocks of pine forest with high anthropogenic pressure was 138.2 Mg ha^{-1} and that of oak forest was 92.0 Mg ha^{-1}. There was significant reduction in biomass accumulation in the forests with higher fuelwood pressure. The forests with difficult access accumulated higher AGB stocks compared to the forests with better access from the adjacent human settlements. Communities with agricultural diversification like apiculture and agroforestry practices were found more effective in forest biomass conservation compared to those who dedicate on sole Milpa cultivation and extensive bovine livestock production. Establishment of dendroengery banks, silvopasture systems and the use of ecological cooking stoves have been started in those communities with higher fuelwood scarcity.

Keywords: Aboveground biomass; anthropogenic pressure; firewood; agroforestry; dendroenergy

CHARACTERIZATION OF SOLID FUELS USED IN THE PRODUCTION OF RED CERAMICS IN THE STATE OF RIO GRANDE DO NORTE

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Abstract
The bricks and roofing tiles industries in the state of Rio Grande do Norte primarily use wood as fuel to burn their products. These industries still employ rudimentary furnaces in their combustion processes, what often results in a high fuel consumption. The purpose of this work was to follow a case study during the sintering of ceramic bricks and roofing tiles in the so-called "caipira" kilns in the region of Seridó / RN with a focus in the characterization of the firewood and in the consumption of this fuel. Samples of the species Mimosa tenuiflora (Willd.) Poiret (Jurema Preta) and Prosopis juliflora (Sw) DC (Algaroba) were gathered from the wood stacks in the industry courtyard before each burning process. From each of these samples, 4 cm diameter discs of wood were taken. The analysis of the basic density, the moisture content and the average wood consumption was carried out in each treatment. In treatment 1, the proportion of 50% of each species was used. In treatment 2, the proportion of 75% of Algaroba and 25% of Jurema Preta was utilized. In treatment 3, a proportion of 90% of Algaroba and 10% of Jurema Preta was adopted. As for treatment 4, only the Algaroba species was used. Data were interpreted through analysis of variance, "F" test and regression, and the means were compared by the Tukey test ($p < 0.05$). The equivalent proportion of firewood use (T1) resulted in lower consumption, even with a high moisture content and a lower basic density than found in the literature.

Keywords: solid biofuels; energy efficiency; *Mimosa tenuiflora; Prosopis juliflora*.

CHARACTERIZATION OF SUGARCANE BAGASSE BRIQUETTE, SUGARCANE STRAW BRIQUETTE AND A MIXTURE OF BOTH

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Abstract
The increase in population over the years has resulted in a greater demand for food and, consequently, also increasing the amount of agricultural, agro industrialand urban waste. Waste from sugarcane in Brazil is a major source of biomass and an alternative to fossil fuels, but the use of this biomass presents some disadvantagessuchas problemswithstorage, due to its large volume, lower energy density and higher transport and distributioncosts. As an alternative, we suggest the process of biomass energetic densification of briquettes as a way of makingabetter use ofthebiomass, increasing the amount of energy per volume, loweringcostsandmaking itstransportation and storageless complicated. The objective of this project was to producesugarcanebagassebriquettesand sugarcane straw in a 42-meshgranulometry, in proportions of 100% sugarcane straw, 100% sugarcanebagasseand the mixture of 50% strawand 50%bagasse, without the use ofagglutinativesand without changes intemperaturealong the compacting process. The quality of the compaction process was evaluated by the volumetric expansion of the briquettes. The briquettes produced from straw were the ones that suffered less volumetric variation, followed by those ofbagasse. Both presented a greater uniformity compared to those of mixture that, in turn, demonstrated a greaterexpansion and also greater loss of mass. The biomass characterization was obtained from the immediate chemical analysis, and the bagasse sample showed the highest volatile content (86.87%), followed by the mixture of bagasse and straw (83.86%) and straw (83. 09%).Regarding the ashcontent, the numberswere: 5.90%for the mixture, 4.37% for the bagasse and 4.30% for the strawbriquette. The ash content and the volatile content are parameters used to define the quality and the way in which the fuel is consumed. The lower the ash content, the better the firing and, consequently, the more energy can be extracted from the combustion process. This way, the strawbriquetteshowed to be very promising, however, the volatile content, a parameter related to the efficiency of the combustion process,showed agreater concentration in the bagasse briquette. The possibility of mixing the characteristics of both materialsyieldsatisfactory results, taking into account the economic factor and the use of residues, showing that it is interesting to mix the two biomasses for the manufacture of briquettes used as fuel.

Keywords: briquettes, biomass, densification, bioenergy, sugar cane

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba.

COMPACTATION OF BIOMASS BLENDS FOR SOLID FUEL PRODUCTION

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Abstract
Forest biomass has a multifunctional role, which includes energy source, conservation of biodiversity and mitigation of environmental impacts. The optimization of forest biomass for energy purposes can be done by compacting the waste to obtain briquettes. To reduce the moisture of the residues generated in the industrial processes and to increase the volume of use can be produced the blends. The objective of this work was to characterize chemically and physically the urban pruning biomass, bark and wood saw dust of hybrid *Eucalyptus urophylla* x *Eucalyptus grandis*, and mixtures (blends) produced from these materials. The materials were previously crushed and milled. Fifteen replicates were produced per treatment, being: A (100% bark); B- (50% bark + 50% pruning); C- (50% bark + 25% pruning + 25% saw dust). For the chemical characterization, the immediate analysis according to NBR 8112/86, and superior calorific value (PCS) according to NBR 8633 were made. The tests of mechanical resistance and the analysis of the expansion of the briquettes were done. The eucalyptus bark biomass presented the highest ash content, but did not result in significant losses in fixed carbon content or decrease in the higher calorific value. Treatment C (50% bark + 25% pruning + 25% saw powder) showed greater dimensional stability. Treatment B (50% bark + 50% pruning) showed a medium dimensional stability and a better behavior in static and dynamic mechanical tests.

Keywords: forest residues; briquettes; bioenergy.

Acknowledgments: Acknowledgments to CNPq and the research group Biomass and Bioenergy

CONSUMPTION AND CHARACTERIZATION OF THE FORESTRY BIOMASS UTILIZED IN THE TOBACCO CURE PROCESS

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Abstract
The tobacco production is an activity of great expression in the south of Brazil, and it requires annually a large volume of firewood, utilized in the cure process of the tobacco leaves, representing up to 10% of its production cost. As an alternative to the firewood, the use of agroindustry residues, such as sawdust, has been showed to be promising, because it gives proper destination to it, decreasing the emission of pollutants, besides the lower cost and easy handling. However, the high variability ends up reducing the sawdust gross heating value. An alternative are the pellets, which besides being homogeneous, have superior properties for the combustion process. The objective of this study is to analyze the consumption and to characterize the forestry biomass utilized in the tobacco cure process in farmers from Candelária, South of Brazil, aiming the energetic efficiency of the culture. The consumption of forestry biomass (firewood, sawdust and pellets) and the formation of residues after combustion were monitored in two properties of tobacco producers. Besides that, samples were collected for qualification of the biomass through physicochemical analysis. In terms of available energy, the consumption for each kilogram of dry tobacco was 77.23 MJ for firewood, 61.40 MJ for sawdust and 37.51 MJ for pellets. The use of pellets was 45.17% more efficient in comparison to the other biomasses utilized in this study. Despite having presented inferior chemical characteristics (heating value and energy density), the sawdust had a lower consumption related to the firewood. The pellets presented the best physicochemical characteristics for use as energy, with emphasis on heating value, lignin content and energetic density, as well as the lowest consumption and the lower loss of organic fraction present in the combustion residues.

Keywords: Bioenergy; Tobacco production; Energetic efficiency.

DETERMINATION OF THE FRICTION COEFFICIENT FOR DIFFERENT SURFACES USED TO TRANSPORT CASSAVA RHIZOME AND SUGARCANE STRAW BRIQUETTES

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Abstract
Brazil produces about 736 million tons of cane and 23 million tons of cassava rhizome annually. Consequently, there is a high generation of waste, which can be transformed into solid fuel. In order to do this, the energy densification can be applied, producing briquettes, which can optimize transport and storage of biomass by increasing the calorific value per volume unit. For a satisfactory use of the fuel, it is important to know about the particle interactions with the machinery, which can be described by the Discrete Element Method (DEM), one technique developed to analyze the behavior of granular materials such as pellets and briquettes. This study aims to calculate the friction coefficient between two densified biomasses – cassava rhizome and sugarcane straw briquettes – and three types of surface – acrylic, MDF and metal – since these are possible floors to transport the materials. Therefore, it is intended to collaborate optimizing the transportation and the application of the DEM. This coefficient was obtained by calculating the tangent of the generated angle with the elevation of an inclined plane made in MDF, in which the plates of the abovementioned materials slid on three fixed briquettes of each biomass. we sought to measure the angle at which the plate slid with a constant speed. Measurements with the equipment were made with 25 replicates. It was possible to ascertain a proximity in the coefficients for the acrylic and MDF surfaces, 0.50 and 0.52 respectively for the rhizome, while for the straw it was obtained 0.4. The coefficient on the metal surface showed a superior result: 0.68 for the rhizome and 0.49 for the straw. When performing an analysis of variance (ANOVA) it was observed the value of the calculated coefficient F is higher than the tabulated, confirming that, for the 95% confidence interval, the treatments applied, i.e. change of the plate material to slide on the briquettes, is significant for the variation of the friction coefficient. Given these results, future models that make use of DEM may be more accurate, since often these values are derived from estimates that do not always reflect the reality, because there is little literature on the subject. In addition, it can be observed that the transport made in wooden boxes, for example, will be less harmful for these briquettes when compared to the metal plates of the trucks and / or containers.

Keywords: biomass; waste; transport.

DIFFERENT TYPES OF LIGNOCELLULOSIC MATERIALS FOR ENERGY GENERATION IN THE CERAMIC INDUSTRY

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Abstract
This work aims at the physical-chemical characterization of four tree species such as *Eucalyptus* sp, *Pinus* sp, *Citrus sinensis* and *Hevea brasiliensis* with potential for their use as biofuel for feeding ceramic furnace and generating energy in the form of heat. For the accomplishment of this work the samples of each species were collected and the immediate analysis of the samples was carried out according to ASTM D3172-89, the high heating value was also determined according to ASTM D865-13. Also, the chemical analyzes of the samples were carried out using the extractor soxhlet extractive content in cyclohexane/ethanol, according to TAPPI T 204 cm-97 standard and TAPPI T 207 cm-99 hot water, the Klason lignin content was also determined with the TAPPI T 222 om - 02 standard, as well as the holocellulose content according to TAPPI T 249-85, the alpha-cellulose content was determined according to TAPPI T 203 - cm99. For all the results were applied to ANOVA and Tukey for treatment of the obtained data, the sample of *Hevea brasiliensis* presented the highest moisture content 12.72%, for the ash content the *Pinus* sp sample was the one that presented the value of 1.60%, for the volatile material content the sample of *Eucalyptus* sp presented value of 83.61%, already for the values of fixed carbon the sample of *Citrus sinensis* presented the value of 20,03%. For the chemical analyzes in the total extractive content, *Citrus sinensis* presented a value of 21.76%, for the Klason lignin content the *Pinus* sp sample had a value of 39.24%, the sample that presented the highest holocellulose value was *Eucalyptus* sp 60.29%, as well as for alpha-cellulose in the value of 42.72%. The *Pinus* sp sample was the one with the high heating value in the value of 20,090 J/g and the highest value for the lower heating value in the value of 18.757 J/g. According to the results obtained in the analyzes we can conclude that all species have potential for applications in ceramic furnace, but we highlight *Pinus* sp as the one that presented the highest results for heating value.

Keywords: bioenergy, agroforestry wastes, calorific value.

Acknowledgments: This study was supported by CAPES PVE 117/2012: UFSCar – Federal University of São Carlos.The first author would like to thank Graduate School: Bioagricultural and Science in Nagoya University-Nagoya

EFFECT OF PARTICLE TORREFACTION ON PELLET PROPERTIES

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Abstract
The use of torrefaction particles for pellet production is a trend in the global market for modern biomass. Although particle torrefaction is an advantageous process for densified products, the industry still seeks optimal torrefaction parameters. Thus, the objective of this work was to elucidate the best particle torrefaction temperature and its influence on the quality of the pellets. For the production of the particles, Pinus sp. aged 20 years, from a plantation in the Zona da Mata Mineira. Wood was peeled and later turned into flakes for grinding hammer mill. After grinding, the particles were sieved, collecting what was retained between the 1 mm and 3 mm sieve. For wood torrefaction, the particles were initially oven dried at 103 ± 2 ° C until 0% moisture. The particles were torrified for 6 minutes at temperatures of 200 ° C, 250 ° C and 300 ° C. After pelletizing, the pellets were climatized in a climatic chamber with a mean temperature of 23 ° C and a mean relative moisture of 60% until reaching a constant mass. In order to qualify the pellets, the following properties were measured: diameter, length, bulk density, hardness, fines content, mechanical durability, calorific value, fixed carbon, mass of volatiles and ash. The thermal treatments promoted several modifications in the properties of the pellets, among them, the increase of the upper calorific value, fixed carbon, mechanical durability and bulk density is outstanding. The torrefaction of the particles reduced the equilibrium moisture, volatile mass and the percentage of fines of pellets. Among the temperatures tested, the best results were obtained from the pellets manufactured with particles torrified at 300 ° C. From the results of this work, it is recommended that the towered route of particles be investigated with the addition of binders for later torrefaction.

Keywords: Pelletization, heat treatment, energy biomass.

EFFECT OF PRESSING TIME ON DENSITY AND RESISTANCE OF FUEL BRIQUETTES FROM CASSAVA RHIZOME

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Abstract
Brazil is among the largest cassava producers in the word, however during cassava harvest large amount solid wastes are produced; considering that only root is used for consumption and part of stalk for replanting, in which the remainder with rhizome, in many situations, are incorrectly discarded. The objective of this research is to promote the cassava rhizome utilization through briquettes production and analyze which pressing time is most appropriate for compacting process in order to obtain a better product. The Briquettes were produced using compaction pressure of 1559.07 kgf.cm^{-2} and five different time pressure duration applied: zero measure (T1), 30 seconds (T2), 1 minute (T3), 1 minute and 30 seconds (T4) and 2 minutes (T5); all without binders additionand/or temperature in the process. It was used the biomass with approximately 12% moisture content, and granulometry retained in 16 mesh (1.19 millimeter) sieve after grinding. Through a density the briquettes analysis during a period72 hours after production, it was obtained that treatment that remained with highest density was T4; besides that, a mechanical strength test was performed, obtaining the following data: 975.03 MPa (T1), 1294.45 MPa (T2), 1358.99 MPa (T3), 1460.10 MPa (T4) and 1297.83 MPa (T5). Finally, to obtain potential the material burning, it was performed a Higher Heating Value test, obtaining 17.13 kJ/kg, and an immediate chemical analysis getting for Volatile Content 72.45%, for Ashe Content 14.45% and for Fixed Carbon Content 13.10%. It is concluded that, briquettes production using T4 pressing time promotes a better binding between biomass particle used, however results obtained using T3 were also satisfactory without significant difference between T4, enabling its use. Cassava rhizome had potential as a solid fuel source in the fuel briquettes form as an alternative to eliminate the incorrectly discarded.

Keywords: biomass, wastes, densification.

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba.

EFFECT OF TEMPERATURE AND TIME DURING *Pinus elliottii* WOOD TORREFACTION

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Abstract
The growing demand for energy has made the use of fossil fuels radically exploited, which contributes to an environmental crisis. Forestry biomass is an alternative to fossil fuels, as it is a renewable energy source and the manufacturing industry and benefiting from timber products generate a large amount of waste. Torrefaction, a process normally carried out in inert environments between 200 and 300 ºC, is being extensively studied as a way to improve the processing of biomass and for the purpose of up grading solid biomass fuel. The benefits accomplished by torrefaction include higher heating value or energy density, higher hydrophobicity or water-resistivity, lower atomic O/C and H/C ratios and moisture content, and more uniform properties of biomass. The objective of this paper was to investigate and understand the influence of torrefaction temperature and time on yield, chemical composition and energetic properties of *Pinus Elliottii* wood chips. Using a furnace, the pine chips underwent seven heat treatments at temperatures of 150, 200, 225, 250, 275, 300, 350°C. The sample was introduced in the reactor at the corresponding torrefaction temperature for 30 and 60 min. The propertieS determined were moisture content (ABNT NBR 14929), immediate analysis (ABNT NBR 8112), upper and lower calorific values (ABNT NBR 8633, ASTM 711-87), and the calorific values including the influence of moisture (net calorific values). With increasing torrefaction temperature showed higher fixed carbon content, less moisture equilibrium moisture content, higher calorific upper, lower content of volatiles and lower mass yield. The torrefied material at 275ºC for 60 min had half the moisture content to 17% more energy per unit mass than wood in nature and energy yield 68%, showing the best treatment.

Keywords: bioenergy; carbonization; solid biufel

ENERGETIC CHARACTERIZATION OF PINUS SAWDUST AND SUGARCANE STRAW BLENDS FOR BRIQUETTES MANUFACTURING

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Abstract
The use of wood is related both to economic issues and to the low technological level of some segments, especially the industrial ones, where the ceramics of the state of Rio Grande do Norte (RN) uses wood in the direct burning, without a previous study for such use. In considering this demand for wood biomass and the development of cultures of the genus Eucalyptus in Brazil, the present study aimed to characterize the wood properties of *Eucalyptus urograndis* clones and to indicate, based on the results, the material with has the best potential for energy purposes. Three clones were evaluated in the fourth year of age, AEC0224 (T1), AEC0144 (T2) and GG100 (T3), from a planting in the Forest Experimentation Unit of the Specialized Academic Unit in Agricultural Sciences (UAECIA) of the Federal University of Rio Grande do North (UFRN). The analyzes were carried out at the Wood and Energy Laboratory (LAPEM) of the Federal University of Viçosa (UFV), where the wood was evaluated for determination of the basic density (Kg.m-³), upper calorific value (Kcal), as well as components of the immediate chemical analysis (AQI) of wood: volatile materials (%), fixed carbon (%) and ash (%). For the variable basic density, the test found that treatment 1 and treatment 2 were statistically the same and differed from treatment 3, which obtained a higher average in relation to the others. On the other hand, for the variable calorific value, it was verified that the 3 treatments did not differ statistically. For AQI, the treatments did not differ statistically when comparing volatile materials and fixed carbon, but it was observed that the T3 obtained a lower value than the others for the ash content. Thus, it was concluded that the clone GG100 (T3) presents better characteristics as its energy properties.

Keywords: high calorific value, basic density, energy from wood.

Acknowledgments: UFRN - Laboratórios de Tecnologia de Produtos Florestais e de Estudos em Solos (GESOLO); UFV - Laboratório de Painéis e Energia da Madeiras (LAPEM)

ENERGETIC PROPERTIES OF *Pinus patula* WOOD

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Abstract
The genus *Pinus* has being extensively planted in the States of Paraná and Santa Catarina. The *Pinus patula* Schltdl Cham. is a kind of specie originating from Mexico and that has being introduced to supply mainly the lumber and lamination industry. Pinus plantations are managed for the production of multi-products wood, being that the wider the possibilities of use better will be the profitability conditions. Thus, this research aimed to determine the energetic properties of *Pinus patula* wood to evaluate the possibility of its use as raw material for energy production. The basic specific mass, moisture content, volatile content, fixed carbon content and ash content of 12-year-old *Pinus patula* wood were determined following the recommendations of standards NBR 11941, NBR 7190, ASTM E872 and ASTM E1534 and the means and respective standard deviation were obtained. The wood of *Pinus patula* presented 0.32±0.01 g/cm³ of basic specific mass, 68.00±0.40% of moisture content, 87.99±0.94% of volatile content, 11.79±0.97% of fixed carbon content and 0.22±0.02% of ashes content. The low values of basic specific mass and fixed carbon make their wood less appropriate for producing charcoal or your "in nature" use for energy production. As for the high moisture content, evidences the need for longer storage time in the yard or the use of forced drying. However, the low ash content indicates that there will be a low generation of residues after the burning of this wood, which is a desirable feature of the steel industry. Therefore, it is possible to affirm that this species is less indicated for the production of charcoal, thus requiring complementary studies to evaluate the possibility of its use as energy source in compacted products, such as pellets or briquettes.

Keywords: charcoal; immediate chemical analysis; carbonization

ENERGY AND MECHANICAL CHARACTERIZATION OF BRIQUETTES MADE FROM WASTE

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Abstract
The objective of this work was to evaluate the use of paraffin as a binder in the formation of sorghum briquettes. Three treatments were used: briquetting without paraffin and without temperature (T1); with paraffin and without temperature (T2) and with paraffin and with temperature (T3). Some biomass characteristics were observed as: moisture content, bulk density and energy characteristics (fixed carbon content, volatile content, ash content and calorific value). The mechanical characteristics (expansion, maximum strength at the moment of rupture and friability) were also evaluated. The moisture content of the biomass was 20% and the bulk density was 0.12 $g.cm^{-3}$. The calorific power of the biomass without and with paraffin were 4446 $kcal.kg^{-1}$ and 7139.82 $kcal.kg^{-1}$, respectively. The paraffin increased the volatile content of the biofuel, from 80.35% to 85.82%. T3 provided better results with a stabilization after, a mechanical resistance of 0.75 Mpa and a friability index of 0.96%. All treatments were classified as very poorly friable materials. The briquetting process improved the biomass density and decreased the moisture content minimizing transport and storage costs.

Keywords: biomass, binder, biofuel, compaction.

ENERGY POTENTIAL OF *Pinus caribaea* VAR. *Hondurensis* WOOD

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Abstract
In recent years, most countries have been encouraging the use of renewable energy, such as wind, solar, biomass, ocean and geothermal energy. The main reason for this search for renewable energy sources is the need to reduce the use of oil and its derivatives in the countries' energy matrix in order to reduce heating gas emissions. The aim of this work was to evaluate the potential of the forest biomass *Pinus caribaea* var. *hondurensis* for energy purposes. The moisture content of the material, the proximate analysis (determination of the volatiles materials, ash and fixed carbon) and the high heating value were determined. Regarding the results, the moisture content obtained was 12.1 ± 0.2%. In the proximate analysis, the volatiles materials was 87.40 ± 0.80%, ash was 0.30 ± 0.02% and fixed carbon was 12.3 ± 0.82%. The high heating value was 20454 ± 74 J/g. It is concluded that although the biomass *Pinus caribaea* var. *hondurensis* presents fixed carbon content below the values of the literature, it presented expressive high heating value, being shown as potential for energetic purposes.

Keywords: biomass energy; biofuel; reforested wood

Acknowledgments: UFSCar Sorocaba and CAPES

ESTIMATION OF PRODUCTS OF SLOW PYROLYSIS AND STANDARD ENTHALPY THROUGH PHYSICAL-CHEMICAL AND THERMAL DATA FOR CELLULIGNINS FROM SUGARCANE BAGASSE, BARLEY STRAW, AND *Eucalyptus grandis*

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Abstract
A wide range of products can be obtained from agro-industrial residue as a raw material using chemical, biological, and thermochemical techniques. Pyrolysis is one of the promising technologies that make it possible to use the energy present in the biomass. Cellulignins were obtained from sugarcane bagasse, barley straw, and *Eucalyptus grandis* forest waste generated by acid hydrolysis for xylitol production. These cellulignins were used as feedstock for the thermoconversion process. The higher heating value and chemical and elemental compositions were determined so that a mathematical model could be created to predict the products of slow pyrolysis. The model shows that cellulignin derived from *Eucalyptus grandis,* sugarcane bagasse, and barley straws have a similar trend. Carbon monoxide and methane equivalent mass yield increase and tar decreases as temperature increases. The predicted heat of pyrolysis is highly influenced by HHV variations of cellulignins.

Keywords: biomass, modeling, pyrolysis products.

Acknowledgments: The authors would like to acknowledge the São Paulo Research Foundation (FAPESP), and National Council for Scientific and Technological Development (CNPq), Brazil, for financial support

EVALUATION OF PARTICLE SIZE INTERFERENCE ON THE SUGARCANE BAGASSE CHARACTERIZATION

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Abstract
Due to the heterogeneous composition of sugarcane bagasse (*Saccharum officinarum*) ensuring a suitable preparation process for the physicochemical characterization of this biofuel is extremely important to guarantee the reliability of the results. The objective of this work was to compare the results of the physical and chemical tests of sugarcane bagasse submitted to different preparation processes, using a cryogenic and knife mill. The results showed that only the cryogenic preparation technique allowed to reach the requirements of the preparation standards and also results with more precision due to the fibrous constitution of the material. However, the preparation in the knife mil is a fast, low cost and easy operation method, allowed to obtain similar results.

Keywords: biomass, characterization, knife mill, cryogenic mill, grinding.

EVALUATION OF THE ENERGETIC PROPERTIES IN BRIQUETS PRODUCED WITHOUT THE USE OF BINDER AND TEMPERATURE

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Abstract
Briquetting through combinations of temperature and compaction pressure is a well-known process that reuses solid waste to produce fuels with high energy density. However, as far as we know, there are no published works that address the production of briquettes without the use of binder and temperature that show an increase of their energy density. The primary objective of this work was to evaluate the energetic properties of briquettes of the angico wood (Anadenanthera macrocarpa) that were produced without the use of binders and temperature. Powder residues obtained from the dry machining of this wood with particle size ≤ 0.85 mm, were compacted in pressures of up to 300 MPa.The compacts or briquettes intact obtained in different pressures were immersed in a solution of water mixed with carbon compounds solids until saturation of their porous microstructures with said solution. To ensure that the pores were filled only with the carbon compounds solids, all the briquettes were submitted to a heat treatment in the kiln until the total removal of water of their microstructures. The briquettes obtained at different pressures were characterized by immediate analysis, energy density, and combustion index. The results showed that the compaction pressures used in this work produced briquettes intact with energy density values up to 5379 MJ / m³. Also, the presence of carbon compounds solids in the pores of the microstructure of the briquettes contributed for the energy density of these materials to increase for to 6439 MJ / m³.

Keywords: energy density, angico briquettes (anadenanthera macrocarpa) and compaction pressure.

Acknowledgments: This work thanks to the Mechanical Engineering Laboratory at UFMT, Rondonópolis.

EVALUATION OF THE PROPERTIES OF BIOMASS FOR THE PRODUCTION OF SOLID BIOFUELS

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Abstract

The efficient use of biomass as fuel requires prior knowledge of the composition and properties of the material in order to be able to develop technologies for its efficient combustion while ensuring that emissions of pollutants remain within acceptable limits. Therefore, the analyzed of the chemical and physical properties of these materials is essential in terms to evaluate their potential for energy purposes. Given the need for an improved understanding of biofuels, this study aimed to characterize samples of waste biomass derived from the manufacturing process of panels composed of wood (*Eucalyptus* spp.) and urban waste, to production of solid biofuels, used as sources of energy. The 12 types of biomass wastes were characterized in terms of their physical and chemical properties, following standard procedures. The physical properties determined were the apparent density (ABNT NBR 6922, SCAN-C46:92, ABNT NBR 14984) and the moisture content (ABNT NBR 14929). The chemical properties determined were the immediate analysis (ABNT NBR 8112), the higher and lower calorific values (ABNT NBR 8633, ASTM 711-87) and the calorific values including the influence of moisture (net calorific values). The wastes that presented the poorest qualities for use as fuels were eucalyptus bark, industrial waste, and sweepings, which all had high ash contents close to 10%, as well as the lowest calorific values over all the types of biomass waste tested. Amongst these three fuels, eucalyptus bark was likely to be the most difficult to burn, due to its high in nature moisture content and the presence of large particles, which would result in a lower flame temperature within the combustion chamber, hindering the drying process of the particles and causing losses in the system. In addition, maintenance and cleaning of equipment would need to be performed more frequently. The remaining wastes showed satisfactory characteristics for use as fuels, with performance being determined by the in nature moisture content, particle size, and type of combustion equipment employed. From the environmental perspective, preference should be given to biomass wastes that do not contain resin and additives in their composition.

Keywords: lignocellulosic wastes, bioenergy, heat combustion.

INFLUENCE OF THE GRANULOMETRIC DISTRIBUTION OF SUGARCANE BAGASSE EFFICIENCY OF THE ACETOSOLV PROCESS

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Abstract
One of the strongest branches of the Brazilian agribusiness is the sugar cane monoculture with the main objective of producing ethanol and sugar, which supply the national and international markets. In addition to these products of great interest, these large-scale productions also generate large amounts of waste, in the case of bagasse and sugarcane straw. The Acetosolv extraction process uses acetic acid as an organic solvent, together with hydrochloric acid and water as catalysts with the main objective of extracting the lignin. The aim of this work is to evaluate the influence of fiber granulometry on the lining extraction during the acetosolv process and with that to establish the ideal fiber size to obtain greater lignin extraction. Three different granulometries were established, being 35, 20 mesh plus the fibers present in collector, separated through the separating process. For characterization of the material, analyzes were performed as moisture and determination of the mean fiber size. Each acetosolv extraction was performed after extraction in water and organic solvents. The tests were carried out in triplicate with a solvent solution established for 10g of raw material, 100ml of acetic acid, 10mL of water and 1,0mL of hydrochloric acid at a temperature of 70ºC. The average values were 10.48%, 14.48% and 12.52% for 35.20 and collector treatments, respectively. The extraction process is more efficient when the fiber are present in a smaller size, being possible to notice the increase of the yield in the treatments of the fibers of smaller particle size. However, further tests should be performed to reduce experimental errors and increase statistical validity between the treatments.

Keywords: lignin; acetosolv pulping; experimental conditions

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory and Research Group on Lignocellulosic Materials at UFSCar, Sorocaba.

INFLUENCE OF TOTAL EXTRACTIVES ON THE HIGH HEATING VALUE AND THERMAL DEGRADATION OF BIOMASS

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Abstract
Issues related to renewable energy have been increasingly addressed and discussed. In this context, biomass is an alternative for the generation of renewable and available energy. The objective of this study was to evaluate the influence of total extractives on thermal behavior and high heating value in different biomasses. The materials used were pinus and eucalyptus wood, collected at the campus of UFSCar Sorocaba and sugarcane bagasse, in the city of Porto Feliz. The extractives were extracted with cyclohexane, ethanol and hot water. The analyzes were made of in natura material and without extractives. The high heating value (HHV) was performed in an IKA calorimeter pump model C200 and the thermogravimetric analysis in a TGA of the brand Perkin Elmer model Pyris 1 TGA with a flow of nitrogen gas of 20 $ml.min^{-1}$, a heating rate of 20 $°C.min^{-1}$ to the temperature of 800 °C. Pinus had a total extractive content of 6.77 ± 0.30% and a HHV of 20.34 ± 0.27 MJ kg in the in natura material and 19.61 ± 0.15 MJ/kg in the material without extractives. The bagasse resulted in a total extractive content of 5.17 ± 0.58% and a HHV of 18.31 ± 0.10 MJ/kg in the in natura material and 17.99 ± 0.16 MJ/kg in the material without extractives. In the eucalyptus, material with a lower total extractive content, 3.16 ± 0.82%, there was no significant difference between HHV which was 19.06 ± 0.29 MJ/kg for in natura material and 18.95 ± 0.04 MJ/kg for the material with no extractives. In all materials it was observed that the extractives anticipate the beginning of the degradation and are the first ones to be volatilized besides raising the high heating value.

Keywords: bioenergy, renewable resources, tga

Acknowledgments: CAPES, Grupo de Pesquisa Biomassa e Bioenergia, UFSCar.

MAPPING THREE-DIMENSIONAL MOISTURE CONTENT OF WOOD CHIPS PILES FOR ENERGY PRODUCTION

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Abstract
The aim of this study was to apply geostatistics to predict the spatial pattern of variation in moisture content of eucalypt wood chip piles intended for energy production to generate subsidies for adequate sampling and handling of the material. For this purpose, wood chip piles were installed in three different storage cycles using newly cut material for 7, 30, and 60 days. Sampling was performed in axial (top, middle, and base) and lateral positions, such that all samples were georeferenced in relation to the distance from the ground and the center of the pile. The moisture content of the wood chips at each sample point was determined by gravimetric method. The moisture values were submitted to geostatistical analysis and kriging. Our results confirmed the spatial dependence of moisture content over the piles stored at 7 and 30 days; however, the effect of rainfall was crucial to reduce the spatial dependence of humidity values, as noted in the pile stored at 60 days. Our results showed that geostatistics is a useful tool for the creation of reliable sampling protocols as well as to study the distribution of moisture content throughout the stored pile. The geostatistical mapping of moisture in the wood chip piles clearly demonstrated the effect of precipitation in the inner parts of the structure serving subsidies for decision-making on the proper handling of the stored outdoor structures.

Keywords: spatial dependence; kriging; bioenergy; moisture content; biomass

METHODOLOGY FOR VALIDATION OF DENSITY TESTS AND COMPARISON BETWEEN THE RESULTS OBTAINED BY DIN AND ASTM STANDARDS

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Abstract
The laboratory tests are of paramount importance for the analysis and physical-chemical characterization of the materials. Standardization entities usually standardize some tests in order to ensure that the methodology used guarantees a reproducibility of the experiment and a reliability of the result. However, in order to perform some laboratory-scale tests, it is necessary to use an adaptation to fit a sample amount or a non-operational parameter. The objective of this work was validated by an apparent density test, following the standards ASTM E873 and DIN EN 17828, but with adaptations without volume of sample and test vessel. For a run for made with dimensions reduced proportionately. The validation procedure was performed, at different times, by three people previously trained, with six materials of different physical characteristics. The results are more varied and are generated. It was also possible to verify that a characteristic of the material influenced the measurement and the final result. Finally, it was concluded that a greater repetition is recommended to reduce the error due to variation of results between as measurements.

Keywords: analytical method, repeatability, measures

OVERVIEW OF THE PRODUCTIVE POTENTIAL OF PELLETS IN BRAZIL

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Abstract

This study aimed to identify the existing pellet industries in Brazil and their productive potential, the data was confronted with the main sources of lignocellulosic material as potential for use as biomass. The information was obtained through a review of scientific articles and technical reports. *Sixteen* pellet producing industries were identified in Brazil, 41.3% in Paraná, 24.3% in Santa Catarina, 15.8% in Rio Grande do Sul and 18.6% in São Paulo. These regions shelter 84.6% of the areas with pine forest plantations in Brazil and the harvest residue of these plantations is one of the main sources of raw material for pellets. About 75,000 tons of this biofuel were produced in 2015, an increase of 51.85% over the previous year (2014), due to the international market demand. It was also identified that, of this production, 57,698 tons of pellets (76.93%) were consumed by the domestic market, being the biggest consumers: bakeries, pizzerias and hotels; and 17,302 tonnes were exported (23.07%). In general, 92.3% of these industries are small, producing up to 8 thousand tons per year and 7.69% producing more than 30 thousand tons annually. The main sources of identified cellulosic material were: sawmills residues; sugarcane bagasse; elephant grass; bamboo, rice hulls and black acacia wood, but pine wood pellets are the most prominent types in relation to other residues. It was concluded that Brazil has great potential for the production of pellets for energy purposes, since it has a wide range of options for the supply of raw materials and soil and climatic conditions that facilitate the production of biomass. Studies are required to confirm that the potential raw materials identified have the properties necessary for pellet production.

Keywords: biofuel; residue; thermal energy

Acknowledgments: The first author would like to acknowledge the financial support from CAPES for a fellowship.

PHYSICAL CHARACTERIZATION OF THE ENERGY DENSIFICATION FROM CASSAVA RHIZOME BIOMASS

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Abstract
The world's demand for energy is growing and supplying it is one of the worries of the world today. Among the possible sources of energy, renewables have been gaining prominence due to their lower pollution and not tending to depletion, unlike fossil sources. In Brazil, there is a high availability of renewable energy sources, and although the technology for exploiting these sources still has a high price, biomass stands out as a source whose exploitation is less costly. As Brazil is one of the world leaders in cassava production, with 23 million tons per year, there is, consequently, a great amount of residues resulting from this cultivation. In this work, the composition of the cassava rhizome, one of the unused wastes of the plant, is analyzed by means of the immediate chemical analysis and also the behavior of this compacted biomass, as well as the volumetric expansion of the briquettes, aiming to verify if it is a suitable material to be used as fuel. For the expansion analysis, 24 briquettes were made, 12 from 16-mesh granulometry, 12 from 42, and their dimensions were measured over time. About 4 months after compaction, when stability in volumetric increment is expected, the measurements were started with the briquettes exposed to the environment, measuring daily the dimensions and the relative humidity for two weeks.The briquettes made from 16 and 42 mesh reached final volumes 87.1% and 91.4% lower than the volume before compaction, respectively, noting that compaction is advantageous to avoid that the residues occupy planting space, besides facilitating its handling and storage. The calorific value obtained was 10.16 KJ / g, being high enough for the material to be used as fuel. With analysis of variance (ANOVA) involving the two granulometries as treatment, it was possible to verify that for a 95% confidence interval, the variation in the sample volumes was, in fact, significant. While the ANOVA for the different atmospheres of the environment where the samples remained exposed pointed out that the amplitude of the oscillation in the volume was not significant for the same confidence interval.

Keywords: biomass, energy, bionenergy.

Acknowledgments: We thank the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba and Prof. Silvio Rainho and prof. Fernando Sérgio Okimoto from FCT-UNESP, Presidente Prudente

POTENTIAL USE OF *Attalea maripa* (AUBL.) MART. LEAF FOR THE PRODUCTION OF SOLID BIOFUELS

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Abstract
Brazil presents many species of palm trees of potential use for the production of agroenergy. Among them, the government has prioritized studies on five species: *Elaeis guineensis* Jacq. (dendê), *Acrocomia aculeata* (Jacq.) Lodd. ex Mart (macaúba), *Orbignya phalerata* Mart. (babaçu), *Astrocaryum aculeatum* G. Mey. (tucumã) e *Attalea maripa* (Aubl.) Mart. (inajá). The areas of occurrence of inajá extend all over the North region, mainly in the amazonian estuary. This monocaule palm, which can reach 3.5 to 20 m in height, develops well in many different environments, from open, degraded areas to rainforests. Although the biomass of *A. maripa* (Aubl.) Mart. be abundant, studies on its use for energy purposes are still incipient. In this context, the aim of this research was to perform the physical, chemical and energetic characterization of the inajá leaf for the production of solid biofuels. The collection of leaves occurred in five towns in the northeastern of Pará: Cametá (CA), Abaetetuba (AB), São João de Pirabas (SJP), São Caetano de Odivelas (SCO) and Capitão Poço (CP). Were delimited 25 plants to obtain sample composed by each local. The averages of the physical variables studied, moisture content and basic density, were 50.09% and 0.29 g.cm^{-3}, respectively. The chemical analysis indicated an average content of volatile materials of 79.42%, ash content of 2.44% and fixed carbon of 17.95%. For the energy analysis, the high calorific value observed was, on average, 4 585.47 kcal/kg. The results show considerable and adequate characteristics for the use of the inajá leaf in the production of solid biofuels, except for the moisture content, so it would be recommended to dry the material.

Keywords: inajá; palm tree; alternative energy

PREPARATION OF BIOCARBON PELLETS THROUGH THE LIGNOCELLULOSIC BIOMASS OF THE AFRICAN PALM RACHIS (*Elaeis guineensis* JACQ).

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Abstract
This project describes the process to obtain biocarbon pellets from the lignocellulosic residual biomass (African palm rachis). The process began with a physico-chemical characterization of biomass for the analysis of the properties that benefit the coal formation, a proximal analysis, cellulose, lignin and hemicellulose content were determined and the TGA of the sample was analyzed. Subsequently, biochar was obtained through two thermochemical processes (torrefaction and HTC) in a batch reactor of 1L capacity. Temperatures of 210, 230 and 250 ° C, times of 15.0; 20.5 and 30.0 min and with two types of atmosphere (inert and oxidative) were applied, the caloric power was determined, and a proximal analysis was performed. The optimum value was obtained at a temperature of 210 ° C, a time of 15 min and an oxidative atmosphere. It was determined that the calorific value increased as the temperature applied in the biomass transformation process increased while the content of volatiles and ash decreased with optimal values of 27.28 MJ / kg, 50,16 % and 1.00 % respectively. Finally, the biochar obtained was used to determine the effect of the binder (cassava starch) on pelleting, where the concentrations used were 0; 5 and 10%. The properties analyzed were durability, water resistance, impact resistance, proximal analysis and calorific power. It was evidenced that higher concentration of binder agent increase the caloric power, durability and impact resistance but the water resistance was lower.

Keywords: african palm rachis, pellet, htc, torrefaction, cassava starch.

PRESSURE TIME INFLUENCE IN ENERGY DENSIFICATION OF CASSAVA BRANCH BIOMASS

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Abstract
Global demand for renewable energy has increased in recent years, due to the depletion of oil and natural gas sources, and consequent increase in fuel costs. In Brazil, renewable energy comes mainly from hydroelectric power. Thus, investments and studies on technologies for the use of biomass as an energy source are necessary. Briquetting is a process of densification of residues, and can be used for compaction of residues of vegetable origin for the purpose of generating energy. In view of this, the study of this work was to produce and evaluate briquettes of vegetal biomass residues and to test different times and granulometry of pressing, from the use of cassava (branch) residues. Initially the cassava branch was collected, abundant in the Porto Maria settlement, located in Rosana-SP. This material was dried to a moisture content of less than 12% and ground into a mill. Subsequently, the tests of calorific power, volumetric expansion and volatiles were carried out. After drying, 48 cylindrical briquettes were made in a hydraulic press, which was separated into two different granulometries, namely 16 mesh. In the granulometry cited, the material was pressed through a pressure of 10 kg/cm^2e 20 $kg/cm^2$for 1 minute and 2 minutes, respectively. The calorific value was obtained in a calorimetric pump with a value of 17812 MJ/kg. It was observed that the briquettes produced in the aforementioned granulometry and in the first pressure, presented a volumetric expansion of 13,18% and 18,02% in the times of 1 and 2 minutes, respectively. In the second pressure used, the values were 13,75% and 12,48% in the same order of time discussed in the previous pressure. In the analysis to the volatile test, the result was attractive since it presented the value of 81,5% which shows a good ignition power. As for the volumetric expansion analysis, at the pressure of 10 $kg/cm^2$the highest value obtained was for the pressing time of 2 minutes. Differently, at the pressure of 20 $kg/cm^2$the highest value reached was in the time of 1 minute. This requires an in-depth study to understand why these results.

Keywords: briquette, volatile, calorific power

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba.

PRODUCTION AND EVALUATION OF BRIQUETTES FROM THE MACAUBA EPICARP (*Acrocomia aculeata*) AND *Pinus* sp. WOOD

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Abstract
There is growing social concern about the predominance of non-renewable sources of energy in the production chains in Brazil. In this context, Brazil is among one of the largest producers of agroforestry biomass, besides being a great generator of waste of this nature, materials that can add value to the productive processes, as fuel, by means of their compaction. The Macaúba (*Acrocomia aculeata*) is an oleaginous palm tree of high economic value for its great productivity and the wide possibilities of taking advantage of the different parts of the plant. This palm is one of the most promising species for the production of biodiesel, and during its use, there is generation of large amount of waste. In this context, the aim of this study was to evaluate the feasibility of using the Macaúba residue in the production of briquettes. For this purpose, residues of *Pinus* sp., in association with Macaúba were also used in different proportions. It was initially carried out the characterization of the residues according to: bulk density, immediate chemical analysis and superior calorific value. The briquettes were produced from treatments such as T1 (100% Macaúba), T2 (75% Macaúba + 25% Pinus), T3 (50% Macaúba + 50% Pinus), T4 (25% Macaúba + 75% Pinus) and T5 (100% Pinus). To qualify the briquettes, the following characteristics were evaluated: the apparent density, burst load, energy density, lower calorific power and useful calorific power. The data were submitted to the Lilliefors test for normality and the Cochran test to evaluate the homogeneity of variances. The F-test was then analyzed for variance, and the means were compared by the Tukey test, at 5% significance. It was concluded that the residue from Macaúba has the potential to be used as a source of energy by briquetting; higher percentages of Macaúba residues promoted the increase in bulk density values and higher calorific value of briquettes.

Keywords: Biomass energy, quality of briquettes, agroforestry residues.

PROPOSED A METHOD FOR THE PRODUCTION OF BRIQUETTES WITH A HIGH POTENTIAL FOR ENERGY APPLICATIONS

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Abstract
The primary objective of this work is to propose an alternative method for the production of wood briquettes with high energy potential. Briquettes of different woods were produced without the use of binders and temperature. Powder residues obtained from the dry machining of these forests with particle size ≤ 0.85 mm, were compacted in pressures of 200 MPa.The compacts or briquettes intact obtained were immersed in a solution of water mixed with carbon compounds solids until saturation of their porous microstructures with said solution. To ensure that the pores were filled only with the carbon compounds solids, all the briquettes were submitted to a heat treatment in the kiln until the total removal of water of their microstructures. The briquettes obtained were characterized by immediate analysis, energy density, and combustion index. Regardless of which wood the compact was produced, the results showed that the method besides producing intact briquettes was significantly efficient to increase the energy density of these materials. In the case of the wood cumaru (Dipteryx odorata) was obtained values of the energy density of 7079 MJ/m³ e 7055 MJ/m³ for the briquettes of this wood without and with the carbonaceous addition in their microstructures respectively.

Keywords: energy density, briquettes and addition of carbonaceous solids

QUALITY OF BRIQUETTES PRODUCED WITH AGROFLORESTRIAL WASTES

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Abstract
Brazil stands out in the percentage of use of renewable energies in its matrix, with the participation of biomass. Among them are the briquettes that can be made with the use of agroforestry residues, which accumulate in the environment, cause serious problems. The objective was to evaluate the use of agroforestry residues in the production of briquettes. For this, residues of Jatropha curcas L. and eucalyptus wood were used and the following characteristics were evaluated: apparent density, immediate chemical composition and higher calorific value. The briquettes were manufactured under a temperature of 120 ° C, pressure of 1500 PSI, with pressing and cooling times of 5 minutes. For the analysis of the quality of the briquettes were determined: dimensions, apparent density, energy density, explosion charge, lower calorific value, useful calorific value and hygroscopic equilibrium moisture. The residue of eucalyptus wood presents itself as a potential source of energy generation. According to the properties of the briquettes, it is recommended the production of briquettes with higher proportions of eucalyptus, because it presents better energetic qualities, associated to smaller proportions of Jatropha curcas L., that will contribute to the junction of the particles.

Keywords: solid biofuels; power generation; energy potential.

QUALITY OF WOOD PELLETS WITH ADDITION OF STARCHES FOR ENERGY USE

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Abstract

With the increase of the participation of the pellets in the energy matrix, studies related to the quality of these products become fundamental, mainly with respect to the transport, storage and use. In view of this, the objective of this study was to evaluate the effect of the addition of different percentages of corn starch and wheat starch on the physical, chemical and mechanical properties of pine pellets. Three trees of Pinus taeda were collected at thirty years of age. The trees were peeled, transformed into particles with a mean size of 3 mm and a slender shape. Wheat starch and corn starch were used in the percentages of 1, 2, 3, 4 and 5% of addition, in relation to the dry mass of particles, in addition, pellets were produced without addition of additive, used as a control. Were prepared 3,500 grams of blend for each treatment. The pellets were produced with addition of water vapor and average pellet matrix temperature of 110 °C. For the characterization of the wood and the additives, the basic and bulk density, moisture content, high and net heating value and the elemental chemical composition were determined. Pellets were characterized by determination of bulk density, moisture content, high and net heating value, energy density based on HHV, immediate chemical composition, mechanical durability and fines content. With database, they were submitted to analysis of variance and test of means. It was observed that the additives have a higher bulk density in than the wood, due to the particle size, however, lower high heating value due to the presence of hydroxyl groups (-OH) in their structure. The additives pellets of corn starch did not present significant effect as a function of the amount of additive only for the bulk density property. Pellets added with wheat starch showed higher bulk density and mechanical durability in the 5% addition percentage. For the fines content, there was no significant effect of the addition of additives, presenting an average value of 0.13%. It is concluded that *Pinus taeda* wood and additives present production potential. The addition of corn starch up to 4% showed better results. Adaptations must be made to the feed process of the pelletizer using non-stick equipment.

Keywords: pelletization, energy of wood, additive.

SATELLITE IMAGES AS A QUANTITATIVE TOOL THE EXPANSION OF SUGARCANE IN A SECTION OF THE PONTAL OF PARANAPANEMA

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Abstract
The fuels from organic matter have been receiving high investments in order to reduce the uses of fossil fuels. Therefore, to reduce the use of this energy source by clean energy, sugar cane has been one of the raw materials for a given generation, production of ethanol, but also with the development of new uses for its bagasse, for example in the manufacture of briquettes. Studies on the environmental phenomena through satellite images have been one of the tools adopted to implement these analyzes of the terrestrial environment, and when it comes to the quantification of the biomass production, the use of the images to make these expansions become relevant for these evaluations. The objective is to perform a spatialization of sugarcane expansions in a section of Pontal do Paranapanema, and in order to quantify this expansion, adopting the use of images of different auxiliary dates in order to perform this temporal analysis. With the spatialization of the sugarcane cultivation areas one can visualize where these are, and can make their use in this production. These processes are realized using the software SPRING (Geographic Information Processing System) and for image classification two methods will be tested: the Bhattacharya which is a regionally supervised classifier, which uses the distance Bhattacharya to measure the statistical separability between the pairs of spectral classes; and MaxVer (Maximum verisimilitude) which is a pixel supervised classifier, where samples are selected for classifier training. In order to confirm the detected targets in the classifications, implementing the "terrestrial truth" characterized by the real use of the soil of the studied area, where it is executed by the exact process that compares the arrays of classified pixels and terrestrial truth, Kappa who has predetermined the intervals that characterize the accuracy of the classification made in relation to terrestrial truth.

Keywords: remote sensing, sugarcane, biomass, spatialization

TERMOGRAVIMETRIC CHARACTERIZATION OF BIOMASS IMPREGNATED WITH BIODEGRADABLE IONIC LIQUID

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Abstract
Different classes of solvents such as mineral acids and ionic liquids have proved capable of disrupting the hydrogen bonds between the different polysaccharide chains. Recently, a specific family of protic ionic liquids (PILs) has been developed with functionality in various industrial applications, adding to the benefits and advantages of its use, since they are absent of aromatic or halogenated molecular structure, making them structurally free of toxicity. This work aimed to verify the influence of the protic ionic liquids 2-HDEAS, 2-HEACi, 2-HEAL impregnated in the *Prosopis juliflora* (mesquite) biomass, through the thermogravimetric analysis of the macrocomponents hemicellulose, cellulose and lignin. Tests are performed in a simultaneous thermogravimetric analysis equipment (TG-DTA, Shimadzu DTG-60H), under inert atmosphere, 100 mL/min of nitrogen, 10 °C/min heating rate, and platinum crucible The devolatilization of the raw biomass and biomass impregnated with the 2-HDEAS, 2-HEACi and 2-HEAL PILs were 82.69, 83.52, 84.17 and 100%, respectively. Devolatization was determined from the TGA curves. It was verified that all the PILs present great potential in the degradation and dissolution of the macrocomponent structure of *Prosopis juliflora*.

Keywords: Biomass, lignocellulosic, torrefaction, ionic liquid.

TORREFACTION AND DENSIFICATION OF SUGARCANE BAGASSE

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Abstract

Biomass erroneously is considered as a lower fuel and is rarely included in energy statistics, whereas it should in fact be considered a renewable and equivalent source of fossil fuels. Considering only firewood as a source of biomass is a mistake, as it makes the use of other sources, such as charcoal, seasonal agricultural waste, forest residues and bird manure, ignored in many countries. What makes it difficult to use these wastes for energy generation are the properties and the conditions in which they are available: low density, high humidity, size and undesired geometric format. Sugar cane biomass consists of sugarcane bagasse and straw (green leaves and straw), the straw represents approximately 25 to 35% of the total energy in the plant, and the bagasse approximately 30 to 40% , so for each ton of cane ground for the production of sugar and ethanol, an average of 250 kg of bagasse and 200 kg of straw is generated. In the form of briquets, some advantages are highlighted: briquette energetic density, transport costs reduction, faster temperature and heat generation, lower storage infrastructure cost, low labor movement and preservation the environment. Torrefaction is an alternative process to improve the thermal quality of the biomass, as it degrades the hemicelluloses that are responsible for the absorption of water. In this work, sugar cane bagasse was torrefaied in two ways: one making the bagasse briquette first, then torrefied it and the other consist in torrefied the bagasse first and then making the briquette. The tests of immediate analysis, calorific power and tumbling were performed. It was obtained that the torrefied bagasse had a calorific value of 20,947 MJ / kg, volatile content of 71.41%, ash content of 5.73%, fixed carbon 22.86%, while the non-torrefied bagasse presented 17193 MJ / kg, volatile content 86.87%, ash content 4.37%, Fixed Carbon 8.76%. As for the durability of the material it was obtained through the test of tumbling so for the briquette made and then torrefied it, the friabiliade is96,06% and its durability is 3,92%, while torrefied first the material and then the briquette is made its friability is100% and its durability is 0%. It was concluded that the torrefaction of the material caused an improvement in the material, especially in relation to the calorific value, since there was an increase of 21.83%, and 38.32% in relation to the fixed carbon, which shows that this material burns more slowly in a furnace. About The friabiliade and the durability of the briquettes we can conclude, they do not form and thus it is proposed as a further study, the realization of blends between bagasse and straw and other materials and also the use of binders.

Keywords: biomass, bioenergy, combustion, pyrolysis

THEME: WASTES

BIOGAS AND BIOHYDROGEN PRODUCTION BY HUMUS-ASSOCIATED MICROORGANISMS USING AGRO INDUSTRIAL WASTES AS SUBSTRATE

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Abstract
By 2030 the world wide population will be around 8.5 billion for that reason is mandatory to generate new sustainable energetic alternatives. In this scenario hydrogen and methane are an excellent candidate for this purpose due to its energetic yield and sustainability. The most of the mesophilic studies have been focused either in wastewater or activated sludge consortium. Nevertheless, to our knowledge there exist not studies either producing biohydrogen or biogas using humus-associated microorganisms. The word humus comes from Latin which means the dark organic material in soils, produced by the decomposition of vegetable or animal matter and essential to the fertility of the earth. It is well known that microorganisms from the digestive tract of *Eisenia foetida* has shown an anti-recalcitrant activity even capable to degrade lignocellulosic material. On another hand, agro industrial wastes such as sugarcane molasses, sugarcane bagasses, and Tequila vinasses are abundantly available natural carbon sources. However, due to the recalcitrant properties of these compounds do not allow its use in a simple way. Furthermore, a pretreatment is required to be able to use the assimilable carbohydrates present in these compounds which represent and increasing in production costs. The aim of this study was to evaluate the anti-recalcitrant activity of this consortia during the methane and hydrogen production by dark fermentation using agro industrial wastes as substrates. We analyzed the biogas and biohydrogen production in 110 mL serological bottles in anaerobic conditions by triplicate using an inverted burette with NaOH 1N, the hydrogen and methane production was corroborated by GC and VFA were analyzed by mean HPLC. Here, we reached 172.9 and 73.3 mL of Hydrogen and biogas in 706 h, using molasses 10% (v/v) as substrate, respectively. Interestingly, Baggase reached 137.1 mL of hydrogyen, being the second best assimilable compound. Neither for hydrogen nor methane, Tequila vinasse was a useful substrate. Butyric and propionic acid were the highest molecules (12.31 and 3.96 g/L) found at the end of the fermentation.

Keywords: agro-industrial wastes, biogas, humus-associated microorganisms

CHARACTERIZATION OF BIOMASS AND BRIQUETTES OF DRYLAND RICE

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Abstract
The biomass from agriculture residues can be used in many ways, for example in the energy generation by direct burning or in compacted form. In the harvest of dryland rice, a large amount of straw remains in the soil and due to its high *C*:*N* ratio, the decomposition time is long, which can disrupt the next crop planting. Therefore, the dryland rice straw, can be a source of raw material for the energy generation. The present work had the purpose to characterize the biomass *in natura* and compacted, in the form of briquettes, of the dryland rice straw (*Oriza sativa* L.). The dryland rice straw used for energy (proximate analysis and calorific values) and physical (moisture content, bulk and energy densities) characterization of biomass *in natura* was obtained from grain harvest (crop 2016/2017), at the experimental farm of the Federal University of Goiás, Goiânia-GO. After characterization of the biomass, the rice straw was crushed and laboratory briquettes were produced, with a temperature of 120°C, pressure of 140 kgf, compaction and cooling time of 5minutes each, for later energy and physical-mechanical characterization (bulk and energy densities, durability, tensile strength by diametrical compression and expansion). The biomass average results were: (i) bulk density of 0,13 $g.cm^{-3}$ and energetic density of 0,51 $Gcal.m^{-1}$ (ii) moisture, ash, volatile and fixed carbon content of 5,5; 17,2; 71,3 and 11.5%, respectively; and (iii) higher calorific value of 3882 kcal.kg-1, lower calorific value of 3558 $kcal.kg^{-1}$ and useful calorific value of 3330 $kcal.kg^{-1}$. The results indicated that the biomass of rice straw presents inferior characteristics in relation to other biomasses used on a large scale in Brazil to produce energy, such as *Eucalyptus*, mainly in relation to the high ash content and to the higher calorific value, being 16% inferior to the wood. After compaction of the rice straw, an increase of the mass density in the order of 10 times (from 0,13 to 1,20 $g.cm^{-3}$) and consequently of the energy density, from 0.5 to 4.7 $Gcal.m^{-1}$, evidencing the importance of the compaction processes, since the mass and energetic density are fundamental parameters for the energy purposes. The values obtained for the tensile strength by diametrical compression and durability of briquettes (4.2 MPa and 99.8%, respectively) indicate their high mechanical strength and low friability; the water absorption, expressed by the volumetric expansion was 4.9%, considered high, which may indicate low dimensional stability. It is concluded that the dryland rice straw presents characteristics that make it possible to use it in briquettes forms, being an indicated way for its use as an energy source.

Keywords: bioenergy; agriculture residues; oriza sativa

CHEMICAL AND ENERGY CHARACTERIZATION OF STEM AND BRANCH OF *Mezilaurus itauba* AND *Alexa grandiflora*

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Abstract

The use of forest residuals in Amazon may support the economic development of traditional communities of the forest to provide appropriate destination to the huge volume of material that remains in the forest after de tree's extraction, wich may difficults the emergence of seedlings and natural recovery and minimize the use of noble species to energetic purposes. The caracterization of these residuals is essential in this sense for it is not known if the residuals (branch) has the same properties of the main stem of these species. Therefore, this paper aims to analyze chemically and energetically the residuals of stem and branch of the species Itauba (*Mezilaurus itauba* (Meisn) Taub. Ex Mez) and Melanciera (*Alexa grandiflora* Ducke) in order to verify your potential for energy generation. For each treatment (stem and branch) were collected residuals from three individuals of each species. The soluble extractive were analyzed at cold and hot water and the extractive content were analyzed at alcohol/toluene. The insoluble lignin contents were also determined as well as the holocelulose and wood ashes percentage. The material was submited to pyrolysis (450ºC and rate of 1.67ºC.min^{-1}) for species charcoal caracterization. The content of fixed carbon, ashes and volatile were determined, as also as the charcoal calorific power. Triplicates were made for all the analysis. The data were submited to ANOVA and T or Wilcoxon test, depending on the normality with p0.05. The content of extractive in water and in alcohol/toluene, the content of lignin and holocelulose in addition to the *Mezilaurus itauba* wood calorific power did not presente significant difference between stem and branch. For *Alexa grandiflora* species only, the content of extractive in ethanol/toluene and the superior calorific power statistically differs when compared the stem and branch residuals. Concludes that *Mezilaurus itauba* species presents more homogeneous energetic characteristics between the stem and branch than *Alexa grandiflora* species, however the residuals of booth species presents suitable properties for energetic use.

Keywords: energetic use of forestry residuals; wood for energy; amazonia

CHEMICAL COMPOSITION OF *Phyllostachys nigra* AND *Bambusa tuldeoides* COLUMNS WITH ENERGY APPROACH

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Abstract
In Brazil the wood wastes of the genus *Pinus* and *Eucalyptus* are the source of biomass commonly used to generate energy by direct burning by the industries. The country also has a great variety of bamboo species whose growth characteristics make it superior in terms of area utilization in relation to forest species and may have exploited its lignocellulosic potential in the biomass energy generation segment in natura form. The objective of this study was to evaluate the chemical composition of culms *Phyllostachys nigra* and *Bambusa tuldeoides* stems at 3 years of age, aiming to investigate the potential for burning taking into account this parameter. Samples of the species were ground and sawdust after grading of 40/60 mesh fractions was determined by determination of the ashes (TC), extractive (ET) and lignin (TL) contents, considering the methodology recommended by TAPPI T211om- 93, T 264 cm-97 adapted and T 222 om-98, respectively. Holocellulose content was determined by subtracting the value of 100% of the total quantified components (ash, extractives and lignin). The chemical composition of Phyllostachys nigra stem accounted for 64.76% of holocellulose, 30.44% of lignin, 3.35% of extractives and 1.45% of ash. On the other hand, the stem of Bambusa tuldeoides had 69.11% of holocellulose, 22.80% of lignin, 8.09% of extractives and 1.80% of ash. Taking into account the chemical composition of the evaluated species as an isolated factor, it is observed that the species Bambusa tuldeoides presents a greater energetic potential since the extractive content was quite high in the stems of this species, considered the component of higher heating value in the composition of lignicellulosic materials, but it should be taken into account the higher content of ash in its composition. On the other hand, the species Phyllostachys nigra, due to the lower holocellulose content and higher lignin content, can provide a carboniferous waste with a higher gravimetric yield, since lignin contributes significantly to the formation of residual carbon due to its complex structure and with a higher proportion of elemental carbon as opposed to holocellulose.

Keywords: bamboo; lignin; extractives; cellulose

COMBUSTION AND PYROLYSIS STUDY OF THE BIOMASS PEEL OF THE AVOCADO THROUGH THERMOGRAVIMETRIC ANALYSIS

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Abstract
Avocado is a fruit produced by several countries, is widely used in the food industry, pharmaceutical, as well as in the manufacture of cosmetics, because it is characteristic to have oil, vitamins C, E, K, some B vitamins, and minerals in their composition. The avocado residue consists of the peel and seed, and its percentage in the fruit can range from 30% to 40%. The study of products of biomass origin, has grown over the years, due to the industrial sector is concerned with the loss of economy and impacts to the environment. Thus, work presents an analysis of the thermogravimetric (TG) and thermogravimetric (DTG) curves in a dry sample of the avocado peel (AP), in order to determine the behavior of the thermodecomposition of the AP biomass sample. Under these circumstances, the oven drying procedure was applied at a temperature of 70°C of the avocado peel, in a period of 24 hours. After this process, thermogravimetric (TG) and differential thermogravimetric (DTG) tests were performed, using a heating ramp of 10ºC to 700ºC in air and nitrogen, with an air inlet flow of 100mL min^{-1} and an amount of mass of the avocado peel of 1.5µg. As a result, it was possible to identify in the TG and DTG curves, in the temperature range of up to 153 ° C, the release of energy and volatile content occurs. Therefore, the loss of mass by 50% of the AP is related to the process of decomposition of the lignin and its degradation occurs at the peak temperature of 450°C, however the hemicellulose has its degradation between the temperature range of 150°C to 375°C. At the end of the analysis, the residual mass of the AP obtained in the curve in air atmosphere was around 1.00% and in Ni 35%.

Keywords: avocado residue, lignin, hemicellulose, thermal analysis.

Acknowledgments: This work gratifies the Bioenergy Laboratory of UNESP, ICT, Sorocaba, FAPESP (2011 / 18748-6) for financial support and CAPES for granting the scholarship

DATA MINING, METHODOLOGY ANALYSIS AND METRICS STANDARD FOR SELECTION, COMPARISON AND ENVIRONMENTAL TECHNO-ECONOMIC IMPROVEMENT OF LIGNOCELLULOSIC BIOMASS CONVERSION

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Abstract

Different pretreatments are being tested under a wide range of operating conditions to meet different lignocellulosic structures and the production of a range of derived chemicals. The aim of this work is a bibliographic summary to identify standardized methodology analyzes of pretreatment processes, that pointed out: (a) due to the heterogeneity of the lignocellulosic structures, there is currently no single method to simultaneously treat different types of plants or parts of the same plant in the same reactor; (b) the effects and degree of severity of pretreatments on each lignocellulosic structure are distinct and influence the yields and types of products generated; (c) not always the best sugar yields after pretreatment are reproduced after enzymatic hydrolysis or final fermentation products, due to inhibitor formation and inefficient lignin removal; (d) the maximum utilization of all components of the plant cell wall is decisive to obtain the lowest sales value of the main product, not only the higher yield of the pretreatment and the final conversion; (e) it is critical to develop more flexible processes with regard to the type of biomass in order to reduce costs with the purchase and quality of the raw materials; and (f) Pretreatment is one of the most expensive stages of the overall project and should therefore be more optimized and economical. Pretreatment also influences capital and operational cost by requiring a greater number of stages, or energy, water and material resources throughout subsequent processes. Continuous techno-economical analysis of processes evolution is essential to identify improvements, select the most promising pretreatments for each type of biomass and generate the desired product and determine which technology is most appropriate to be applied in a commercial plant or in a single process step. Standardized and organized laboratory and pilot scale process data collection, published in articles and patents, in a single data storage structure is crucial for an agile, simple, reliable monitoring of the history of the evolution of the pretreatment, hydrolysis and conversion of lignocellulosic biomasses. Also, an interface software will expedite comparison of optimum operating conditions, including economical, energy and environmental aspects of the project. Such a routine contributes to improve the decision-making and reducing the risks of investment in PD&I and marketing.

Keywords: Lignocellulosic biomass, Pretreatment, Techno-economical analysis, Biofuels

DETERMINATION OF ELEMENTARY, CHEMICAL AND ENERGY CHARACTERISTICS OF BRAZILIAN CASTANE (*Bertholletia excelsa*) WASTE IN THE STATE OF PARÁ

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Abstract
The objective of this work was to determine the elemental chemical, molecular chemical and energetic composition of the residual biomass of Brazilian castane. Residues of bark were collected in the city of Castanhal-PA. Some of the material was crushed, sifted and graded granulometrically to be conditioned in an air conditioning room and the analyzes were performed. The *in natura* part was only acclimatized to be carbonized in a Mufla oven, with a heating rate of 1,67°C.min^{-1} and a temperature of 450° for 60 minutes, and the cooling occurred naturally and gradually, for the proper crushing of the charcoal and sifting process. The results for biomass presented an average of 55,76% of lignin; 4,54% of extractives; 2,61% of minerals and 37,09% of holocellulose. For the immediate chemical composition, the values of the averages obtained were 10,61% of humidity; 65,67% of volatiles; 2,08% ash and 21,64% fixed carbon. The elemental analysis presented average results of 53,54% of carbon, 5,69% of hydrogen, 1,57% of nitrogen, 0,11% of sulfur and 37,01% of oxygen. In the immediate chemistry of charcoal, averages of 4,93% of moisture were found; 25,81% volatiles; 1,76% ash and 67,50% fixed carbon. The residues have high levels of lignin, fixed carbon, volatile substances and low ash content, thus determining the potential for the use of Brazilian castane biomass residues in direct burning for energy production, charcoal and also the production of activated carbon and biochar.

Keywords: biomass, lignin, charcoal, carbon.

DETERMINATION OF THE PHYSICAL-CHEMICAL PROPERTIES OF SOLID WASTE FOR USE IN THE PYROLYSIS PROCESS

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Abstract
Brazil is still very incipient in the use of Municipal Solid Waste (MSW) for the generation of fuels and electric energy. Law No. 12.305/10 establishes the National Solid Waste Policy (NSWP), considered efficient and adequate for solving the problems caused by MSW. However, the NSWP is considered a process of high cost when compared to the landfill. Due to the need to seek clean and renewable forms of energy, the pyrolysis process can be an alternative in the production of primary energy. This is a thermochemical conversion process, which occurs at high temperatures and involves several chemical reactions, whose liquid organic aqueous fraction is called bio-oil. This work studied the physicochemical characteristics of some types of waste (food scraps, cardboard and paper) and their potential for power generation. The samples presented similar elemental composition and the moisture content for energy generation: 7 % for food scraps (FS), 6 % for cardboard and 4 % for paper. Thermogravimetric analysis were performed to establish that the optimum temperature pyrolysis, in addition to determine the ash content, values above 20 % may cause loss of energy in the process or soot in the liquid fraction. The lower heating value (LHV) presented typical values of biomasses, between 13 MJ/kg and 20/MJ kg. Considering the obtained results, these samples presented energetic potential for use in the pyrolysis process.

Keywords: bio-oil, urban solid waste, pyrolysis, energy.

EFFICIENT USE OF BAGASSE ASH FOR PLANT BIOMASS PRODUCTION

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Abstract
The Brazilian sugarcane industry produces over 9 million tons of water free bagasse ash yearly. This by-product contains varying amounts of minerals essential for plant nutrition, including phosphorus (P) and potassium (K). The P-concentration in bagasse ash is up to 5g/ kg ash and the reuse of P from bagasse ash could reduce the rock phosphate consumption by at least 45,000t annually. Here we study (i) the availability of P from bagasse ash to soybeans, (ii) the potential of additional fertigation to increase the P-uptake by improving the soybean nutrition, and (iii) the potential of fertigation to increase the growth of bagasse ash- and triple-superphosphate-treated (TSP) soybeans. In this experiment soybeans inoculated with N-fixing rhizobia were cultivated in pots under greenhouse conditions. Nutrient poor substrate was homogeneously mixed with three concentrations of P (0-164mg/ L) in form of bagasse ash (processed at 600°C, air-fuel ratio approx. 2.5) or TSP, respectively, and the K-concentration was adjusted to the highest K application present in the ash treatment. Half of the replications of each treatment were additionally fertigated once the week with a modified 1/3-strength Hoagland's solution, without P. Soybean plants were harvested for biomass and P-recovery analyses after 14 and 41 days. The availability of P in bagasse ash was significantly lower compared to TSP. As a result, the ash-treated plants produced significantly less total-biomass with a higher root fraction and accumulated less P (total and relative). An increase in ash and thus in total P eliminated the differences in total-biomass accumulations but not in root mass fraction. Furthermore, the additional nutrient supply via fertigation significantly increased the biomass accumulation but not the P-uptake. In conclusion, (i) for receiving comparable fertilization effects of P applied as bagasse ash and TSP, a high dose of bagasse ash application, i.e. 140t/ ha, is needed. This is economically not feasible since estimated production of 75t/ha of sugarcane generates only 91kg/ ha of water free bagasse ash. (ii) Additional fertigation improves the soybean growth but irrespective of the P-source applied it has no effect on P-uptake. The next studies are focused on bagasse processing methods and conditions, and post-processing ash modifications by thermochemical treatments for increasing the availability of P to soybeans.

Keywords: bagasse ash, phosphorus availability, nutrient poor substrate, soybeans, fertigation

Acknowledgments: This research was conducted within the project "ASHES" funded by the German Federal Ministry of Education and Research (BMBF), grant number 031A288D.

ELEMENTARY, CHEMICAL AND ENERGY CHARACTERIZATION OF DENDÊ (*Elaeis guineensis* JACQ.) WASTE, IN THE STATE OF PARÁ

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Abstract

The objective of this work was to perform the elemental, chemical and energetic characterization of the palm biomass for indication of use. The residue was collected in the municipality of Igarapé Açu-PA, consisting of *dendê* pie, obtained from the processing to remove oil and olive oil. Part of the material was stored in plastic bags, sealed and identified, then crushed and sieved in sieves with a grain size of 40, 60, 100, 200 and 270 mesh. The materials classified by granulometry were conditioned in an air conditioning room, with temperature conditions of 20±2°C and humidity of 65±3%, until reaching a constant mass, with humidity of 12%. The other part of the in natura material was only acclimated to after being charred. The biomass was dried at 12% moisture and transformed into charcoal at a temperature of 450°C, with a heating rate of 1.67°C min^{-1} and residence time of 30 minutes, being cooled naturally and gradually after reaching the final carbonization temperature and time. For the elemental analysis (CHNS), the fraction retained in the 270 mesh screen, indicated for the analysis, was used. The result obtained for the molecular chemical composition of the biomass was 32.67% of lignin; 24.92% of extractives; 2.58% of minerals and 39.83% of holocellulose. For the immediate chemical composition, averages of 7.97% of moisture, 79.71% of volatiles, 2.47% of ash and 9.85% of fixed carbon were found. The elemental analysis presented 53.79% of carbon, 6.71% of hydrogen, 1.96% of nitrogen, 0.07% of sulfur and 35% of oxygen. In the immediate charcoal chemistry, we found 4.56% of moisture, 22.09% of volatiles, 3.17% of ash and 70.18% of fixed carbon. The residues of palm biomass presented high levels of fixed carbon, structural carbon and lignin, thus having the potential to be used in direct energy production, activated carbon and biochar production.

Keywords: Biomass, Fixed carbon, Lignin, Energy.

ENERGETIC USE OF THE SPENT COFFEE GROUNDS

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Abstract
Brazil is one of the world's largest consumer of coffee, with demand in the order of 21 million sacs per year. This consumption is associated to a large waste production during the preparation of the beverage, generating the spent coffee grounds and this waste can be an interesting source of energy. Thus, the objective of this work was to evaluate the energetic potential of spent coffee grounds. The spent coffee grounds used for energy characterization (proximate analysis and calorific values) was obtained in Laboratory of Wood Quality and Bioenergy of the Federal University of Goiás. After characterization of the biomass, pellets were produced in laboratory pelletizer for later analysis of their characteristics (dimensions, moisture content, densities and durability). The average results for spent coffee grounds were: (i) ash, volatile and fixed carbon content of 2.2; 81.4 and 12.4%, respectively, and (ii) 5594 kcal.kg^{-1} for the higher calorific value. The average results for spent coffee grounds pellets were: (i) moisture content of 4.5% (ii) diameter and length of 6 and 30 mm, respectively (iii) individual density of 1.2 g.cm^{-3}, bulk density of 0.5 g.cm^{-3} and energy density of 6.8 Gcal.m^{-3} and (iii) durability of 98.8%. The biomass and pellet characteristics of the spent coffee grounds attended the quality specifications required by the international marketing standards, except for the ash content. The spent coffee grounds presented characteristics that indicate their potential for use as a source of energy in the form of pellets, with similarity to other biomasses consolidated in energy production, such as *Eucalyptus* and other lignocellulosic residues.

Keywords: bioenergy; residues; pellet

ENERGY POTENTIAL OF BIOMASS RICE HUSK IN BRAZIL

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Abstract
Renewable energy sources have taken considerable place in the world energy matrix and among them biomass is responsible for approximately 8.22% of the national electricity. Rice (*Oryza sativa* L.) is considered one of the most produced and consumed cereals in the world, in Brazil only about 11 million tons of rice are produced for consumption and this number tends to increase. In this way, this work has the objective of analyzing the energy potential of the biomass of the bark orizícola in Brazil and compare the energy production with the quantity of supply. According to data from the last harvests, rice production increased in all regions of the Brazilian territory, with the South region being the largest producer. The production of this cereal generates a great amount of residues, like its husk in example, therefore it can be used for the generation of electric energy, since it has a great calorific power. In addition, this biomass is about 30% of the total weight of the husked rice. This way, the harvest data for 2016/2017 were collected in order to calculate the biomass energy potential in all regions of Brazil, reaching a total of 12,328.1 (MW / year).Currently, twelve mills use rice husks for energy generation and there would not be a better use of the residue, because the rice husk has high content of silica (SiO_2), and its incorrect destination would cause harmful impacts to the environment. Brazil has a considerable total energy potential for the rice husk biomass, and if this potential were used it would generate on average seven times more than the capacity exploited today. Only the state of Rio Grande do Sul generates an average 213.14 KW/year in its mills, which could easily supply more than 3 million people or four times the size of its capital, Campo Grande. With the use of the rice husk biomass for the production of electric power in thermoelectric mills, the husk is used in a sustainable way, providing an economy for the companies of this branch.

Keywords: electrical matrix, *Oryza sativa*, renewable source.

ENERGY POTENTIAL OF RAPID-GROWTH TIMBERS

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Abstract
Themes linked to the study and characterisation of alternative materials have been constantly addressed, with regard to the selection of more appropriate materials for energy applications. With the growing demand for new studies that can enable new species in contrast to *Eucalyptus* spp., providing characteristics close to the growth and energy potential. The *Schizolobium Parahyba* (GUAPURUVU), in the literature, has an annual average increment in solid volume with bark up to 45 m³/ha/year, closely resembling some species of *Eucalyptus* spp., as the hybrid presented. Therefore, the objective of this work will be the physical, chemical and energetic characterisation of the timbers of the hybrid *Eucalyptus grandis x Eucalyptus urophylla* and de *Schizolobium Parahyba* (GUAPURUVU) for the bioenergy application. The physical properties of the two biomasss will be determined, such as moisture content, bulk density and particle size analysis. As for chemical characterisation, the total extraction levels, insoluble lignin, holocelulose, alpha-cellulose and hemicelluloses will be determined. They will be characterized as immediate analysis, in determining the levels of ash, fixed carbon and volatile materials, determination of higher calorific value and thermogravimetric analysis. After determining the physical, chemical and energetic properties of the two biomasss to be studied, it is expected to confirm the energy potential of these materials for bioenergy applications.

Keywords: biomass, bioenergy, calorific power, thermogravimetric analysis.

Acknowledgments: I thank the laboratory of biomass and bioenergy from the UFSCar-campus Sorocaba.

EVALUATION OF ALKALINE PRETREATMENT ON THE ENZYMATIC HYDROLYSIS OF CARNAUBA STRAW RESIDUE

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Abstract

The carnauba (*Copernicia prunifera*) is a typical Brazilian northeast palm tree that plays an important role in the carnaubas´ wax production. This activity presents a huge residue generation, such as the straw that is rich in cellulose, thus showing a potential use in the production of second generation ethanol. However, due to the high lignin and hemicellulose load associated with cellulose in a complex structure, making difficult the enzymatic attack, so having the need of an adequate pretreatment of this material. The objective of this study was to optimize the enzymatic hydrolysis of carnauba straw residue, focusing on the alkaline biomass pretreatment. Therefore NaOH solutions at concentrations of 1.0% (w/v) (PA1), 2.0% (w/v) (PA2), 3.0% (w/v) (PA3) and 4.0% (w/v) (PA4) were used. The chemical compositions of carnauba straw natural and pretreated were evaluated according to NREL, and biomass characterization was also performed by DRX and FTIR analyzes. The natural and pretreated residues were subjected to enzymatic hydrolysis for a period of 96 hours. The materials chemical characterization showed that all the pretreatments used were able to remove a significant amount of lignin and hemicellulose, which can improve the enzymes access, favoring the increase of cellulose conversion. In relation to DRX analysis, it happen an increase in crystallinity index reaching up to 55.15% after the pretreatment PA4, which may be associated to the removal of hemicellulose and amorphous lignin, related to cellulose. After the enzymatic hydrolysis, the PA4 pretreated residue showed the best performance with a conversion of 78%. Spite of a slightly lower performance of the residue that presented higher cellulose conversion, the pretreated material PA2 is an alternative to reduce costs in the production of cellulosic ethanol.

Keywords: carnauba, pretreatment, enzymatic hydrolysis.

EVALUATION OF CHEMICAL COMPOSITION OF TIMBER WASTE OF *Ilex paraguariensis*, *Hovenia dulcis* AND *Eucalyptus robusta* AND ITS ENERGY POTENTIAL

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Abstract
Brazil is a country with a great forestry vocation, in which numerous timber species are grown, which serve to supply the entire forestry-based production chain. In this productive chain there are several processing steps, which lead to waste generation. Among the waste that stand out are the industrial, generated by sawmills, factories of panels and furniture. Usually these waste are burned to generate energy or used for fertilization. In this aspect, the chemical composition of wood can affect these applications, so their knowledge is valuable information. Thus, the objective of the study was to evaluate the chemical composition of wood waste of *Ilex paraguariensis*, *Hovenia dulcis* and *Eucalyptus robusta*. For that, we used the wood shavings of *Hovenia dulcis* (Uva-do-Japão) and *Eucalyptus robusta*, approximately 36 and 40 years old, respectively. As for *Ilex paraguariensis* (Erva-mate), pruning waste were used, in the form of small sticks, with a varied age. The waste were transformed into sawdust and classified using the 40/60 mesh fraction for the determination of ash, extractive and lignin contents based on TAPPI standards. Holocellulose content was determined by subtraction (extractives and lignin). For the *Hovenia dulcis* waste, 66.3% of holocellulose, 24.7% of lignin, 9.0% of extractives and 1.9% of ash were observed. For the waste of *Eucalyptus robusta*, 61.2% of holocellulose, 35.2% of lignin, 3.6% of extractives and 0.1% of ashes were obtained. For *Ilex paraguariensis* waste, 58.6% of holocellulose, 22.9% of lignin, 18.5% of extractives and 3.2% of ashes were observed. Based on the chemical composition obtained, it can be observed that the waste with the greatest potential for energy generation would be *Eucalyptus robusta*, because it presents high lignin content, which increases the calorific value, and low ash content, which is favorable, since it reduces the need to clean the boiler. The *Hovenia dulcis* waste have reasonable potential for generating energy, based on their chemical composition. However, *Ilex paraguariensis* waste would not be suitable for energy generation, since they have low lignin content, high ash content, and high extractive content, which is explained by being pruning waste, basically composed of sticks of young branches. Thus, based on the chemical composition, wood waste of *Hovenia dulcis* and *Eucalyptus robusta*, especially the latter, have potential for energy generation.

Keywords: use of waste; energy potential; wood chemistry

EVALUATION OF ENERGY POTENTIAL: *Sorghum bicolor* WASTES

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Abstract
Studies and uses of biomass for energy purposes have become increasingly frequent. Non-renewable energy sources, such as fossil fuels, are primarily responsible for CO2 emissions into the atmosphere. The aim of this study is to characterize sorghum wastes (*Sorghum bicolor*) physical and energetic properties for energy applications. Physical it will be characterized moisture content. Energetically, proximate analysis (ash, volatile materials and fixed carbon) and higher calorific value will be determined. After the determination of the physical and energetic properties, it is hoped to confirm the potential of these biomasses for energetic purposes.

Keywords: wastes; biomass; thermogravimetric analysis; chemical analysis.

Acknowledgments: Biomass and Bioenergy Research Group - (UFSCar Sorocaba) and CAPES.

IDENTIFYING POTENTIAL EFFECTS OF SUGARCANE EXPANSION ON BIODIVERSITY: AN EVALUATION OF CONNECTIVITY IN A LANDSCAPE IN STATE OF SÃO PAULO, BRAZIL

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Abstract
The expansion of crops – e.g., for bioenergy production – can be associated with direct and indirect effects on biodiversity, as the fragmentation of habitats and, consequently, the connectivity loss. Landscape connectivity is related to specific characteristics that can either facilitate or constrain the movement of species between habitats patches. Both the persistence of species and conservation of ecosystem in fragmented areas can be impacted by changes in landscape connectivity. The aim of this study was to assess changes in the functional connectivity, considering a group of forest-dwelling mammals, associated to intense sugarcane expansion. The selected area corresponds to a landscape of 13,000 ha, located in the municipality of Novo Horizonte, in the central region of São Paulo state, Brazil. The Circuit Theory was applied to model the mammals' group movement pattern, using land use maps of 1995 and 2015 (after and before sugarcane expansion). The index of Probability of Connectivity (PC) was calculated both for habitat and non-habitat areas in each year in order to evaluate the landscape connectivity changes for species with dispersal abilities of 500 m. The results showed that land use change, mainly due to sugarcane expansion (cropped over 40% of region's area by the end of the period) increased the resistance level of the matrix and, as consequence, decreased the species ability to move between habitat patches. Habitat areas were indirectly impacted because land use changes in non-habitat areas reduced the flux between different patches. However, the importance of pasturelands for keeping the connectivity increased in the period. The applied methodology allows the identification of the most affected sites. The procedure can be used for assessing the potential impacts of land use changes in wider areas, and also to support landscape design.

Keywords: bioenergy; land-use-change; functional connectivity

Acknowledgments: The authors would like to thank Capes (Coordination for the Improvement of Higher Education Personnel) for the financial support.

MOISTURE CONTENT IN MECHANICAL PROPERTIES OF BRIQUETTES MANUFACTURED OF PINUS RESIDUES

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Abstract
Silvicultural forest residues have been triggered as suitable sources for the industry power generation. However, some environmental variables such as moisture ultimately influence the mechanical characterization of forest residues as well as their burning rate performance. The aim of this study was to examine the influence of moisture on mechanical properties of briquettes of pinus. The selected materials used to manufacture briquettes were bark and needles of *Pinus* sp. Higher calorific values were 19.118 $J.g^{-1}$ for bark and 18.975 $J.g^{-1}$ for needles. In order to analyze the mechanical strength of the briquettes it was applied tensile test by diametrical compression. When exposed to different moisture content conditions, volumetric expansions dropped from 54,35% to 12,55% for bark and 68,47% to 15,37% for needles, in general aspects. Highest values of mechanical resistance were obtained in briquettes exposed to 10% of moisture while lowest values were observed at 16% of equilibrium moisture content (EM). Therefore, these results trigger important procedures for handling, transportation and storage of briquettes.

Keywords: keywords: forest wastes , solid fuel, mechanical resistance.

Acknowledgments: This work acknowledges the Biomass and Bioenergy Group at UFSCar, Sorocaba as well as CNPq for the research financing.

NEW USES OF COCOA BARK

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Abstract
Cocoa (Theobroma cacao L.) is a tropical source from Central and South America. Cocoa belongs to the Malvaceae family and is widely appreciated by the world for being the raw material for the production of chocolate, serving as a source of income for thousands of farmers. In Brazil, its production covers six states, moving approximately 60 billion dollars per year. In five years, cocoa production in Pará grew from 68.4 thousand tons produced annually to 105.8 tons annually, which gives the state a participation of 42% in national production. The average growth of local production is 13% per year. The bark of the fruit of the cacao is a byproduct that in most cases is not used. The authors point out that fresh fruit peels can be used for animal feeding, energy production (methane gas) and organic fertilization in the form of compost. In the present work, the Theobroma cacao L bark was used as biorefinery feedstock. The chemical composition of the raw material showed high contents of amounts of hemicelluloses and cellulose and moderate lignin. This makes Theobroma cacao a suitable lignocellulosic material for the obtaining of biorefinery products. The treatments were applied for its fractionation Acid hydrolysis, in order to evaluate the efficacy and yield of the different biorefinery methods (temperature and time). The liquid fractions were characterized and analyzed by different techniques (ATR-IR, HPLC). The results confirmed that is possible to obtain hemicellulosic products that could be applied for the obtaining of several products by fermentation.

Keywords: biorefinery; biomass; acid hydrolysis

Acknowledgments: The authors thank PROPESP / UFPA, for supporting research

OBTAINING A NEW MATERIAL FROM TWO NATURAL RESOURCES

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Abstract
Black liquor is the byproduct of the kraft pulping process widely used as source for energy generation into the pulp and paper industries. This product is an industrial waste containing many organic compounds such as Na_2CO_3, Na_2S, Na_2SO_4, H_2S, $Na_2S_2O_3$ and dissolved lignin. This kraft lignin can be extracted and applied for higher value-added products due to its antioxidant, antifungal and antibacterial properties. Lignin is an amorphous biopolymer formed of phenylpropane units with more than 50% of aromatic compounds. Thus, the combination of lignin with thymol – a natural biocide extracted from plants – may result in a product with interesting characteristics for preservation of lignocellulosic materials against biodeterioration. The present study aimed to produce thymol-lignin suspensions and analyze their thermal behavior and chemical composition. The suspensions were prepared as following: 20mL H_2O and 3,5mL HCl 5mol/L were mixed, followed by the addition of thymol diluted in 1:3 EtOH and lignin solution dissolved in 1mol/L NaOH through vigorous agitation. Two thymol-lignin suspensions were produced: experiment 1 consisting of 25% thymol, 50% lignin and 25% H_2O and experiment 2 consisting of 50% thymol, 25% lignin and 25% H_2O. These suspensions were subjected to midinfrared spectroscopy with attenuated total reflectance (ATR) to verify the organic compounds . The material was oven-dried at 60±3°C and analyzed by thermogravimetric analysis (TGA). The thermograms showed chemical interaction between thymol and lignin, in which the samples from experiments 1 and 2 showed initial water loss up to 100°C and later the thymol degradation occurred between 100 and 180°C, after which, they presented a behavior similar to that of lignin. The spectra collected by midinfrared showed characteristic peaks of lignin and thymol, besides shifts in some peaks probably due to the chemical interaction between them, observed in the bands 1337 and 1636cm^{-1}, referring to the hydroxyl groups and the carbon and hydrogen bonds, respectively. Therefore, the method used for preparation of the suspensions was efficient to mix lignin and thymol, which were naturally immiscible in water. The thermal behavior and the chemical composition illustrate a lot of potential applications for this material, supporting the appreciation to develop new products from kraft lignin.

Keywords: black liquor, industrial wastes, lignin, thymol, biorefinery.

Acknowledgments: This work was supported by EmbrapaFlorestas and CAPES.

OPTIMIZATION OF THERMAL PROCESSES FOR THE USE OF RESIDUES FROM BIOETHANOL AND SUGAR PRODUCTION IN BRAZIL

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Abstract

Within the BMBF-funded Brazilian-German cooperation project ASHES, the thermal utilization of bagasse and other residuals from the sugar processing industry was examined. In the laboratory scale, tests were carried out on the KLEAA system of the KIT-ITC to determine relevant fuel parameters. Subsequently, Fraunhofer UMSICHT carried out tests on combustion plants on a technical scale with different plant sizes of 30 kW, 100 kW and 440 kW. The primary objective was to gain knowledge regarding the combustion and emission behavior of these fuels. Experiments were also carried out at the CUTEC's art-fuel facility, a gasification unit in the pilot plant scale, and thus gained information regarding the gasification behavior of bagasse and other residuals from sugar cane processing industry. These findings were used to identify optimization potentials at various points and elaborate concepts for their improvement. Within in the next steps of the project the further development of these concepts will be focused. In cooperation with the Brazilian project partners several of these concepts should be implemented into practice after the project.Tests in pilot scale furnaces with bagasse, sugar cane straw and various mixtures have shown that very efficient combustion with low residual carbon contents in the ash and low CO emissions is possible. Due to the nature of the bagasse, the handling behavior of the bagasse is difficult. By compacting not only the transportability is considerably increased, but also the use of screw conveyors possible, which allows use in smaller decentralized systems. In addition, the release of particulate matter is significantly reduced. In contrast to bagasse, the use of sugar cane straw mainly leads to higher PM emissions, but also chlorine concentrations increase significantly. Bagasse-fired power plants in Brazil are usually equipped with scrubbers, which are mostly operated with fresh water. On the one hand, these systems have weaknesses, in particular with regard to their separation characteristics, in particular with fine particles; on the other hand, their use is associated with a high water consumption. Against this background, various considerations have been made and the results for a possible retrofit option are shown below. Since electrostatic precipitators have a low pressure loss, they would be relatively easy to retrofit in an existing system. In the presentation, estimates are shown which display possible reduction effects of particulate matter with regard to the entire plant park.

PELLETIZING WITH SORGHUM PELLETS (*Sorghum bicolor*): PROSPECTS FOR CLEAN ENERGY PRODUCTION

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Abstract
Pelletization is the technique most recently used in Brazil to compact biomass of agricultural or agroforestry waste material called pellet with high energy density. Therefore, the objective of this study was to evaluate the energy potential of sorghum derived pellets (Sorghum bicolor (L.) Moench) after determining their physical and chemical properties. In general, all sorghum pallets have the minimum values specified by EN 14961-6 (DIN, 2012) for non-wood pallets. The pellets produced were submitted to three different treatments: T1: 100% sorghum, T2: sorghum + 2% starch and T3: sorghum added in steam. The results were evaluated and compared to the European marketing standards and indicated that the pellets produced with sorghum + 2% starch presented the worst performance with higher humidity, low bulk density, higher fines production and low energy density. However, the pellets produced only with sorghum presented the highest values of energy density and apparent, besides offering greater resistance. We conclude that the treatment with 100% sorghum is the most feasible for the production of pallets with homogeneous by-products and easy to handle.

Keywords: Sorghum, pelletization, energy potential.

PHYSICAL-CHEMICAL CHARACTERIZATION, THERMAL AND ENERGY POTENTIAL OF BIOMASS OF *Euterpe oleraceae* MART. PRODUCED IN COMMUNITY IN THE STATE OF PARÁ

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Abstract
Brazil is a country that has large stocks of biomass of agricultural, forestry, industrial and still residual origin, being highlighted the Pará that presents itself as one of the states with potential to biomass converter in energy, due to the diverse economic activities, including The extraction of wood and non-timber products, especially in isolated regions, located in the Amazon, where a large part of the problems can be minimized through the use of alternative energy sources such as bioenergy. The objective of this study was to determine the physical, chemical and thermal characteristics of the bunches generated from açaí extractivism in a community in the municipality of Cachoeira do Arari, State of Pará, as well as to identify the energy potential of this biomass in the locality. The region chosen in the study is located in the Island of Marajó/PA because it is an isolated locality, without the supply of electric energy and that presents as main product the açaí. How samples of bunches were collected in the properties visited. After-sales of the açaí extraction process were: moisture content; density; content of volatile materials; ash content; fixed carbon content; upper and lower calorific value; and the energy potential. A high moisture content of açaí bunches (65.97%) was found; an average density value to 0.39 g/cm^3; an average of high volatile material (75.78%); an analysis of the curls presented ashes content (3.62%); An average of fixed carbon content was 20.60%; the average calorific value of which is 3.973 kcal/kg and less than 3.426 kcal/kg; and the result of the biomass energy potential in the locality was supplied to the quantity available. Through this research, it is possible to conclude that although there is a guarantee of good availability of biomass of bunches for energy finance, its use can only be effected with a previous drying treatment to reduce the moisture content to an appropriate value, which after this process would increase its availability for energy generation in several ways, especially electric and charcoal.

Keywords: açaí, bioenergy, waste

Acknowledgments: This work acknowledges the Forest Products Technology-Bioenergy Laboratory at UFRA, Belém.

PRESSURIZED WATER PRETREATMENT TO INCREASE SUGAR PRODUCTION FROM GREEN COCONUT

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Abstract
In light of the environmental issues, the reuse of lignocellulosic industrial waste has been proposed. However, a pre-treatment of these materials is necessary, aiming at the accessibility of the cellulose in the following stages of production. Therefore, this study focuses on evaluating the sugar production from green coconut during pressurized water pretreatment and at post enzymatic hydrolysis of the pretreated biomass. The green coconut shell was subjected to 70 ° C, 150 bar and a water flow rate of 1 $mL.min^{-1}$ during 4 hours. Samples collected periodically from the system output stream were analyzed by HPLC and Folin Ciocalteu method. The solid fraction was characterized (chemical composition, XRD and FTIR), submitted to enzymatic hydrolysis and the sugar monomers produced were quantified. The liquid fractions of the pretreatment provided a defined profile of released glucose, xylose, phenolic components and acetic acid from the green coconut shell over time. After 40 min of operation, most of fermentable sugars were released under these conditions, forming a liquor with a sugar content about 10 g/L. Post-treated biomass showed a reduction of cellulose (26% to 17%) and hemicellulose (23% to 18%) and an increase in lignin content (32% to 44%). Despite this new biomass chemical composition, the pretreated material had lower crystallinity indexes and modifications in its chemical groups. Such conformation favored cellulosic conversion from 15 % (untreated biomass) to 55% (no washed pretreated biomass), producing 63.5% more glucose than the untreated green coconut shell during enzymatic hydrolysis. Thus, the pressurized pre-treatment favored the fermentable sugar production from the green coconut husk and there is also the possibility of utilizing the sugars present in the pre-treatment liquid fraction.

Keywords: green coconut, pressurized pretreatment, enzymatic hydrolysis.

PRODUCTION OF CELLULOSE ACETATE FROM THE LIANAS

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Abstract
Lianas are woody-stemmed vines that begin their lives as terrestrial seedlings and grow by leaning on other plants, thus spreading through their crowns in search of the light they need to survive. Research carried out on the biotechnological production of polymeric materials from alternative sources of raw material has become more frequent because it presents low cost in its execution and has an economic value. The use of alternative lignocellulosic raw materials (straw, pruning waste, forest, agricultural or industrial waste ...) and the application of new green technologies are being under intensive investigation for biorefinery development processes. Due to the abundance of Lianas in all regions, especially in the Amazon region, the present study had as objective to evaluate the chemical composition of the lianas to obtain biorefinery products and the production of cellulose acetate from the lianas. Cellulose acetate can be produced by two different methods: Homogeneous or heterogeneous acetylation reactions. However both occur through the use of acetic acid as solvent, acetic anhydride as an acetylating agent, and sulfuric acid as the catalyst. The chemical composition of the raw material showed high levels of lignin and moderate amounts of hemicellulose and cellulose, as well as the presence of inorganic and extractives. This makes the lianas present as a promising lignocellulosic material for use in biorefineries.

Keywords: biorefinery; biomass, chemical composition

Acknowledgments: The authors thank PROPESP / UFPA, for supporting research

QUALITY CHARACTERIZATION OF BRIQUETTES PRODUCED FROM SUGARCANE RESIDUES

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Abstract
The Brazilian sugar cane production is currently the first one in the world – it is responsible for 11% of the agricultural residues, evidencing the necessity of studies that can provide more knowledge about this material, such as better destinations for it. Briquettes and pellets can be an option to produce biofuels made by agricultural residues compression. This study aims to provide the quality characterization of the briquettes made by different residual concentrations of sugar and straw. The residues were dried and mixed in defined proportions (5 treatments). The materials were chemically characterized by ash content, volatile matter and fixed carbon. In addition, with the briquettes already made, it was observed their longitudinal expansion, also resistance and friability tests were made. The sugarcane bagasse presented lower content of ash and volatile matter and higher fixed carbon content when compared tothe straw. The briquettes manufactured essentially with straw presented smaller dimensional stability, since they presented greater longitudinal variation. Thus, it can be observed that briquettes with a higher proportion of sugarcane bagasse showed higher compressive strength and lower friability, presenting lower percentage of fines.

Keywords: biomass, straw, waste, energy.

Acknowledgments: CAPES and BIomass and Bioenergy Group

SIMULATION AND OPTIMIZATION OF A PROCESS TO IMPLEMENT CARBON CAPTURE SYSTEMS TO TREAT GAS WASTE

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Abstract
The greenhouse gas most discharged in atmosphere and probably the main contributor to the climate change is the carbon dioxide (CO_2). Among the anthropological emissions, more than 50 % come from gas effluent of energy and heat productions and gas waste of some industrial processes. In this context, the CCUS (Carbon Capture, Utilization and Storage) processes have been an important way to mitigate the gas waste problem. However, it is a challenge to find a low-cost design to operate this process efficiently. Then, in order to promote the advancement and applicability of carbon capture processes, an industrial process comprising chemical absorption was simulated using a process simulator. Design and operating parameters were handled taking into account associated capital and operating costs. This process was optimized using the particle swarm optimization (PSO) with Scilab making a direct communication with the simulator. By using this optimization method it was possible to achieve the best configuration and operating conditions of the absorption system to minimize the costs maintaining the amount of CO_2 in the gas outlet stream lower than 5 ppm.

Keywords: gas waste, carbon capture, absorption, optimization.

THE INFLUENCE OF THE EXTRACTIVE CONTENT IN THE HIGH HEATING VALUE OF FOUR TYPES OF GRASS

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Abstract
With the growing demand for energy consumption, it is necessary to search for alternative energies. This work presents new possibilities in the use of different materials as biofuels. The objective of this work is to verify the influence of extractive content on high heating value. The entire methodology was based on the TAPPI t204-om-97 standard, using the following materials: T1: Brachiaria grass (Brachiaria sp.), T2: Elefante grass (Pennisetum purpureum), T3: Colonião grass (Panium maximum) and T4: Gordura grass (Melinis minutiflora), all collected in the area of the Federal University of São Carlos campus in the city of Sorocaba. The results found for T1, T2, T3 and T4 where 9.23%, 14.08%, 13.24%, 15.12% average for substances extracted in organic solvent (cyclohexane and ethanol) and 19.63%, 9.44%, 11.26%, 12,74% for substances extracted in water. The total extractives were 28,86%, 23,52%, 25,71% and 28,06%. All treatments had close values of high heating power when tested with extractives, but behaved differently when tested without extractives. more studies will be needed to test how extractives in organic solvent or water affect the high heating value.

Keywords: bioenergy; renewable sources; grass; calorific power

Acknowledgments: This work acknowledges the Biomass and Bioenergy Laboratory at UFSCar, Sorocaba

THE RECYCLING OF PHOTOVOLTAIC MODULES BEFORE THE END OF THEIR USEFUL LIFE UNDER THE LOSS OF ENERGY GENERATION EFFICIENCY IN FIRST GENERATION MODULES

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Abstract
The growing demand for energy means that the search for and use of alternative sources of clean energy generation is intensifying. In this context, the use of the solar source becomes increasingly increasing through the use of photovoltaic modules. The useful life of the alternative can be consulted as it is useful for the modules in an average of 20-25 years, in addition to there being a possibility of subjecting the modules to suffer problems throughout their useful life which make it a generation efficiency reduced, thus requiring replacement by new families for failure or end of life. In this way large volumes of solar modules become waste. In order to recover raw materials and mitigate environmental impacts, a recycling of materials can be an interesting route. Thus, the objective of this work is a study of the feasibility of recycling photovoltaic modules in front of the loss of efficiency of the generation of modules in first generation modules and thus answering the question of where the development of a module replacement previously installed by virtue of A cost ratio of energy and gas generation with a recycling of this material. There is still no research in question, it is a promise because with a NBR10004, it indicates a danger of photovoltaic modules, that this waste is classified as class I (hazardous waste) and that the European Union requires all suppliers of photovoltaic solar panels to finance collection and recycling costs at end of life.

Keywords: recycling; photovoltaic modules; energy efficiency.

Acknowledgments: I thank Coordinator Antônia Sônia Alves Cardoso Diniz from the Energy Studies Group of PUC Minas for the support in the revision of this document.

FULL PAPERS

THEME: ALGAE

Acutodesmus obliquus CULTURE USING GLYCEROL AS EXTERNAL CARBON SOURCE TO INCREASE LIPIDS PRODUCTION: EXPERIMENTAL AND MATH MODEL

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Abstract

Microalgae have potential to third generation biofuels production, it may partially substitute fossil fuels. Therefore, microalgae can be cultivated in different medium, where it can have diverse lipids, carbohydrate and proteins concentration to biofuels production. Studies use glycerol as a carbon source to increase the lipids that in the biodiesel production are used. Thus, this work aims to evaluate an experimental and mathematical model of *Acutodesmus obliquus* microalgae lipids and cell growth in two culture mediums, one using CHU in autotrophic medium and other using a mixotrophic medium with glycerol as external carbon source. Initial inoculum containing 200 cell. mL^{-1} of *Acutodesmus obliquus* was inserted in 10 samples in the erlenmeyers with 1.6 L volume each, using autoclaved CHU medium. It was increased 5 g glycerin in each sample. The culture period was 15 days, with airflow rate 1.5 m^3. s^{-1} and constant light incidence 720 - 760 lumens, at 22 ± 2 ºC. Lipids are quantification using Folchet al., method in 1957 modified by Hosseini et al., in 2015. The microalgae growth was analyzed with dry biomass gravimetric measurement. Results obtained in the experiments and math model show that high microalgae growth and lipids production was in mixotrophic medium using glycerol. Then, it concludes experimentally and mathematically that the used glycerol can be efficient to increase lipids production for this microalga.

Keywords: mathematical model, *Acutodesmus obliquus*, lipid production.

Introduction

Microalgae have technological applications that are promising in the biofuels generation. However, the microorganisms are lipids and carbohydrates producers, where the first can beused in biodiesel production (TAN et al., 2018) and the second can be used in third generation ethanol production. These technologies are still limited to laboratory scale, being necessary studies for industrial production (ZABED et al., 2017). In this context, the transient mathematical models development for the lipid production from microalgae determination and control is a tool that predicts and potentiate an oil from biomass generation.

Some models have been proposed to describe the microalgae growth rate related to nutrients limitation (nitrogen, phosphorus, potassium, carbon sources, etc.) and light incidence, even involving the modeling of biomass, lipid and sugar yields in (BEKIROGULLARI, M. et al., 2017; DESCHÊNES, J.S. AND WOUWER, A.V, 2015; DESCHÊNES, J.S. AND WOUWER, A.V, 2016; MAIRET, F. et al, 2011). Therefore, the models that consider two or more parameters that contribute equally to microalgae biomass growth are called multiplicative models (BEKIROGULLARI, M. et al., 2017).

Thus, the literature proposes a dynamic model for the lipids production from *Isochrysis affinis galbana* microalgae biomass. The proposed model considers that the carbon input in the cell is divided between two storage forms, sugars and lipids, as well as other elements called functional ones (carbohydrates and proteins are included) (MAIRET, F. et al, 2010). This study proposes a dynamic model that represents lipid production in two different culture media development, using CHU and CHU half with 5 % glycerol. For the model adjustment, it will be used the data referring to the experimental races. The light incidence and airflow on this case will be kept constant.

Materials and methods

Acutodesmus obliquus microalgae and culture medium

The inoculum was isolated at the Nucleus of Research and Sustainable Self Development (NPDEAS), located at the Federal University of Paraná. The species is native to the city of Curitiba and it was obtained from the local sanitation network. The experiments were divided into two stages and cultured for a 15 days period, with light radiation between 720 – 760 lux, air flow 1.5 $m^3.s^{-1}$, in erlenmeyers with volumes of 1.6 L. The first experiment used 15 samples containing adapted CHU medium (SANTOS, 2016), and the second 15 samples containing adapted CHU medium and 5 $g.L^{-1}$ technical glycerol. Each batch erlenmeyers were sacrificed every 3 days in order to analyze biomass and total lipids increase.

Microalga growth analyzes

Dry biomass was quantitated every three days using a micro glass fiber membrane with 0.7 μm particulate retention and 10 mL inoculum volume. Afterwards, the membrane containing the biomass remained in the oven at 100 ºC for 24 h, and was subsequently measured using SHIMADZU AUW220D analytical balance with four decimal places accuracy. The total dry biomass production was calculated using day 15 for the inoculum grown in CHU medium and day 9 for the inoculum cultured in CHU + glycerol medium, by follow equation.

$$P = \frac{b_f}{\Delta T} \tag{1}$$

Where P is the total biomass production in (mg.L-1.days-1), bf is the biomass concentration in the crop in g.L-1 and ΔT is the time variation in the cultivation in days.

For total biomass productivity below equation was used.

$$P_t = \left(\frac{P_{chu+gli}}{P_{chu}} - 1 \right) \times 100 \tag{2}$$

Where, P_t is the total biomass productivity in %, $P_{chu+gli}$ is the inoculum in CHU + glycerol medium in ($mg.L^{-1}.days^{-1}$) total production and P_{chu} is the inoculum in CHU medium in ($mg.L^{-1}.days^{-1}$) total production.

Obtaining biomass for lipid analysis

To obtain the biomass the inoculum pH was modified in a range between 6 and 7 using 80 % hydrochloric acid (HCl). Subsequently, 0.210 g of Tanfloc was inserted for each 1 L of inoculum. After that, the decantation was waited, then filtered and the biomass dried in an oven at 60 °C for a period of 24 hours.

Total lipid content

The method for lipids quantification used Folch et al. (1957) adapted by Hosseini et al. (2015). Initially weighed 0.05 g of biomass previously ground in a crucible with pistil. The samples were then placed on the SCHUSTER L200 ultrasound for a 30 minutes period with a 40 kHz frequency. These were then centrifuged at 4000 rpm for 15 minutes in the Daiki 80-2B-DM centrifuge. After these procedures, the supernatant was removed from the sample by placing it in a pre-weighed penicillin tube. The steps described above were performed three times in each sample. Subsequently, the penicillin tubes were placed in the oven at 60 °C until solvent total evaporation. The lipid content was calculated using the gravimetric method.

The total lipid yield considered day 15 for the inoculum grown in CHU medium and day 9 for the inoculum cultured in CHU + glycerol medium and was obtained by equation:

$$P_{tlip} = \left(\frac{P_{lip(chu+gli)}}{P_{lip(chu)}} - 1 \right) \times 100 \qquad (3)$$

Where P_{tlip} is the lipids total productivity in %, $P_{lip(chu+gli)}$ is the lipids in CHU + glycerol medium in ($mg.L^{-1}.days^{-1}$) total production and $P_{lip(chu)}$ is the lipids in CHU medium in ($mg.L^{-1}.days^{-1}$) total production.

Mathematical modeling

The elaborated mathematical modeling was based on the microalgae cellular mechanisms different hypotheses for the glycerol use (PARANJAPE, LEITE E HALLENBECK, 2016):

a) The microalgae may not have the necessary system to incorporate the medium glycerol and, this way, the molecule presence does not interfere in the culture;
b) Glycerol can act as an inhibitor in the microalgae metabolism and cause a lower cellular development;
c) The glycerol molecule can be absorbed and converted into energy for the photosynthesis accomplishment, causing a greater growth;
d) Glycerol can be stored inside the cell for other purposes, not only for energy reserves and, for this way, reducing cell growth.

The photosynthesis speed for glucose production can be described as depending on the glycerol concentration as shown in following equation:

$$v_f = v_{\max f} [X] v_{gli} \qquad (4)$$

Where, v_f is photosynthesis speed, v_{maxf} is the photosynthesis maximum speed, v_{gli} is a term that is influenced by the glycerol concentration in the medium and [X] is the total biomass concentration.

The term v_{gli} can be described as:

$$v_{gli} = \frac{K_{gli}}{K_{gli} + [gli]} \qquad (5)$$

Where [gli] is the glycerol concentration in the culture medium and K_{gli} is the saturation constant for glycerol.

The lipid production rate can be described as:

$$v_{lip} = v_{lpglc} + v_{lpgli} \qquad (6)$$

Where v_{lpglc} is the rate lipid production from the glucose produced in photosynthesis and v_{lpgli} is the lipids production rate from glycerol.

The lipid production rate from the glucose produced in photosynthesis can be described as:

$$v_{lpglc} = \frac{V_{max\,lglc}[X][glc]}{K_{lglc} + [glc]} \qquad (7)$$

Where $v_{maxlglc}$ is the maximum lipids production rate from glucose, [glc] is the glucose concentration within the cell and K_{lglc} is the saturation constant for glucose.
The lipid production rate from glycerol can be described as:

$$v_{lpgli} = \frac{V_{max\,lg\,li}[X][gli]}{K_{lg\,li} + [gli]} \qquad (8)$$

Where $v_{maxlgli}$ is the maximum lipid production rate from glycerol and K_{lgli} is the saturation constant for glycerol.

The other cellular components (proteins, carbohydrates and the like) production can be described as:

$$v_x = v_{max\_x}[X]v_{glc}v_{nh3} \tag{9}$$

Where v_{max_x} is the other cells components maximum production speed, v_{glc} is the term that takes the available glucose effect and vnh3 is the nitrogen effect term.

The v_{glc}can be described as:

$$v_{glc} = \frac{[glc]}{K_x + [glc]} \tag{10}$$

Where [glc] is the glucose concentration within the cell and k_x is the saturation constant for glucose.

The term v_{nh3} can be described as:

$$v_{nh3} = \frac{[N]}{K_{nh3} + [N]} \tag{11}$$

Where [N] is nitrogen concentration in the culture medium and K_{nh3} is the saturation constant for nitrogen.

The mass balance for system components ([N], [gli], [glc], [lip] e [X]) can be described as:

The parameters used in the modeling are: v_{maxf}=107291.6628; k_{gli}=379504.3850; $v_{maxlglc}$=0.0099; k_{lglc}=6369.4939; k_{lgli}=0.00000002; v_{maxx}=0.10525907; k_x=110.066236; k_{nh3}=0.213e-4 and $v_{maxlgli}$=0.0021; y_{nx}=0.29.

Results and discussion

$$\frac{d[N]}{dt} = -y_{N/X}v_x \tag{12}$$

$$\frac{d[gli]}{dt} = -v_{lpgli} \tag{13}$$

$$\frac{d[glc]}{dt} = -v_{lpglc} - v_x + vf \tag{14}$$

$$\frac{d[lip]}{dt} = v_{lpgli} + v_{lpglc} \tag{15}$$

$$\frac{d[X]}{dt} = v_{lpgli} + v_{lpglc} + v_x \tag{16}$$

The glycerol concentration used in the experiment was established as 5 $g.L^{-1}$, which is the ideal value for *Acutodesmus obliquus* microalgae cultivation to biomass increase (ANDRULEVICIUTE et al. 2014). The simplified model was able to describe many of the experimental results.

Figure 1 shows the dry biomass and lipids increase in the inoculum cultured in CHU medium (figure A and C) and in CHU + glycerol medium (figure B and D), respectively.

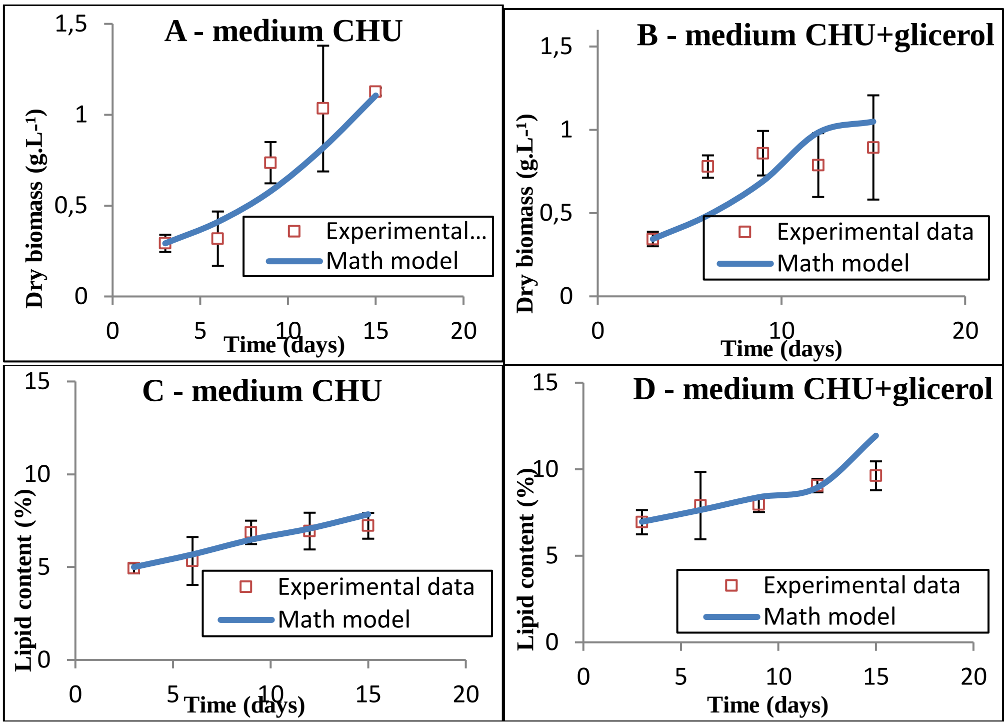

Figure 1 – (A) Inoculum biomass in CHU medium increase. **(B)** Dry biomass of inoculum in CHU + glycerol medium increase. **(C)** Lipids in the inoculum in CHU medium increase. **(D)** Increase of the lipids in the inoculum in CHU + glycerol medium.

The action mechanism in the microalga in relation to the glycerol can use the tri-alcohol to generate other products inside the cell, not acting directly as energy source for the photosynthesis production. This way, the cellular growth presented will be smaller (PARANJAPE, LEITE AND HALLENBECK, 2016), fact that was observed in the experimental data, proving the hypothesis **(d)** that was established in the mathematical model.

Using equation (2) and (3), the total productivity dry biomass and lipid biomass were calculated, respectively, for the inoculum cultured in CHU medium and for the inoculum cultured in CHU + glycerol medium, considering on the first the 15th cultivation day and the 9th day on the second. The total productivity values for the inoculum grown in CHU + glycerol medium were 27.16 % higher for biomass and 83.81 % higher for lipids, compared to the inoculum cultured only in CHU medium.

Conclusion

The mathematical model was adjusted in relation to the experimental data great majority. It was observed that some points were not described, which can be justified suggesting that the model can be adjusted or repeated experiments for results better analysis. In general, it is observed that the use of 5 g.L^{-1} of glycerol provides a higher total biomass and lipid yield in the cells, being 27.16 % and 83.81 % greater than culture in medium containing only CHU. These data demonstrate that mixotrophic cultivation with glycerol is an alternative to increase the lipids productivity, making the biodiesel from microalgae production economically viable.

References

Ndruleviciute, Vaida et al. Biomass and oil content of *Chlorella sp.*, *Haematococcus sp.*, *Nannochloris sp.* And *Scenedesmus sp.* Under mixotrophic growth conditions in the presence of technical glycerol. *Journal Of Applied Phycology*, v. 26, n. 1, p.83-90, 2013.

Bekirogullari, M. et al. Production of lipid-based fuels and chemicals from microalgae: An integrated experimental and model-based optimization study. *Algal Research*, v. 23, p.78-87, 2017.

Deschênes, Jean-sébastien; Wouwer, Alain Vande. Dynamic Optimization of Biomass Productivity in Continuous Cultures of Microalgae *Isochrysis galbana* through Modulation of the Light Intensity. *Ifac-papersonline*, v. 48, n. 8, p.1093-1099, 2015.

Deschênes, Jean-sébastien; Wouwer, Alain Vande. Parameter Identification of a Dynamic Model of Cultures of Microalgae *Scenedesmus obliquus*- An experimental study. *Ifac-papersonline*, v. 49, n. 7, p.1050-1055, 2016.

Folch, J., Lees, M., Sloane Stanley, G.H. A simple method for the isolation andpurification of total lipides from animal tissues. *J. Biol. Chem.*v.226, n. 1, 497–509, 1957.

Hosseini, Nekoo Seyed et al. Microalgae cultivation in a novel top-lit gas-lift open bioreactor. Bioresource *Technology*, v. 192, p.432-440, 2015.

Mairet, Francis et al. Modelling lipid production in microalgae. *Ifac Proceedings Volumes*, v. 43, n. 5, p.493-498, 2010.

Mairet, Francis et al. Modelling microalgae growth in nitrogen limited photobiorector for estimating biomass, carbohydrate and neutral lipid productivities. *Ifac Proceedings Volumes*, v. 44, n. 1, p.10591-10596, 2011.

Paranjape, Kiran; Leite, Gustavo B.; Hallenbeck, Patrick C.. Strain variation in microalgal lipid production during mixotrophic growth with glycerol. *Bioresource Technology*, v. 204, p.80-88, mar. 2016.

Santos, Beatriz. *Estratégias para aumentar a produtividade de biomassa de microalgas com carbono orgânico*. Dissertação (Mestrado em Engenharia e Ciência dos Materiais) – Setor de tecnologia, Universidade Federal de Paraná, Curitiba, 2016.

Tan, Xin Bei et al. Cultivation of microalgae for biodiesel production: A review on upstream and downstream processing. *Chinese Journal Of Chemical Engineering*, v. 26, n. 1, p.17-30, 2018.

Zabed, H. Et al. Bioethanol production from renewable sources: Current perspectives and technological progress. *Renewable And Sustainable Energy Reviews*, v. 71, p.475-501, 2017.

ENZYMATIC HYDROLYSIS OF THE BY-PRODUCT GENERATED IN THE CARRAGEENAN PROCESSING FROM *Kappaphycus alvarezii*, FOLLOWED BY ACID HYDROLYSIS

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Abstract
Carrageenan is an important hydrophilic colloid that accumulates in numerous species of red macroalgae. In the processing of *Kappaphycus alvarezii* to obtain carrageenan, is generated a by-product composed mainly of glucans and galactans. The main objective of this study was to evaluate the enzymatic hydrolysis followed by an acid hydrolysis (mild conditions) of this by-product, to produce monomeric sugars. The by-product was subjected to enzymatic hydrolysis at 45°C and 120 rpm, using an enzymatic load of 10 $FPU.g^{-1}$ of three commercial enzymatic extracts: Cellic CTec 2 (Novozymes), Celluclast (Novozymes) and Cellulase (Sigma). All the experiments were performed at 2% (w/v) consistency. After 72 hours of hydrolysis, a total conversion of glucan to glucose was achieved using the three extracts under study. However, the Cellic CTec 2 extract showed a higher rate of hydrolysis. It was conducted an enzymatic hydrolysis using the commercial enzymatic extract Cellic CTec 2 with an enzymatic load of 100 $FPU.g^{-1}$. This experiment showed conversion percentages of glucan and galactan of approximately 100% and 30%, respectively, after 72 hours of hydrolysis. Besides, it was possible to observe an almost complete hydrolysis of glucan (92.7%) in the first 4 hours. An acid hydrolysis in mild conditions was performed aiming to increase the hydrolysis of glucan and galactans but avoiding the formation of hydroxymethylfurfural. For the acid hydrolysis was used the enzymatic hydrolyzate obtained using the extract Cellic CTec 2 (enzymatic load: 100 $FPU.g^{-1}$) after 4 hours of hydrolysis. It was performed at mild conditions (H_2SO_4 0.5% w/v, 80°C, 90 minutes, 120 rpm). After the acid treatment, was observed an increase of the glucose and galactose concentration from 12.8 to 14.6 $g.L^{-1}$ and from 0.2 to 1.4 $g.L^{-1}$, respectively. Additionally, the concentration of hydroxymethylfurfural reached 0.006 $g.L^{-1}$. It can be concluded that enzymatic hydrolysis followed by acid hydrolysis could be a good strategy for production of monomeric sugars from the by-product of carrageenan production. It was demonstrated that the acid treatment at mild conditions increase the concentration of monomeric sugars and do not produce a significantly amount of hydroxymethylfurfural.
Keywords: Enzymatic hydrolysis, acid hydrolysis, *Kappaphycus alvarezii*.

Introduction

At present, large amounts of ethanol are produced from sugarcane, corn starch and lignocellulosic materials. However, lignocellulosic materials are very recalcitrant to the enzymatic hydrolysis of polysaccharides, requiring a chemical pre-treatment of the material and subsequent hydrolysis for conversions above 30% (MENDES et al., 2011). Another renewable source that can be used to produce biofuels is algae. They are terrestrial and aquatic plants and many species contain high percentages of carbohydrates and low percentage of lignin (MARTONE et al., 2009; WI et al., 2009; GE; WANG; MOU, 2011; JOHN et al., 2011; WEI; QUARTERMAN; JIN, 2013). Due to the low lignin content, polysaccharides are more accessible to enzymatic treatments, which makes algae less recalcitrant than terrestrial plants (John et al. 2011; Masarin et al. 2016). *Kappaphycus alvarezii* is a seaweed of high commercial value, grown as a raw material for the industrial production of carrageenan (ESTEVEZ; CIANCIA; CEREZO, 2004) and has as its main component carbohydrates, reaching values between 55.4% and 78.3% (MEINITA et al. 2012). In the processing of *Kappaphycus alvarezii* to obtain carrageenan, is generated a by-product composed mainly of glucans and galactans. The main objective of this study was to evaluate the enzymatic hydrolysis followed by an acid hydrolysis (mild conditions) of this by-product, to produce fermentable monomeric sugars.

Materials and methods

Biomass of *K. alvarezii* was washed with distilled water and dried at room temperature. After drying, it was treated with KOH solution (6%, w/v), exposed to the sun, washed with distilled water and oven dried. The treated biomass was subjected to extraction with hot water and the suspension generated was passed through a filter. The part retained in the filter was considered "insoluble by-product" and the part that passed through the filter was denominated "semi-refined carrageenan".
The by-product was hydrolyzed with 72% sulfuric acid (H_2SO_4) at 30°C for 1 hour and then with 4% H_2SO_4 at 121°C for 1 hour (FERRAZ et al., 2000; MASARIN et al., 2011). After that, the hydrolysate was filtered, and the material retained in the filters was dried, cooled and weighed. This material retained in the filters corresponds to the insoluble aromatics. For the detection of monomeric sugars, the filtrate obtained before, was injected in a HPLC system. The method described by Kjeldahl with the modifications of the National Renewable Energy Laboratory (NREL) (HAMES; SCARLATA; NREL, 2008) was used for protein determination. For determination of sulfate groups, the samples were subjected to treatment with hydrochloric acid (HCl) and barium chloride (BaCl) as described by Hayashi et al. (2007). The ash content was determined by gravimetry (SLUITER et al., 2005).

The obtained by-product was hydrolyzed with the commercial extracts of cellulases (Cellic CTec 2, Celluclast, Cellulase from Trichoderma) using 10 $FPU.g^{-1}$ substrate. All reactions were performed at 2% (w/v) of consistency in 50mM sodium acetate buffer, pH 4.8 under shaking at 120rpm at 45°C for 72h (Masarin et al. 2016). It was conducted an enzymatic hydrolysis using the commercial enzymatic extract Cellic CTec 2 with an enzymatic load of 100 $FPU.g^{-1}$.

An acid hydrolysis in mild conditions was performed aiming to increase the hydrolysis of glucan and galactans but avoiding the formation of hydroxymethylfurfural. For the acid hydrolysis was used the enzymatic hydrolyzate obtained using the extract Cellic CTec 2 (enzymatic load: 100 $FPU.g^{-1}$) after 4 hours of hydrolysis. It was performed at mild conditions (H_2SO_4 0.5% w/v, 80°C, 90 minutes, 120 rpm).

Results and discussion

The chemical composition of the by-product was determined. The data obtained are similar to those obtained by Meinita et al. (2012) and Masarin et al. (2016).

Table 1 – Chemical composition of by-product of carrageenan production from *Kappaphycus alvarezii*. All reported data are the average values followed by their standard deviations.

Component	%
Glucan	38.4 ± 1.7
Galactan	32.7 ± 3.1
Ashes	8.6 ± 0.2
Insoluble aromatics	8.3 ± 1.1
Sulfate groups	8.1 ± 0.2
Protein	0.4 ± 0.1

Enzymatic hydrolysis of the by-product was performed using the commercial extracts Cellic CTec 2, Celluclast and Cellulases. After 72 hours of hydrolysis, a total conversion of glucan to glucose was achieved using any of the extracts, however, the Cellic CTec 2 extract showed faster hydrolysis. In the first 4 hours, the conversion exceeded 60%, whereas with the extracts Celluclast and Cellulases the conversion was between 30% and 40% after 4 hours (Figure 1). The only extract that was able to hydrolyze the fraction of galactans contained in the by-product was Cellic CTec 2, achieving a conversion of 14.7% after 72 hours of hydrolysis (data not shown).

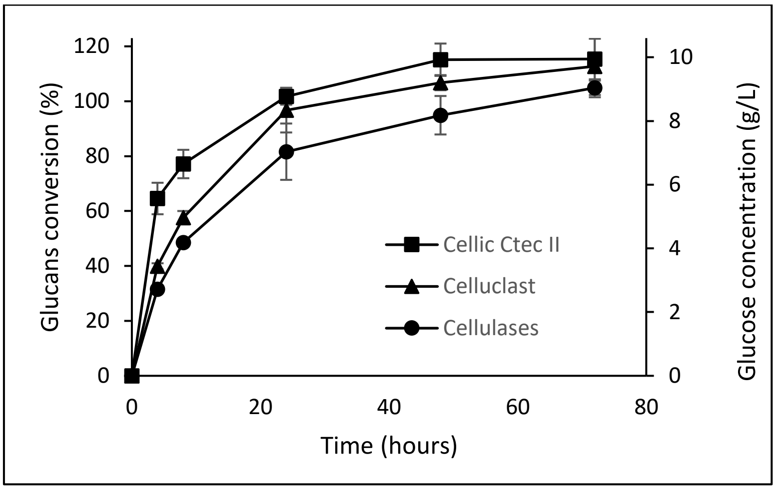
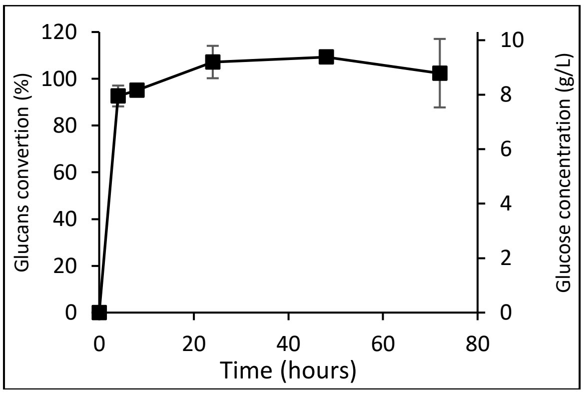


Figure 1. Glucans conversion and glucose concentration after enzymatic hydrolysis using commercial extracts.

The enzymatic hydrolysis of the fraction of the by-product was evaluated using the commercial enzymatic extract Cellic CTec 2 in a quantity 10 times higher than previously used, to improve the hydrolysis of the galactan fraction. The conversion percentages of glucan and galactan after 72 hours of hydrolysis were approximately 100% and 30%, respectively (Figure 2). With this enzymatic charge of the mentioned extract, it is possible to observe an almost complete hydrolysis of glucan in the first 4 hours of hydrolysis due to the high activity of cellulolytic enzymes contained in the Cellic CTec 2 extract (Figure 2a). We also observed a significant increase in the conversion of galactan (30%) when compared to the enzymatic hydrolysis using the same extract but with an enzymatic loading of 10 FPU/g of substrate (14%) (Figure 2b).



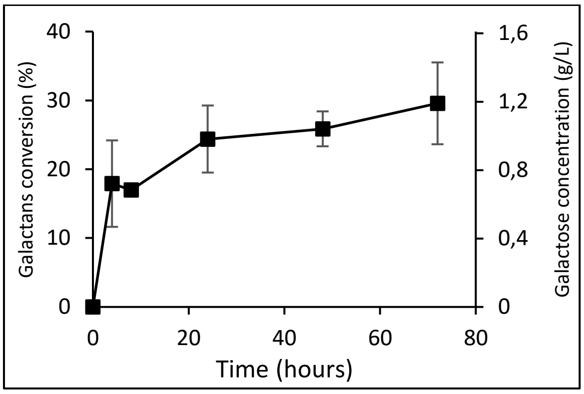


Figure 2. Enzymatic hydrolysis using Cellic CTec 2 100FPU/g of substrate. (a) Glucans conversion and glucose concentration. (b) Galactans conversion and galactose concentration.

The by-product was hydrolyzed using enzymatic extract Cellic CTec 2 (100FPU/g of substrate) for 4 hours and then was subjected to an acid treatment at mild conditions (H2SO4 0.5% w/v, 80°C, 90 minutes, 120 rpm). After the enzymatic treatment the concentration of glucose and galactose was 12.8 and 0.2 $g.L^{-1}$, respectively. With the acid treatment was observed an increase of the glucose and galactose concentration to 14.6 $g.L^{-1}$ and 1.4 $g.L^{-1}$, respectively. Note, the concentration of hydroxymethylfurfural reached 0.006 $g.L^{-1}$, a very low level.

Conclusion

Enzymatic hydrolysis followed by acid hydrolysis of the by-product of carrageenan production from *Kappaphycus alvarezii*, indicates that there is a potential for glucose and galactose production. An example of application would be the production of bioethanol. Thus, since the residue obtained is not considered a food source, this method could be considered as a fourth-generation biofuel production model.

References

Estevez, J. M.; Ciancia, M.; Cerezo, A. S. The system of galactans of the red seaweed, Kappaphycus alvarezii, with emphasis on its minor constituents. *Carbohydrate Research*, v. 339, n. 15, p. 2575–2592, 2004.

Ferraz, A.; Baeza, J.; Rodriguez, J.; Freer, J. Estimating the chemical composition of biodegraded pine and eucalyptus wood by DRIFT spectroscopy and multivariate analysis. *Bioresource Technology*, v. 74, n. 3, p. 201–212, 2000.

Ge, L.; Wang, P.; Mou, H. Study on saccharification techniques of seaweed wastes for the transformation of ethanol. *Renewable Energy*, v. 36, n. 1, p. 84–89, 2011. Disponível em: <http://dx.doi.org/10.1016/j.renene.2010.06.001>.

Hames, B.; Scarlata, C.; Nrel, a S. Determination of Protein Content in Biomass. *Lap 42625*, n. May, 2008.

Harun, R.; Danquah, M. K. Influence of acid pre-treatment on microalgal biomass for bioethanol production. *Process Biochemistry*, v. 46, n. 1, p. 304–309, 2011. Disponível em: <http://dx.doi.org/10.1016/j.procbio.2010.08.027>.

Hayashi, L.; De Paula, E. J.; Chow, F. Growth rate and carrageenan analyses in four strains of Kappaphycus alvarezii (Rhodophyta, Gigartinales) farmed in the subtropical waters of S{ã}o

Paulo State, Brazil. *Journal of Applied Phycology*, v. 19, n. 5, p. 393–399, 2007. Disponível em: <http://dx.doi.org/10.1007/s10811-006-9135-6>.

John, R. P.; Anisha, G. S.; Nampoothiri, K. M.; Pandey, A. Micro and macroalgal biomass: A renewable source for bioethanol. *Bioresource Technology*, v. 102, n. 1, p. 186–193, 2011. Disponível em: <http://dx.doi.org/10.1016/j.biortech.2010.06.139>.

Martone, P. T.; Estevez, J. M.; Lu, F.; Ruel, K.; Denny, M. W.; Somerville, C.; Ralph, J. Discovery of Lignin in Seaweed Reveals Convergent Evolution of Cell-Wall Architecture. *Current Biology*, v. 19, n. 2, p. 169–175, 2009.

Masarin, F.; Cedeno, F. R. P.; Chavez, E. G. S.; De Oliveira, L. E.; Gelli, V. C.; Monti, R. Chemical analysis and biorefinery of red algae Kappaphycus alvarezii for efficient production of glucose from residue of carrageenan extraction process. *Biotechnology for Biofuels*, v. 9, n. 1, p. 122, 2016. Disponível em: <http://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-016-0535-9>.

Masarin, F.; Gurpilhares, D. B.; Baffa, D. C.; Barbosa, M. H.; Carvalho, W.; Ferraz, A.; Milagres, A. M. Chemical composition and enzymatic digestibility of sugarcane clones selected for varied lignin content. *Biotechnology for Biofuels*, v. 4, n. 1, p. 55, 2011. Disponível em: <http://www.biotechnologyforbiofuels.com/content/4/1/55>.

Meinita, M. D. N.; Kang, J. Y.; Jeong, G. T.; Koo, H. M.; Park, S. M.; Hong, Y. K. Bioethanol production from the acid hydrolysate of the carrageenophyte Kappaphycus alvarezii (cottonii). *Journal of Applied Phycology*, v. 24, n. 4, p. 857–862, 2012.

Mendes, F. M.; Siqueira, G.; Carvalho, W.; Ferraz, A.; Milagres, A. M. F. Enzymatic hydrolysis of chemithermomechanically pretreated sugarcane bagasse and samples with reduced initial lignin content. *Biotechnology Progress*, v. 27, n. 2, p. 395–401, 2011.

Sluiter, A.; Hames, B.; Ruiz, R.; Scarlata, C.; Sluiter, J.; Templeton, D. Determination of ash in biomass: Laboratory Analytical Procedure (LAP). *Nrel/Tp-510-42622*, n. April 2005, p. 18, 2005. Disponível em: <http://www.nrel.gov/docs/gen/fy08/42622.pdf>.

Wei, N.; Quarterman, J.; Jin, Y. S. Marine macroalgae: An untapped resource for producing fuels and chemicals. *Trends in Biotechnology*, v. 31, n. 2, p. 70–77, 2013. Disponível em: <http://dx.doi.org/10.1016/j.tibtech.2012.10.009>.

Wi, S. G.; Kim, H. J.; Mahadevan, S. A.; Yang, D. J.; Bae, H. J. The potential value of the seaweed Ceylon moss (Gelidium amansii) as an alternative bioenergy resource. *Bioresource Technology*, v. 100, n. 24, p. 6658–6660, 2009. Disponível em: <http://dx.doi.org/10.1016/j.biortech.2009.07.017>.

THEME: BIODIESEL

CHARACTERIZATION OF BIODIESEL AND ETHANOL BLENDS WITH GASOLINE FOR ATOMIZATION IN A Y-JET INJECTOR

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Abstract
Due to the continuous increase in oil prices and the fact that environmental legislation has become increasingly rigorous, recommending strict limits for pollutant emissions in engines, turbines, furnaces, boilers and industrial combustion processes, it is verified that is in the best interest of the country and companies to investigate the use of biofuels such as mixtures of these fuels with gasoline and diesel in industrial applications, aiming to reduce costs, increase the efficiency of operations, and reduce the emission of pollutants. Combustion of liquid fuels depends on efficient atomization to increase the surface area of the fuel and thus achieve high rates of mixing and evaporation. In order to promote combustion with maximum efficiency and minimum emission of pollutants, an injector must provide a fuel spray that evaporates and disperses rapidly to produce a homogeneous mixture of vaporized fuel and air. Since a significant portion of the industrial combustors operate with liquid fuels and the injector is a fundamental part in combustion systems using such fuels, the present work aims to characterize a Y-jet injector for the atomization of fuel blends that will be used in future applications for combustion systems. A theoretical study of a Y-jet injector will be realized to atomize different blends composed of biofuels (commercial hydrated ethanol and soybean and bovine tallow biodiesel) and fossil fuels (commercial common gasoline) with different proportions. The physicochemical properties of the fuel mixtures will be determined, and the characteristics and quality of the spray generated will be theoretically determined using the Wigg equation to calculate the MMD (mass median diameter) for different injection conditions.

Keywords: Spray, Y-jet injector, ethanol, biodiesel, gasoline

Introduction

Concerns about the rising fuel price and global climate change have led to the search for alternative fuels and blends of biofuels with gasoline in combustion systems and industrial applications aiming to reduce costs, increase the efficiency of operations, and reduce the emission of pollutants. The liquid droplets atomization is the key process of the behavior of a liquid-fuel-fired combustion system and has important applications in several industrial processes and in many aspects of the engine's combustion performance, such as gas turbines and rocket motors. In liquid fuel combustion systems, the atomization process to produce sprays represents one of the main methods for obtaining high evaporating and mixing rates of the fuel, with subsequent ignition and flame formation.

The process of atomization is a process where a liquid jet or sheet is broken up by the kinetic energy of the liquid itself or by exposure to high velocity air or gas (Lefebvre, 1989). The droplets formed during the atomization process are directly related to the mixing and vaporization rates of the fuel, so in general aspects, the small droplets generated through the atomizers devices increases the specific surface area of the fuel leading to high rates of mixing and evaporation as near as possible to the desired design. There are many ways to generate a spray, however, for large-scale facilities such as boilers and industrial furnaces where large flow rates of very viscous fuels have to be handled, one of the nozzles most commonly used is the steam-assisted type with a "Y" configuration (Barreras et al., 2006).

One of the twin-fluid atomizers widely used in industrial combustors is the so-called Y-type injector (Fig. 1). The multiphase flow in the Y-jet is created by injecting of the liquid into the air stream radially, under a particular angle to the axis (Y-shaped junction). The two-phase flow is created inside the mixing chamber and it disintegrates when it reaches the discharge orifice.

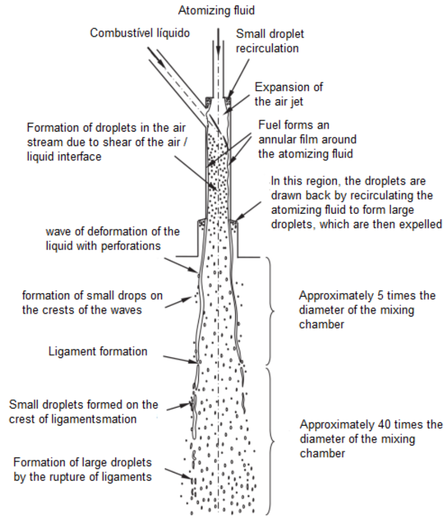

Figure 1 – Droplet formation mechanism in type Y injector (Mullinger and Chingier, 1974).

Flowing into the mixing chamber at a high velocity, the air abruptly expands, creating a recirculation zone. The recirculation drags a small amount of fuel droplets that flows towards the mixing chamber through the duct side. The airflow expansion recovers some of the droplets and returns them to the flow core. The encounter of air and liquid flows occurs at the so-called mixing point, generating a transition zone, where part of the liquid accumulates on the wall of the mixing duct, creating a liquid film, and the other part remains dispersed in the liquid flow core. This last liquid fraction disintegrates into small droplets due to the shear forces which appear at the gas / liquid interface. Many studies were found in literature referring to designs and characterization of Y injectors, such as Mullinger and Chigier (1974), Graziadio et al. (1987), Couto et al. (1992) Andreussi et al. (1992), Song e Lee (1994), Lacava et al. (1998), Lacava (2000) and Pacífico, (2000).

Since many industrial combustors operate with liquid fuels and the injector is a important device in the combustion systems using such fuels, the present work aims to characterized a Y-jet injector for the atomization of fuel blends that will be used in future applications for combustion systems.

A theoretical study of a Y-jet injector will be realized to atomize different blends composed of biofuels (commercial hydrated ethanol and soybean and bovine tallow biodiesel) and fossil fuels (commercial common gasoline) with different proportions. The physicochemical properties of the fuel mixtures will be determined, and the characteristics and quality of the spray generated will be theoretically determined using the Wigg equation to calculate the MMD (mass median diameter) for different injection conditions.

Materials and methods

The spray characteristics are strongly affected by the physicochemical properties of the liquid that will be atomized. The most important properties are density, viscosity, and surface tension (Lefebvre, 1989). In order to determine the mass median diameters (MMD) for each mixture analysed, the properties of blends composed by hydrated ethanol (E), soybean biodiesel and bovine tallow (B) and common gasoline (G) will be determined. The mixtures to be analyzed are shown in Table 1.

Table 1. Fuel blends.

Sample	**Proportion (%)**
B+G	10-90
B+G	25-75
B+G	40-60
B+G	60-40
B+G	80-20
E-G	10-90
E-G	25-75
E-G	40-60
E-G	60-40
E-G	80-20

In order to determine the blends densities was used the picnometry technique that uses a Gay-Lussac type pycnometer (Fig. 2a), to determine the blends dynamic viscosities was used the Ostwald Cannon Fenske viscometer (Fig. 2b) and to determination of the blends surface tensions was used the ring method (Fig. 2c). In order to determine the blends densities, the picnometry technique that uses a Gay-Lussac type pycnometer (Fig. 2a) was used, to determine the blends dynamic viscosities the Ostwald Cannon Fenske viscometer (Fig. 2b) was used, and to the determination of the blends surface's tension the ring method (Fig. 2c) was used.

a) Gay-Lussac pycnometer   b) Ostwald Cannon Fenske viscometer   c) Ring method

Figure 2 – Experimental apparatus.

Due to the random nature of the atomization process, the spray produced by an injector is composed of droplets with a great variability of diameters. Therefore, in order to characterize a spray with a single droplet diameter value, it is necessary to have some statistical function of the sizes of the measured droplets. In the present work the mass median diameters (MMD) and the Sauter mean diameter for each blend analyzed will be theoretically determined using the Y injector proposed by Ayala, 2016 (Figure 3).

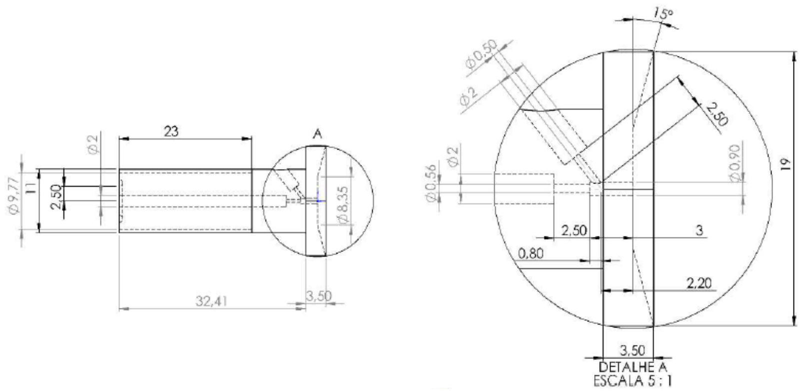

Figure 3 – Y injector proposed by Ayla, 2016.

The mass median diameter (MMD) is the representative diameter such that 50% of the total mass of the atomized liquid consists of droplets with diameters greater than the indicated value and 50% is composed of drops with diameters smaller than the indicated value. The median mass diameter (µm) for the proposed Y injector will be determined using the Wigg equation (Mullinger and Chigier, 1974):

$$MMD = D_{50} = \left[20 * \upsilon^{0,5} * \dot{m}_c^{0,1} \left(1 + \frac{1}{r_{atm}} \right)^{0,5} * R_m^{0,1} * \sigma \right] / (\rho_{ar}^{0,3} * \Delta u)$$

Where,
υ: kinematic viscosity of the fuel (cP);
$\dot{m}$: fuel mass flow (g/s);
R_m: radius of the mixing chamber (cm);
σ: surface tension of the fuel (dynas/cm);
ρ_{ar}: Specific mass of the atomizing fluid (g/cm³);
Δu: relative velocity between the liquid and the air (m/s);
$r_{atm} = \dot{m}_{ar_{atm}} / \dot{m}_c \geq 0{,}1$ the air-liquid ratio.

According to (Liu, 2000), the Wigg equation gives good results for very viscous liquids, but great divergence for liquids like water.

The discrete representation most used in spray studies, with with special interest in mass transfer and combustion, is the D32 or Sauter mean diameter (SMD), defined as the characteristic droplet diameter whose volume - surface area ratio is proportional to the volume - surface ratio of the entire spray. For Y injector, according to Simmons (1997), for pratical spray formation, MMD/SMD=1,2 with a 5% error. So, this equation can be used to determine the mean droplet diameter of the working fluid (Lacava, 2000).

Results and discussion

The results obtained for the physicochemical properties of the blends analyzed are shown in Table 2.

It is verified that an increase in the biodiesel and ethanol percentages in the blends with gasoline leads to an increase in the densities and viscosities of the blends. It is also verified that the higher superficial tension was obtained for the blends containing the highest percentages of ethanol and biodiesel. Higher densities, viscosities, and surface tension lead to a greater resistance of the fuel flow, which which may hamper the atomization process.

Table 2 - Physicochemical properties of the blends.

Sample	Density, ρ, (kg/m^3)	Viscosity, η, (cP)	Surface tension, σ, (N/m)
G-E / 90-10	719,50	0,67	0,0203
G-E / 75-25	748,64	0,81	0,0212
G-E / 60-40	755,25	0,90	0,0208
G-E / 40-60	764,84	1,03	0,0212
G-E / 20-80	766,27	1,31	0,02486
G-B / 90-10	744,96	0,73	0,0208
G-B / 75-25	765,18	0,95	0,0256
G-B / 60-40	785,42	1,30	0,0283
G-B / 40-60	795,39	2,13	0,0287
G-B / 20-80	838,33	3,45	0,0305

Figures 4 and 5 show the effect of the air-liquid ratio (ALR) on the MMD and SMD for a constant fuel mass flow equivalent to 0.88 g/s for each fuel blend and Table 3 shows the ALR and theoretical average diameters obtained.

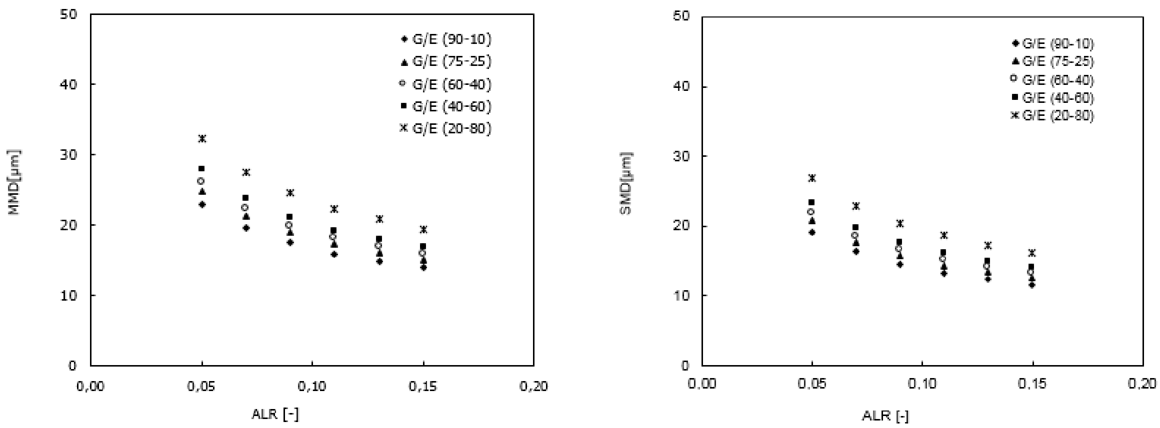

Figure 4 – Theoretical MMD and SMD for the G/E blends

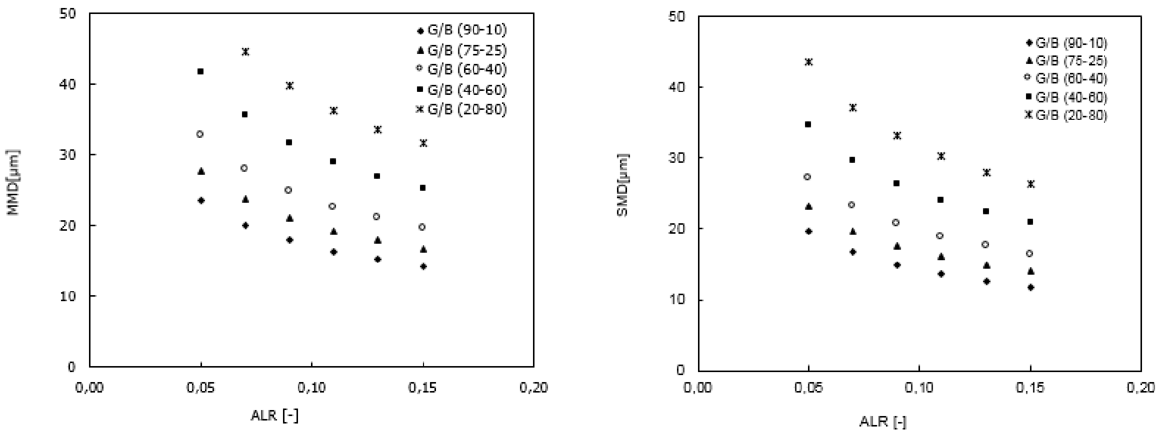

Figure 5 – Theoretical MMD and SMD for the G/B blends

Table 3 - Range of ALR and average diameters

Sample	ALR (-)	SMD (μm)	MMD (μm)
G-E / 90-10	0,05 - 0,15	11,60-19,199	13,92-23,09
G-E / 75-25	0,05 - 0,15	12,55-20,77	15,06-24,93
G-E / 60-40	0,05 - 0,15	13,16-21,79	15,80-26,15
G-E / 40-60	0,05 - 0,15	14,03-23,23	16,84-27,87
G-E / 20-80	0,05 - 0,15	16,27-26,93	19,52-32,31
G-B / 90-10	0,05 - 0,15	11,87-19,65	14,24-23,58
G-B / 75-25	0,05 - 0,15	14,00-23,17	16,80-27,81
G-B / 60-40	0,05 - 0,15	16,45-27,22	19,74-32,67
G-B / 40-60	0,05 - 0,15	21,00-34,77	25,21-41,72
G-B / 20-80	0,05 - 0,15	26,36-43,63	31,63-52,36

For all the analyzed cases, it is verified that the average diameter of the droplets is a non-linear function of the ALR and an increase in the air-liquid ratio, ALR, leads to a decrease in droplet size, such as the spray has a good quality, generating small droplets. It is observed that for all the blends a good atomization can be obtained using a relatively low ARL, ie, only a small amount of air is needed to obtain a spray composed of small droplets. It is observed that the largest droplet sizes are obtained for the G/E (20/80) and G/B (20/80) blends, since such blends presented the highest densities, viscosities, and surface tensions. It is known that the increase in density leads to an increase in droplet size since less interaction occurs with the atomizing air stream, a greater amount of air is necessary to obtain a good atomization. Likewise, increasing the viscosity causes an increase in droplet size, since increasing the viscosity causes an increase in undisturbed liquid sheet length and jet penetration, prevents wave formation, reduces the turbulence, and consequently, the production of spray with larger droplets. It is also known that an increase in the surface tension also leads to an increase in droplet size, once an increase in fluid resistance to a shear force occurs and an increase in surface tension also leads to an increase in droplet size, once a high surface tension represents a consolidation force and during the atomization process counteracts any distortion of the surface of the liquid so that by increasing the surface tension a delay in the formation of ligaments and droplets occurs resulting in larger sizes of drops.

Conclusion

In the present work, the main physicochemical properties that influence the spray characteristics were determined: density, viscosity, and surface tension for different blends of conventional fossil fuels (gasoline) and biofuels (hydrous ethanol and soybean biodiesel and bovine tallow) such as the theoretical mass median diameter (MMD) and the average Sauter diameter (SMD) produced by a Y type injector using different fuel blends.

For all gasoline blends, it has been verified that increasing the biodiesel and ethanol percentage causes an increase in density, viscosity, and surface tension. For all the blends analyzed, it has been found that an increase in the air-liquid ratio, ALR, leads to a decrease in droplet size, such as sprays with good quality is obtained in all the cases, generating small droplets. It was also verified that the larger droplet sizes are obtained for the G/E (20/80) and G/B (20/80) blends, since such blends presented the highest densities, viscosities, and surface tensions, making the atomization process difficult.

References

Andreussi, P.; Tognotti, L.; Michele, G. de; Graziadio, M.; Design and characterization of twinfluid Y-Jet atomizers, *Atomization and Sprays*, v. 2, pp. 45-59, 1992.

Ayala, G. R. C., *Estudo da atomização e caracterização de injetores utilizando óleo pirolítico de pneu usado puro e em misturas com diesel*. Dissertação de mestrado. Universidade Federal de Itajubá, Itajubá, 2016.

Barreras, F., Lozano, A., Barroso, J., Lincheta, E., Experimental characterization of industrial twin-fluid atomizers, *Atomization and sprays*, vol, 16, pp 127 - 145, 2006.

Couto, H. S.: Carvalho Jr., J. A.; Bastos-netto, D.; Mcquay, M. Q.; Lacava, P. T.; Theoretical Prediction of Mean Droplet Size of Y-Jet Atomizers, *Journal of Propulsion and Power – Technical Notes*, 1999, Vol. 15, n. 3, pp. 481 – 485.

Graziadio, M.; Andreussi, P.; Tognotti, L.; Zanelli, S. Atomization of coal-water fuels by pneumatic internal mixing nozzle. *Atomization and Spray Technology*, vol. 3, nº 1, p. 187 – 208, 1987.

Lacava, P. T., *Investigação experimental do enriquecimento do ar na incineração de resíduos aquosos*. Tese de Doutorado em Engenharia Aeronáutica e Mecânica – Instituto Tecnológico de Aeronáutica, 2000.

Lacava, P. T.; Carvalho Jr.; J. A.; Mcquay, M. Q.; Metodologia para el diseño de atomizadores tipo “Y”; *Información Tecnológica*, vol 9, N° 6, pp 283-288, ISSN 0716-8756, Chile, 1998.

Lefebvre, A.H. *Atomization and Sprays*. New York: Hemisphere Publishing Corporation, 1989.
Liu, H.; *Science and Engineering of Droplets, Fundamentals and Applications*, William Andrew Publishing, 2000, New York, pp. 539.

Mullinger, P. J.: Chigier, N. A.; The Design and Performance of Internal Mixing Multijet Twin Fluid Atomizers, *Journal of The Institute of Fuel*, vol 47, N° 43, pp 251 – 261, 1974.

THEME: BIOENERGY – ECONOMY, MARKET AND POLICY

AN APPROACH TO THE ECONOMIC AND ORGANIZATIONAL VIABILITY OF BIOGAS PROJECTS

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Abstract
When describing the availability of waste biomass in a region and its potential for the production of bioenergy, technology developers and politicians often assume that biomass collection, storage and exchange occur seamlessly. Organizational and economic issues, however, can impact its use as a biofuel and limit the potential of bioenergy technologies in a wide range of economic sectors. The aim of this study is to identify the main factors that affect the economic and organizational viability of a representative power generation project that applies an Anaerobic Digestion (AD) technology and uses manure as feedstock, in Argentina. The results of this study show, firstly, that the efficiency of the bioenergy system depends both on the investments along the supply chain, and on the organizational changes in the collection and transportation stage of biomass. Secondly, they highlight three important aspects to assess the viability of such projects: production scale, changes in organizational routines, and their impact on the overall performance of the production unit. These dimensions are crucial if we consider the use of biomass for producing energy, and they call into question the view of AD technology as cost- effective mechanism for manure management and energy generation in Argentina.

Keywords: anaerobic digestion, renewable energy, biogas, feedlots, economic profitability, organizational routines

Introduction

In Argentina, bioenergy technologies are at an early stage of diffusion, and the biomass available is far from being thoroughly exploited. Potential users search for information about technical opportunities, their costs, their impact upon their own performance, and their compatibility with their competencies and learning capacities. However, such information is currently scarce, diffuse and uncertain. This lack of awareness hinders the adoption of this technology. An interactive learning relationship between innovating producers (of technical opportunities) and users (their needs and organizational constrains) may be necessary to boost organizational and technical innovations in pursuit of more cost-efficient bioenergy projects (Lundvall, 1985).

This paper analyzes the organizational viability (routines and knowledge) and economic feasibility (infrastructure investment, operation and maintenance costs) of a representative electrical power generation project that uses cattle manure as feedstock and a Continuous Stirred-Tank Reactor (CSTR) to produce biogas. Although the final product of the project is electrical energy, the main activity of the user is beef production in a cattle-feeding system. Thus, the purpose of this kind of bioenergy plant is to produce energy and to handle manure properly, so the study assumes no additional biomass (energy crops) is used to produce biogas, as this may put an additional burden on waste biomass management.

The study uses information from the cattle feedlot and bioenergy sectors in Argentina for 2017, collected from primary and secondary sources. The current organizational practices applied by feedlots were characterized using information from technical reports, personal interviews with cattlemen and technical experts, and a survey carried out among a non-representative sample of feedlot establishments. The organizational difficulties associated with the efficient application of AD were discussed with representatives of the Cámara Argentina de Feedlots (CAF- Argentine

Chamber of Feedlots) and the Instituto Nacional de Tecnología Industrial (INTI- National Institute of Industrial Technology). Lastly, information on the technical requirements of the CSTR technology and its costs was collected from in-person interviews with local bioenergy technology suppliers.

Manure management in feedlots

Feedlots are establishments engaged in a confined cattle-feeding system for raising beef cattle until they reach the legal and desired weight. They focus on the efficient growth and weight gain of the animals by providing a readily digestible, high-energy diet; reducing the amount of energy expended to find food and managing the cattle to minimize stress and health problems. It is a livestock farming system that, in Argentina, mainly involves open air pens with dirt floors, concrete feed aprons, and a diet made with local products (Eiras, 2017).

Cattle manure management in feedlots must comply with environmental regulations to avoid contamination of the surface and groundwater. Currently, in Argentina, liquid manure is often treated with a system of primary and secondary drainages that flow into treatment and storage lagoons, whose capacity depend on the production capacity of the feedlot and the annual precipitation levels. Solid manure, on the other hand, is scraped off the pens every time they are emptied in order to avoid muddy conditions when it rains and dust emissions when it is dry. This practice must avoid disturbing too much soil below the manure layer, as this compacted layer of soil and manure makes it difficult for water to move downward through the soil to reach water resources. Once scraped, solid manure may be stockpiled or composted in a structure designed to avoid pollution and, after a couple of months, once it is stabilized, manure can be applied as a soil amendment (Pordomingo, 2013; Eiras, 2017). Although, this dual system is an effective way of recycling nutrients and saving money on agricultural production, it poses several challenges: 1) crop nutrient requirements and soils´ capacity to absorb and break down nutrients must be assessed to systematically minimize the risk of introducing pollutants into the environment; 2) the area of land needed for application may exceed the area owned or available to the production unit; and 3) the hauling of manure is not cost-effective and manure itself has no market (Higgins, Wightman & Lehmkuhler, 2013).

Bioenergy technology can contribute to more suitable manure management using the installed drainage system to treat both solid and liquid manure, accelerating its stabilization process, improving its fertilizer qualities, and reducing odors and pathogens (Holm-Nielsen, Al Seadi & Oleskowicz-Popiel, 2009). Extensive research at the international level affirms that AD is a mature technology, with no technical limitations of scale, highly effective and recommended for capturing methane from livestock manure (Lukehurst & Bywater, 2015). It is the most appropriate to convert biomass with a relatively high moisture content into biogas and residue digestate. Biogas can be used as a fuel to produce electric and/or thermal energy, as well as a substitute for natural gas after appropriate cleaning and upgrading. Residue digestate is a biologically stabilized fertilizer, superior to raw manure because some of its nutrients are more readily available to growing plants (Betts Liebrand & Ling, 2009). The most appropriate type of digester to convert slurry waste in biogas is a CSTR (IRENA, 2012).

The minimum scale of analysis

In Argentina, there are 1,440 feedlots registered, raising around 1.3 million heads. Most establishments are in the center region of the country[1] (76%), and they have, on average, 928 heads (SENASA, 2016). Although the supply of beef cattle from feedlots is atomized -70% of feedlots had fewer than 500 animals-, the production is highly concentrated in a few establishments -3% of the establishments accounted for 33% of the cattle heads- (Table 1).

[1] It includes the provinces of Buenos Aires, Córdoba and Santa Fe

Table 1. Structure of feedlot sector in Argentina (2013)

Stratification by number of heads	Number of Feedlots	% of Feedlots	Number of heads	% of heads	Average heads per feedlot
Up to 500	1,153	69	139,672	11	121
501 – 1,000	219	13	157,695	13	720
1,001 - 2,500	200	12	305,872	25	1,529
2,501 – 5,000	68	4	233019	19	3,427
5,001 - 10,000	28	2	185,870	15	6,638
More than 10,000	11	1	223,309	18	20,301
Total	1,679		1,245,437		

Source: Dana (2013)

Despite obvious similarities, all firms differ in their characteristics, behaviors and revealed performances, and feedlot establishments in Argentina, among other aspects, differ in their infrastructure and organizational routines to manage cattle manure. The feedlots surveyed can be divided into four groups (Table 2), showing that, in general, larger (and older) establishments have more infrastructure and more complex routines to manage manure, which may reflect the feedlots´ accumulated knowledge and investment in manure management.

Table 2. Feedlots surveyed according to their infrastructure and organizational routines

Group	Infrastructure and routines				% of sample	Maximum installed capacity
	Drainage system	Waterproof lagoons	Removes manure from pens	Use manure as a fertilizer		
I	Yes	Yes	Yes	Yes	30	≥ 6,000
II	Yes	No	Yes	Yes	30	2,800- 8,000
III	Yes	No	Yes	No	30	2,000- 6,000
IV	No	No	No	No	10	≤ 2,000

Source: Author, based on information from a non-representative sample of registered feedlots

Only the infrastructure and organizational routines of the first group align with the investment and practices an AD technology requires. So, at first glance, the minimum acceptable scale for installing an AD plant in an existing feedlot is a maximum installed capacity of 6,000 heads. However, AD efficiency depends on the ability to maximize methane production and minimize the risk of killing the natural digestion process (IRENA, 2012). To do so, these feedlot facilities and routines must further adapt to maximize daily collection and treatment of manure.

Stress between an efficient bioenergy plant and organizational practices

When it comes to AD and feedlots, the organizational and economic interdependence among these productive activities makes it necessary to consider all the organizational and economic aspects along the supply chain that impact the project´s efficiency.

In the biomass procurement stage, feedlots should install concrete floors in pens to collect manure free of soil, stones or other inorganic elements. Concrete floors allow the flushing or scraping of manure with greater effectiveness, and without risk of contaminating the ground due to cracks in the consolidated floor. It also avoids muddy conditions in rainy regions or seasons, which may otherwise decrease feed intake, slow down average daily gain of cattle, and increase problems with footrot. However, concrete floor in pens also increases the probability of cattle hoof lesions and joint swellings, decreasing feed efficiency and increasing operation costs. So, while the most efficient option for an AD plant is to use 100% concrete lots (100% Scenario), feedlot producers argue that this practice reduces beef cattle productivity due to lesions and discomfort of animals. The organizationally feasible option proposed is to extend the concrete feed aprons until they cover around 25% of the pen (25% Scenario). As cattle produce a greater amount of manure when they are feeding, producers affirm this option may allow to collect and treat around 50% of manure.

Second, feedlots should remove manure from pens daily to maximize the methane released by manure in the digester chamber of the AD plant. This practice implies a huge change in feedlots´ routines, from scrapping off solid manure two or three times a year with empty lots and making stockpiles, to removing manure daily with the animals in the pen and moving it towards the digester chamber. Feedlot producers affirm that cleaning may affect cattle´s habits and feed intake, so this should be done away from mealtimes without disturbing the animals.

Concrete floors and daily cleaning, however, have their benefits. Using a 100% concrete floor in pens reduces the minimum area that each cattle needs to only 5 sq.m (INTA, 2015), while under current conditions feedlots use around 3 times more space per head. If the concrete floor were to cover 25% of the lot, then the load of animals in pens could be increased by up to 20%.

Economic assessment

The cost of an AD plant with the capacity to produce 1 MW ranges from USD 3.9 million to 4.5 million, including installation and start-up costs and the electrical generator equipment. Changes in feedlot facilities, on the other hand, cost 67 USD/sq. m of soil preparation, water-proof insulation and concrete floors in pens (Table 3). It is worth noting that while a 100% Scenario allows the use of 5 sq. m/head of concrete floor, a 25% scenario represents a pen with around 3,75 sq. m/head of concrete floor and 11 sq. m/head of soil.

Table 3. Economic assessment variables by scenario and maximum installed capacity of feedlots

Maximum Installed capacity	MW		Total investment cost U$S		Investment in concrete floor	
	100%	25%	100%	25%	100%	25%
6,000	0.25	0.12	3,959,307	2,929,267	51%	51%
25,000	1.04	0.52	12,714,412	8,877,779	66%	71%

Source: Author

Operating expenses include, firstly, the salary of the labor force and the cost of the machinery and fuel use for cleaning the concrete floor of pens, which vary according to the Scenario and installed capacity. These costs represent around half the operating expenses. Secondly, they include the salary of the workforce that operates and manages the plant (2 full-time workers and one outsource technician).

The economic assessment of these scenarios was estimated assuming an electric power price of 190 U$S/MWh, which is the maximum price set by the national government to biogas projects tendering in 2017 (RenovAr 2), and a 20 years appraisal period. It is also assumed that the investment is paid from own capital and no fiscal benefits are received. Although the price assumed is relatively high[2], the latter assumptions are quite conservative.

Table 4 shows that, even though the Internal Rate of Return (IRR) of a bioenergy project varies with the number of heads, under the conditions described, the minimum viable scale is neither 6,000 heads, nor 25,000. Besides, a 25% Scenario offers worse economic results than a 100% Scenario, as the savings in sq. m of concrete floor are less financially significant than the

[2] The maximum contracted price of a biogas project in national public tenders so far was 177,9 U$S/MWh, while the weighted average price for this technology was 159,7 U$S/MWh.

subsequent loss of collected manure. The economic viability of AD projects is heavily impacted by the investments needed to efficiently collect manure, which poses the challenge of finding alternative ways to collect this biomass or to respond to users´ need to manage it.

Table 4. Internal rate of return (IRR) by scenario and installed capacity

Maximum Installed capacity	IRR 100%	25%
6,000	-8.0	NT
25,000	-4.1	-9.2

Source: author. NT: no IRR estimated as the cash flow of the project is always negative

The purpose of this kind of bioenergy project is not only to produce energy, but also to manage cattle manure, so some of its main benefits do not reflect on energy production but rather on the user's central economic activity: beef cattle production. The installation of concrete floor in pens, although it may increase cattle discomfort, also reduces the space each cattle needs, boosting the feedlot´s production capacity without using additional land (from 6,000 heads to around 10,000, and from 25,000 heads to 41,500). Besides, in the 100% Scenario, concrete floors improve the efficiency of conversion of feed nutrients into body mass by around 10% (INTA, 2015). These benefits should be further studied, as they may offset the investment in concrete floors for livestock pens.

Conclusions

If bioenergy projects are to be successfully applied in a wide range of economic activities, they must offer environmental solutions in a viable economic and organizational way. In other words, they must offer solutions considering the operational routines that must be changed and the investments that should be made along all the supply chain to minimize negative consequences while maximizing benefits.

Feedlots need a simple, efficient and minimal cost system for dealing with manure, and preferably one that reduces net cost to the firm. Technically, an AD system can meet these needs, but its current cost, the additional investments required to efficiently collect manure, and the organizational changes it requires all heavily constrain its viability. These factors restrict those with the ability to transform waste biomass into energy to owners of large scale units with infrastructure and competence to manage manure, regardless of regional availability. Thus, the diffusion of this technology, as a manure management system that produces energy, depends on the development of smaller scale AD plants that fit into the existing feedlot system, or that at least consider its organizational practices.

References

Betts Liebrand, C.; Ling, C. *Cooperative Approaches for Implementation of Dairy Manure Digesters*. 2009. Available in: naldc.nal.usda.gov/download/35107/PDF. Accessed in: 15/06/17.

Dana, G. *Establecimientos de engorde a corral 2008-2013*. Buenos Aires: SENASA, 2013.

Eiras, J. *Estrategia de Manejo de Residuos en Feedlots.* 2017. Buenos Aires: CAF.

Lundvall, B. Product Innovation and User-Producer Interaction Industrial Development. *Research Series* No. 31 Aalborg University Press (1985).

Higgins, S.; Wightman, S.; Lehmkuhler, J. *Feedlot Design and Environmental Management for Backgrounding and Stocker Operations*. Lexington: University of Kentucky College of Agriculture. 2013.

Holm-Nielsen, J.B.; Al Seadi, T.; Oleskowicz- Popiel, P. The future of anaerobic digestion and biogas utilization. *Bioresource Technology*, v. 100, 22, 5478-5484, 2009.

INTA. Informe de la visita al establecimiento “La Micaela” Feedlot en Carlos Tejedor, Provincia de Buenos Aires. 2015. Available in: inta.gob.ar/documentos/informe-de-la-visita-al-establecimiento-la-micaela. Accessed in: 3-6-17.

Irena. Biomass for Power Generation. *Renewable Energy Technologies: Cost Analysis Series*, v. 1, 2012.

Lukehurst, C.; Bywater, A. *Exploring the viability of small scale anaerobic digesters in livestock farming.* IEA Bioenergy, 2015.

Pordomingo, A. (2013). Simposio de Feedlot. Available: www.produccion-animal.com.ar/informacion_tecnica/invernada_o_engorde_a_corral_o_feedlot/122-jornadas_CPMVPC.pdf. Accessed in: 13/05/17.

Senasa. Existencias Bovinas en establecimientos de engorde a corral. March. Base de datos elaborada por SENASA. Buenos Aires, 2016.

CONTROL OF REACTIVITY FLOWS FOR THE REDUCTION OF ELECTRIC LOSSES IN THE TRANSMISSION OF ENERGY IN SUGARCANE MILLS

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Abstract
The electrical losses in the Electric Power System are directly associated to the apparent power flow in the transmission lines. A sugar-alcohol plant connected to an infinite bar can optimize this flow by reducing the reactive power circulating in your system. For this, the voltage control features described in the work are required. The objective of this article is to reduce the electric losses in the system of generation and transmission of a sugar-alcohol plant connected to an infinite bar controlling the existing reactive power flow, in addition to disseminating the ideology to plants with similar operation. The theoretical calculations and practical actions were presented in the operation of the plant for its verification, in addition to simulations using ANAREDE software. It was verified the possibility of controlling the flow of reactives aiming at their reduction and consequently reduction of the electrical losses in the system.

Keywords: Power flow, voltage control, sugar-energy industries.

Introduction

Reactive power in VAr (reactive volt-amperes) in an alternating current electric system always causes an increase in current that results in increased losses [2]. It is known that the industrial sector demands great amount of reactive inductive power mainly due to its electric motors and transformers. The control of reactive flow between the plant generators and the National Interconnected System allows to reduce electric losses by joule effect in energy transmission as a consequence of the reduction of reactive current that circulates in it.

In a circuit with a power factor of 0.5, a current is twice that of the current if the power factor were unitary. In lines with heavy loads as losses due to the flow of reactives can become very significant [4]

The case study was carried out at Iaco Agrícola S/A industry, located in the city of Paraíso das Águas - MS. It has two generating units with 37.5MVA and a power factor of 0.8 each, three parallel elevators transformers with 15MVA each, as well as a 65 kilometers transmission line, that uses as conductor ACSR – Aluminum Conductor Steel Reinforced, linnet, and gauge 336.4MCM.

Another reason for this study is to standardize the operation of the plant generators. It was observed that it operates in underexcitation regime, absorbing reactive power, which could lead to partial or total loss of excitation. This abnormal operating condition, in addition to damage to the machine, due to the overheating imposed on the stator windings, rotor body, retaining rings and other ends of the stator core, can lead the electrical system to instability and even collapse due to the voltage sink caused by the absorption of reactive power of the system by the underexcited generator. It may also cause overexcitation of neighboring machines, which will try to supply the demand for reactive power required by the underexcited generator [2].

In order to conveniently operate a synchronous generator connected to the electric power system, it is necessary to know the limits within which it can operate without risks to its integrity or lifespan. These limits are generally provided by manufacturers and are determined by turbine power, field excitation, stability limits, and thermal conditions of the generator [2]. With the capacity curve of each machine in hand, it will be possible to determine the amount of reactive power they can supply or absorb without changing their active power generation, which is their main function.

Materials and methods

Data were collected for each equipment and single line diagram of the plant in question, capability curve of each generating machine, technical data of the transformers and the transmission line. With the data, it was possible to theoretically model the transmission system, with the maximum active power generation of each machine, the maximum active and reactive power consumption of the plant, the maximum reactive power consumption of the transformers and the reactive power supply of the transmission line, modeled with ANAREDE software, version V. 10.02.03.

After that, the two modes of operation were compared, one with the machines operating in the underexcitation region and the other with the machines operating in the overexcitation region. The same methodology was adopted in practice, effectively operating on the voltage controllers of the machines, in addition to modeling it in ANAREDE software.

The verification of this theoretical technique occurred through the implementation of the control of the reactive flow in the plant, operating on the voltage regulator of the generators. A better result could be obtained if the on-load tap-changers of the three existing elevating transformers were available.

System

Figure 01 depicts the operation in the underexcitation region. Figure 02 depicts the operation in the overexcitation region.

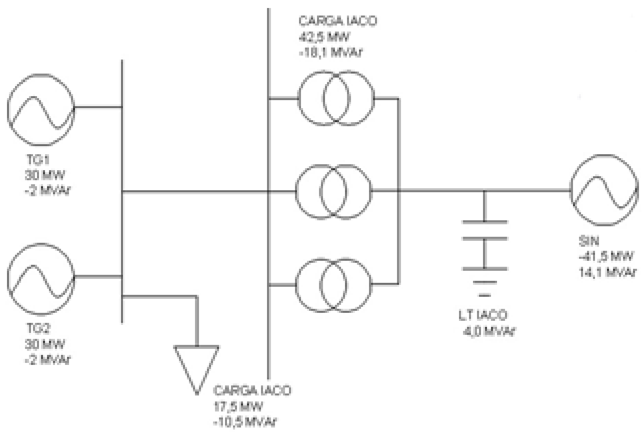


Figure 01 - Single-line diagram with underexcited operation
Source: Author (2016)

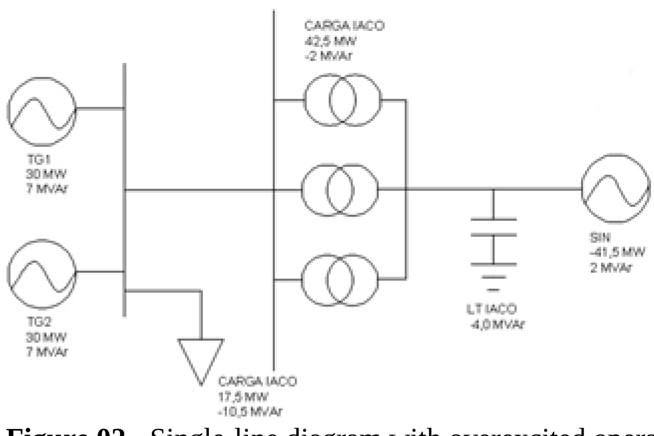


Figure 02 - Single-line diagram with overexcited operation
Source: Author (2016)

Figure 3 shows the machine capacity curve.

To characterize ACSR conductors, the manufacturer's table, NEXANS [3], was used, where the value of the resistance CA-60Hz at 75ºC was used for the linnet cable of 0.2032 ohm / km. By experience, the nominal reactive power consumption of the transformers was adopted at 1.2MVAr. Figure 03 represents the capacity curve of the machines [1].

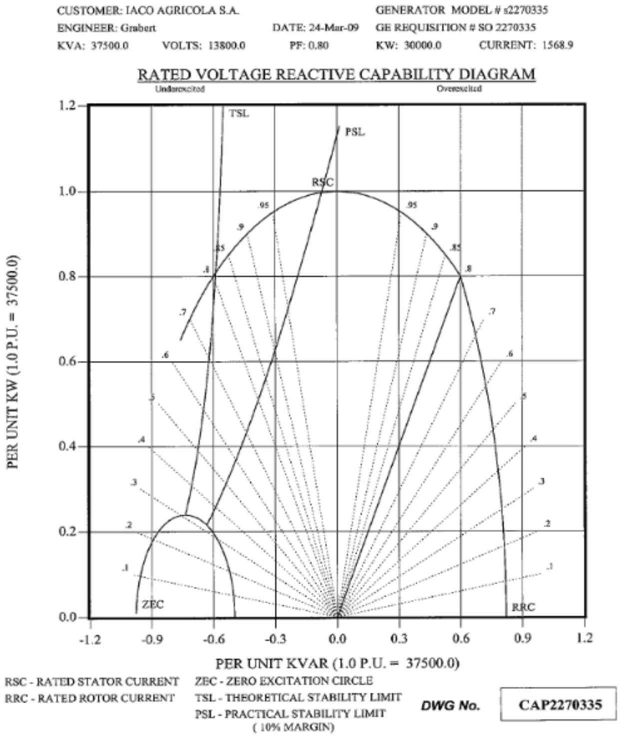


Figure 03 – Machine capacity curve
Source: Grabert, GEVISA (2009)

The value of 4MVAr of reactive power supplied by the transmission line was acquired through ANAREDE software, simulating the empty line according to figure 04 below.

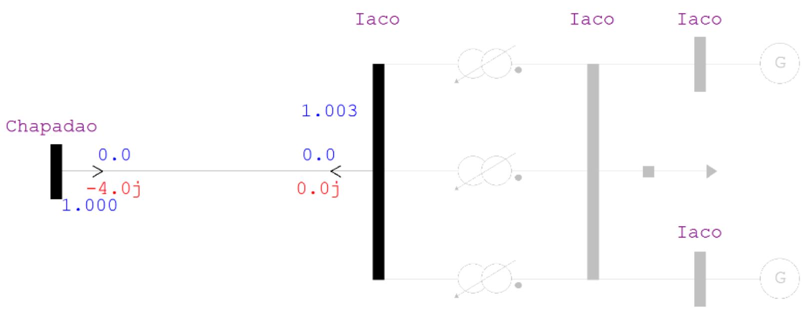


Figure 04 - Reactive power of the transmission line
Source: ANAREDE (2016)

Results and discussion

The theoretical calculations were done for the cases represented by Figures 01 and 02. Both measurements (active and reactive powers) were taken from a base case of actual IACO operation, by the supervision and control system. As described in the methodology, the value of the current in the transmission line for the cases, and consequently the joule losses, will be calculated.

Scenario 01 – Underexcited.

$$S = \sqrt{(P^2 + Q^2)} \qquad (1)$$

Where:
S = Apparent Power in kVA;
P = Active Power in kW;
Q = Reactive Power in kVAR.
$S = \sqrt{(42{,}5^2 + 16{,}1^2)}$ = **45.447 MVA**

$$I = S / (\sqrt{3} * V) \qquad (2)$$

Where:
I = Current in A;
S = Apparent Power in kVA;
V = Voltage in V.
$I = 45.447 / (\sqrt{3} * 0.138)$ **= 190.138 Ampere**

Scenario 02 - Overexcited.

$$S = \sqrt{(P^2 + Q^2)} \qquad (1)$$

$S = \sqrt{(42{,}5^2 + 2^2)}$ = **42.547 MVA**

$$I = S / (\sqrt{3} * V) \qquad (2)$$

$I = 42.547 / (\sqrt{3} * 0.138)$ **= 178.004 Ampere**

Using the mathematical formula to calculate the electrical loss, it was possible to determine the difference between the losses in scenario 01 and 02, and to measure the real values during a month of operation of the plant, according to the calculations below:

$$P = 3 * R * I^2 \qquad (3)$$

Where:
P = Active Power in kW;
R = Resistance in Ω;
I = Current in A.
$P = 3 * (0{,}2032 * 65) * (190{,}138)^2 = 1{,}433$ MW (Scenario 01)
$P = 3 * (0{,}2032 * 65) * (178{,}004)^2 = 1{,}249$ MW (Scenario 02)

The loss difference between the scenarios was 183.5 kW. In one day, losses will reach 183.5 * 24 hours = 4.404 MWh. In a 30-day month, this loss would be approximately 132.12 MWh.

Considering a cost of energy sold at the auction of renewable sources A-3 of 2011 at 120 R$/MWh, the plant would have a monthly saving of approximately **R$ 15,854.50**. For a maximum PLD value, 533.82 R$/MWh, the savings would be **R$ 70,528.30.**

The values of the actual operations were approximated due to the non-availability of the tap changer of the transformers, which would help in the better performance of the system reactive control.

Figure 4 below represents the system in scenario 01, underexcited, while figure 05 represents scenario 02, overexcited.

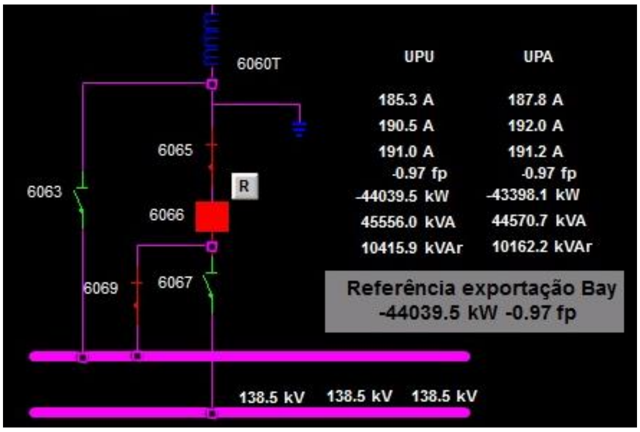


Figure 05 – Photo of IACO supervisor, underexcited
Source: IACO (2016)

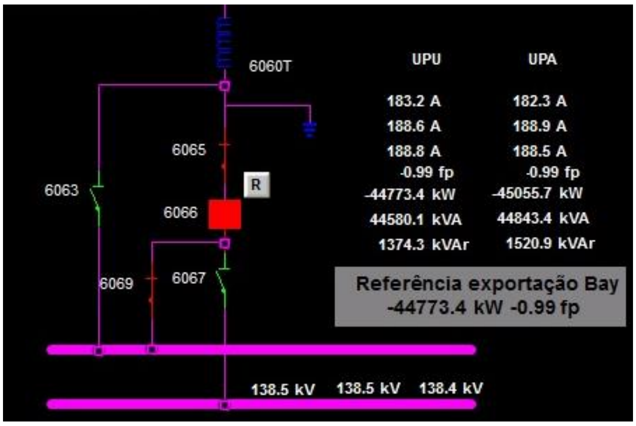
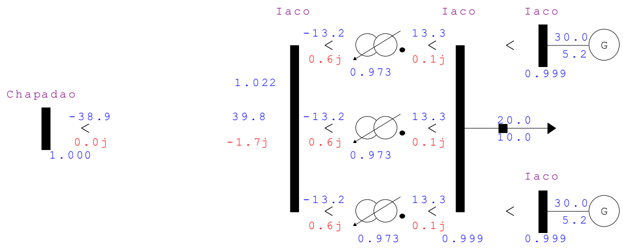


Figure 06 – Photo of IACO supervisor, overexcited
Source: IACO (2016)

The figures show the electrical magnitudes at Chapadão Substation, IACO connection point. It can be seen that in the region of overexcitation the reactive power consumption of the system is low, due to its own generation in the plant. Comparing with the underexcitation scenario, it is noticed that the electric current is smaller, even producing greater amount of active power. Checking the data of the UPU relay, we have in the overexcited scenario a production of 700kW more than in the underexcited scenario, as well as a lower value of electric current. The difference between the scenarios with respect to reactive power is about 9 MVAr.

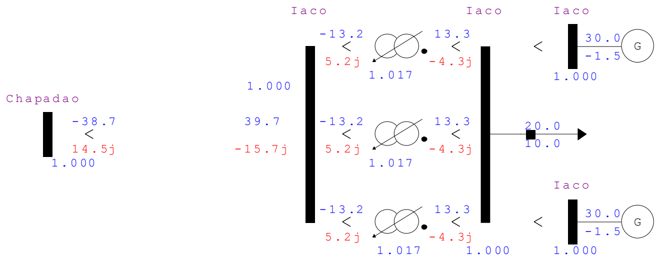
The ideal scenario of operation in the ANAREDE software was simulated considering the reduction of the electrical losses in the transmission system. Figure 7 confirms the theoretical studies performed, indicating the operation of the overexcited generators, inductively, generating a considerable amount of reactive energy. In this way there will be less reactive power circulating in the transmission line, optimizing its system.



GERACAO MW/ Mvar	INJ EQV MW/ Mvar	CARGA MW/ Mvar	ELO CC MW/ Mvar	SHUNT Mvar/ EQUIV	EXPORT MW/ Mvar	IMPORT MW/ Mvar	PERDAS MW/ Mvar
21.1	0.0	20.0	0.0	0.0	0.0	0.0	1.1
10.4	0.0	10.0	0.0	0.0	0.0	0.0	0.6

Figure 07 - Simulation in ANAREDE software (Overexcited)
Source: ANAREDE (2016)

Figure 8 represents the simulation done in the ANAREDE software for the subexcited system, showing that there will be 0.2MVAr more loss.



GERACAO MW/ Mvar	INJ EQV MW/ Mvar	CARGA MW/ Mvar	ELO CC MW/ Mvar	SHUNT Mvar/ EQUIV	EXPORT MW/ Mvar	IMPORT MW/ Mvar	PERDAS MW/ Mvar
21.3	0.0	20.0	0.0	0.0	0.0	0.0	1.3
11.5	0.0	10.0	0.0	0.0	0.0	0.0	1.5

Figure 08 – Simulation in ANAREDE software (Underexcited)
Source: ANAREDE (2016)

Conclusion

It was verified the motivational veracity of this study, that the control of the reactive flow between the IACO plant and the National Interconnected System could reduce the electric losses existing in the transmission of energy. This will bring benefits to the plant, technically and economically. The operation of the generating units will be standardized so that the voltage always remains at the acceptable levels and the machines operate inductively, generating about 25% of the nominal reactive power of each. This operation will return a real monthly saving, due to the reduction of electrical losses in the transmission system.

It is indicated the automation of the tap's of the transformers to increase the possibilities of control of the reactive power. Due to the variation of the voltage level of the National Interconnected System, as a consequence of the load changes throughout the day, only the excitation control features in the voltage regulator are not necessary for the ideal operation of the generator in order to reduce the electrical losses in the transmission.

The use of the methodology presented in this study in other similar plants of the electric sector should be done after analysis of the possibility next to the Electric Power System, where it is responsible for the dispatch of reactive energy and not responsible for the control of voltage in the bar where it is connected.

References

GRABERT. *Rated Voltage Reactive Capability Diagram.* GEVISA, São Paulo, 2009.

Lima, J. C. M.; *Aspectos de proteção e controle do gerador síncrono subexcitado*, 2002. 148f. Dissertação (Mestrado em Engenharia Elétrica), Pontifica Universidade Católica de Minas gerais, Belo Horizonte, 2002.

NEXANS. *Características elétricas do cabo linnet*. Dísponivel em: < https://www.nexans.com.br/eservice/Brazilpt_BR/navigateproduct_540012749/Linnet.html#characteristics>. Access in: 13 may. 2017.

SANTOS, J. V. A., *Fluxo de reativos*. Faculdade Pio Décimo, Aracaju, 2009.

OPTIMIZING BIODIESEL PRODUCTION IN SUB-SAHARAN AFRICA

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Abstract
Sub-Saharan Africa is characterized by low income, economic fragility, monoculture, and low-tech industrial production. In addition, it faces major challenges related to energy crisis and environmental degradation. To ensure energy security, African governments spend about $ 21 million a year on fossil fuel subsidies, which burden national budgets and inhibit investment in renewable energy development. However, as of 2009, several countries in the region (South Africa, Botswana, Ethiopia, Mali, Mozambique, Namibia, Kenya, Senegal, Zambia and Zimbabwe) started a program regarding biodiesel production and use, as an alternative to fossil fuel, besides promoting the generation of employment and income of the rural population. The biomass used is of vegetable origin, namely Jatropha curcas, Cashew and Palm oil. While in South Asia 94% of arable land is cultivated, in sub-Saharan Africa only 22% is effectively cultivated, demonstrating the region's great potential to produce biodiesel oilseeds, especially in the countries of the West African Monetary Economic Union (UEMOA). Given that these countries share the same common currency (CFA franc) and territorial borders. Some countries in this community are already producing biodiesel on small scales, but facing problems of high production costs and logistics, which discourages private initiatives. In this context, the present study aims to analyze which variables define the economic viability / production cost of biodiesel in sub-Saharan Africa. To achieve the objective of this study, a mapping of biodiesel production iniatiatives and use in Sub-Saharan Africa will be carried out; an analysis of the availability of feedstock in the region; demand and size of the biodiesel plant; and tax regime. From this, it is expected to construct an optimization production model and of the location of the production plants with the tools of Mixed Integer Linear Programming, in order to improve the productive efficiency and to minimize the cost of production and logistics.

Keywords: Sub-Saharan Africa, biodiesel, production optimization.

Acknowledgments: The Federal University of Rio Grande do Sul and the Postgraduate Program in Business Management, where this research is being developed.

Introduction

The discussion that had once begun by a small group of researchers to use biodiesel as an alternative biofuel for fossil fuel, is based on the government policies of several countries from the point of view of energy security and reducing the impact of high oil prices (MULUGETTA , 2009). Being a farming crop, sub-Saharan Africa, with an extension of land with agricultural aptitude, is increasingly being seen as a region with great potential for biofuel (WORLDWATCH INSTITUTE, 2015).

In the context of energy security, the region has a long history in consolidating the intercontinental biofuels market. In this sense, several countries in the region have already initiated a program of production and use of biodiesel, such as South Africa, Botswana, Ethiopia, Malawi, Mali, Mozambique, Namibia, Kenya, Senegal, Zambia and Zimbabwe and the raw materials used are predominantly Jatropha curcas, mamona and Palm palm (MULUGUETTA, 2009; GASPARATOS et al., 2015). Thus, the institutionalization of the biodiesel market is a comparative advantage for the economic growth of these countries, pointing out the need for structuring the production chain and developing an optimization model for agroindustrial plants, especially considering the countries of the Monetary Economic Union of West Africa - UEMOA (Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Mali, Niger, Senegal and Togo), considering that some countries in this community are already producing small scale biodiesel, such as Senegal and Mali.

The development of the biodiesel sector poses great challenges for emerging countries, although they have potential for oilseed production, cost of production represents the biggest obstacle to biodiesel profitability. From this perspective, what is the question of how to optimize biodiesel production in sub-Saharan Africa in order to improve production efficiency and minimize the cost of production, mitigating the need for subsidies from governments already weakened by fossil fuel imports? In this context, the present research aims to analyze which variables define the economic viability / cost of biodiesel? The research involves the mapping of biodiesel production and use initiatives in sub-Saharan Africa, analysis of local institutional structures, availability of raw material, plant size, biodiesel demand, tax regime and construction of a mathematical model for optimization of productive efficiency, promoting regional development.

Materials and Methods

To reach the objective of this work, the quantitative research method will be used, with application of Operational Research tools for the optimization problem. From which, a mathematical optimization model will be developed to minimize biodiesel production costs in sub-Saharan Africa.

Optimization is one way to find the best solution to a problem. In this context, one way to solve the optimization problem is to formulate it in mathematical language. The process of transforming the real problem into a mathematical formula is called mathematical modeling (JORGE and STEPHEN, 2000; ARENALES and MORABITO, 2006). Thus, optimizing means maximizing or minimizing a function, subject the constraints to its variables (JORGE and STEPHEN, 2000; ARENALES and MORABITO, 2006).

The following notation can be used,
x is a vector of variables;
f is the objective function, the function of x that must be minimized or maximized;
g is a vector of constraints that the point x must satisfy. This is a function vector of x.
The number of components of g is the number of constraints on x.
In this context, one can use the optimization problem as follows:
Minimize f (x)
Subject to $gi(x) = 0, i \in \varepsilon$
$gi(x) \geq 0, i \in I$

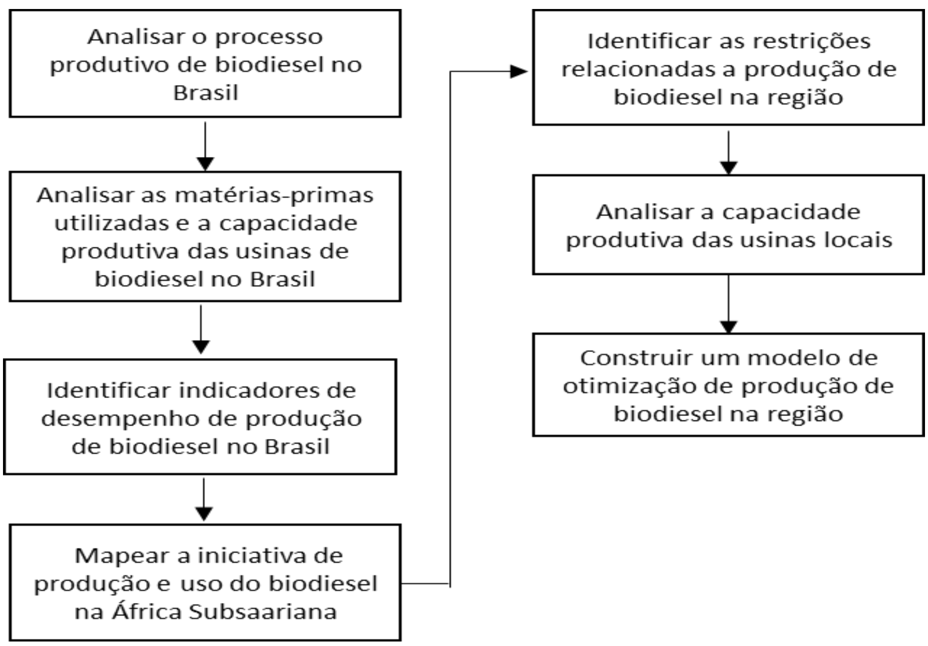
Where,
$x \in R^n$
$f \in R$
$n \rightarrow R, gi \in R$
$n \rightarrow R,$
ε and I are sets of indexes.

To achieve the objectives of this work, a multiple-case study will be carried out, a research modality widely used in the biomedical and social sciences (GIL, 2007). The case study is characterized as a study of a program, an institution, or a social unit. The most common examples for this type of study are those that focus on just one unit: an individual, a small group, an institution, or a program. Alves-Mazzotti and Gewandsznajder (1998) argue that there may also be multiple case studies, in which several studies are conducted simultaneously: several individuals or several institutions. In this sense, an analysis of the production units of biodiesel in sub-Saharan Africa will be carried out, identifying the constraints related to the production process, as well as the structure of the production chain of one biodiesel from a group of countries in the region.

Methodological procedures

The methodological procedures follow as shown in Figure (1) below.

Figure 1. Scheme of methodological procedures of research.



Source: Author, 2018.

Primary data will be collected from selected biodiesel industry visits based on predefined criteria and secondary data from specialized sources of international institutions and biodiesel production industries in a previously selected sub-Saharan African group.

Preliminar Results and Discussion

It is observed that every hour, 9 million people add to humanity, 4 million CO2 are emitted into the atmosphere, 1500 hectares of forests are felled, among other activities (STEFFEN, CRUTZEN and MCNEILL, 2007). It is estimated that by 2050, 86% of the world's population will be in the countries currently under development, which corresponds to 8 billion new consumers in search of developed countries' living standards (FORUM FOR THE FUTURE, 2017).

The intensive use of fossil fuel combined with climate change has led to intensification of environmental pressures on the use of biofuels and biodegradable energy sources. The importance of using biodegradable fuel goes beyond environmental benefits, as several developing countries are investing in biodiesel and ethanol as an alternative to reduce the uncertainty of conventional fuel price volatility, oil substitution, as well as a mechanism to combat poverty, diversification of the productive base and economic growth (MULUGUETTA, 2009, SCHUT, SLINGERLAND and LOCKE, 2010, MDA, 2015, MME, 2015).

The expansion of the productive scale is systematically linked to the objective of reducing the effects of the energy crisis, as well as generating employment and income in the countryside.

This activity reflects in the emerging countries of Latin America (Brazil and Argentina) and sub-Saharan Africa. However, the loss of efficiency in the production process has raised the cost of production, necessitating government subsidies to keep production economically viable. The mechanisms of biodiesel production in sub-Saharan Africa are strongly related to technologies from foreigners, as well as land tenure and use. While in Asia, 94% of the land is cultivated, in sub-Saharan Africa, 22% of arable land is effectively cultivated, which reinforces the need for emergency introduction of biodiesel into the region's energy matrix (WORLDWATCH INSTITUTE, 2015). Producers of raw materials can be divided into two categories, small producers are made up of families engaged in shared farming in the production of food for subsistence and oilseed, while large producers are foreign-owned enterprises. These companies are basically engaged in commercial production for raw materials (GASPARATOS et al., 2015). The fact that biodiesel production is a nascent sector in sub-Saharan Africa, local producers are far behind the technological domain. In this context, the design and development of local technologies that are adaptable to the political, social and environmental context can come from countries with great experience in the production and use of biodiesel, such as Brazil.

Technological transfer can be defined as acquisition or diffusion of knowledge, development of technique for creation and use of a technological apparatus generated in another environment (LIMA, 2004). The success of technology transfer depends greatly on the experience accumulated by the receiving entity in its environment. The authors such as Kremer and Kovaleski (2009) emphasize the notion of the technology transfer process, emphasizing its importance in providing the relative advantage that innovation has to compete or replace existing technologies for the consolidation of companies in the competitive market. In the bioenergy sector, technology transfer is an increasingly present activity due to growing concern with climate change, on the one hand, and as a result of efforts in research and development of bioenergy production and use mechanisms, on the other. The activity has received great acceptance in the world, driven by the policies of incentive and financing of international financial institutions in this context. In the European Union, the Bioenergy Transfer Techonology Network (BTN) project stands out in the transfer of this technology in Europe (EU, 2006). The Project was created in 2002 to develop exemplary models of efficient bioenergy production. The objective was to apply the most recent know-how to solve practical problems in the technological field of bioenergy. The program is managed by the University of Applied Sciences of the Bioenergy Development Center in Finland and also has facilities in research centers in six partner countries, such as Denmark, Estonia, Latvia, Lithuania, Poland and Sweden, forming the innovation sector system in bioenergy in the European Union (EU, 2006).

In Brazil, Costa et. al., (2013) carried out a study on the technological transfer of biodiesel in the State of Paraná. From the analysis of the results, they concluded that innovations and technological transfers can be considered as alternatives for the development and social inclusion of the region, since there is greater mobilization of the government and other actors involved in the process. Taking this understanding to the countries of sub-Saharan Africa, a great effort was made by local governments to encourage the production of biodiesel, not only as an alternative to generate employment and income, but also as an alternative source of energy for the rural population (GASPARATOS et al., 2015).

In terms of optimization, in order to minimize the cost of production, the production methods involving the whole value chain in the biodiesel industry in Africa are improvised by the productive agents, despite the greater involvement of local governments in the biodiesel program (GASPARATOS et al., 2015). In this context, mathematical modeling to minimize production costs will provide support to support local agroindustries in the production of renewable fuels.

Conclusion

Mathematical modeling to minimize production costs is a method widely used in operational research. This modeling can be applied in solving localization problems, transport optimization. To reach the objective of this study, coefficients and production indicators will be compiled to compose objective function and constraints, based on the unitary operations of production, costs and revenues, and technology employed for the entire productive cycle and its limitations. It will also be necessary to carry out a survey of data on indicators related to production, tax regime, labor, availability of land, location of the industrial plant and final consumers.

It will be used the quantitative research method, with application of the mathematical model for the problem of optimization of production. This will map the biodiesel production and use initiative in sub-Saharan Africa; analyze the production process of biodiesel in the region, analyze the availability of raw material; demand and size of the biodiesel plant; and tax regime. From this, build an optimization model in order to improve production efficiency and minimize the cost of production and logistics in the region. The expected result is the development of an optimization model that minimizes biodiesel production costs in sub-Saharan Africa, reducing industry dependence on government subsidies, making the sector more attractive to private enterprise.

References

A. Gasparatos a,b,n; G.P. von Maltitz c,g; F.X. Johnson d; L. Lee e; M. Mathai h; J.A. Puppim de Oliveira e,i; K.J. Willis. *Biofuels in sub-Sahara Africa: Drivers, impacts and priority policy areas.* Renewable and Sustainable Energy Reviews 45 (2015) 879–901.

Alves-Mazzotti, A. J.; Gewandsznajder, F. *O Método nas Ciências Naturais e Sociais: pesquisa quantitativa e qualitativa.* São Paulo: Pioneira, 1998.

Arenales, M; Armentano, V; Morabito, R E Yanasse, H. *Pesquisa operacional*. Ed. Campus, 2006.

Costa et. al., 2013. Transferência de tecnologia na produção de biodiesel: alternativa para inclusão social e desenvolvimento regional no Estado do Paraná. *Revista Brasileira de Gestão e Desenvolvimento Regional*. 2013. Disponível em: <http://www.rbgdr.net/revista/index.php/rbgdr/article/view/869>. Acesso em: 29 jan. 2018.

EU-European Union. BTN - *The Bioenergy Technology Transfer Network. Regional Policy. 2006*. Disponível em: <http://ec.europa.eu/regional_policy/en/projects/estonia/btn-the-bioenergy-technology-transfer-network >. Acesso em: 29 jan. 2018.

Fonseca, J. J. S**.** *Metodologia da pesquisa científica*. Fortaleza: UEC, 2002. Apostila.

Forum for the future. *Future Centre*. 2017. Disponível em: <https://thefuturescentre.org/>. Acesso em: 29 jan. 2018.

Gil, A. C. *Como elaborar projetos de pesquisa.* 4. ed. São Paulo: Atlas, 2007.

Jorge, Nocedal; Stephen J. Wright. *Numerical Optimization.* Mathematics Subject Classification (2000): 90B30, 90C11, 90-01, 90-02

Kremer, C. D. & Kovaleski, J. L. *Transferência tecnológica de um sistema de monitoramento automatizado da produção: benefícios e dificuldades*. In: Anais do XXIX ENEGEP (Encontro Nacional de Engenharia de Produção), Salvador, 2009, CD-ROOM.

Lima, I. A. *Estrutura de referência para a transferência de tecnologia no âmbito da cooperação universidade-empresa: estudo de caso no CEFET-PR.* 2004. Tese (Doutorado em Engenharia de Produção) – Universidade Federal de Santa Catarina, Florianópolis, 2004.

Ministério do desenvolvimento agrário – MDA. *Biodiesel*, 2015. Disponível em: <http://www.mda.gov.br/>. Acesso em: 29 jan. 2018.

Ministério de minas e energia. biodiesel. *O Programa Nacional de Produção e Uso do Biodiesel*. 2005. Disponível em: <http://www.mme.gov.br/web/guest/pagina-inicial/outras-noticas/-/asset_publisher/32hLrOzMKwWb/content/percentual-obrigatorio-de-biodiesel-passa-para-8- >. Acesso em: 29 jan. 2018.

Mulugetta, Y. (2009). *Evaluating the economics of biodiesel in Africa, Renewable and Sustainable.* Energy Reviews, Vol. 13, No. 6-7, pp. 1592-1598

Schut, Marc; Slingerland, Maja; Locke, Anna c. *Biofuel developments in Mozambique*. Update and analysis of policy, potential and reality. Energy Policy 38 (2010) 5151–5165.

Steffen, Will; Crutzen, Paul J. and McNeill, John R. (2007). *The Anthropocene: Are Humans Now Over whelming the Great Forces of Nature?* Ambio Vol. 36, No. 8, December 2007.

Worldwatch institute. *Biofuels in Africa May Help Achieve Global Goals, Experts Say*. 2015. Disponível em: <http://www.worldwatch.org/node/5284>. Acesso em: 29 jan. 2018.

THE IMPACT OF STATE INTERVENTION IN THE RENEWABLE ENERGY MARKET

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Abstract
This paper analyzes the impact of state intervention in the energy sector, specifically the renewable energy sector in Argentina, from a regulatory perspective. It examines the use of regulations and prices as public policy instruments to achieve an efficient and sustainable investment process, which in turn enables the development of a diversified electricity generation matrix. This research project contributes to the formulation and design of public tools and regulatory mechanisms, which may be applied to energy generation activities to promote the diversification of an existing energy matrix. Firstly, the paper presents the current state of the energy generation system in Argentina, characterizing its main aspects and illustrating the share of renewable energy in the industry. This analysis also describes the national energy matrix, its installed power capacity, and the demand for fossil fuels to produce energy. The results show a very low share of renewable energy in the national energy matrix and a growing dependence on fossil fuels, especially natural gas, to generate electricity. Secondly, the paper evaluates the advantages and disadvantages of regulatory and price incentive mechanisms—e.g. feed-in tariffs, competitive tenders, and compulsory quotas—applied to foster investment in renewable energy plants, particularly bioenergy plants. Lastly, it compares these findings with regional and international experiences to identify the regulatory best practices that could be replicated in Argentina.

Keywords: public policies, electric system;

Introduction

While global energy consumption is rapidly increasing, traditional energy resources are not growing proportionately, creating powerful uncertainty regarding the future of energy. Global warming, caused in part by fossil fuels, poses environmental challenges that cannot be ignored. In the case of Argentina, fossil energy sources, particularly natural gas, are the principal component of the national energy matrix, with a contribution of more than 50% of Argentina's primary energy. However, national production of this resource is stagnant, and the country has increasingly resorted to importing it. The need for an external supply of this energy resource has led to large fiscal deficits and to a negative balance of payments. Because this situation is unsustainable over time, different policy measures are needed to gradually resolve these fiscal and environmental distortions. Among the possible measures to be considered for implementation, the promotion and development of renewable energies (RE)[3] makes a strong showing.

However, despite technological advances, many of the technologies currently used to generate electricity from renewable sources are not yet economically competitive with conventional, fossil fuel-based alternatives. As such, it is difficult to attract private sector investment in renewable energy plants under free market conditions, making it necessary to implement public policies to promote such investment. The justification for such policies lies in

[3] In Argentina, hydroelectric plants generating power over 50 MW are excluded from this category.

the market's inability to capture the social benefits and costs associated with these projects, chiefly the energy independence and environmental benefits that they offer.

Likewise, the energy sector affects other productive activities that are essential to households, affecting the social sensitivity and generating an impact on production, consumption, and quality of life. Regulatory schemes are therefore necessary to internalize these externalities, ensuring the most efficient use of scarce resources.

Regulatory activity is one of the central themes of economic policy. It is a form of public intervention that restricts, influences, or conditions the behavior of economic actors. Regulatory frameworks may involve various forms of intervention, including price controls for regulated activities and compliance with technical, informational, and economic conditions. Effective use of these policies demands the study of the provision of public services from a variety of perspectives to guarantee the following:

- The optimal allocation of resources, allowing the provision of public services in a reliable, efficient, continuous, and secure manner.
- That investments undertaken by public utility companies not only accommodate current demand, but also account for projections of future demand.
- That the price structure allows for the recovery of the investments made, for the provision of energy at an efficient cost, and in turn for the generation of fair and reasonable profits in relation to the activities carried out.
- The coverage of the totality of potential user demand, including those users unable to afford standard energy prices, or whose access to services may be complicated by distance or by technical limitations.

The above conditions impose on the State the non-delegable mission of designing public policies and long-term regulation for the management and provision of public services – in this case, of the electricity sector.

Principal Mechanisms for the Regulation and Promotion of Renewable Energies

The principal incentive mechanisms used globally to increase the use of RE are feed-in tariffs, competitive bidding processes, and quotas. There are other secondary incentives that complement these mechanisms, such as subsidies and tax incentives.

The feed-in tariff (FIT) is a legal instrument that establishes a special rate per unit of electricity provided to the network. In this way, the producer gains certainty regarding the minimum rate paid for electric power. The basic elements of the FIT are as follows:

a. Competitive bidding process (also known as a renewable energy generation tender): The regulator defines a market reserved for a given quantity of electricity from renewable sources and organizes a bidding process between RE suppliers for the allotted production. The bidders submit proposals, each defining a price per unit of electricity for which they would be willing to operate, and the regulator evaluates these proposals based on the offered prices as well as compliance with other requirements. The proposals are then classified in ascending order of price until the bid amount is reached. Each of the selected suppliers is awarded a long-term contract to supply energy at the specified price, known as a power purchase agreement (PPA).

b. Quota system: consists of the definition, by the appropriate regulatory authority, of a minimum percentage of electric power generation or installed capacity from renewable sources. Participants in the electricity market (on both the supply and the demand side) are required to meet this quota, with fines established for non-compliance. Energy is sold at the market price, which can represent a strong obstacle to the development of RE. The quota system may be complemented by a supply of tradeable green certificates, which reflect the amount of RE generated. In this way, actors can compensate for failure to reach the assigned targets, through the surplus RE generation of another actor; otherwise, they submit to the payment of the associated penalty.

There is no single path for the promotion of RE; however, the optimal alternative for each country depends on its respective policy objectives for its energy sector.

National Situation[4]

Argentina has a high dependence on non-renewable energy sources such as oil, natural gas, and coal, which represent 87% of its primary energy matrix. Natural gas, however, remains the principal component with a share greater than 50%. This is the result of a state policy, implemented since the end of the 1940s, that has made natural gas a fundamental pillar of the national energy matrix (Einstoss Tinto & Sicra, 2016). In this matrix, non-fossil energy sources such as hydro, nuclear, wind, solar, and biodiesel provide only a minor contribution towards the total.

During the period from 1992-2016, the annual energy demand in the Mercado Eléctrico Mayorista (MEM) increased 4% annually on average, and the maximum power demand increased by an average of 660 MW per year (an annual rate of 4%). In response, the installed capacity of the electric power plant associated with the MEM grew by 160%, from 13,000 MW in 1992 to almost 34,000 MW by the end of 2016.

The growth of the energy supply during these years was driven, in large part, by an increase in installed capacity from combined-cycle plants powered by fossil fuels. This trend exacerbated the dependence of the electrical system on thermal generation in general and on natural gas. Currently, approximately 30% of natural gas consumed in the country powers electricity generation sites.

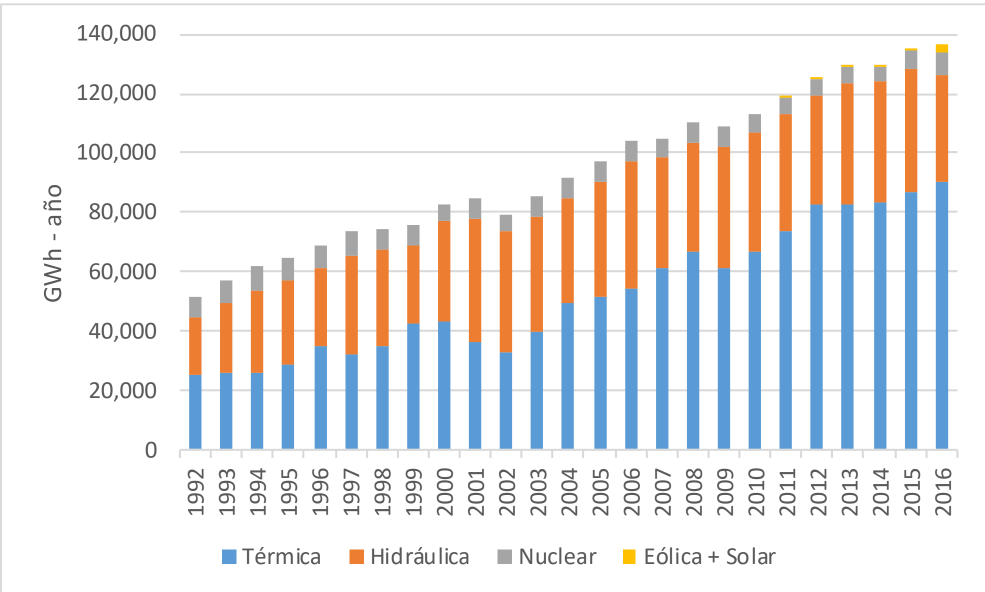

Figure 1- Change in annual generation of electric energy (MEM) by technology. Units are GWh (1992-2016). Source: Authors' own work based on data from CAMMESA (2016)

Although the consumption of natural gas for the generation of electric energy has increased steadily since 1997, its share has declined from 98% in the year 2003 to 71% in the year 2016, driven by supply restrictions. Meanwhile, the use of fuels such as Fuel Oil and Gasoil has increased as a replacement for natural gas in thermal generation machines. These fuel sources

[4]Las energías renovables en la Argentina. Un nuevo panorama, Agosto 2017, Boletín del Centro de Estudios de la Regulación de los Servicios Públicos (CERES), Universidad de Belgrano. http://repositorio.ub.edu.ar/handle/123456789/8512

increase the system's cost of energy generation and are more damaging to the environment. On the other hand, the country's thermal power plants have a significant proportion of obsolete and inefficient equipment that operate as a reserve to meet peak demand, with relatively high operating costs.

Despite both marked international trends and Argentina's high potential for the generation of RE, its share of the country's primary energy matrix has remained at very low levels, and still lower within the national electricity generation matrix. Although the production of electricity from renewable sources has increased by 78% between 2011 and 2016, from 1,500 GWh to 2,600 GWh, its current share of the energy supply remains close to 1.9%.

The electrical energy market shows significant supply restrictions that impact its sustainability over time. The situation requires different policy alternatives in order to gradually resolve the distortions currently present in the market. One of the alternatives that has gained considerable momentum in recent years is the promotion of energy from renewable sources, both as an essential component of energy policy and of environmental preservation.

In an attempt to promote the diversification of the national energy matrix, in 2006, the Ley Nacional 26.190 declared the generation of electrical energy from renewable sources to be of national interest and mandated that, by the end of 2016, 8% of electricity consumed in the country was required to originate from these sources. Four years later, the national government auctioned the purchase of 1,015 MW of electrical energy from renewable sources through the Programa Generación Renovable (GENREN). However, only 7 of the 39 awarded projects were installed, offering a total power of 139 MW, only 13.7% of the total output auctioned. Legal and economic instability were the principal factors that impacted access to international financing for these projects.

In 2015, the Ley n° 27.191 was passed, which declared the generation of electrical energy from renewable sources to the provision of public services to be of national interest, and established obligations for market actors as well as financial and tax incentives to promote investments in the sector. As part of these obligations, the law established that all users of electricity in the country must, directly or indirectly, contribute to the gradual increase in the share of energy from renewable sources in their own consumption, beginning with 8% at end of 2017 and arriving at 25% by the end of 2025. Large users of the MEM – clients of the Public Distribution Service Providers with power demands greater than or equal to 300 kW- must individually and effectively meet these objectives. To achieve this, these users may either produce RE themselves, or contract the purchase of RE – either directly through a generator, through a distributor who may acquire it in their name, through a vendor, or through CAMMESA. The purpose of this condition is to promote the commercialization of RE between private entities, therefore driving the growth of a market for these services independent of CAMMESA demand.

Users with a power demand of less than 300 kW must also comply with the percentages and deadlines stipulated in the law, but in such cases the Ministry of Energy and Mining will take the appropriate steps to incorporate a renewable energy supply into the MEM. Further, this organization must promote the diversification of the electrical energy matrix with the goal of enabling the development of varying technologies and geographical diversity of RE enterprises, in order to take advantage of Argentina's vast potential in this area.

To begin meeting these objectives, at the beginning of 2016 the Ministry of Energy and Mining launched, under the framework of the RenovAr Plan (round 1), a bidding process for the contracting of 1,000 MW of power from renewable energy sources. The offering was a success, with the government receiving 123 bids from 76 firms for a total of 6,366 MW. In this first stage, 29 projects were awarded for a total generation of 1,142 MW; following this success, the government offered a second round (RenovAr 1.5) in which those projects which had passed technical review were invited to improve their bidding prices. In this way, 30 more projects were awarded for a total further generation of 1,292.7 MW. Overall, 59 were awarded for a total output of 2,423.6 MW, with 35% originating from solar photovoltaic energy and 33% from wind energy, although with only two of the awarded projects generating bioenergy. The technological diversification of RE sources promoted by the Ley 27.191 requires an institutional design more in line with the opportunities offered by each energy source.

For the moment, the results of the bids carried out by the Ministry of Energy and Mining, under the framework of the RenovAr Plan, shows an auspicious outlook that would appear to confirm the potential for the establishment of RE as an economically and productively viable option for the country. However, RE development depends on removing the economic and political-institutional barriers that inhibit the competitiveness of the sector, advancing the definition of a regulatory framework for the electricity market that brings greater certainty to the various actors involved, and promoting the creation of a market for the commercialization of electric energy from renewable sources between private companies, as expressed in the law.

International Experience

The analysis of regional and international experiences in terms of RE, by quantifying key sector variables (e.g. share of RE in the energy matrix, generation and installed capacity) allows the comparison of the RE situations in control countries and the identification of regulatory best practices for possible replication in Argentina.

Regulatory laws concerning the promotion of RE in the United States, the European Union, and Latin America were examined. Latin America is one of the main sources of RE promotion globally. According to the Interamerican Development Bank (IDB), Latin America is already the “greenest” region on the planet in terms of RE generation, with 60% of its consumption of electricity coming from renewable sources (mainly hydraulic), while the global average does not exceed 25%. The combined region of Latin America and the Caribbean contains 8.5% of the global population and 8.7% of world GDP, but produces 20.4% of the world’s hydroelectricity. The region has a clean matrix due to its large installed hydroelectric generation capacity, and yet it remains subject to problems arising from the growth of energy demand, lack of transmission infrastructure, and inability to compensate for the fluctuations produced by RE generation. This reflects a failure in research and technical innovation within the region to overcome these difficulties.

In the region, between 2010 and 2015, there was a total investment of 80 billion dollars in non-conventional renewable energy sources (excepting hydroelectric), with 16.4 billion dollars in 2015 alone, representing 6% of global investment – during which period Argentina remained totally excluded from this investment process. This year, México y Chile join the list of the top ten 10 principal RE markets, behind Brazil. Accordingly, this research project intends to perform a comparative analysis with Uruguay, Chile, Colombia and Brazil.

Final Objective

Once the key sector variables for each control country have been quantified, the data will be analyzed to observe and quantify the successes of each country and identify the respective regulatory best practices that drive them.

As mentioned at the beginning of this summary, the final objective of this research project is the identification of regulatory best practices that will enable the sustainable development of RE in Argentina, with the elapsed time since implementation of these regulations permitting a comparative analysis to identify “lessons learned” and “regulatory failures,” and finally to make regulatory policy recommendations that will contribute to the promotion of RE in our country.

References

THEME: BIOGAS

ELECTRICITY RECOVERY FROM ORGANIC WASTE OF SLAUGHTERHOUSES OF ARAGUAÍNA CITY IN THE AMAZON REGION – A CASE STUDY.

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Abstract

The municipality of Araguaína in the state of Tocantins is located 380 km from the capital city, Palmas. Araguaína is known as the state's economic capital, since it stands out in the most varied sectors of the economy, especially the stockbreeding. The currently herd in the Tocantins State is of about 8 million heads of cattle in the process of fattening for slaughter purposes, achieving significant values in the sales sector, exporting about 51,779,353 kg of meat per year. However, such exorbitant production generates environmental impacts, such as waste and production of harmful gases to the environment. This scientific paper presents a case study applied to Araguaína city, which currently has five large slaughterhouses installed in their limitations with daily slaughter of about 5,000 head of cattle. The methodology used is a case study with data collection through application of forms and questionnaires in the local slaughterhouses to stablish the *status quo* of knowledge about energy recovery systems in the region and to quantify the amount of organic waste produced that could be used to produce biogas. An estimate of the potential electricity generated from this waste was done using a biogas conversion factor for electricity found in the literature. The potential of biogas production using the slaughterhouses waste was 2,153,017 m^3 / year. This amount of biogas can generate about 3,074,508 kWh / year of electricity, which can be used by the units under study. It is possible to conclude that the use of slaughterhouses waste to produce electricity is an interesting solution to the waste management in the bovine industry reducing to the companies' utilities costs and the environment harms involved.

Keywords: Biogas, livestock, energy efficiency.

Introduction

Delimitation

This research is conducted on the slaughterhouses of Araguaína city, municipality located in the state of Tocantins, north of Brazil.

Justification

Organic waste in its natural decomposition by anaerobic bacteria generates methane gas in high amounts, which when released into the atmosphere contributes significantly to the greenhouse effect and, consequently, to global warming. This gas has a high-energy potential and can be used for electric power generation. In this process, the methane gas is converted into carbon dioxide, which has a much lower contribution to the global warming. Biogas is composed of methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), hydrogen (H_2), oxygen (O_2) and hydrogen sulphide (H_2S), methane being 50% of the composition. Countless advantages are provided by the use of biogas, such as: reducing the greenhouse effect by reducing methane released into the atmosphere and contributing to the minimization of urban solid waste, renewable and animal waste (BLEY Jr., 2009).

The city of Araguaína - TO, one of the largest suppliers of meat to Brazil and also to abroad, has five slaughterhouses in its vicinity. Study, quantify and diffuse the possibility of energy recovery from the organic residues resulting from the slaughter of cattle contributes significantly to the reduction of environmental impacts of this economic activity and, in addition, also contributes to the generation of renewable energy for the national energy matrix.

According to the Municipal Livestock Research of IBGE, in Brazil the total herd is 1,634 billion animals; in the Tocantins state there are 243,744 cattle in fattening for slaughter purposes, and consequently there is a large amount of manure produced by them, throughout this life cycle.

The biodigester is the equipment used for the treatment of animal wastes for biogas use purposes. It is constituted of a closed chamber where the biomass (in general debris of animals) undergoes the process of anaerobic fermentation. As result of such fermentation, biogas and biofertilizers are produced. In this way, it is conceivable to describe the biodigester as a device to contain biomass and its product: biogas, which can be used in several ways, one of them being the generation of electricity (GASPAR, 2003).

According to Bley, Jr. (2015), the biogas produced in biodigesters in Brazil has great potential as renewable energy because it is spread throughout the space and is more accessible with respect to the cost of operation. All that which is organic has the methane capable of being transformed into electricity.

Animal waste is the best raw material for biodigesters, because of the high amount of anaerobic bacteria coming from the animal intestinal tract. The use of biodigesters has numerous advantages, in addition to reducing CO2 emissions, by the replacement of fossil fuels, also minimizes gas irradiation, especially methane gas (CH4), generated during the fermentation process. Also stabilizes the waste that would normally be treated by the slaughterhouses in stabilization ponds, a system that is not efficient in comparison with the treatment made with biodigesters, since making no final product available such as biogas (JUST, 2007).

As the biogas has a high amount of methane (CH4) in its composition, it is suitable as fuel in engines that use the internal gas combustion method to move electric power generators. The versatility of biogas is enormous as a renewable energy, since the mechanical energy is generated from the chemical energy. Using processes of controlled combustion, the generators are driven by stationary motors that result in the instantaneous conversion of electricity (BLEY Jr, 2009).

Materials and methods

The methodology used is a case study with data collection through application of forms and questionnaires in the local slaughterhouses to stablish the *status quo* of knowledge about energy recovery systems in the region and to quantify the amount of organic waste produced that could be used to produce biogas. It was also used the literature to determine the conversion factor and the amount of waste from the slaughterhouses abattoir. Data from the local electricity distribution company (Energisa Tocantins) and the Planning Secretariat of Tocantins (SEPLAN) where used to know the electricity consumption data in the city of Araguaína.

Description of methods

The methodology for collecting the necessary information to determine the energy potential of using biogas obtained through the biodigestion of the remaining waste from the slaughter in Araguaína Tocantins was performed through the application of a specific questionnaire sent to 3 large companies of the segment located in the delimitations of Araguaína. With the application of the form it was possible to estimate the amount of waste, daily slaughter, the company's knowledge about energy recovery systems and possible implementations of such systems. With the data in hand the literature was used to determine the amount of biogas that can be generated with the raw material available to the slaughtering units of the municipality under study.

Determining the potential of electricity generation for bovine manure

In order to determine the number of metric tons of biogas/year from the anaerobic decomposition of the manure from the slaughtering, the number of animals (heads) slaughtered per year, the weight of the waste to be used in the biodigestion process, the biogas specific mass (1.16 kg/m ^{3}) and the volume of biogas specifically generated by bovine manure were considered (BARRERA, 1993)

Equation 01:

$$Biog\acute{a}s\left(\frac{m^3}{ano}\right) = \frac{[\,cabeças\ x\ Et\ x\ Pb]}{massa\ especifica\ do\ biog\acute{a}s} \quad (1)$$

Where:
Et = Total manure [kg manure / (day. Energy unit)];
Pb = Biogas production [kg biogas / kg manure]

According to BARREIRA (1993) 1 m^3 of biogas is equivalent to 1.423 kWh of electricity. This ratio applied on equation 1 determines the potential to generate electricity from the waste of the slaughtering process of the five units located at Araguaína city.

Results and discussion

Number of cattle slaughtered in Araguaína-TO

According to Planning Secretariat of Tocantins (SEPLAN), there are five large slaughterhouses located in Araguaína, with a daily slaughtering capacity of around 1,000 cattle on each unit, information confirmed in a form applied to 2 companies installed in the county.

Considering the operation of the units, it was used a total 270 days of normal operation per year for the calculation of the annual abattoir. It is possible that the annual slaughtering capacity of Araguaína municipality is 1,350,000 head, according to Table 1.

Table 1 - Cattle slaughtered annually in Araguaína-TO

Category	**Number of heads (per day)**	**Number of heads (per annum)**
Cattle	5,000	1,350,000

Source: Adapted from SEPLAN, Socioeconomic data city of Araguaína-TO in the year 2017.

Potential for the generation of biogas from bovine manure

Based on reference data provided by the National Biomass Reference Center in 2011, it was possible to determine the amount of biogas that can be generated with the annual slaughter of cattle in the city of Araguaína, the data are described in Table 2.

Table 2 - Potential of biogas to be generated with slaughterhouse wastes in Araguaína

Origin of the animal	**Amount of waste (kg / head)**	**(kg biogas / kg waste)**	**Methane Concentration**	**Biogas (m^3/ano)**
Cattle	50	0.037	60%	2,153,017

Source: Adapted from CENBIO (2011)

The amount of biogas that can be generated from the total of animals slaughtered per year in Araguaína-TO based on equation 1 can be verified in table 1.

According to GONÇALVES T. (2016) the herd with the greatest biogas generation potential in Brazil is the cattle herd. However, the cattle herd is not the most efficient in the field of biogas, bovine manure is about 40% and 30% less efficient than swine and chicken manure, respectively. However, the cattle herd in Brazil is larger than the others. The amount of manure produced by cattle is also significantly higher than the others, it is 10 kg per day, but the yield of the residue is lower if the quantity per yield ratio is realized. (GONÇALVES, 2016)

The energy recovery from bovine manure is the least disseminated because its fattening method is different from the others. It is usually created in open fields, while swine and chickens pass through the method of confinement. Therefore, the collection of residues is not feasible given the size of the cattle and the costs to build a structure capable of holding them. (GONÇALVES, 2016)

An energy recovery system in slaughterhouses seems to be feasible since the waste is obtained after the slaughter of the animal. It is located in the industry sewage system. Such wastes would be treated in stabilization ponds, a system that still generates environmental impacts and has its efficiency contested. Another great advantage is the quantity of manure from the slaughter, while the animal produces 10 kg of manure a day, according to FELICIO P. (1988), the average weight of manure in cattle weighs about 50 kg, so it is clear the advantage of using residues from slaughtering and not from the process of confinement. (FELICIO P. E. 1988)

Power generation potential

Considering that 1,428 kWh of electricity can be produced with 1 m^3 of biogas it was possible to determine the potential of electricity generation from cattle slaughtering of Araguaína-TO slaughterhouses units. The value found is shown in table 3. The effective electricity generation through the use of slaughterhouse waste was approximately 3,074,508 kWh / year. Since the total electricity consumption in the city of Araguaína in 2015 was 252,774,000 kWh, according to the local electricity distribution company (Energisa), it is possible to notice the high potential of electricity production from biogas in the city. It is important to note that the city's industries consumed only 20,726,000 kWh in the year 2015, sector that includes the cattle slaughtering units. According to the Energy Research Company (EPE), the total electricity production in the state of Tocantins was 12,747 GWh. All these data highlight the potential of the electric energy production method of this research.

Table 3 - Potential of electricity generation from bovine manure in Araguaína-TO

Material	Electric power (kW h / year)
Bovine waste	3,074,508

The use of waste for electricity generation is a plausible alternative, since the methane emissions related to the beef production is a clear environmental problem in Brazil. According to data from the Greenhouse gas emission estimation system SGEE in the year 2015, the emissions caused by livestock farming related to cattle are responsible for about one quarter of the total emissions; therefore, it is clear the environmental benefits as well as economical ones by the implantation of the energy recovery system with biodigester.

Conclusion

It is possible to conclude that the generation and use of biogas in the slaughterhouse industry segment is quite feasible. These companies can reduce electricity costs or even sell the surplus to the electricity grid, adding value to a raw material that until then did not provide any benefit or use to the units.

In Brazil, the electricity production systems with biodigesters using chickens and swine wastes have a higher incidence, since they follow the confinement system, which is not usually the case in cattle raising. On this sector, the cattle are fattening in the extensive system that is not viable for energy recovery systems since it would have high costs with logistics, transportation and conditioning. These difficulties does not occur when the raw material is obtained in the slaughterhouse unit, solving the problems mentioned above and highlighting the alternative described in this article as a viable alternative.

References

Barrera, Paulo. *Biodigestores: Energia, fertilidade e saneamento para a zona rural.* 2. Ed. São Paulo: Ícone, 1993.

Bley Jr., C. *Biogás: a energia invisível.* 2ª ed. rev. e ampl.; São Paulo : CIBiogás; Foz do Iguaçu: ITAIPU Binacional, 2015.

Bley Jr., C. Embrapa – *Agroenergia da biomassa residual: perspectivas energéticas, socioeconômicas e ambientais.* 2. Ed. Foz do Iguaçu: FAO. 2009.

ENERGISA-TO – Companhia de eletricidade do estado de Tocantins - *Estatísticas de consumo de eletricidade no municipio de Araguaína- TO.*

EPE - EMPRESA DE PESQUISA ENERGÉTICA. *Balanço Energético Nacional 2017.* Disponível em: http://www.epe.gov.br/sites-pt/publicacoes-dadosabertos/publicacoes/PublicacoesArquivos/publicacao-160/topico-168/Anuario2017vf.pdf. Acesso em 10 de novembro de 2017.

Felício, P.E. *O pecuarista recebe pela carne, mas o boi não é feito só de bifes.* C.R.M.V.-4, São Paulo, v.26 p.15-17, 1988.

Folle, J.; Seixas, S.M; Marchetti, D. *Construção e funcionamento de biodigestores*. Disponível em: <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/549425/construcao-e-funcionamento-de-biodigestores>. Acesso em: 15 de novembro 2017.

Gaspar, R. M. B. L**.** *Utilização de biodigestores em pequenas e médias propriedades rurais com ênfase na agregação de valor: um estudo de caso na região de Toledo* – PR. 2003.

Gonçalves, T. de A. C.; Couto, M. A. P. G.; Borges, E. R.. *Avaliação do potencial energético a partir de dejetos animais*. XXI Congresso brasileiro de engenharia química: Fortaleza Ceará. 2016

MMA - Programa das nações unidas para o desenvolvimento - PNDU Ministério do Meio Ambiente. Estudo sobre o Potencial de Geração de Energia a partir de Resíduos, visando incrementar o uso de biogás como fonte alternativa de energia renovável. Disponível em: <http://www.mma.gov.br/estruturas/164/_publicacao/164_publicacao10012011033201.pdf >. Acesso em: 15 de novembro 2017.

SGEE-Sistema de estimativa de emissões de gases de efeito estufa. *Balanço de emissões de gases no Brasil no ano de 2016*. São Paulo, SP. 2016.

SEPLAN-TO- Secretaria de orçamento e planejamento do estado de Tocantins – *Perfil socioeconômico do municipio de Araguaína-TO.* Disponível em: https://central3.to.gov.br/arquivo/348465/. Acesso em 4 de novembro de 2017.

OPTIMUM CONTROL OF HYDROGEN PRODUCTION BY *Cyanothece* sp. ATCC 51142.

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Abstract
Hydrogen has received considerable attention in the last years as a sustainable energy source due to its non-polluting feature and high energy density. The production of hydrogen through fermentation offers a great potential as an alternative process in the future. However, the knowledge of the process is still a challenge and studies on process modeling and optimization, in silico, can help in this task. The aim of this work was to perform a study of optimum control of the fed-batch process of hydrogen production by *Cyanothece* sp. ATCC 51142 in order to maximize the amount of hydrogen generated during the entire process. The results demonstrate that different schemes of feeding can improve hydrogen production, leading to significant values when compared with data reported in the literature.

Keywords: Biohydrogen, Optimization, Fed-batch process.

Introduction

Since the current energy matrix is mainly composed of fossil fuels that have limited reserves and release massive amounts of pollutants to atmosphere, replacing the current matrix has become one of the challenges of the twenty-first century. For this purpose, hydrogen is an alternative that has received considerable attention due to its advantages, for instance, its high energy density and its combustion without emission of pollutants (DINCER; ACAR, 2017).

The production of hydrogen by microorganisms, especially in fermentation process, has been gaining attention as a promising area since it allows the use of different sources of carbon as a substrate, such as glycerol and industrial waste (GHOSH et al., 2017). Among the different microorganisms that can generate hydrogen, the nitrogen-fixing cyanobacteria are highlighted. In particular, *Cyanothece* sp. ATCC 51142 has a remarkable hydrogen production rate (DECHATIWONGSE et al., 2014), which stimulates studies on turning a reality the use of cyanobacteria for hydrogen production to compose a significant portion of energy matrix.

Some studies have been conducted to improve the hydrogen production by cyanobacteria. Different effects during the cyanobacterial growth rate and productivity of hydrogen were explored (BANDYOPADHYAY et al., 2010; MIN; SHERMAN, 2010; ZHANG; DECHATIWONGSE; HELLGARDT, 2015). Meanwhile, finding the optimal conditions such as nutrient ratio concentration to biomass concentration, photobioreactor configuration and feeding time in combined batch-fed-batch process is still a complex problem, which requires studies beyond experimental ones.

Process modeling, simulation and optimization can help to provide significant information to analyze and describe the activity of microorganism, as well to improve the production of the hydrogen generated by fermentation process (NATH; DAS, 2011).

Several dynamic models have been developed to simulate the phases of microorganism growth. ZHANG et al. (2015) have modeled the fixed volume fed-batch process of hydrogen production by cyanobacteria. This model is applicable to all cyanobacteria growth phases, with exception of the lag phase, and is an adaptation from the classical Droop model, which considers that growth rate of the microorganism is affected by nutrients in the culture and inside the cells. Five growth phases have been reported for *Cyanothece* sp. ATCC 51142 (DECHATIWONGSE; MAITLAND; HELLGARDT, 2015): lag phase (period in which the cells have to adapt to the new environment), first growth phase (in which biomass concentration increases rapidly), second growth phase (in which the nitrogen-fixing process is stimulated), stationary phase and decay phase.

The aforementioned model proposed by ZHANG et al. (2015) makes it possible to perform an optimization study aiming at maximizing the final amount of hydrogen generated. This can be applied both in batch or a combination of batch/fed-batch process. Actually, mathematically the problem takes a form of the optimal control one, which seeks to analyze the whole process or system with the aim of determining optimal values for the control variables in a way that the process constraints are met and at the same time its performance is maximized (KIRK, 1970).

Therefore, the aim of this work is to carry out the study of optimal control during the entire batch/fed-batch process of glycerol fermentation by *Cyanothece* sp. ATCC 51142, manipulating the feeding scheme when in fed-batch stage, in order to maximize the hydrogen produced. The problem is tackled with a meta-heuristic method, namely the particle swarm optimization (PSO), which is formulated to find the best candidate (particles) within the population space, by emulating the journey of a swarm (KENNEDY; EBERHART, 1995).

Materials and methods

The process begins in batch mode, until there is a considerable biomass concentration. At a certain instant of time, which will be defined, the fed-batch mode starts with a feeding nitrate concentration that will also be determined. The entire process (batch/fed-batch) lasts 720 hours (30 days), which corresponds to the same operating period tackled in similar published works, such as a comparison with results already reported in the literature is possible (DEL RIO-CHANONA et al., 2015; ZHANG et al., 2015)**.** In addition, it is necessary to have, throughout the process, low value of feed rate to enable an insignificant fed volume at the end of the operation, so the culture volume is maintained around 1.0 *L*, since it is a fixed volume process.

The model used was derived by ZHANG et al. (2015) and is presented in Equations 1-9. Table 1 brings the model parameters fitted by those authors.

$$\frac{dX}{dt} = \mu_{max} \cdot \left(1 - \frac{k_q}{q}\right) \cdot \frac{C}{C + K_c} \cdot X - \mu_d \cdot X^2 \tag{1}$$

$$\frac{dC}{dt} = -Y_{C/X} \cdot \mu_{max} \cdot \left(1 - \frac{k_q}{q}\right) \cdot \frac{C}{C + K_c} \cdot X - \frac{F_{in}}{V} \cdot C_{Fed} \tag{2}$$

$$\frac{dN}{dt} = -Y_{N/X} \cdot \mu_{max} \cdot \frac{N}{N + K_N} \cdot \frac{C}{C + K_c} \cdot X - \frac{F_{in}}{V} \cdot N_{Fed} \tag{3}$$

$$\frac{dq}{dt} = Y_{q/X} \cdot \mu_{max} \cdot \frac{N}{N + K_N} \cdot \frac{C}{C + K_c} - \mu_{max} \cdot \left(1 - \frac{k_q}{q}\right) \cdot \frac{C}{C + K_c} \cdot q \tag{4}$$

$$\frac{dO}{dt} = Y_{O/X} \cdot \mu_{max} \cdot \frac{N}{N + K_N} \cdot \frac{C}{C + K_c} \cdot X - Y_d \cdot \mu_d \cdot X^2 \cdot f(O) + \frac{F_{in}}{V} \cdot O_{Fed} \tag{5}$$

$$\frac{dH}{dt} = \left(K_{H_2,1} \cdot \frac{dX}{dt} + K_{H_2,2} \cdot X\right) \cdot f(N) \cdot (1 - f(O)) \tag{6}$$

$$f(N) = 0.5 \cdot \frac{((N - 100)^2)^{0.5} - (N - 100)}{((N - 100)^2 + 0.1)^{0.5}} \tag{7}$$

$$f(O) = \frac{O}{(O^2 + 0.1)^{0.5}} \tag{8}$$

$$F_{in} = \frac{0.1}{720 - T} \tag{9}$$

where X is biomass concentration ($g \cdot L^{-1}$), C is glycerol concentration ($mmol \cdot L^{-1}$), N is nitrate concentration ($mg \cdot L^{-1}$), q denotes the nitrogen quote, O is oxygen concentration (*%*) and H is hydrogen production ($mL \cdot L^{-1}$).

Terms *f(N)* and *f(O)* are switch functions responsible for controlling hydrogen production calculation: when *f(N)=1* and *f(O)=0* hydrogen is generated; on the other hand the hydrogen production is inhibited when *f(N)=0* and *f(O)=0*. C_{Fed}, O_{Fed} and N_{Fed} are glycerol inlet concentration ($mmol{\cdot}L^{-1}$), oxygen inlet concentration (*%*) and nitrate inlet concentration ($mg{\cdot}L^{-1}$), respectively. V is reactor volume defined in 1.0 L, F_{in} is the influent flow rate ($L{\cdot}h^{-1}$) and T *(h)* is the switch time, when batch process is finished and when fed-batch period begins. The parameters present in the model are maximum biomass specific growth rate (μ_{max}), biomass specific respiration rate (μ_d), nitrogen quota yield coefficient ($Y_{q/X}$), normalized minimum intracellular nitrogen source concentration (k_q), half-velocity constant of nitrogen (K_N), half-velocity constant of glycerol (K_C), glycerol yield coefficient ($Y_{C/X}$), nitrate yield coefficient ($Y_{N/X}$), oxygen yield coefficient ($Y_{O/X}$), oxygen consumption coefficient (Y_d), hydrogen yield coefficient accounting for the influence of cyanobacterial growth on hydrogen production rate ($K_{H_2,1}$) and yield ratio of hydrogen to biomass ($K_{H_2,2}$).

Their units are expressed in Table 1.

Table 1 – Values of parameters of the model.

Parameter	**Value**	**Parameter**	**Value**
$\mu_{max}\ (h^{-1})$	0.0485	$\mu_d\ (L{\cdot}g^{-1}{\cdot}h^{-1})$	0.0235
$Y_{q/X}$	0.6536	k_q	0.10
$K_N\ (mg{\cdot}L^{-1})$	19.098	$K_C\ (mg{\cdot}L^{-1})$	0
$Y_{C/X}\ (mmol{\cdot}g^{-1})$	14.049	$Y_{N/X}\ (mg{\cdot}g^{-1})$	427.40
$Y_{O/X}\ (L{\cdot}g^{-1})$	121.65	$Y_d\ (L{\cdot}g^{-1})$	403.40
$K_{H_2,1}\ (mL{\cdot}g^{-1})$	0	$K_{H_2,2} (mL{\cdot}g^{-1}{\cdot}h^{-1})$	2.3418

Source: Zhang et al. (2015).

It is possible to note than K_C is 0, since glycerol throughout the process is always available and, according to the model, only limiting nutrients significantly affect the growth rate of cyanobacteria. Furthermore, $K_{H_2,1}$ is 0. Therefore, the production of hydrogen is directly determined by the concentration of biomass in the culture, which in turn is determined by the nitrate concentration. This is because, due to the existence of nitrate and oxygen in the first growth phase, the generation of hydrogen is inhibited, while in the second phase the hydrogen production is little influenced by the low growth rate.

It is important to emphasize that the presented model is only valid when all conditions are met, including the condition that the substrate concentration (glycerol) is sufficient during the whole process.

For the optimal control problem employed in order to optimize hydrogen production, two manipulated variables were taken into account: the nitrate concentration to be fed (N_{Fed}) and the switch time (T) that determines when fed-batch process starts. The problem is formulated supposing that, when the fed-batch process initiates, the concentration of nitrate in the feed stream is kept constant up to the end of the process. Adopted operating conditions can be found in Table 2.

In mathematical terms the problem is as follows:

$$\max_{T,N_{Fed}} H\ (720) \qquad (10)$$
$$s.t.\quad equations\ 1-9$$

Table 2 – Operating Conditions.

Initial biomass concentration (X_0)	0.2 $g{\cdot}L^{-1}$
Initial glycerol concentration (C_0)	600 $mmol{\cdot}L^{-1}$
Initial oxygen concentration (O_0)	20 %
Initial nitrogen quota (q_0)	1
Initial nitrate concentration (N_0)	150 $mg{\cdot}L^{-1}$
Initial hydrogen concentration (H_0)	0
Glycerol inlet concentration (C_{Fed})	50 $mmol{\cdot}L^{-1}$
Oxygen inlet concentration (O_{Fed})	90 %
Total operating time (t)	720 h

In order to show a better visualization of the results and to emphasize the effectiveness of the optimization, the process simulation was also performed with arbitrary values (T = 150 h and N_{Fed} = 90000 $mg{\cdot}L^{-1}$).

The work presented is programmed in Python environment, version 3.6.2 and with Sublime Text (3rd version), executed in a computer with Intel (R) Celeron (R) CPU 1.80 GHz B830, with 4 GB RAM and 64 bit Windows operating system. The PSO was considered with 50 particles during 1000 iterations and with 0.050, 0.050 and 0.025 for the values of inertia, cognitive and social parameters.

Results and discussion

The processing time for the PSO to return the optimal values was approximately 5 hours, which is reasonable considering it is an offline study. PSO indicated that the optimal switch time was about T = 48 h and the optimal nitrate inlet concentration was N_{Fed} = 98447.53 $mg{\cdot}L^{-1}$, which leads to a total hydrogen production of 1937 $mL{\cdot}L^{-1}$. Process simulation run with the arbitrary values for switch time and nitrate feed concentration indicated a total of 1695 $mL \cdot L^{-1}$ of hydrogen.

Figure 1 shows the optimal and general (result of the arbitrary inputs) profiles during the entire process. It is possible to observe that the stationary phase of the biomass concentration, in the case of optimal conditions, was extended during the process, while in process with non-optimal conditions (arbitrary values) there is a decrease of the biomass concentration before the fed-batch initiates.

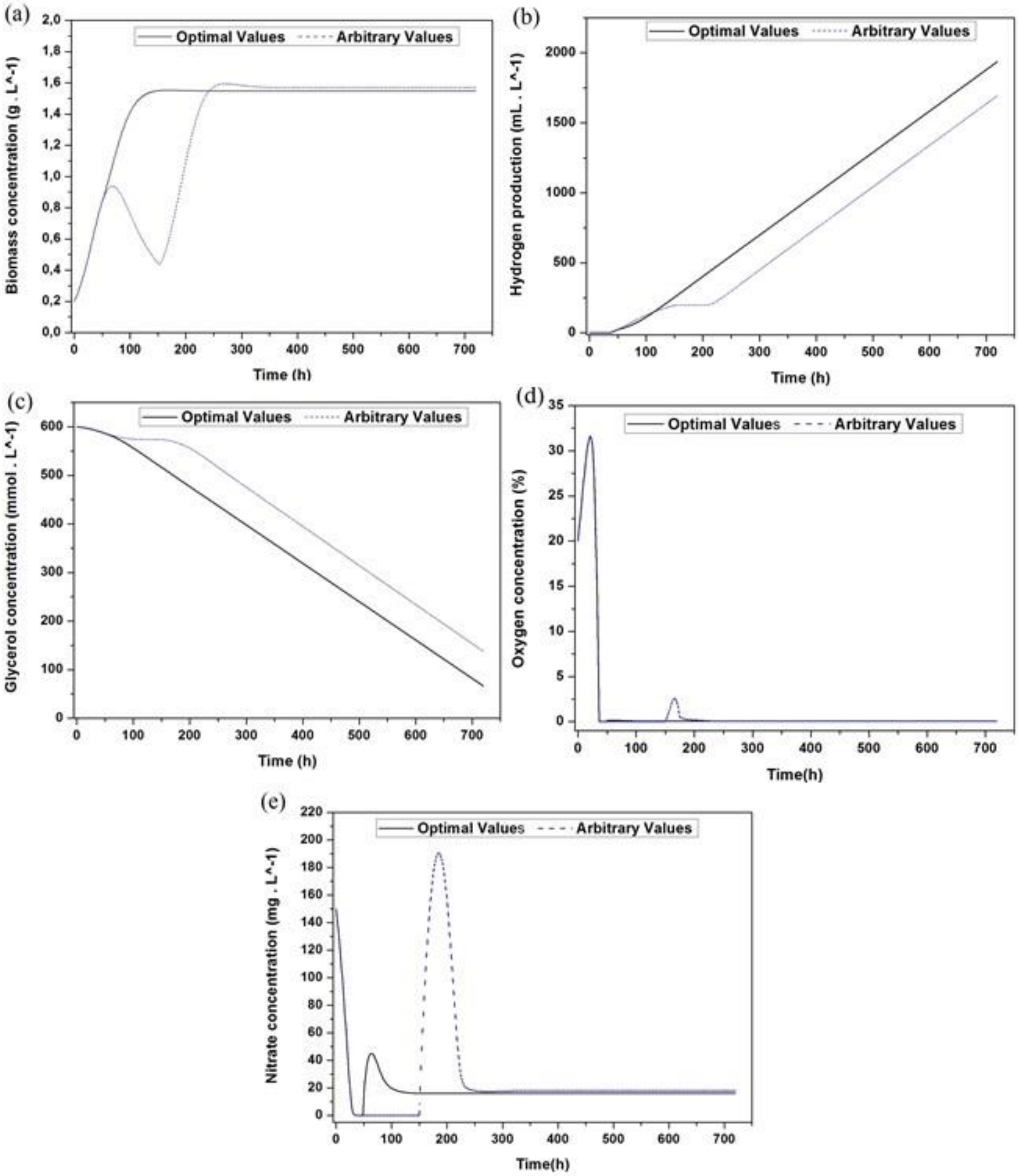

Figure 1 – Profiles of the batch/fed-batch process: (a) biomass concentration; (b) hydrogen production; (c) glycerol concentration; (d) oxygen concentration; (e) nitrate concentration.

Therefore, due to the low concentration of biomass in the latter, the oxygen and nitrate, whose concentrations increase in the beginning of the feeding period, takes longer to be consumed. This leads to inhibition of the activity of the nitrogenase enzyme and, consequently, the hydrogen is not generated in aerobic conditions. It is important to observe that, with the optimal conditions, the decay phase does not initiate before the switch time. Since biomass concentration is relatively high when feeding begins, oxygen is rapidly consumed by the biomass and the anaerobic conditions are rapidly re-established. Also, nitrate concentration does not exceed the threshold value, beyond which nitrogenase inhibition occurs (> 100 $mg{\cdot}L^{-1}$). Therefore, with the optimal conditions, hydrogen production is not interrupted due to feeding.

The production of hydrogen obtained in this work is 24 % higher than the one calculated by ZHANG et al. (2015), who used the IPOPT solver, which uses a primal-dual interior point method. The better result of this work indicates that the result previously reported in the literature was a local optimum. The method here adopted is also not able to assure that global optimum was found, but a very good local optimum was identified.

Conclusion

The strategy addressed in this work to enhance hydrogen production was effective. The optimal control problem, tackled with the application of PSO, led to optimal profiles maximizing the performance index of the whole process, *i.e.*, total hydrogen production, while process constraints were met. The production of hydrogen was significantly improved in this study increased 24% when compared with data reported in the literature.

References

Bandyopadhyay, A. et al. High rates of photobiological H2 production by a cyanobacterium under aerobic conditions. *Nature Communications*, v. 1, n. 9, 2010.

Dechatiwongse, P. et al. Effects of light and temperature on the photoautotrophic growth and photoinhibition of nitrogen-fixing cyanobacterium Cyanothece sp. ATCC 51142. *Algal Research*, v. 5, n. 1, p. 103–111, 2014.

Dechatiwongse, P.; Maitland, G.; Hellgardt, K. Demonstration of a two-stage aerobic/anaerobic chemostat for the enhanced production of hydrogen and biomass from unicellular nitrogen-fixing cyanobacterium. *Algal Research*, v. 10, p. 189–201, 2015.

Del rio-chanona, E. A. et al. Optimal Operation Strategy for Biohydrogen Production. *Industrial and Engineering Chemistry Research*, 2015.

Dincer, I.; Acar, C. Innovation in hydrogen production. *International Journal of Hydrogen Energy*, v. 42, n. 22, p. 14843–14864, 2017.

Ghosh, S. et al. Hydrogen from food processing wastes via photofermentation using Purple Non-sulfur Bacteria (PNSB) – A review. *Energy Conversion and Management*, v. 141, p. 299–314, 2017.

Kennedy, J.; Eberhart, R. Particle swarm optimization. *Neural Networks, 1995. Proceedings., IEEE International Conference on*, v. 4, p. 1942–1948 vol.4, 1995.

Kirk, D. E. *Optimal Control Theory: An IntroductionEnglewood Cliffs: Prentice-Hall*, 1970.

Min, H.; Sherman, L. A. Hydrogen production by the unicellular, diazotrophic cyanobacterium cyanothece sp. Strain ATCC 51142 under conditions of continuous light. *Applied and Environmental Microbiology*, v. 76, n. 13, p. 4293–4301, 2010.

Nath, K.; Das, D. Modeling and optimization of fermentative hydrogen production. *Bioresource Technology*, v. 102, n. 18, p. 8569–8581, 2011.

Zhang, D. et al. Analysis of the cyanobacterial hydrogen photoproduction process via model identification and process simulation. *Chemical Engineering Science*, n. 128, p. 130–145, 2015.

Zhang, D.; Dechatiwongse, P.; Hellgardt, K. Modelling light transmission, cyanobacterial growth kinetics and fluid dynamics in a laboratory scale multiphase photo-bioreactor for biological hydrogen production. *Algal Research*, v. 8, p. 99–107, 2015.

SEGREGATION OF ORGANIC MATTERS FROM THE ORIGIN OF SMALL COMMUNITIES AND ITS IMPACT ON THE EFFICIENCY OF BIOGAS GENERATION IN COMMUNITY BIODIGESTORS.

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Abstract
Biogas is the gas that comes from the decomposition of organic matter and represents an increasingly promising renewable source of energy, as well as being an alternative to mitigate environmental impacts caused by the accelerated production process of solid household waste and serves as a tool in the management of solid waste. The gas formed by the anaerobic digestion process is composed of a mixture of gases, basically by methane gas (CH_4), a colorless, odorless, and high calorific gas. The implementation of an appropriate waste management brings, if selectively collected, economic and environmental benefits. Based on this panorama, the present work reports the state of the art that justifies a deeper investigation on the hypothesis that the methanogenesis, fundamental stage of the anaerobic digestion process, depends fundamentally on the quality of the substrate used. In this way, this research is intended to indicate through an ongoing laboratory project that considers tests performed with different substrates from domestic solid waste, with organic matter segregated or not in the origin and, thus, highlight importance of segregation and a route of proper waste management at source for small communities and maximization of biogas generation efficiency in community biodigesters.

Keywords: biogas; solid waste; organic matter; source segregation.

Introduction

Biogas represents a renewable and alternative source of energy increasingly used worldwide for the generation of electricity and as a substitute for various fossil fuels, as well as being an important tool in the management of urban solid waste - USW. The use of anaerobic digestion technology (also known as biomethanization) for the management of the organic fraction of urban solid waste - OFUSW is a reality that has been multiplying around the world. The implementation of Waste Management Plans, aimed at reducing, reusing and recycling the materials considered as "junk" has aroused society's interest by generating a true production cycle for the use of the material, which, selectively collected, brings economic benefits and environmental impacts.

The hypothesis is based on a bibliographical review and an ongoing laboratory study that point out that the anaerobic digestion process depends fundamentally on the quality of the substrate used, that is, on its organic matter content and the absence of other chemical substances, present in the common urban solid waste, which could inhibit the microbial processes, or, even, do not allow the occurrence of the biodecomposition. As well as, it is intended to point out alternative management of this waste in small communities.

Materials and methods

The methodology used in this work consists primarily of a bibliographical survey on the biochemical processes of organic matter decomposition in solid urban waste, as well as the gravimetric composition of the USW of the city of Belo Horizonte. This study can point out an experimental alternative based on experiences reported in the literature on the biogas generation from the organic portion present in the common residue and to prove the hypothesis formulated and indicate management possibilities.

Results and discussion

The OFUSW biomethanization technology is generally used in mechanical-biological treatment plants. The material is subjected to manual and mechanized sorting processes for the recovery of recyclable materials and treatment of the organic fraction of the waste. The organic fraction is directed to biological treatment processes for stabilization, usually via biomethanization or accelerated composting (ARCHER et al., 2005). One of the main aspects that differentiate the biomethanization technologies of OFUSW is the total solids content of the material that will be introduced in the digesters (GOMES et al., 2012). This means that dry systems generate a smaller amount of liquid effluents, resulting in savings in investment and operation in effluent pretreatment and treatment systems. It is possible to observe if the biological medium of the dry-run systems is more robust, better supporting the changes in the substrate and the application of high organic loads.

According to the Energy Research Company (2014), incineration and biological processing are essentially the two forms adopted to offer electric energy and biofuel. Within a broader view, the energy use of USW also includes the recycling of the collected material and allows the substitution of inputs for the production of which there is usually a large energy consumption. By easing demand pressures from raw materials, including natural resources and energy, recycling is, in principle, an environmentally efficient way of using USW energy.

Although the energy use of urban waste does not present sufficient potential to support a long-term expansion of the country's electricity supply or biofuel supply, it is an important element of a regional or local strategy which transcends the energy dimension. In reality, it comprises an arrangement of social policies (health, sanitation, etc.), regional (local development) and environmental (mitigation of waste impacts).

Regarding the characterization of the technologies currently applied to manage the USW with a focus on obtaining energy, it is concluded that the joint action between recycling and biodigestion is much more advantageous than incineration or biodigestion without recycling. Increasingly, the technologies associated with the higher level of recycling are conducive to better energy use of the USW.

However, reaching the high selection level is quite difficult, since historically the wastes are mixed. One of the main alternatives adopted is the segregation of recyclables by waste pickers, but only reaches the equivalent of 10% of recyclable potential.

Recycling of any material can be said to comprise four phases: segregation at source, selective collection, sorting, and revaluation and transformation. The first two stages represent the great challenge of recycling, insofar as they involve a process of raising the awareness of the population towards the practice of selective collection, as well as investments in logistics and distribution of the selected material to the appropriate destinations. In the revaluation phase, the decontamination and adequacy of the collected material is carried out, so that it can be used as raw material in the manufacture of new products. The last phase, of transformation, completes the cycle, with the effective use of the revalued material as input in the transformation industry.

In Brazil, the biomethanization technology is still little explored and the energy recovery of biogas occurs in a very incipient way. It is also worth noting that several Brazilian municipalities do not have adequate management of solid urban waste, disposing their waste in an irregular manner. In addition to environmental and socioeconomic problems, the disposal of municipal solid waste in dumps makes it difficult to take advantage of the biogas generated in the decomposition of these wastes.

In their studies, MAYER (2013) concludes that the evaluation of the influence of different inocula on the anaerobic treatment of organic solid wastes in a batch reactor was of great importance to know which the most favorable conditions would be, aiming at the biological solubilization of the substrate under study.

As highlighted, the process of anaerobic digestion occurs from the degradation of organic matter by a range of anaerobic microorganisms. In view of this, it is desirable to inoculate anaerobic reactors with an anaerobic biomass already adapted to the substrate and with high methanogenic activity, which is the stage of the process where practically all methane production occurs. In this way, the starting process of anaerobic reactors is optimized, guaranteeing the environmental stability and productivity of biogas in the digester. In addition, the monitoring of the methanogenic community has stood out as a powerful tool of analysis of the microbial dynamics established in the processes of biomethanization.

Studies indicate that since the residues are segregated at the moment of their generation, the percentage of inert weight observed was very low, corresponding to less than 1% of the total generated (FERREIRA, 2015). This aspect is of great importance, since it allows a better efficiency of operation of the reactor, besides generating a smaller volume of sludge. In relation to the basic laboratory analyzes of the food residue, mean values of ST = 23.6% (total), SV = 22.2% (volatile) and SF = 1.4% (fixed) were obtained. It can be noticed that the residues present a high content of organic solids (94%), composing almost all the analyzed samples, thus proving the importance of segregation in the generation source. In view of these characteristics, the biological treatment of the organic residue is strongly recommended. The following factors should be considered in the project, such as the design of the reactor, the study of the influence of the amount and type of biomass used in the process, the biogas quantification methodology and the development of the analytical technique to identify the composition of the biogas generated.

The classification of the USW mainly facilitates the technical and economic decisions taken in the management of SW. Such procedure goes from the management of the handling, packaging, storage, collection and transport until the treatment, disposal and final use. In order to meet the general objective of this study, it is necessary to carry out an adequate classification of FORSU, taking into account factors such as:

- Geographic location and characteristics of the area to be considered: geographically delimited and the socioeconomic characteristics of the area.
- Climate and temporal variations: day of the week, months, years, Christmas, vacations, tourism, among others

Taking this classification into consideration, the option adopted for the analysis of the area will be the gravimetric composition of the residues, which is the ratio of weight - expressed as a percentage of each component - and total weight of residues. The determination of the gravimetric composition of the residues is an essential data to be obtained. In the case of household and commercial waste, the components in the gravimetric composition are: putrescible organic material, ferrous metals, nonferrous metals, paper, cardboard, plastics, rags, glass, rubber, leather, wood, among others.

After a better understanding of the waste management process, it is concluded that the anaerobic biodigestion of organic matter occurs through the action of prokaryotic fermentative and anaerobic microorganisms and requires the cooperation of different microbial groups. Such autoregulatory mechanisms arise from interactions between the different prokaryotic groups that participate in the process with distinct and specific functions, capable of maintaining the pH, hydrogen pressure, and redox potential of the system in order to optimize the metanogenesis. Equation (1) represents in a global way the anaerobic decomposition of the organic matter, that is, in the absence of oxygen.

$$\mathbf{C_6H_{12}O_6 \rightarrow 3CH_4 + 3CO_2 \quad \Delta G^o = -428\ kJ/mol} \qquad \text{equation (1)}$$

To better understand the decomposition, it is necessary to go deeper into the process. Anaerobic degradation of organic matter is chemically a complex process, involving hundreds of possible compounds and intermediate reactions, which are catalyzed by specific enzymes and catalysts. Bacteria act symbiotically, using organic matter in an assimilative way for the population of the process. It occurs in four main phases, and may include a fifth phase, depending on the chemical composition of the matrix to be treated as some authors point out. The process can be represented diagrammatically according to FIG 1.

According to SAKUMA (2013), in hydrolysis, complex particulate materials (polymers) are degraded in simpler dissolved materials (smaller molecules). In acidogenesis, the products metabolized in the hydrolysis are degraded by the acidogenic fermentative bacteria. In the last step, acetogenesis, acetogenic bacteria produce substrates for methanogenesis, that is, for the formation of methane gas. At this stage, bacteria are divided into two major groups: acetoclastic methanogens, capable of producing methane from acetate (accounting for about 60 to 70% of methane production), and hydrotrotrophic methanogenic bacteria that are capable of producing methane from hydrogen and carbon dioxide.

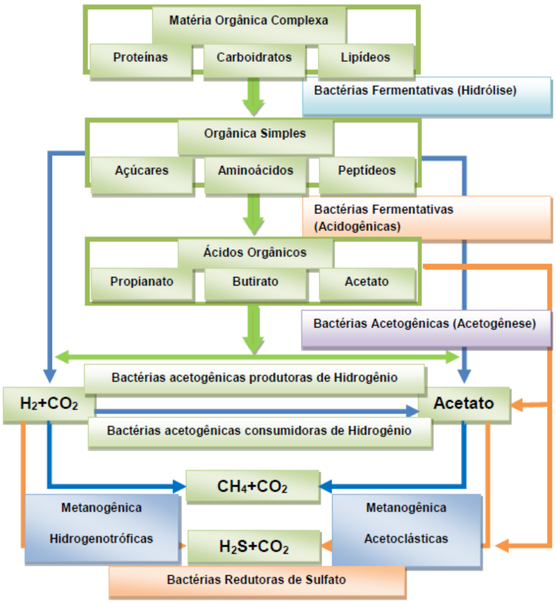

Figure 1: Metabolism of biodigestion (SAKUMA, 2013)

The municipality of Belo Horizonte is among the 10 most populous cities in Brazil, according to the Brazilian Institute of Geography and Statistics (2016), with an estimated population of 2,513,451 inhabitants. Municipal Law No. 10,534 / 2012 classifies household solid waste as residues of residences, public and collective buildings, and trade, services and industries, provided they have the same characteristics as residues. Refer to the masses of residues from the following collections:

• Indifferent Collection of Household Waste
• Selective Recyclable Materials: Paper, Metal, Plastic and Glass

The Municipal Solid Waste Management Plan of the Municipality of Belo Horizonte - of 2016 evaluated all the residues described above and pointed out that studies on the characterization of household waste were developed by the Superintendency of Urban Cleaning in 1985, 1991, 1995 and in the period from October 2002 to September 2003, and since 2009 has been carried out monthly by Macaúbas Environment. Due to methodological differences and the dispersion of analyzes, the results of the historical series obtained at the Solid Waste Treatment Center Macaúbas, organic residues predominate when compared to the other components. In Table 01 it is possible to observe a comparison between the gravimetric compositions of the Municipal Secretary of Urban Cleaning of Belo Horizonte, of SWTC Macaúbas and of the National Plan of Solid Waste of 2011.

Table 01 - Comparison between gravimetric compositions presented

Source / Study	Organic matter	Recyclable	Others
Municipal Secretary of Urban Cleaning of Belo Horizonte	61,59%	25,55%	12,86%
SWTC Macaúbas	48,77%	35,29%	15,95%
National Plan of Solid Waste	51,40%	31,90%	16,70%

Source: PMGIRS BH, 2016.

Thus, for the purposes of this study, the gravimetric composition presented by the CTRS Macaúbas study will be considered, since it presents more recent data for the reality of Belo Horizonte.

Conclusion

After this bibliographic review on the subject that enabled the definition of the main aspects to be evaluated, it is proposed the assembly of three (3) biodigestor prototypes. One will have characteristics of substrates based on the gravimetric composition of the Municipality of Belo Horizonte not segregated, the other with substrate of the same reference, but considering that there was segregation of the organic matter at the origin and the third with a substrate with a mixed inoculum, that is, considering that there was inadequate segregation of organic matter and it is partially contaminated. The construction of the biodigester will take into account the availability of necessary materials, operational conditions and availability of organic matter that would be used to supply the biodigester.

To monitor the system and to better evaluate the biodigester, an electronic assembly with arduino and two sensors, the temperature and the concentration of methane and an auxiliary protoboard are used. The choice of measuring methane concentration and temperature was defined based on the theoretical study, since temperature is one of the main factors that influence anaerobic digestion, and the other factors are more stable, due to the size of the project and the used. The methane concentration measurement (in particles per million ppm) will allow a verification of the rate of change of production and the production of a possible graph of concentration variation with respect to time.

After the retention step in the biomethanisation matrix, the gas and the substrate will be analyzed in the laboratory and all the results to date will be the basis for the validation of the hypothesis that the organic matter segregated in the origin of domestic solid waste influences positively in the biomethanization.

It is recommended the continuity of the laboratory analysis more uniform validation of the premises already validated by the bibliographic review of the viability of the segregation in organic solid waste origin in the small communities and indication of the final biogas production potential from community biodigesters.

Considering the above and an adaptation of the proposed by GUIMARÃES (2017) of management devices if domestic waste in the generating sources the best initial management alternative is indicated by the following flowchart, in this way the residue is directed to the platforms of community biomethanization in a way more efficient.

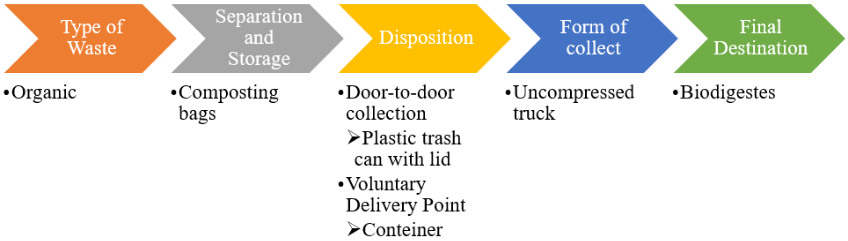

Figure 2: Process Flow (GUIMARÃES, 2017 - Adapted)

References

Archer, E.; et al. Mechanical-biological-treatment: a guide for decision makers processes, policies & markets. Londres, Juniper Consultancy Services Ltd, v. 1. 2005.

Associação brasileira de normas técnicas. NBR 10004 - Resíduos sólidos: classificação. Rio de Janeiro: ABNT, 2004.

EPE [Empresa de Pesquisa Energética]. Inventário Energético dos Resíduos Sólidos Urbanos – Série Recursos Energéticos, Rio de Janeiro, 2014.

Ferreira, B. O. Avaliação de um sistema de metanização de resíduos alimentares com vistas ao aproveitamento energético do biogás, 2015.

Guimarães, C. C., et al. Identificação e seleção de dispositivos de manejo se resíduos domésticos nas fontes geradoras. XXIX Congresso ABES/FENASAN, São Paulo, 2017.

Gomes, F. C. de S. P.; Aquino, S. F. de; Colturato. L. F. de D. B. Biometanização seca de resíduos sólidos urbanos: estado da arte e análise crítica das principais tecnologias. Eng Sanit Ambient, v.17, n.3, p. 295-304, Set. 2012.

Mayer, M. C. Estudo da influência de diferentes inóculos no tratamento anaeróbio de resíduos sólidos orgânicos, p. 59-60, abr. 2013.

SLU [Superintendência de Limpeza Urbana]. Plano Municipal de Gestão Integrada dos Resíduos Sólidos do Município de Belo Horizonte – PMGIRS/BH, 2016.

Sakuma A. C. Desenvolvimento e análise experimental de biodigestores modulares de baixo tempo de residência. 118f, ago. 2013.

THEME: CHARCOAL

COMPARATIVE MACROSCOPIC ANATOMY OF WOOD AND AFTER CARBONIZATION IN SEVERAL TEMPERATURES OF FOUR COMMERCIAL SPECIES FOR IDENTIFICATION PURPOSES

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Abstract
Knowledge of the anatomical characteristics of charred wood can be as important as that of in natura wood when the purpose is to inspect the illegal trade of charcoal or even the need for an expertise due to fire in some building. Thus, the objective of this work was to investigate alterations in the anatomy of the wood of four forest species after undergoing thermal rectification and carbonization at various temperatures. The material used in this study was obtained from Xiloteca of the State University of São Paulo (UNESP), Campus de Itapeva, because the species were scientifically identified. The species studied were: cumaru (*Dipterix* sp.), jatoba (*Hymenaea* sp.), grevilea (*Grevillea robusta*) and cedro (*Cedrela* sp.). The treatments applied were: *in natura*, 100ºC, 200ºC, 350ºC, 400ºC and 450ºC. The specimens had the shape of a cube, with dimensions of 20 x 20 x 20 mm, whose faces were oriented in the anatomical planes transverse, tangential and radial. Samples were run through a series of sieves, from granules 100 to 1500, and then oven dried at 100°C, wrapped in aluminum foil, thermally rectified and charred at programmed temperatures in the muffin, until reach each of the stipulated temperatures, in which they remained for 3 at 200°C and 2.5 hours at 350°C, 400ºC e 450°C, respectively. After each treatment, the samples were weighed and photographed. For the purpose of identification of the species, in thermal rectification treatment or even a carbonization, up to 350ºC the samples still had enough structure for the identification of the species.

Keywords: identification of wood, identification of charcoal, anatomy of wood.

Introduction

The knowledge of the anatomical characteristics of charred wood may be as important as that of *in natura* wood when the purpose is to inspect the illegal trade of charcoal or even the need for an expertise due to fire in some building.
Thermal rectification is an alternative process of adding value to wood, inhibiting xylophagous attacks and improving dimensional stability. The temperature in the process can reach in some cases near 200ºC (MOURA; BRITO, 2011). Carbonization is on the thermal scale above thermal rectification (SANTOS, HATEKEYAMA, 2012).

The charcoal process consists in heating the original material between 300ºC and 500ºC, in the "near absence" of air, until the extraction of the volatile material (ANEEL, 2008).

Gonçalves (2010) showed that carbonization up to 400ºC did not show any major changes in the structures of the wood and coal of the Cerrado species: *Copaifera langsdorffii*, *Dalbergia violacea*, *Dimorphandra mollis*, *Stryphnodendron polyphyllum*, *Caryocar brasiliense*, *Couepia grandiflora*, *Tapirira guianensis*, *Qualea grandiflora*, *Vochysia tucanorum* and *Pouteria torta*.

Studies show that up to 450°C, the anatomical structure of the wood is maintained and with this, it is still possible to verify the cellular characteristics of the wood component even though it is charred (MUNIZ et al., 2012).

Brazilian charcoal is mostly made from *Eucalyptus*, yet native woods are mixed in the process. These native woods are not authorized to be cut because there are laws about this, the Forest Origin Document (DOF), established by Administrative Rule 253 of August 18, 2006 for

Ministry of the Environment (MMA), as an act of preservation of those that are not yet totally extinct.

The anatomical verification of the wood when it is charred can be analogous to the wood *in natura*, but to a certain limit of the alteration of its biological structures. This may be important, for example, in forensic science as an important tool for discovering evidence in crimes of various natures, being used by police expertise. The basis of data collection involves areas of chemistry, physics and biology, among others (FERREIRA, 2016).

Gonçalves et al. (2016) studied 25 species of the Cerrado and used micrographs of the cross sections in order to have rapid analysis of the coal and serve as a base for police agents and operations to preserve the Cerrado forest.

Thus, the objective of this work was to investigate alterations in the anatomy of the wood of four forest species after undergoing thermal rectification and carbonization at various temperatures.

Materials and methods

The material used in this study was obtained from Xiloteca of the State University of São Paulo (UNESP), Campus de Itapeva, because the species were scientifically identified. The species studied were: Cumaru (*Dipterix* sp.), Jatoba (*Hymenaea* sp.), Grevilea (*Grevillea robusta*) and Cedro (*Cedrela* sp.).

Two samples per treatment oriented in transverse, tangential and radial planes and having dimensions of 20 x 20 x 20 mm were made and sanded (polished) in a series of sandpaper numbers from 100 to 1500 granaries. Figure 1 shows how the specimen was assembled for posterior verification of anatomical changes on a macroscopic scale. As a legend, a point represents the transverse plane, two points represent the tangential plane and three points represent the radial plane. Then with a bench drill, holes were drilled at these points so that after carbonization, the samples could maintain the identification of their respective anatomical planes.

Figure 1 - Samples of the same species on their three anatomical planes before drilling.

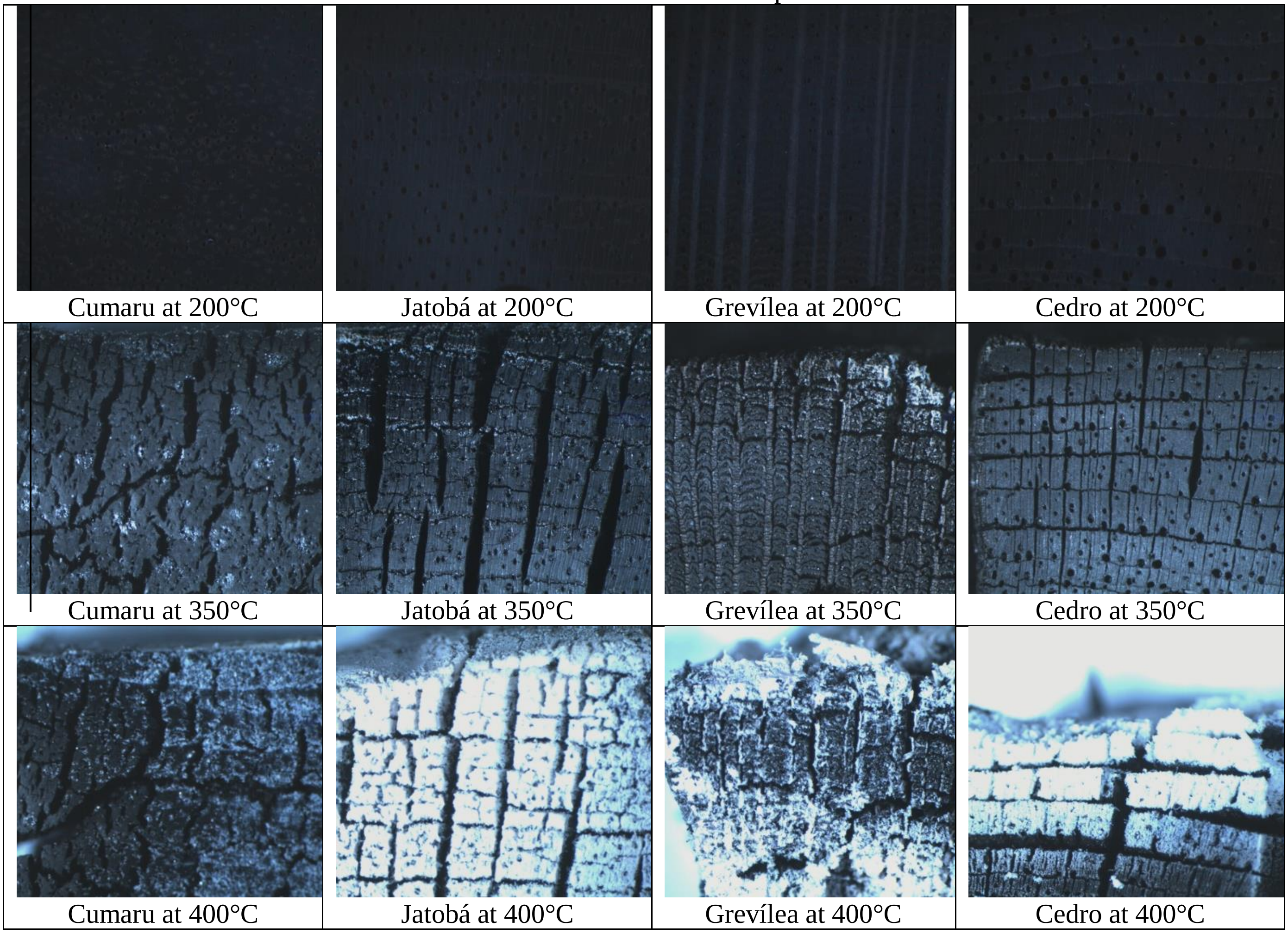
Transverse **Tangential** **Radial**

In a forced-air circulation oven, the samples were dried at 100°C and subsequently thermally rectified for three hours at 200°C. Then, they were carbonized in a muffle furnace at temperatures of 350°C, 400°C and 450°C for a time of two and a half hours. The heating procedure was programmed at the desired temperature in the muffle, reaching the temperature of 200 ° C left at this temperature for three hours, after which time it cooled until the following day. The procedure was repeated for temperatures 350 ° C, 400 ° C and 450 ° C leaving at these temperatures for two and a half hours. At these temperatures the samples were left inside the dish to cool to the next day. Between each heating stage, the samples were weighed on analytical balance and photographed using a Leica stereoscope.

Results and discussion

The images obtained from the wood rectified at 200°C and charred wood at 400ºC are shown in Figure 2.

Figure 2 - Transverse plane obtained from the wood rectified at 200°C and charred wood at 350ºC and 400ºC of the four species studied.

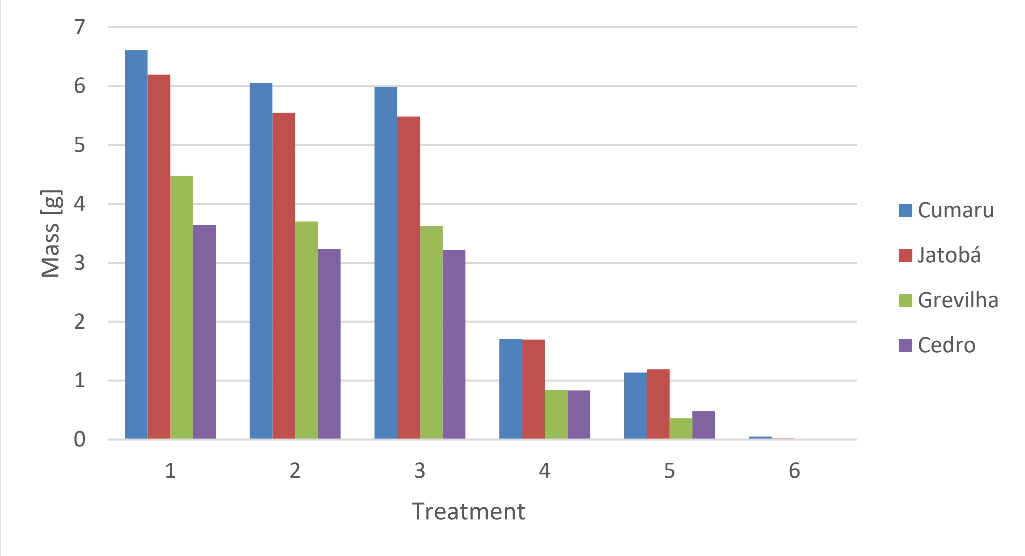


For a better understanding in Figure 3, the abscissa axis (numbers 1 to 6) refers to the treatments, that is, the stages through which the samples were submitted, ie:

1 - Polished (*in natura*).
2 - 100°C (thermal rectification temperature)
3 - 200°C (thermal rectification temperature)
4 - 350°C (carbonization temperature)
5 - 400°C (carbonization temperature)
6 - 450°C (carbonization temperature)

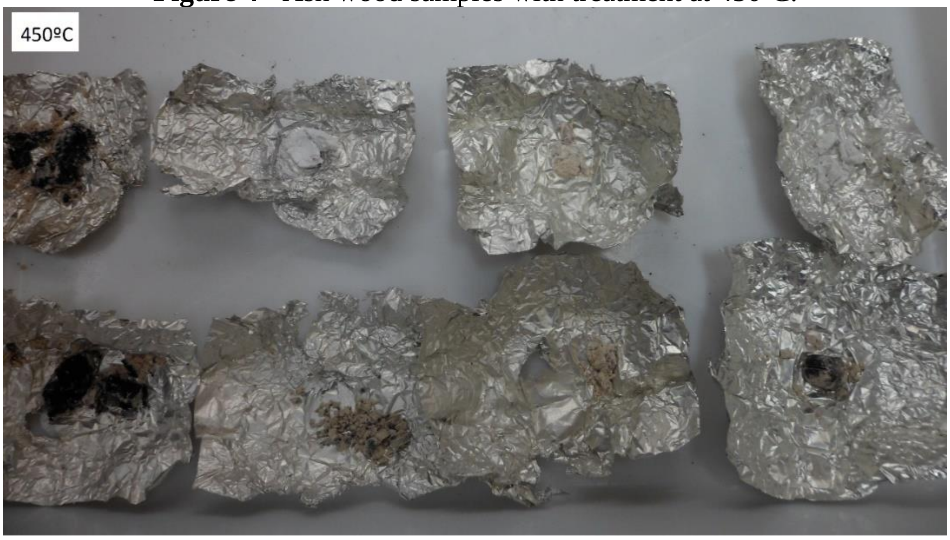
By weighing the samples in stages 2 to 6, ie at temperatures of 100°C, 200°C, 350°C, 400°C and 450°C, the following results were obtained:

Figure 3 – Final mass of the wood samples as a function of the treatments.



It is observed in Figure 2 that all species in stages 2 and 3 lose mass in the process known as thermal rectification (up to 200°C) with slight modification, but it is from carbonization, above 350°C (stages 4 to 6), that there is a significant loss of mass, mainly with cumaru, and in stage 6 the samples are only as ash, as can be seen in Figure 4.

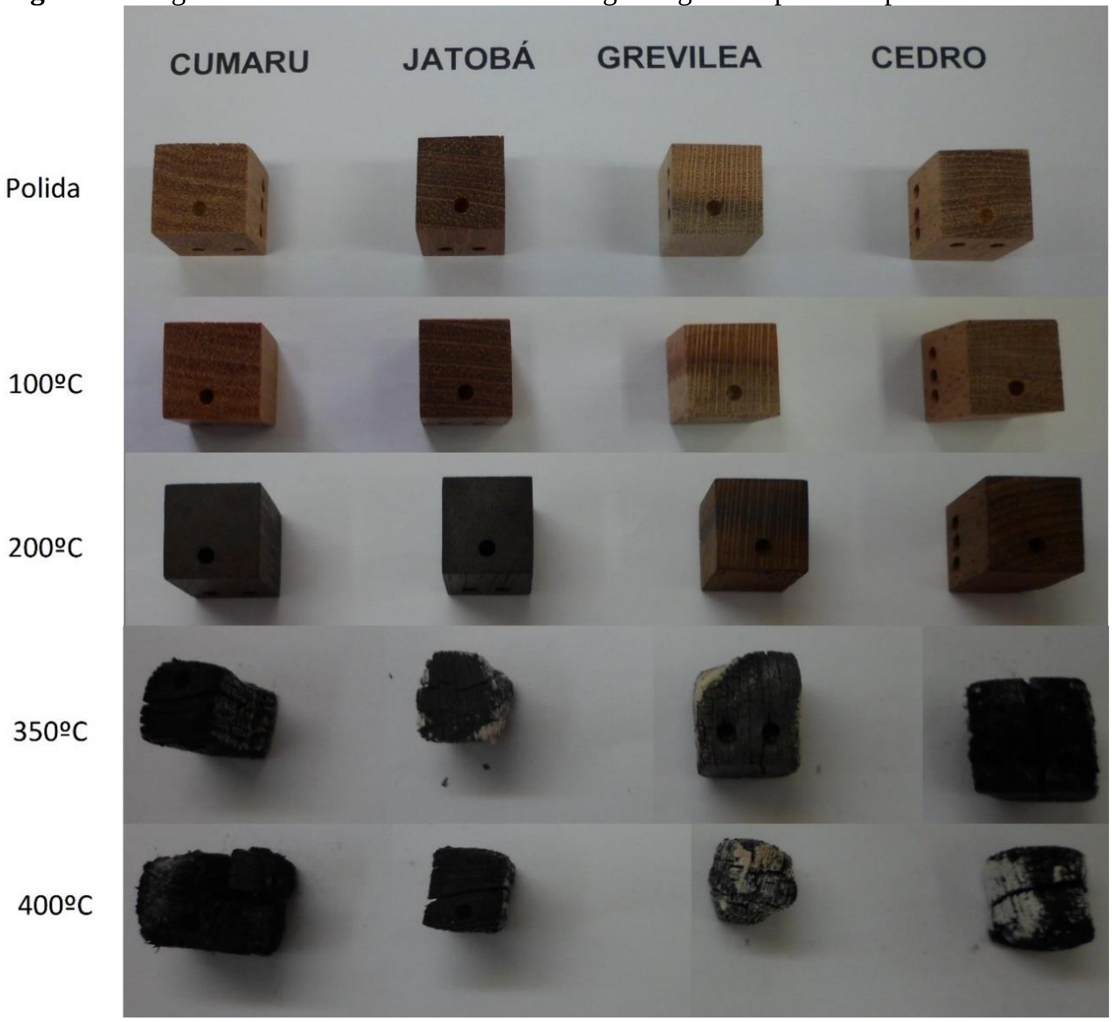
Figure 4 - Ash wood samples with treatment at 450ºC.



In Figure 5, all the wood samples in stages 1 to 5 were observed, that the jatoba was the one that had the greatest change in its shape and that the other species appeared to be more conserved. From this temperature (350ºC), it is possible to observe that all samples were compromised and anatomically altered their characteristics.

Comparing with the studies, carbonization up to 400ºC did not show any major changes in the wood and coal structures of cerrado species: *Copaifera langsdorffii*, *Dalbergia violacea*, *Dimorphandra mollis*, *Stryphnodendron polyphyllum*, *Caryocar brasiliense*, *Couepia grandiflora*, *Tapirira guianensis*, *Qualea grandiflora*, *Vochysia tucanorum* and *Pouteria torta* (Gonçalves, 2010). Already Muniz et al. (2012) found that up to 450°C the anatomical structure of the wood is maintained and with this, it is still possible to verify the cellular characteristics of the wood component even though it is charred.

Figure 5 - Stages of the heat treatment from the beginning of the process up to 400ºC.



Conclusion

Three important aspects can be concluded with the results obtained:

- At the temperature increase up to 200ºC, the wood samples had visual changes and little loss of mass.

- From 350ºC the wood samples, besides losing amount of considerable mass, had their anatomical conditions quite affected. Being that at 400ºC it is no longer possible to observe any anatomical characteristic that leads to an identification of the species.

- At 450 ° C, the wood is totally in the form of ash.

Therefore, for the purpose of identifying the species, in the treatment of thermal rectification or even a carbonization, in the case of fire or charcoal processing, up to 350ºC can still present sufficient structure for the identification of the species.

References

Agência nacional de energia elétrica. Atlas de energia elétrica do Brasil. Brasília: Ed. 3. Brasília: ANEEL, 2008. 236 p.

Duarte, P. H. Ferreira, C. A.; Pires, M. R.; Resende, D. R.; Mori, F. A.; Estrutura anatômica macroscópica de três espécies nativas após carbonização em diferentes temperaturas. In: III CBCTEM Congresso Brasileiro de Ciência e Tecnologia da Madeira 2017. 10 p.

Ferreira, A. G.; Química forense e técnicas utilizadas em resoluções de crimes. *Acta de Ciências e Saúde*, v. 2, n. 5, pp. 32-44, 2016.

Gonçalves, T. A. P. *Anatomia do lenho e do carvão de espécies arbóreas do cerrado no Estado de São Paulo*. 2010. 106 f. (Dissertação de Mestrado), Faculdade de Ciências Agronômicas – UNESP, Botucatu. 2010. Available in: <http://www.fca.unesp.br/Home/Extensao/GrupoTimbo/manualUsodaMadeira.pdf> Accessed in: 20/01/2018.

Gonçalves, T. A. P.; Nigoski, S.; Marcati, C. R.; Ballarin, A. W.; Muñiz, G. I. B. A contribution to the identification of charcoal origin in Brazil II – Macroscopic characterization of Cerrado species. *Anais da Academia Brasileira de Ciências*, v. 88, n. 2, pp. 1045-1054, 2016.

Moura, L. F.; Brito, J. O.; Efeito da termorretificação sobre as propriedades colorimétricas das madeiras de *Eucalyptus grandis* e *Pinus caribaea* var. *hondurensis*. *Scientia Forestalis*, v. 39, n. 89, pp. 069-076, 2011.

Muñiz, G. I. B.; Nisgoski, S.; Shardosin, F. Z.; França, R. F.; Anatomia do carvão de espécies florestais. *Revista Cerne*, v. 18, n. 3, p. 471-477, 2012.

Santos, S. F. O. M.; Hatekeyama, K.; Processo sustentável doe produção de carvão vegetal quanto aos aspectos: ambiental, econômico, social e cultural. *Produção*, v. 22, n. 2, pp. 309-321, 2012.

DESIGNATION OF EUCALYPTUS GENOTYPES FOR ENERGETIC USE COMBINING SELECTION INDEX AND DIFFERENT METHODS OF CLASSIFICATION

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Abstract
One of the stages of forest breeding program is the selection of genotypes that present features compatible with pre-established levels of interest. In the charcoal sector for steel use, it is necessary to evaluate chemical, physical and anatomical characteristics of wood and charcoal, wishing to select superior genotypes for this purpose. However, the complete characterization of a large number of clones is financially infeasible. Therefore, the objective of this study was to present a methodology to pre-select *Eucalyptus* sp. clones for the production of high quality charcoal, based on variables of easy-determined and low-cost, aggregating different classification and selection criteria. For this, the genetic values of the variables: volume (VOL), wood dry mass (DM), basic density (BD) and heartwood/sapwood ratio (H/S) were calculated using the *SELEGEN - REML/BLUP* software. The clones were classified as superior or inferior according to the pre-established standard, based on the median of each variable. In parallel, the selection index proposed by Mulamba and Mock was used, hierarchizing the genotypes for each characteristic, assigning higher absolute values to those of better performance. After the different classifications, groups were formed, according to the following criterion of importance: BD> VOL> DM> H/S. The first group of interest corresponds to the clones that are superior in all the variables. The second group comprises the clones which are superior in BD, VOL, DM and inferior in H/S, and so on. In this way, combining different criteria: classification by median and group formation (it is an exclusion criterion) and selection index of Mulamba and Mock, we selected the 16 genotypes with greater aptitude for energetic use, which will follow to the stages of chemical, physical and anatomical characterization of wood and charcoal.

Keywords: Charcoal, clones, rank

Introduction

Brazil is the largest producer and consumer of charcoal, which is mainly used in steel industry to produce pig iron and steel (PEREIRA et al., 2017). To meet the demand for charcoal in this sector, approximately 1 million hectares of forest are planted (IBÁ, 2017), using *Eucalyptus* sp. as its main species.

Charcoal qualitity is directly influenced by the wood used in its production (TRUGILHO et al., 2001). OLIVEIRA et al. (2010) states that superior quality and efficient charcoal is obtained using denser wood, with greater calorific power and adequate chemical constitution.

The description of these wood characteristics, as well as the use of their genotypic values, are important in the selection of superior genotypes to charcoal production (BOTREL et al., 2010). However, there is a cost related to determine wood properties, which is accentuated due to the large number of genotypes available in clonal banks and genetic improvement projects of forestry companies, resulting in many chemical, physical and anatomical analyzes.

For this reason, it is important to develop methods to select suitable genotypes reducing the number of analyzes required. An alternative might be pre-selecting superior genotypes, intending to form a small group, composed of clones that have good indices physical, dendrometric and anatomical variables, proven to contribute positively to the quality of charcoal. In addition, use this set to perform all the analysis necessary for the final selection.

Therefore, this work presents a method to pre-select *Eucalyptus* sp. clones aiming at the production of superior quality charcoal, based on easy-determined low-cost variables, such as the: heartwood/sapwood ratio, wood basic density, wood volume and dry mass, aggregating different classification and selection criteria.

Materials and methods

In this work, 64 clones of *Eucalyptus* sp. (Table 1) were used. They were grown in 3x3 meters spacing, cut age 7 years. The clones came from a clonal bank in lines of 10 plants, belonging to a forest company located in the municipality of Três Marias - MG.

Three trees of average diameter were sampled for each clone. From each tree, six disks 10 cm thick corresponding to DBH (diameter at breast height), 0%, 25%, 50%, 75% and 100% of the commercial height were taken, up to the minimum diameter of 6 cm. The disks were sent to the Laboratório de Painéis e Energia da Madeira (LAPEM) at the Universidade Federal de Viçosa (UFV), where basic density and the heartdwood/sapwood ratio were determined.

Table 1 – Information about phenotypic and genotypic values of all variables used to classify genotypes, calculate the median and selection index.

CLONE	VOL		BD		H/S		DM		CLONE	VOL		BD		H/S		DM	
	P	G	P	G	P	G	P	G		P	G	P	G	P	G	P	G
1	0.18	0.20	570.24	570.89	0.59	0.62	100.55	113.45	33	0.25	0.26	537.01	540.35	0.7	0.72	135.15	142.00
2	0.34	0.33	568.06	568.88	0.72	0.74	192.00	188.91	34	0.36	0.35	591.58	590.49	1.48	1.31	212.75	206.02
3	0.22	0.24	546.26	548.85	1.39	1.37	122.28	131.38	35	0.45	0.42	584.31	583.82	1.1	1.10	262.54	247.10
4	0.24	0.25	544.11	546.88	0.57	0.60	132.31	139.66	36	0.31	0.31	517.08	522.05	1.2	1.19	158.69	161.42
5	0.32	0.32	586.49	585.82	1.49	1.46	188.03	185.63	37	0.20	0.22	571.19	571.76	1.48	1.45	115.36	125.67
6	0.22	0.23	569.00	569.75	0.83	0.84	122.46	131.53	38	0.27	0.28	591.63	590.54	1.03	1.03	161.13	163.43
7	0.44	0.41	577.76	577.80	0.86	0.87	252.63	238.93	39	0.29	0.30	602.15	600.20	0.47	0.50	177.57	177.00
8	0.32	0.32	590.11	589.15	0.7	1.38	190.20	187.42	40	0.29	0.29	574.40	574.71	0.78	0.80	164.01	165.81
9	0.38	0.36	581.67	581.26	0.89	0.90	219.17	208.34	41	0.32	0.32	561.44	562.80	1.04	1.04	180.20	179.17
10	0.23	0.24	587.00	586.29	0.88	0.89	132.86	140.11	42	0.37	0.36	552.17	554.29	0.96	0.96	202.99	197.97
11	0.37	0.36	591.41	590.34	1.58	1.55	219.64	211.71	43	0.30	0.30	557.07	558.79	1.5	1.47	167.27	168.50
12	0.15	0.18	603.57	601.51	0.5	0.54	92.27	106.62	44	0.30	0.30	570.55	571.17	1.12	1.11	169.48	170.32
13	0.22	0.23	553.85	555.83	0.7	0.73	123.23	132.16	45	0.26	0.27	571.45	572.00	1.02	1.02	150.18	154.40
14	0.27	0.27	580.63	580.43	1.22	1.21	154.14	157.67	46	0.31	0.31	530.35	534.23	0.78	0.79	166.23	167.64
15	0.30	0.30	596.14	594.68	1.01	1.02	177.59	177.02	47	0.29	0.29	540.63	543.69	0.63	0.65	157.35	160.32
16	0.25	0.26	541.64	545.92	0.89	0.90	134.59	144.17	48	0.26	0.27	558.09	559.73	1.22	1.21	145.73	150.73
17	0.37	0.36	537.17	540.50	0.61	0.64	197.37	193.33	49	0.46	0.43	554.92	556.81	0.69	0.72	254.60	240.55
18	0.34	0.33	543.83	546.62	1.31	1.29	184.50	182.72	50	0.29	0.29	589.72	588.79	1.09	1.09	172.49	172.81
19	0.43	0.41	602.21	600.26	1.14	1.13	261.51	246.25	51	0.33	0.32	533.24	536.89	0.86	0.87	174.03	174.08
20	0.44	0.42	587.30	586.56	1.5	1.47	260.80	245.67	52	0.18	0.20	558.66	560.25	1.05	1.05	100.51	113.42
21	0.26	0.27	626.77	621.08	0.67	0.70	162.83	165.60	53	0.24	0.25	595.79	594.36	1.2	1.19	144.95	150.08
22	0.24	0.25	679.90	671.64	0.65	0.68	161.14	163.44	54	0.30	0.30	551.08	553.28	1.3	1.28	165.72	167.22
23	0.17	0.20	640.82	635.73	0.8	0.82	111.71	122.66	55	0.44	0.41	559.16	560.71	1.47	1.45	244.67	232.36
24	0.22	0.24	655.79	649.49	0.84	0.86	147.35	152.07	56	0.25	0.26	577.61	577.66	1.47	1.44	145.51	150.55
25	0.33	0.32	607.78	605.38	1.07	1.07	199.50	195.09	57	0.27	0.28	537.93	541.20	1.05	1.05	147.65	152.31
26	0.26	0.27	581.24	580.99	1.2	1.19	150.14	154.37	58	0.30	0.30	549.88	552.18	1.44	1.41	166.05	167.49
27	0.32	0.31	602.19	600.24	1.15	1.15	191.29	188.32	59	0.36	0.35	610.87	608.21	0.94	0.95	218.57	210.83
28	0.46	0.43	604.46	602.32	1.45	1.42	278.23	260.05	60	0.29	0.29	566.15	567.13	0.53	0.56	161.92	164.09
29	0.34	0.34	620.73	617.27	1.1	1.09	214.35	207.34	61	0.27	0.28	603.59	600.62	0.92	0.93	163.16	165.85
30	0.31	0.31	602.58	600.60	1.69	1.64	187.32	185.05	62	0.26	0.26	574.50	574.80	1.21	1.20	147.31	152.03
31	0.35	0.34	562.17	563.47	1.59	1.56	195.62	191.89	63	0.36	0.35	581.92	581.48	1.16	1.15	211.24	202.32
32	0.26	0.27	641.83	636.66	0.91	0.92	167.64	168.80	64	0.33	0.32	566.04	567.02	1.11	1.11	186.64	142.00
Accuracy		0.90		0.95		0.96		0.90	Accuracy		0.90		0.95		0.96		0.90

VOL: Volume (m^3), BD: Basic density (Kg/m^3), H/S: heartwood/sapwood ratio, DM: Dry matter (Kg), P: Phenotypic value, G:Genotypic value.

The determination of heartwood/sapwood ratio (H/S) followed the methodology described by EVANGELISTA (2007). Using a magnifying glass with ten times magnification, the boundary region between heartwood and sapwood was identified on each disk, observing the color change and the presence of pores obstructed by linden trees in the heartwood. Two perpendicular lines were drawn from one end to the other of the disks, passing through the core center. Using a ruler with 0.1 mm precision, measurements of the total diameter and heartwood diameter were made on both lines. The heartwood/sapwood ratio was calculated by the following formula:

$$(H|S) = \frac{Dh^2}{D^2 - Dh^2} \qquad (1)$$

Meaning: Dh: Heartwood diameter, in cm; and,
D: Disk inside-bark diameter, in cm.

The mean values of the H/S ratio for each clone were calculated from the weighted means of the H/S ratio of the wood discs for each tree, using the log volumes between two consecutive discs as weighting factor.

The basic density of the wood was determined according to the method of water immersion, according to the standard ABNT NBR 11941 (ABNT, 2003). The mean values of basic density of each clone were calculated by weighing the densities of the wedges taken along the trunk, using the log volumes between two consecutive discs as a weighting factor, as described by VITAL (1984).
The average of dry matter value to each clone was obtained by the multiplication of its wood's average basic density x volume, according to the equation:

$$WDM = VOL \times WAD \qquad (2)$$

Meaning: WDM = Wood's dry matter (Kg);
VOL = Clone's average volume (m^3);
WAD = Wood's average density (Kg/m^3);

The data of the volumes were obtained by cubing the trees, performed by the company that owns the clones.

For the selection of the clones thegenotypic's values were calculated. For such calculation it was used the software "*SELEGEN – REML/BLUP*®". The chosen mathematical model was the one numbered eighty - tree:

$$y = Xu + Zg + e \qquad (3)$$

Meaning: y = the data vector;
u = the scalar relative to the general average (fixed effect);
g = the vetor of the genotypic effect (assumed to be random);
e = the vector of error or waste (random).

The capital letters represent the incidence matrix for the cited effects. The choice of the model occurred by the completely randomized experimental design, test of not related clones with one plant by experimental plot.

Once it was known the genotypic value, the clones were ranked and classified as superior or inferior, according to the intended pattern to each feature. For instance, to basic density, volume and dry matter, it's intended that the genotype shows higher values, whereas in heartwood/sapwood ratio it is more suitable those that have lower values, since this variable negatively influences the quality of the vegetal charcoal.

The median of each variant was calculated, so the clones which showed values above the value of the median to basic density, volume and dry matter were considered superior (SUP) to that features, yet the ones who showed values below the median were named inferior (INF). To the heartwood/sapwood ratio, the clones whose values were below the median were considered superior, while those with higher values than the median were considered inferior. Alongside this, the index selection proposed by MULAMBA e MOCK (1978) was used to create a hierarchy of genotypics for each feature, alloting higher absolute values to those with better performance. After the classification was made, it was summed up the sequence of each genotypic relative to each feature, resulting in a new measurement that is elected as selection index (CRUZ et al., 2012).

Afterward the distinct classification, groups were made, according to the pre-established importance's criterion for each variant. The variant basic density (BC) was chosen as the most important, due to its great influence over the quality of the vegetal charcoal suitable to the steel industry, followed by volume (VOL), dry matter (DM) and heartwood/sapwood ratio (H/S). Therefore, the first interest group was composed by the clones that were superior in all features. The second group cointained the clones which were superior in BD, DM, VOL and lesser in H/S, and so on, constituting distinct groups, that were denominated in classes, as it's exemplified in the Table 2.

Results and discussion

Thus, combining the use of different criterions: classification using the median, group formation (this is an exclusion criterion) and Mulamba e Mock selection index, 16 genotypes were selected with higher aptitude to energetic using.

The estimation of the genotypic value, which is the phenotypic value adjusted by the environmental effect, showed a average accuracy of 93% on the four features evaluated (Table 1). The high accuracy means great relation among the predicted values and the real ones, ensuring great safety on the superior clones selection (VILELA DE RESENDE; DUARTE, 2007).

The Table 2 shows the selected genotypics and its respective classification about the individual ranking by each variant, according to its median value and also shows the ranking obtained by the Mulamba and Mock's method. To select the clones, it were observed simultaneously the position of the genotype at the ranking generated by the Mulamba and Mock's index, as its sequence for each variant and its class. Thus it's ensured the genotypes that allow positive gains on the 4 features were selected, according to the order of importance and considering its superiority for the most features.

Table 2 - Selection table of the genotypes, showing the ranking to each feature, as the classification obtained by the median and the ranking generated by the index selection of Mulamba and Mock.

Ran: Genotypic position at each variant's ranking, Gen: Genotype, Gen Value: Genotypic value, Med: Genotypic classification according to its median value, M&M:

DENSITY (Kg/m^3)				VOLUME (m^3)				MATTER (Kg)				HEARTWWOD/SAPWOOD						
Ran	**Gen**	**Gen Value**	**Med**	**Ran**	**Gen**	**Gen Value**	**Med**	**Ran**	**Gen**	**Gen Value**	**Med**	**Ran**	**Gen**	**Gen Value**	**Med**	**Classification**	**M&M**	**Class**
7	59	608,21	SUP	13	59	0,35	SUP	9	59	210,83	SUP	26	59	0,95	SUP	SUP_SUP_SUP_SUP	1	1
31	7	577,80	SUP	5	7	0,41	SUP	6	7	238,93	SUP	19	7	0,87	SUP	SUP_SUP_SUP_SUP	2	1
28	9	581,26	SUP	9	9	0,36	SUP	10	9	208,34	SUP	23	9	0,90	SUP	SUP_SUP_SUP_SUP	8	1
16	15	594,68	SUP	32	15	0,30	SUP	26	15	177,02	SUP	28	15	1,02	SUP	SUP_SUP_SUP_SUP	19	1
13	19	600,26	SUP	7	19	0,41	SUP	3	19	246,25	SUP	40	19	1,13	INF	SUP_SUP_SUP_INF	3	2
9	28	602,32	SUP	1	28	0,43	SUP	1	28	260,05	SUP	55	28	1,42	INF	SUP_SUP_SUP_INF	4	2
26	35	583,82	SUP	3	35	0,42	SUP	2	35	247,10	SUP	37	35	1,10	INF	SUP_SUP_SUP_INF	6	2
6	29	617,27	SUP	16	29	0,34	SUP	11	29	207,34	SUP	36	29	1,09	INF	SUP_SUP_SUP_INF	7	2
8	25	605,38	SUP	20	25	0,32	SUP	15	25	195,09	SUP	34	25	1,07	INF	SUP_SUP_SUP_INF	9	2
19	34	590,49	SUP	12	34	0,35	SUP	12	34	206,02	SUP	51	34	1,31	INF	SUP_SUP_SUP_INF	14	2
27	63	581,48	SUP	14	63	0,35	SUP	13	63	202,32	SUP	42	63	1,15	INF	SUP_SUP_SUP_INF	16	2
14	27	600,24	SUP	25	27	0,31	SUP	19	27	188,32	SUP	41	27	1,15	INF	SUP_SUP_SUP_INF	18	2
15	39	600,20	SUP	34	39	0,30	INF	27	39	177,00	SUP	1	39	0,50	SUP	SUP_INF_SUP_SUP	10	3
3	32	636,66	SUP	46	32	0,27	INF	31	32	168,80	SUP	24	32	0,92	SUP	SUP_INF_SUP_SUP	22	3
49	49	556,81	INF	2	49	0,43	SUP	5	49	240,55	SUP	10	49	0,72	SUP	INF_SUP_SUP_SUP	5	4
40	2	568,88	INF	18	2	0,33	SUP	18	2	188,91	SUP	13	2	0,74	SUP	INF_SUP_SUP_SUP	11	4

Classification position generated by the Mulamba and Mock's selection index.

The calculation of the median, which is a value that divides a set of ordered data in the half, results in the same number of values above and below this value (DANCEY; REIDY, 2013). Stablishing the upper or lower ranking for each genotype according to the median allowed us to organize the genotypes into groups or classes, defining an exclusion criterion. Thus, only clones remaining in the first four classes are interesting for selection, since they are superior in all or at least three characters. This method allowed the reduction of the number of clones to twenty-five.

The use of the Mulamba and Mock index (1978) allowed us to achieve a final product considering all the characters together. The rank arranged by this method, which considers the sum of the positions corresponding to each variable of the same genotype, proved to be efficient to classify the clone. However, in this case, the exclusive use of this procedure can lead to imprecision in the result since this index is influenced by extreme values. For example, a genotype that is the first in the H/S ranking may be ahead of other genotypes that have good DB and VOL values, which are more important characteristics from the point of view of wood quality for charcoal production. Therefore, it is interesting to also observe the position of the genotype in the individual rank of the characteristics, as well as the class it belongs, in this way it is possible to make a safer choice of which clones should be preselected and to follow for the complete characterization of the properties of wood and charcoal.

Conclusion

The proposed methodology allows to select in a safe way the genotypes that present positive gains for several characters simultaneously, also attending to criteria of importance of the variables, and thus, to allocate the most suitable ones to carry out the chemical, physical and anatomical analyzes of wood and charcoal. In this way it is possible to reduce costs with these analyzes and to optimize the process of selection eucalyptus clones aiming the production of high quality charcoal for steel use.

References

Associação brasileira de normas técnicas – ABNT. *NBR 11941: Madeira: determinação da densidade básica.* Rio de Janeiro**:** 6 p. 2003.

Botrel, M. C. G.; Trugilho, P. F.; Da Silva Rosado, S. C.; Da SilvA, J. R. M. Seleção de clones de *Eucalyptus* para biomassa florestal e qualidade da madeira. *Scientia Forestalis*, v. 38, n. 86, p. 237- 245, 2010.

Cruz, C. D.; Regazzi, A. J.; Carneiro, P. C. S. *Modelos Biométricos Aplicados ao Melhoramento Genético*. 4. ed. Viçosa: UFV, 2012. 514 p.

Dancey, C. P.; Reidy, J. *Estatística sem matemática para psicologia*. Penso Editora, 2013.

Evangelista, W. V. *Caracterização da madeira de clones de Eucalyptus camaldulensis Dehnh. e Eucalyptus urophylla ST Blake, oriunda de consórcio agrossilvipastoril*. 2007. 120 f. Dissertação (Mestrado em Ciência Florestal) - Universidade Federal de Viçosa, Viçosa, 2007.

Indústria brasileira de árvores - IBÁ. *Anuário Estatístico da Indústria Brasileira de Árvores: Ano Base 2016*. Brasília, DF. 2017

Mulamba, N.; Mock, J. Improvement of yield potential of the ETO blanco maize (Zea mays L.) population by breeding for plant traits [Mexico]. *Egyptian journal of genetics and cytology*, v. 7, p. 40-51, 1978.

Oliveira, A. C.; Carneiro, A. D. C. O.; Vital, B. R.; Almeida, W.; Pereira, B. L. C.; cardoso, M. T. Parâmetros de qualidade da madeira e do carvão vegetal de *Eucalyptus pellita* F. Muell. *Scientia Forestalis*, v. 38, n. 87, p. 431-439, 2010.

Pereira, E. G.; Martins, M. A.; Pecenka, R.; Angélica De Cássia, O. C. Pyrolysis gases burners: Sustainability for integrated production of charcoal, heat and electricity. *Renewable and Sustainable Energy Reviews*, v. 75, p. 592-600, 2017.

Trugilho, P. F.; Lima, J. T.; Mori, F. A.; Lino, A. L. Avaliação de clones de Eucalyptus para a produção de carvão vegetal. *Cerne***,** Lavras, v. 7, n. 2, p. 104-114, 2001.

Vilela De Resende, M. D.; Duarte, J. B. Precisão e controle de qualidade em experimentos de avaliação de cultivares. *Pesquisa Agropecuária Tropical*, v. 37, n. 3, 2007.

Vital, B. R. Métodos de determinação da densidade da madeira. *SIF (Boletim Técnico, 1)*, p. 21, 1984.

X-RAY DENSITOMETRY OF *Eucalyptus urophylla*'S WOOD AND CHARCOAL

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Abstract

The transformation of wood in charcoal occurs through a thermal treatment known as pyrolysis, which is constituted by multiple heating phases, resulting in the wood's chemical alteration, loss of water content, rupture and degradation of the cell wall and its anatomical elements. There are few specific studies about the modifications in the anatomy of *Eucalyptus* wood originated by the carbonization process and its application in the development of the charcoal's structure and overall quality. The main objective was to determine the apparent density through X-ray densitometry of both wood and charcoal from a *Eucalyptus urophylla* clone, of 6 years of age. The sampling process was carried out by the removal of diametric samples measuring 2mm in thickness at the position of the DBH. After determining the apparent density at 12% of equilibrium moisture, by X-ray densitometry, the samples were carbonized in an electric oven (muffle furnace up to 450°C) and its densities determined through the same technique. The relative apparent density values on the wood and charcoal samples tended to increase in the pith-bark direction. Besides, the results indicate that the wood's apparent density is overall, 40% greater than the charcoal's.

Keywords: anatomy, apparent density, wood quality.

Introduction

It is a common procedure to evaluate the tree's wood and, more specifically its apparent density expressed by the mass and volume ratio, at 12% relative wood humidity (ABNT 7190, 1997). In the determination of the wood's apparent density, it is commonly practiced some destructive methods, usually making it impossible the precise evaluation of the small samples as well as the density between the growth rings. However, recently, the non-destructive methods like the attenuation X-ray presents larger advantages in the determination of apparent density as well as analysis time optimization, better accuracy and improved efficiency in data processing (ARIZAPANA-ALMOCINAD, 2013; SURDI et al., 2014). The X-Ray Densitometry establishes an important wood characterization tool, allowing the assessment of the deterioration effect of eucalyptus trees attacked by "white-rotten" fungi, the heartwood-sapwood limits, the forestry management effects in the wood's properties, the annual biomass production, as well as other wood properties and the relation with its anatomical structure (TOMAZELLO FILHO et al., 2008). Innumerous authors have applied said methodology such as Silva et al. (2004), Tomazello Filho et al. (2008), Benjamin (2006), Sette Junior et al. (2009); Henriques (2012), Arizapana-Almocinad (2013) e Knapic et al. (2014) evaluating the radial variation of the *Eucalyptus grandis* wood's apparent density, which aged between 2 to 20 years old, obtaining an average value ranging from 0,46 to 0,80 g/cm^3 at the medulla and bark regions.

The digital x-ray technique applies the basic x-ray densitometry fundaments, permitting the acquiring of the wood's internal structure image which relates with its chemical composition, density and humidity level. This methodology is used to the detect with precision the internal and external growth rings' density and associated with climatic conditions, carbon fixations, fertilization influence, silviculture practices and wood quality (MANNES et al., 2007; KEUNECKE et al., 2012; CHERUBINI et al., 2013, SURDI et al., 2014).

To express the wood and charcoal quality, the density is adopted as one of the best standards.

Mendes et al. (1982) stated that the density is of the utmost importance on charcoal quality due to its influence in affecting the other properties and, even if the charcoal density may vary due to its characteristics such as granulometry and the presence of cracks. Variables related with the carbonization process may affect the produced charcoal's density, such as the final carbonization temperature and the heating speed. Oliveira et al. (1982), studying technologies to enhance *Eucalyptus grandis* exploitation of seven different localities and the babaçu coconut to charcoal production in laboratory scale, concluded that for the real density and porosity characteristics a carbonization temperature rise occurs. The relative apparent density has an intimate relation with the wood density which was originated from. It was noted in this work that, the greater the wood density, the greater the produced charcoal density and the lower porosity, and the charcoal originated from the babaçu coconut has a greater density and therefore a lower porosity compared with *Eucalyptus grandis* charcoal.

Hence the facts presented, this work was executed with the intent to study the wood apparent density variation radial wise by the X-Ray Densitometry method, as well as to verify the application of said technique to determine apparent density on charcoal of a *Eucalyptus urophylla* clone.

Materials and methods

Starting off 3 trees selected from a *Eucalyptus urophylla* clone, aging 6 years old, it was collected wood disks at 1.3 m (DBH), afterwards, diametric samples (20x10 mm width x thickness) (Figures 1A and 1B), glued together on a wood support and cut out on the radial direction, a very thin sample measuring 2,0 mm in thickness on a parallel-circular double-saw equipment (Figures 1C and 1D). The radial sections were accommodated inside a climatization chamber (20°C for 24 hours, at 60% of relative air humidity and 12% relative wood humidity) (SURDI et al., 2014).

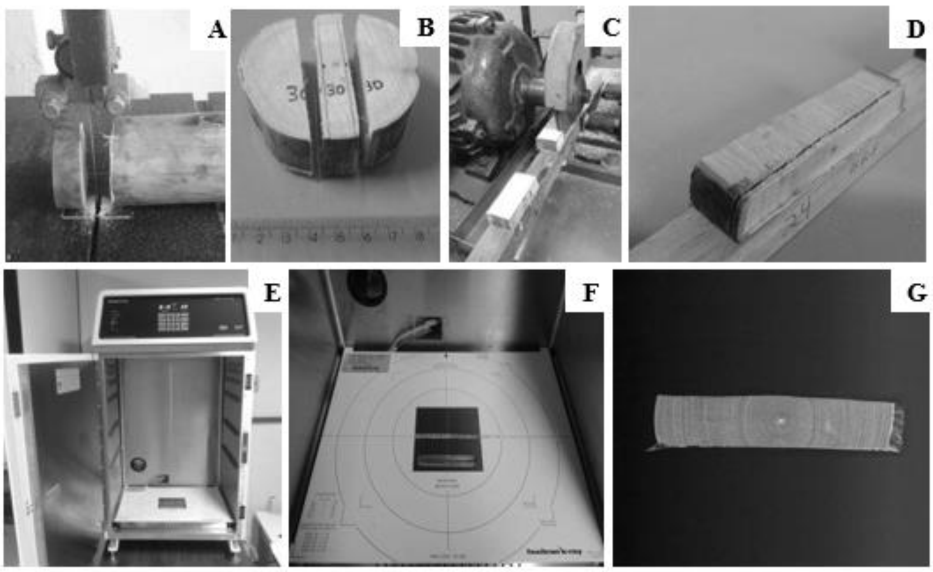


Figure 1: Obtaining of the digital images of wood of *Eucalyptus grandis* in X-ray equipment (A, B, C and D) cutting and preparation of the wood sample (2 mm thickness); (E, F) X-ray equipment LX-60; (G) digital image of the wood.

The slim samples of the radial section of the wood combined with the cellulose acetate calibration scale were inserted in the shielded compartment of the digital x-ray Faxitron model LX-60 previously calibrated for automatic reading (30 Kv, 19 seconds). The digital images with ultra-contrast and resolution were saved in DICOM format (FAXITRON, 2009) (Figure 1E and

1F). During the assembly process of the grey-scale (Figura 1G) and the calibration scale was analyzed using *software ImageJ*, to determine the radial values of wood apparent density (at every 50 µm) obtained by the software and transferred to the electronic spreadsheet to the confection of the apparent density diametric profiles.

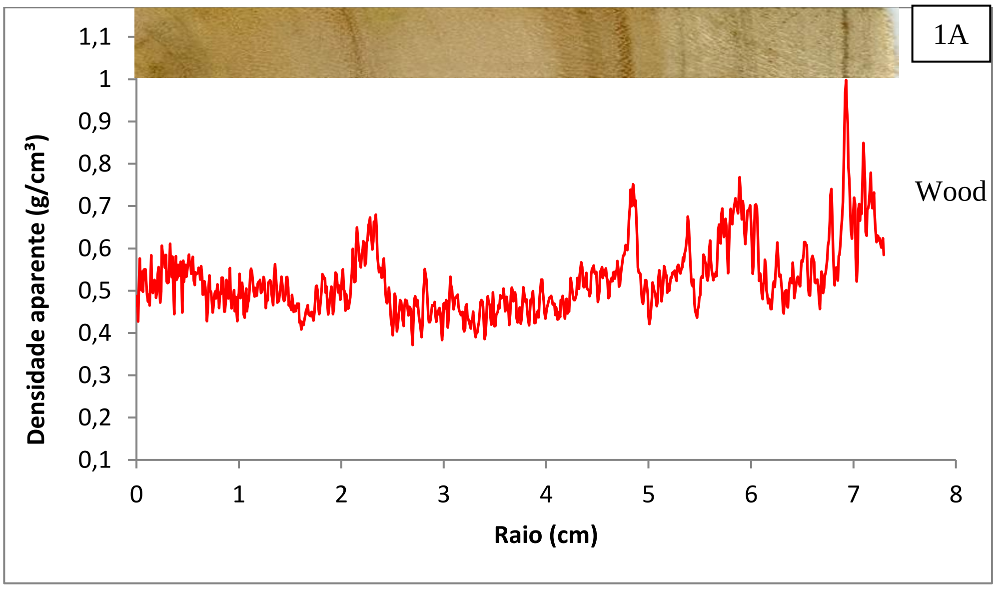
The transversal sections of the wood utilized to determine apparent density via wood x-ray of the *Eucalyptus grandis* were charred on an adapted electric oven (muffle furnace); the heating control was digital, with 15°C increments in temperatures every 30 minutes, which translates to an average heating rate of 0,5°C per minute. The initial temperature was always set at 150°C and the maximum temperature was limited to 450°C, remaining stable for 30 minutes. The total carbonization time was therefore of 10 hours.

Besides the average apparent density, it was determined the minimum and maximum apparent density having repeated those values for every tree analyzed.

Results and discussion

The profiles and values of the average, minimum and maximum apparent densities of the wood samples and tree's charcoal are on Table 1 and Figure 1.

Parameters	**Apparent density (g cm^{-3})**	
	Wood	**Charcoal**
Average apparent density	0,527	0,315
Maximum apparent density	0,998	0,623
Minimum apparent density	0,372	0,169



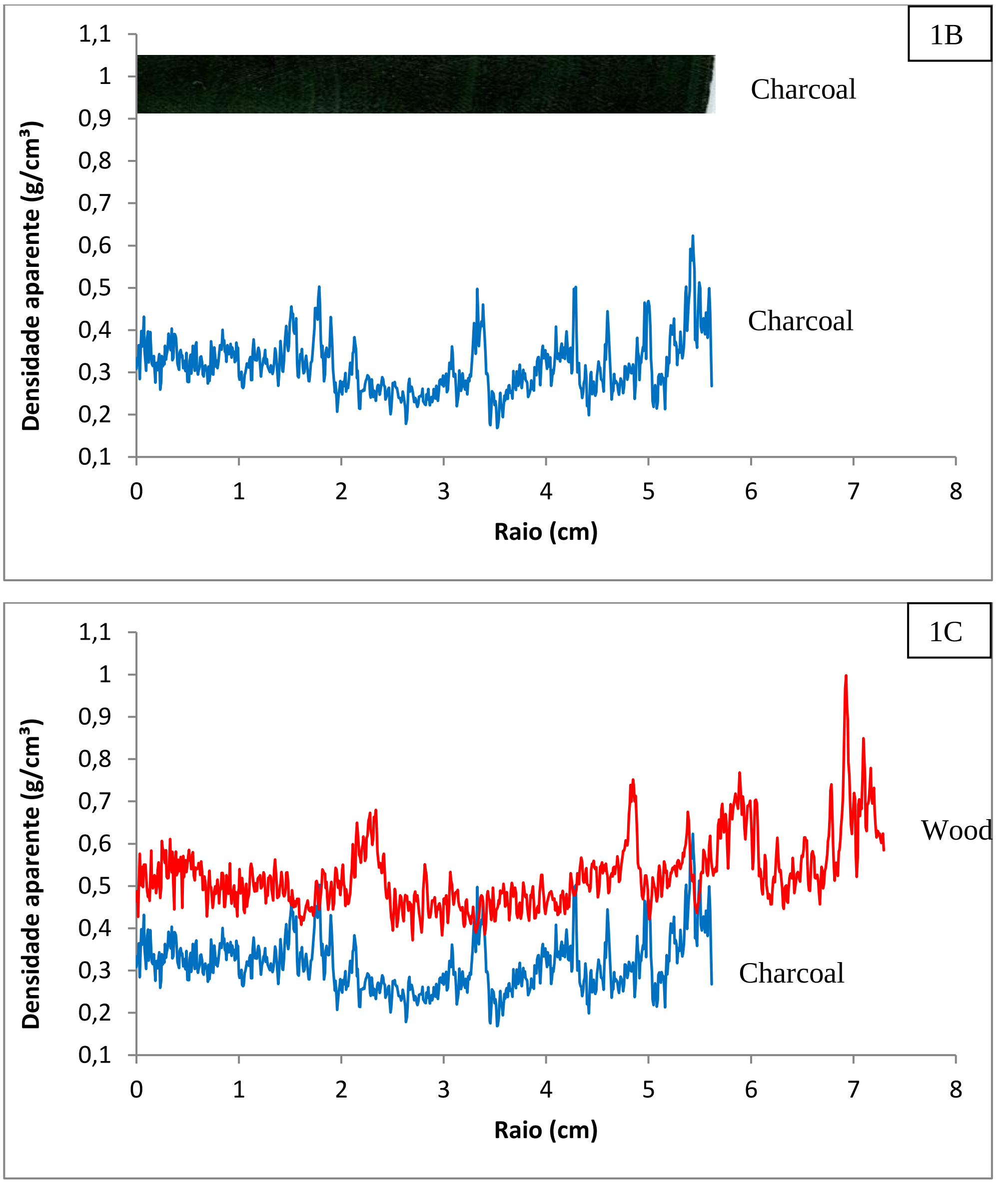


Figure 2 – Variation of the apparent density of the wood and of *Eucalyptus urophylla* wood

In relation to the average apparent density values, the wood that presented 40% greater than the charcoal. Such behavior is common, once that during the carbonization occurs some thermal degradation of the primary components and the emission of volatiles, lowering the charcoal's density in comparison to in natura wood. The maximum apparent density in the wood (0.998 $kg.cm^{-3}$), was also well superior to the charcoal's (0.623 $kg.cm^{-3}$). The minimum apparent density tended the same manner with greater values on the wood (0.372 $kg.com^{-3}$), and lower on the charcoal (0.169 $kg.cm^{-3}$). It was observed that there was a raise in the apparent density on the medulla-bark direction in all samples, either wood and charcoal.

The apparent density profiles of the wood and the charcoal allowed to verify the presence of density peaks, limiting distinct regions on both woods, an internal medulla region and the external. The first profile represents the apparent density variation of the wood's radius from the medulla to the bark (Figure 1A); the second profile corresponds to the variation of the charcoal's apparent density, as shown on (Figure 1B). It was noted that the variation was similar on both profiles, however, the magnitude of the variation was reduced on the charcoal (Figure 1C). This occurs due to the thermal degradation and the expelling of volatile material that usually happens during the carbonization.

Density peaks occurred demarcating distinct regions in the wood, indicating the clear presence of the medullar region with lower density values. According to Tomazello Filho et al. (2008), there is the occurrence of lower apparent density values in the central region (medulla), with the gradual increase toward the bark; radial value oscillations due to the presence of vessel elements with greater diameter, density peaks on the fibers' thickened growth layers; and lower vessels diameter.

The charcoal samples suffered length reductions to samples of the present study. Previous to the carbonization process, the samples measured an average of 7.24 cm of length and afterwards, with the same conditions, suffered an average reduction of 22%, measuring 5.61 cm in length. The reduction percentage was greater in the length than thickness, which may be attributed to the disposition of the vegetal tissue and to cell organization. The same behavior was observed in the Arantes et al. (2016) work.

Conclusion

- The X-Ray Densitometry technique is very reliable to the determination of relative apparent density of charcoal.
- The relative apparent density average values tended towards a raise in the medulla-bark direction in every wood and charcoal samples.

References

Arantes, M.D.C.; Trugilho, P.F.; Tomazello Filho, M.; Lima, J.T.; Vidaurre, G.B. Densitometria de raios x na madeira e carvão de clone de *Eucalyptus grandis W. Hill ex Maiden X Eucalyptus urophylla S. T. Blake. Revista Árvore*, Viçosa, v.40, n.1, p.155-162, 2016.

Arizapana-Almonacid, M. A. *Avaliação do crescimento e da qualidade do lenho de árvores de Eucalyptus urophylla, de 8 anos, de teste de progênies, visando a produção de carvão vegetal.* 2013. 159 p. Dissertação (Mestrado em Recursos Florestais) – Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, 2013.

Associação brasileira de normas técnicas. NBR 7190: projeto de estruturas de madeira. Rio de Janeiro, 1997.

Benjamin, C. A. *Estudo da estrutura anatômica e das propriedades físicas e mecânicas da madeira de Corymbia (Eucalyptus) e Eucalyptus grandis.* 2006. 158 p. Tese (Doutorado em Energia na Agricultura) – Faculdade de Ciências Agronômicas, Universidade Estadual Paulista "Júlio Mesquita Filho", Botucatu, 2006.

Cherubini, P. et al. Olive tree-ring problematic dating: a comparative analysis on Santorini (Greece). *Plos One***,** Berkeley, v. 8, n. 1, p. 1-5, 2013.

Henriques, E. P. *Variabilidade genética de caracteres de produção e qualidade da madeira, para carvão vegetal, em progênies de Eucalyptus urophylla S. T. Blake.* 2012; 84 p. Dissertação (Mestrado em Ciência Florestal) – Universidade Estadual Paulista "Júlio de Mesquita Filho", Botucatu, 2012.

Keunecke, D. et al. Combination of X-ray and digital image correlation for the analysis of moisture-induced strain in wood: opportunities and challenges. *European Journal of Wood and*

Wood Products, Berlin, v. 70, p. 407-413, 2012.

Knapic, S. et al. Early assessment of density features for 19 Eucalyptus species using X-ray microdensitometry in a perspective of potential biomass production. *Wood Science and Technology*, New York, v. 48, p. 37-49, 2014.

Oliveira, J.B.; Gomes, P.A.; Almeida, M.R. Caracterização e otimização do processo de fabricação de carvão vegetal em fornos de alvenaria. In: FUNDAÇÃO CENTRO TECNOLÓGICO DE MINAS GERAIS. Carvão vegetal: destilação, carvoejamento, propriedades, controle de qualidade. Belo Horizonte: 1982. p.62-102.

Mannes, D. et al. Neutron imaging versus standard X-ray densitometry as method to measure tree-ring wood density. *Trees*, Berlin, v. 21, p. 605–612, 2007.

Mendes, M.G.; Gomes, P.A.; Oliveira, J.B. Propriedades e controle de qualidade do carvão vegetal. In: PENEDO, W.R. (Ed.). Produção e utilização do carvão vegetal. Belo Horizonte: CETEC, 1982. p.76-89.

Sette Junior, C. R. et al. Efeito da aplicação de potássio e sódio nas características do lenho de árvores de *Eucalyptus grandis* W. Hill, aos 24 meses de idade. *Revista Floresta*, Curitiba, v. 39, n. 3, p. 535-546, jul./set. 2009.

Silva, J. C. et al. Influência da idade e da posição radial na massa específica da madeira de *Eucalyptus grandis* Hill ex. Maiden. *Revista Floresta*, Curitiba, v. 34, n. 1, p. 13-22, jan./abr. 2004.

Surdi, P. G. et al. Perfil de densidade do lenho utilizando métodos radiográficos. *Scientia Forestalis* (IPEF), v. 42, p. 229-236, 2014.

Tomazello filho, M. et al. Application of technique in nondestructive evaluation of eucalyptus wood. *Maderas: Ciencia y Tecnologia.* Concepción**,** v. 10, n. 2, p. 139-150, 2008.

THEME: ETHANOL

APPLICATION OF THE CHEMICAL RIPENER ETHEPHON IN SWEET SORGHUM

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Abstract

Chemical ripeners or plant growth regulators are synthetic products used on agricultural crops to enhanced feedstock quality. Ethephon is widely applied to sugarcane, restricting scientific informations about to its potential to *Sorghum spp*. species. Thus, the aim of this paper was to evaluate influence of this chemical ripener on the sweet sorghum cv. CMSXS 646 juice quality. Field experimentation was carried on São Paulo Technology and Agrobusiness Agency, located at Andradina, Brazil. It was applied a randomized block design, considering four commercial product levels (0.0, 0.35. 0.70 and 1.40 L c. p. ha^{-1}), with four replications. Chemical ripener was applied before crop flowering period by sprayer (CO_2 pressurized). After 30 days plants were harvested and stalks samples were intended to laboratory for °Brix, Pol, Purity, Reducer Sugars (RS), Total Reducer Sugars (TRS), Fibers and Recoverable Theoretical Sugars (RTS) evaluation. Data set was subjected to regression analyze ($P<0.01$ and $P<0.05$). Quadratic regressions rejected nullity hypothesis and adjusted significantly to almost every parameters, explaining at least 56.39 % of variations checked. Regarding to control, chemical ripener dosages reduced °Brix, TRS, Purity, Fibers and RTS, however increased RS. It was concluded that Ethephon levels (0.35. 0.70 and 1.40 L c. p. ha^{-1}) are not indicates to sweet sorghum cv. CMSXS 646 treatment, because decreased feedstock technological quality.

Keywords: ethanol; renewable energy; plant growth regulators

Introduction

Brazil is international reference in sugar-energy technology and world leader on first generation bioethanol production. Thus, sugarcane and sweet sorghum are agricultural crops important a lot to energy matrix of this country (BOARETTO et al., 2014).

Originary from African continent, sweet sorghum (*Sorghum bicolor* L. Moench) is a C_4 plant characterized by wide physiographic adaptation to tropical and subtropical regions, rusticity to drought, pests and diseases, high photosynthetic potential and mechanization ability. Moreover, this energetic crop is indicated so to first and second generation bioethanol industrialization, principally, along sugarcane off-season, due to short commercial cycle and fermentable sugars concentration on stalks (HAN et al., 2011; VIANA et al., 2016).

Industrially, sweet sorghum juice quality is less than sugarcane. However, there are technologic ways to enhance it, such as nutritional management, genetic breeding, chemical ripener application, etc. (MESCHEDE et al., 2012; HEERDEN, 2012). So, the aim of this paper was to evaluate Ethephon influence on sweet sorghum cv. CMSXS 646 juice quality.

Materials and methods

The field experimentation was carried on São Paulo Technology and Agrobusiness Agency, located at Andradina, Brazil. According to Köppen-Geiger, regional climate is classified as Aw, characterized by dry winter and summer rainy.

It was applied a randomized block design, considering four levels of commercial product (0.0, 0.35. 0.70 and 1.40 L c.p. ha^{-1}), with four replications.

Soil acidity and natural fertility were corrected by dolomitic limestone (2 t ha^{-1}) and NPK (0.6 t ha^{-1}) fertilizer. After 60 days from soil preparation, sowing was done distributing fifteen sweet sorghum cv. CMSXS 646 seeds by linear meter at plots with five plantation lines (10 m length) spaced at 0.5 m (DURÃES, 2011).

Before flowering period (60 days from tillage sowing), Ethephon was applied by sprayer (CO_2 pressurized) containing with six flat spray nozzles (AXI 11002). Application was done morning period under temperature and air relative humidity corresponding to 27.5 ± 2.5 °C and 70 ± 10 %, no subsequence rainfall (VIANA et al., 2015).

After 30 days from chemical ripener application, plants were harvested and stalk samples were intended to laboratory for °Brix, Pol, Purity, Reducer Sugars (RS), Total Reducer Sugars (TRS), Fibers and Recoverable Theoretical Sugars (RTS) evaluation. Data set was subjected to regression analyze (P<0.01 and P<0.05), using *Software R* (Version 3.3.1).

Results and discussion

Quadratic regressions rejected nullity hypothesis and adjusted significantly to almost every parameter, explaining at least 56.39 % of variations checked (Figure 1).

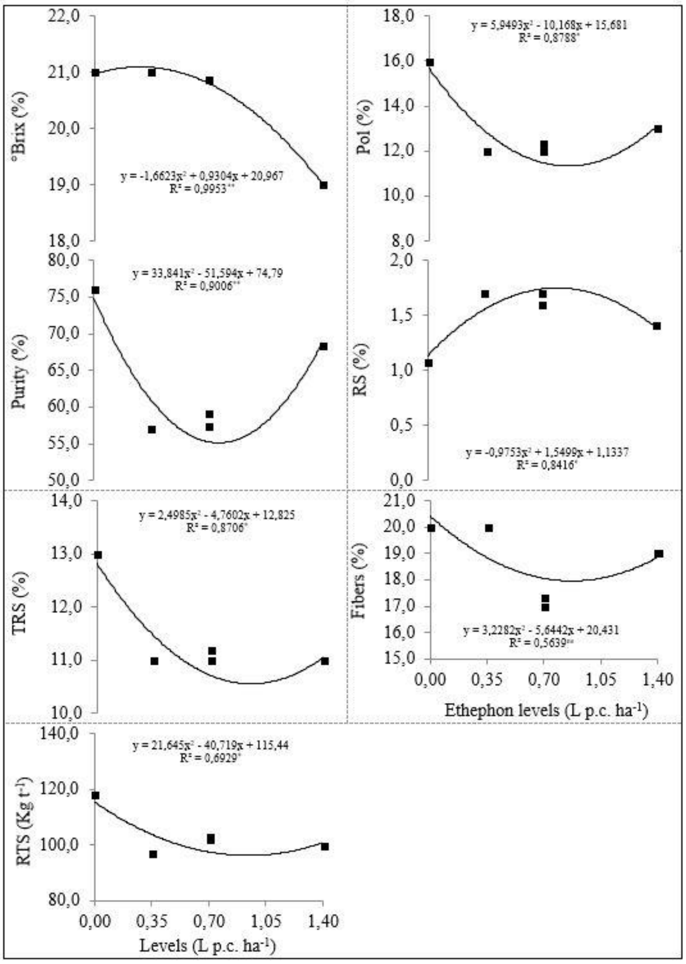

Figure 1. Ethephon effects on sweet sorghum cv. CMSXS 646 juice technological parameters; significance: ** (P<0.01); * (P<0.05); ^{ns} (P≥0.05).

Juice from stalks subjected to 1.40 L c.p. ha^{-1} presented two °Brix percentage points less than control, which showed similar performance regarding to remains Ethephon levels (0.35 and 0.70 L c.p. ha^{-1}). According to Dutta et al. (2015) there is a negative relation between TSS rate and Ethephon concentration, probability due to negative effects from free radicals induced by ethylene excessive accumulation on parenchyma cells. Although decreases checked in this paper, juice °Brix concentration stayed above to standard limit desirable to first generation bioethanol sustainable industrialization from sugarcane and sweet sorghum crops (ALMODARES; HADI, 2009).

Pol presented graphic configuration opposite regarding to °Brix. This was justified by to inverse relation between these parameters. In addition, every Ethephon levels had negative effects on sucrose concentration, reducing it in about to four percentage points, contrasted to control. In general, results of this research diverged to Silva et al. (2010) and Viana et al. (2016); those researchers checked Ethephon synergic effect on sweet sorghum cv. 80007 juice Pol. As Kumar et al. (2008) soil fertility, genotype, crop sanity and chemical ripener types and dosages are examples of biotic and abiotic factors that influenced energetic crops sucrose rate.

About Purity, 0.35 and 0.70 L c. p. ha^{-1} dosages associated to more inexpressive results, 57.5 and 59.2 %, respectively; whereas 1.40 L c. p. ha^{-1} presented 68.4 %, value about to eight percentage points less than control (78.2 %). Believed that Purity increase along regression curve was due to °Brix decrease and Pol enhance, because these parameters are inversely involved on equation to it calculation. Feedstocks with low purity percentage not are desirable to alcohol production, because difficult fermentable sugars conversion process to ethanol molecules, due to imbalance on °Brix and Pol relation (VIANA et al., 2015).

Unlikely °Brix, Pol and Purity, Ethephon levels increased glucose and fructose concentration, contrasted to control, which presented 0.7, 0.6 and 0.4 RS percentage points less than 0.35, 0.70 and 1.40 L c. p. ha^{-1}, respectively; however, results verified in this paper stayed below to standard limit (1.8 % RS). As Audilakshimi et al. (2010) sugarcane and sweet sorghum juices with high RS rate are desirable a lot to sugar-energy industry, cause promote reducer sugars fermentation.

Although Fibers reduction, Ethephon levels are not able to keep it below standard limit desirable to bioethanol industrialization (up to 13 %). Feedstocks with high fibers percentage not are indicated to alcohol commercial production, because limit milling process, due to largest tissue recalcitrance and low fermentable sugars concentration, since there is negative relation between lignocellulose and sugars (CAPUTO et al., 2008).

Ethephon negative effects too were observed to RTS, because 0.35, 0.70 and 1.40 L c. p. ha^{-1} levels reduced RTS in about to 23.0, 17.0 and 20.0 Kg t^{-1} regarding to control yield, respectively. This condition is not desirable to sugarcane and sweet sorghum, because RTS is directly related to raw material price paid to producers (VIANA et al., 2015).

Conclusion

Ethephon levels (0.35, 0.70 and 1.40 L c. p. ha^{-1}) are not indicates to sweet sorghum cv. CMSXS 646 treatment, because decreased °Brix, Pol, Purity, RS, TRS and RTS.

References

Audilakshmi, S.; Mall, A. K.; Swarnalatha, M Seetharama, N. Inheritance of sugar concentration in stalk (Brix), sucrose content, stalk and juice yield in sorghum. *Biomass and Bioenergy*, v. 34, p. 813820, 2010.

Boaretto, L. F.; Carvalho, G. Borgo, L. Creste, S. Landell, M. G. A.; Mazzafera, P.; Azevedo, R. A. Water stress reveals differential antioxidant responses of tolerant and non-tolerant sugarcane genotypes. *Plant Physiology and Biochemistry*. v. 74, p. 165-175, 2014.

Caputo, M. M.; Beauclair, E. G. F.; Silva, M. A.; Piedade, S. M. S. Resposta de genótipos de cana-de-açúcar à aplicação de indutores de maturação. *Bragantia*, v. 67, p. 15 – 23, 2008.

Durães, F. O. M. Sorgo sacarino: desenvolvimento de tecnologia agronômica. *Agroenergia em Revista*, p. 7 – 8, 2011.

Dutta, U. Evaluation of ethephon-induced oxidative stress to gonadal disorder and its amelioration by ethanolic extract of shoot of *Bambusa balcooa* Roxb. in Albino rat. *Toxicology Letters*, v. 2, n. 238, p. S269-S270, 2015.

Han L. P.; Wang X.; Guo X.; Rao M. S.; Steinberger Y.; Cheng X.; Xie G. H. Effects of plant growth regulators on growth, yield and lodging of sweet sorghum. *Research on Crops*, v. 12, n. 2, p. 372 – 382, 2011.

Heerden van, P. D. R. Evaluation of Moddus® as a new chemical ripener for the South African sugar industry: preliminary finding. *South African Sugarcane Research Institute*, v. 85: 193 – 195, 2012.

Kumar, S. R.; Shrotria, P. K.; Deshmukh, J. P. Characterizing nutrient management effect on yield of sweet sorghum genotypes. *World Journal of Agricultural Sciences*, v. 4, n. 6, p. 787 – 789, 2008.

Meschede, D. K.; Velini, E. D.; Tonin, F. G.; Carbonari, C. A. Alterações no metabolismo da cana-de-açúcar em função da aplicação de maturadores. *Planta Daninha*, v. 30, n. 1, p. 113-119, 2012.

Silva, M. A.; Gava, G. J. C.; Caputo, M. M.; Sorrilla, P. F.; Bassetto, S. C. Productivity of stalk and sucrose in sugarcane in relation to cultivar and ripener interaction. *Scientia Agraria*, v. 11, n. 4, p. 323329, 2010.

Viana R. S.; Figueiredo, P. A. M; Lisboa, L. A. M.; Assumpção, A. C. N. D; Sá, M. E.; May, A. Aplicação de maturadores químicos na qualidade tecnológica do sorgo sacarino cv. Biomatrix 535. *Revista Brasileira de Milho e Sorgo*, v. 14, n. 3, p. 326 – 334, 2015.

Viana R. S.; Figueiredo, P. A. M; Lisboa, L. A. M.; Magalhães, A. C. Morpho-anatomical aspects and technological quality of saccharine sorghum submitted to planta regulators. *Revista Brasileira de Herbicidas*, v. 15, n. 2, p. 175 – 183, 2016.

HYDROLYSIS OF PARAMYLON OBTAINED FROM *Euglena gracilis* FOR BIOETHANOL PRODUCTION

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Abstract
Due to the accelerated economic growth and the consequent exhaustion of fossil reserves, it is important to develop sustainable and renewable energy generation techniques. Nowadays microalgae are considered a promising source of energy for the production of biofuels due to the fact that they show rapid growth, do not require arable land and do not contribute to global warming or the greenhouse gases emissions. The aim of this work was to evaluate methods of hydrolysis of paramylon to obtain high levels of simple sugars from *Euglena gracilis* for future bioethanol production. In order to do so, the microalga was cultivated for 34 days in mixotrophic conditions and additionally stressed for 6 days with 0.01 g L^{-1} of $FeCl_2$ to increase polysaccharide paramylon production. During the stress phase, cells increased in volume and gradually burst, releasing the sugar into the medium. Therefore, no extraction step was needed and biomass was directly submitted to acid hydrolysis to obtain monosaccharides. A factorial experimental design with a central point was used to evaluate which combination of parameters (temperature, acid concentration and reaction time) would improve hydrolysis performance. The results obtained showed that the highest concentration of monosaccharides was achieved by an autoclave treatment with a 0.06% (v/v) concentration of sulfuric acid at 127°C for 10 minutes.

Keywords: microalgae, acid hydrolysis; bioethanol; experimental design

Introduction

The increasing energy demand and use of fossil fuels has economic and environmental consequences, such as the rise in the price of petroleum-based fuels (oil crisis), environmental devastation, global warming, dioxin emissions, carbon and sulfur accumulation in the atmosphere, that contribute to the increase of the greenhouse gas and acid rain indexes in the atmosphere (JOHN et al., 2011; SCHMITZ; MAGRO; COLLA, 2012). In 2006, studies showed that worldwide emissions of carbon dioxide (CO_2) from fossil fuel combustion increased by more than 20%, reaching 8.38 billion tonnes compared to the year 2000 (ECODEBATE, 2008).

Due to the problems related to the use of fossil fuel, the need of alternative sources of oil arises. Currently, those commonly used do not respond satisfactorily to socio-environmental and economic issues (KLEIN, 2013), because they lead to environmental pollution, affect human health and generate economic instability at an international level (FIRMINO; FONSECA, 2008). Therefore, we are searching for renewable sources of energy that are sustainable in the broadest sense of the term, with low environmental impact, that is, (i) leading to lower greenhouse gas emissions when considering the total cycle, (ii) none or little soil degradation, (iii) minimum consumption of water and energy in the production process, (iv) concern for human health, (v) while still being economically profitable.

Among the biofuels available for commercialization, bioethanol is characterized by lower toxicity, higher biodegradability and less polluting emissions (JOHN et al., 2011). It can be produced from vegetable raw materials (first generation), lignocellulosic biomass (second generation) and recently microalgae (third generation). The latter has gained worldwide attention for its production in smaller and non-arable areas, not compromising productive soil nor tropical rainforests (UEDA, RYOHEI; HIRAYAMA, SHIN; SUGATA, KIYOSHI; NAKAYAMA, 1996) and higher productivity per area when compared to other raw materials used for biofuels production (SUBHADRA; EDWARDS, 2010; KLEIN, 2013).

Microalgal bioethanol production involves an extensive process that mainly depends on biomass and comprises several steps from cell wall disruption until ethanol analysis. The cell wall disruption process is a crucial phase for bioethanol production (HARUN et al., 2010) because it will provide starch for the hydrolysis steps.

Microalgae can accumulate starch in different types and numbers of granules in their cytoplasm. In *Euglena gracilis*, they are named paramylon granules. Paramylon is a carbohydrate similar to starch, but it presents β-1,3 glycosidic linkage. Since the granules are located in the cytoplasm, it is necessary to break the cell to release them in the medium, in order to use paramylon as a carbon source during the fermentation process (CLARKE & STONE, 1960).
Starch needs to be hydrolyzed into simple sugars so they can undergo fermentation into ethanol in the alcoholic fermentation process. This can be achieved by acid or alkaline treatment, as well as enzymatic. Alkaline hydrolysis was investigated by Harun *et al*. (2011) in respect to sodium hydroxide concentration, temperature and pre-treatment time for *Chlorococcum infusionum*. From 5 g of dry biomass powder, the highest glucose concentrations (350.13 mg / g) were obtained using 0.75% (w / v) NaOH for 30 minutes in an oven at 120 ° C.

Lee *et al*. (2013), used 5% (w/v) residual biomass of *Dunaliella tertiolecta* and performed acid hydrolysis in an autoclave at 121 °C for 15 minutes in samples containing different concentrations of hydrochloric acid (0.1, 0.3, 0.5, 0.7 and 1 mol/L) and sulfuric acid (0.05, 0.15, 0.25, 0.35 and 0.5 mol/L). In comparison to the acid treatment, enzymatic hydrolysis from the same residual biomass concentration was performed using the commercial cellulase enzymes amyloglucosidase and Viscozyme L, varying the temperature (35 to 55 °C) and pH (3.5 to 6.5).
In relation to acid hydrolysis, the highest saccharification yield was obtained from the samples treated with 0.5 mol/L hydrochloric acid, reaching approximately 30% (w/w). In relation to the samples treated with enzymatic hydrolysis, the amyloglucosidase showed higher efficiency in the saccharification yield (42% (w/w)). The combination of both methods (chemical-enzymatic saccharification) did not have a significant effect on the yield, which reached 43.4% (w/w).

Ho *et al*., 2013 studied physicochemical hydrolysis with sulfuric acid (1% v/v) and autoclaving at 121 °C for 20 minutes, and enzymatic hydrolysis using *Pseudomonas* sp. CL3. They found that both methods were effective in producing sugars from *Chlorella vulgaris* FSP-E. They obtained a yield of 93.6% of glucose from 50 g L of biomass using acid hydrolysis and 90.4% of glucose from 20 g/L of biomass, using enzymatic hydrolysis

While more promising results have been observed using acid hydrolysis, this treatment can generate by-products that inhibit fermentation and therefore, compromise ethanol production. Sugar can be degraded to 5-hydroxymetilfurfural (5-HMF) and furfural. Furfural can be degraded to levulinic acid and formic acid (ULBRICHT; NORTHUP; THOMAS, 1984). The concentration of hydrolysis by-products depends on hydrolysis conditions. Higher concentrations inhibitors are produced with higher acid concentrations (CARLSEN et al., 1991; HARUN; DANQUAH; FORDE, 2010).

In order to investigate the potential of *Euglena gracilis* for bioethanol production, this study aims to evaluate the efficiency of different methods of paramylon hydrolysis. A two-level full factorial design was performed with 3 factors: autoclave temperature, sulfuric acid concentration and reaction time. Furthermore, the production of simple sugars by acid hydrolysis was compared to enzymatic hydrolysis.

Material and methods

Strains and culture conditions

Microalga *Euglena gracilis* was a donation from MNHM (Museum National de Histoire Naturelle – Paris). It was cultivated in medium with additional organic carbon source.

Light intensity was approximately 100 µmol photons m^{-2} s^{-1}. No aeration nor CO_2 supplementation was performed. Cultures were grown in increasing volumes in Erlenmeyer flasks in order to obtain sufficient biomass. Microalgal growth was evaluated by measuring cell density (cells/mL) with a Neubauer chamber and an optic microscope (Zeiss, AxioStar).
In the attempt to increase paramylon production, microalgal culture was stressed with the addition of $FeCl_2$ (0.1 g/L), once stationary phase was reached.

Hydrolysis

Acid hydrolysis

An experimental planning was carried out for sulfuric acid hydrolysis of a 5% maize solution (Maizena®), a raw material composed basically of starch. Evaluated variables were temperature, acid concentration and hydrolysis time, as described in Table 1. All tests were performed in a vertical autoclave (AV Plus Phoenix).

Table 1 – Full factorial design for sugar simple production by acid hydrolysis

Essays	Temperature (°C)	Time (min)	% (v/v) H_2SO_4 (Synth)
1	111	5	0,04
2	111	5	0,08
3	127	5	0,04
4	127	5	0,08
5	111	15	0,04
6	111	15	0,08
7	127	15	0,04
8	127	15	0,08
9	119	10	0,06
10	119	10	0,06
11	119	10	0,06

After hydrolysis, samples were centrifuged (Centrifuge 5702 from Eppendorf) at 4400 rpm for 10 minutes. Supernatant was collected and pH was corrected to 4-5 with NaOH (0.1 mol/L).

Enzymatic hydrolysis

Enzymatic hydrolysis was carried out in triplicate with Cellulase (Trichoderma reensei ATCC 26921). A concentration of 50mL/L of enzyme was added in each 250 mL Erlenmeyer flask containing the microalgal culture for hydrolysis. It was performed in shaking incubator (TE-420, Tecnal) 180 rpm, in 250 mL flasks, 30 °C for 24 hours.

Analytical procedures

Reducing sugars were analyzed by DNS method (MILLER, 1959) and hydroxymetilfurfural (*HMF) was quantified by UV-vis spectrophotometry (*Cary 60 G6860A). Standard curves are shown in Figures 1 and 2.

Figure 1 – Standard curve for reducing sugars

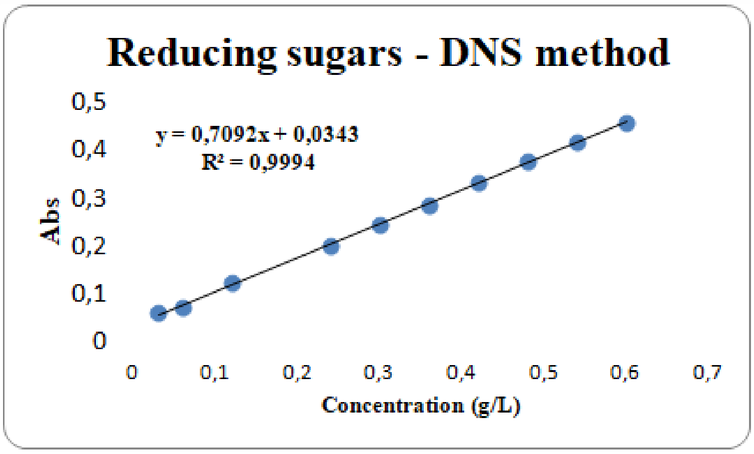
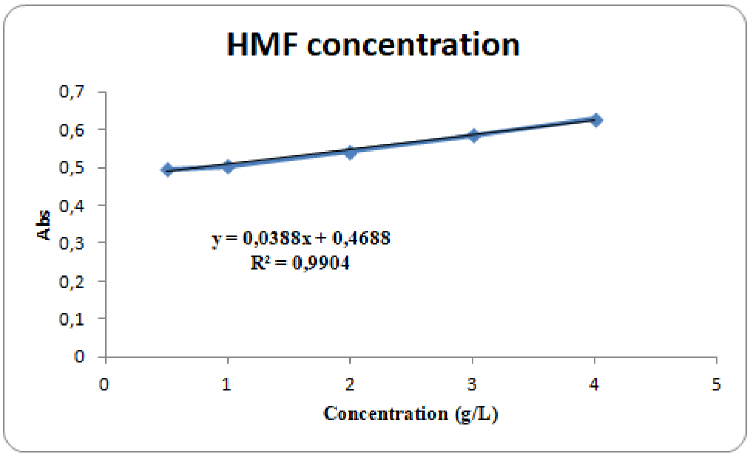


Figure 2 – Standard curve for HMF



Software

Experimental planning was performed was using Action 2.6 (Estatcamp)

Results and discussion

Two-level factorial design of acid hydrolysis

The combination of three independent variables (temperature, acid concentration and hydrolysis time) was examined and their effects on acid hydrolysis of the maize solution were evaluated by using two-level factorial design. The conditions evaluated and the response in simple sugar yield are depicted in Figures 3a-c.

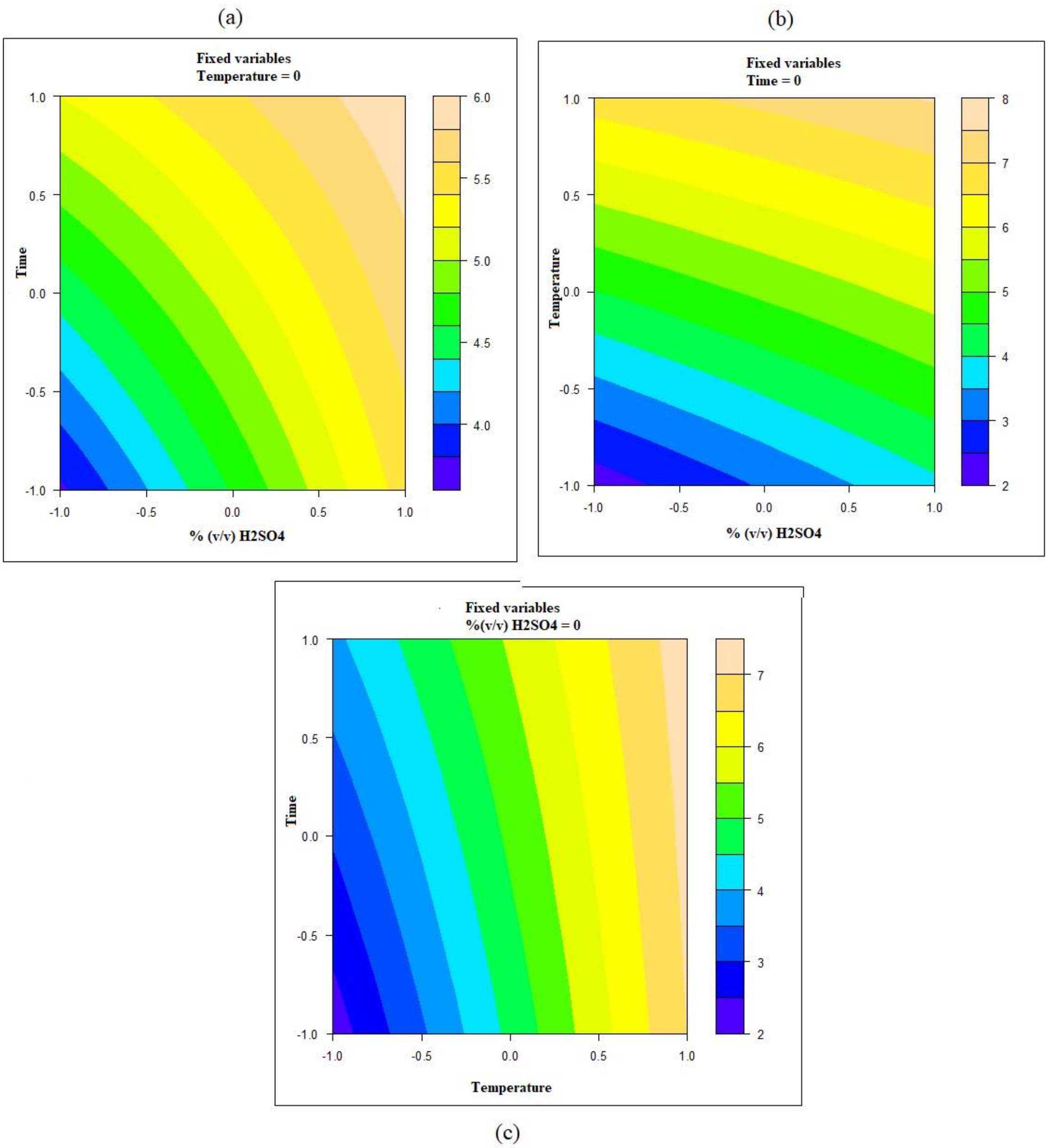


Figure 3 – Results of the experimental design. (a) Correlation between time (t) and % (v/v) acid concentration (C); (b) Correlation between temperature (T) and % (v/v) acid concentration; and (c) Correlation between time (t) and temperature (T)

According to these results, temperature is the only variable that plays a significant role in hydrolysis, i.e., in increasing simple sugar yield. Therefore, regardless of reaction time and acid concentration, the temperature is the main variable for acid hydrolysis carried out in an autoclave. Based on these results, conditions for further hydrolysis experiments on microalgal biomass and paramylon were selected as temperature of 127 °C, 10 min reaction time, and 0,06% (v/v) sulfuric acid concentration. Higher temperatures could not be evaluated due to limitation of autoclave equipment. Meanwhile, acid concentration of 0,06% (v/v) was chosen because higher values would lead to higher production of fermentation inhibitors (CARLSEN et al., 1991; HARUN; DANQUAH; FORDE, 2010).

Analysis of variance (ANOVA) of the factorial design was performed using Action (2.6) and indicated the significance of the results due to the high determination coefficient (R^2 = 0.8896) and to the fact that F_{cal} was higher than F_{tab} for regression and F_{calc} was smaller than F_{tab} for residual (Table 2).

The following regression equation was obtained using statistical:

$$Y = 5{,}09736 + 0{,}618625 * C + 2{,}0398 * T + 0{,}4754 * t \qquad (1)$$

Where:
C = Acid concentration in %(v/v);
T = Temperature in °C;
t = time in min.

Table 2 – Analysis of variance for regression models of experimental design.

	Degrees of freedom	Sum of squares	Mean squares	Fcalc	Ftab
Regression	6	39,97378575	6,662297625	5,372674655	4,009749313
Residual	4	4,960134795	1,240033699		
Lack of fit	2	2,198932795	1,099466398	0,796367957	9
Error	2	2,761202	1,380601		

Simple sugar analysis from Euglena gracilis biomass

Once acid hydrolysis protocol was determined by experimental design using maize solution, its efficiency was evaluated on microalgal biomass and compared to enzymatic hydrolysis.

Paramylon from *Euglena gracilis* was hydrolyzed by diluted sulfuric acid or enzyme treatment. The simple sugar composition was analyzed using UV-vis. For both treatments, hydrolysis of stressed samples started with 20 g/L microalgae concentrate, while hydrolysis of non-stressed samples started with 11 g/L biomass. Enzymatic hydrolysis was more efficient, yielding approximately 5 times more glucose than acid hydrolysis, reaching approximately 5 g/L. These results corroborate with those reported by Miranda HERNÁNDEZ *et al*., (2015).

Simple sugar yield depends on the original biomass and starch content and hydrolysis efficiency. Lee *et al.*(2013) obtained approximately 1.5 mg/mL of sugar using 0.1 mol/L of sulfuric acid. Ho *et al*. (2013) obtained approximately 23g/L of sugar concentration from 50g/L of biomass (Chlorella vulgaris FSP-E) from sulfuric acid hydrolysis.

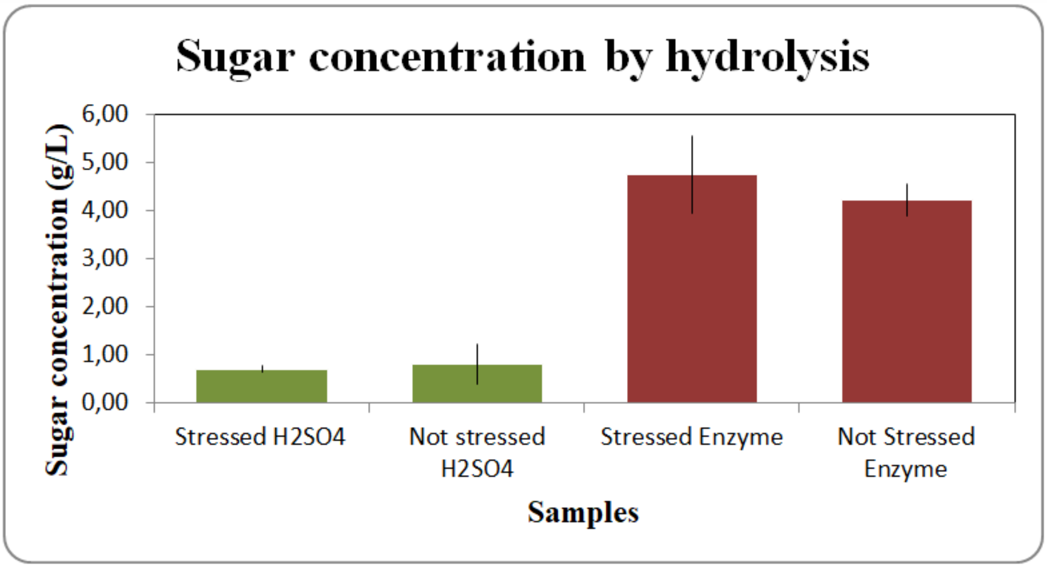


Figure 4 – Simple sugar concentration after acid (green) and enzymatic (red) hydrolysis.

According to MARKOU and GEORGAKAKIS (2011), carbon, nitrogen, phosphorus and some micro-nutrients like iron, nickel, copper, zinc, manganese cobalt, boron and chlorid are essential for microalgae growth. Several studies show that the iron supplementation can alter microalgal metabolism and increase starch accumulation (SERNA; ISAZA; BETANCUR, 2010; DRAGONE et al., 2011; WAN et al., 2014). In studies of intracellular biosynthesis in *Euglena gracilis* with equimolar concentrations of Fe (II)/Fe (III) ions, Brayner and collaborators (2012) showed that, similarly, there was an absorption of the ions in the cellular membrane of this microalga, which suggests a rupture of it.

However, in the present work, $FeCl_2$ stress did not seem to have an effect over paramylon production in *E. gracilis*, since the simple sugar concentration was statistically similar among stressed and none stressed cells, when submitted to both hydrolysis treatments. Therefore, the use of only $FeCl_2$ was not enough to increase final simple sugar yield. Nevertheless, $FeCl_2$ addition led to cell rupture, pouring intracellular paramylon is into the culture medium. In the experiments reported here, cells that remained intact after the iron stress were still extracted due to the acid and heat from the hydrolysis treatment. Further work is currently being performed with equimolar iron solution, to better understand the effect of this stress factor on *E. gracilis*.

HMF analysis

HMF concentration was determined by spectroscopy UV-vis (λ = 284 nm) in the hydrolysates samples by acid and the results are table 3.

Table 3 – HMF concentration from acid hydrolysis.

Essays	**HMF concentration (g/L)**
Stressed H_2SO_4	5,8
Not Stressed H_2SO_4	4,1

According Miranda *et al.* (2012), the concentration of sulfuric acid is an important parameter for the conduction of autoclave acid hydrolysis. They concluded that high concentrations result in the degradation of monosaccharides in sugar degradation products (hydrometilfurfural, furfural, propionic acid, acetic acid, lactic acid and formic acid).

Conclusion

Microalgae can be an alternative source for ethanol production once, with the appropriate strain and environmental condition, they can accumulate high sugar content. However, it is necessary to transform complex sugar into simple sugar by hydrolysis in order to proceed with fermentation. According to the experimental design here employed, temperature is the only significant variable to increase simple sugar yield for acid hydrolysis carried out in the autoclave. Furthermore, since higher sulfuric acid concentration generate more fermentation inhibitors, the best set of conditions to be further applied on *E. gracilis* paramylon were: temperature of 127 °C, 10 min reaction time, and 0,06% (v/v) sulfuric acid concentration.

The stress based on $FeCl_2$ was not an important step for final simple sugar yield. Results from hydrolysis of stressed samples and non-stressed samples were similar regardless of acid or enzymatic process. Consequently, the use of $FeCl_2$ alone to increase sugar concentration is not necessary. When comparing acid and enzymatic paramylon hydrolysis, the latter was shown to be much more efficient and resulted in 5 times more sugar than sulfuric acid.

Taken together, these results can contribute to the establishment of appropriate methods for bioethanol production from microalgal biomass and represents an innovative first step in the evaluation of the potential of *E. gracilis for this purpose***.**

References

Brayner, R.; Coradin, T.; Beaunier, P.; Grenèche, J. M.; Djediat, C.; Yéprémian, C.; Couté, A.; Fiévet, F. Intracellular biosynthesis of superparamagnetic 2-lines ferri-hydrite nanoparticles using Euglena gracilis microalgae. *Colloids and Surfaces B: Biointerfaces*, v. 93, p. 20–23, 2012.

Carlsen, H. N.; Degn, H.; Lloyd, D.; Melo, H. F. de. Resposta ao estresse ácido em leveduras da fermentação alcoólica industrial. *Journal of General Microbiology*, v. 137, n. 12, p. 2879–2883, 1991. Disponível em: <http://mic.microbiologyresearch.org/content/journal/micro/10.1099/00221287-137-12-2879>.

Dragone, G.; Fernandes, B. D.; Abreu, A. P.; Vicente, A. A.; Teixeira, J. A. Nutrient limitation as a strategy for increasing starch accumulation in microalgae. *Applied Energy*, v. 88, n. 10, p. 3331–3335, 2011. Disponível em: <http://dx.doi.org/10.1016/j.apenergy.2011.03.012>.

Firmino, R. G.; Fonseca, M. B. *Uma Discussão Sobre Os Impactos Ambientais Causados Pela Expansão da Agricultura: A Produção de Biocombustíveis no Brasil*. Paraíba, 2008.

Harun, R.; Danquah, M. K. Influence of acid pre-treatment on microalgal biomass for bioethanol production. *Process Biochemistry*, v. 46, n. 1, p. 304–309, 2011. Disponível em: <http://dx.doi.org/10.1016/j.procbio.2010.08.027>.

Harun, R.; Danquah, M. K.; Forde, G. M. Microalgal biomass as a fermentation feedstock for bioethanol production. *Journal of Chemical Technology and Biotechnology*, v. 85, n. 2, p. 199–203, 2010.

Harun, R.; Jason, W. S. Y.; Cherrington, T.; Danquah, M. K. Exploring alkaline pre-treatment of microalgal biomass for bioethanol production. *Applied Energy*, v. 88, n. 10, p. 3464–3467, 2011. Disponível em: <http://dx.doi.org/10.1016/j.apenergy.2010.10.048>.

Harun, R.; Singh, M.; Forde, G. M.; Danquah, M. K. Bioprocess engineering of microalgae to produce a variety of consumer products. *Renewable and Sustainable Energy Reviews*, v. 14, n. 3, p. 1037–1047, 2010.

Hernández, D.; Riaño, B.; Coca, M.; García-González, M. C. Saccharification of carbohydrates in microalgal biomass by physical, chemical and enzymatic pre-treatments as a previous step for bioethanol production. *Chemical Engineering Journal*, v. 262, p. 939–945, 2015.

Ho, S. H.; Huang, S. W.; Chen, C. Y.; Hasunuma, T.; Kondo, A.; Chang, J. S. Bioethanol production using carbohydrate-rich microalgae biomass as feedstock. *Bioresource Technology*, v. 135, p. 191–198, 2013. Disponível em: <http://dx.doi.org/10.1016/j.biortech.2012.10.015>.

John, R. P.; Anisha, G. S.; Nampoothiri, K. M.; Pandey, A. Micro and macroalgal biomass: A renewable source for bioethanol. *Bioresource Technology*, v. 102, n. 1, p. 186–193, 2011. Disponível em: <http://dx.doi.org/10.1016/j.biortech.2010.06.139>.

Klein, B. C. *Cultivo de microalgas para produção de bioetanol de terceira geração*. 2013. Universidade de Campinas, 2013.

Lee, O. K.; Kim, A. L.; Seong, D. H.; Lee, C. G.; Jung, Y. T.; Lee, J. W.; Lee, E. Y. Chemo-enzymatic saccharification and bioethanol fermentation of lipid-extracted residual biomass of the microalga, Dunaliella tertiolecta. *Bioresource Technology*, v. 132, p. 197–201, 2013. Disponível em: <http://dx.doi.org/10.1016/j.biortech.2013.01.007>.

Markou, G.; Georgakakis, D. Cultivation of filamentous cyanobacteria (blue-green algae) in agro-industrial wastes and wastewaters: A review. *Applied Energy*, v. 88, n. 10, p. 3389–3401, 2011. Disponível em: <http://dx.doi.org/10.1016/j.apenergy.2010.12.042>.

Miranda, J. R.; Passarinho, P. C.; Gouveia, L. Pre-treatment optimization of Scenedesmus obliquus microalga for bioethanol production. *Bioresource Technology*, v. 104, p. 342–348, 2012. Disponível em: <http://dx.doi.org/10.1016/j.biortech.2011.10.059>.

Schmitz, R.; Magro, C.; Colla, L. Aplicações ambientais de microalgas. *Revista CIATEC-UPF*, v. 4, n. 1, p. 48–60, 2012.

Serna, C. P.; Isaza, R. A.; Betancur, L. F. R. Efecto de adición de iones hierro y zinc sobre la producción de etanol de dos cepas recombinantes de Saccharomyces cerevisiae. *Revista Colombiana de Biotecnología*, v. 12, n. 1, p. 158–168, 2010. Disponível em: <http://www.revistas.unal.edu.co/index.php/biotecnologia/article/view/15581/38077>.

Subhadra, B.; Edwards, M. An integrated renewable energy park approach for algal biofuel production in United States. *Energy Policy*, v. 38, n. 9, p. 4897–4902, 2010. Disponível em: <http://dx.doi.org/10.1016/j.enpol.2010.04.036>.

Ulbricht, R. J.; Northup, S. J.; Thomas, J. A. A review of 5-hydroxymethylfurfural (HMF) in parenteral solutions. *Toxicological Sciences*, v. 4, n. 5, p. 843–853, 1984.

Wan, M.; Jin, X.; Xia, J.; Rosenberg, J. N.; Yu, G.; Nie, Z.; Oyler, G. A.; Betenbaugh, M. J. The effect of iron on growth, lipid accumulation, and gene expression profile of the freshwater microalga Chlorella sorokiniana. *Applied Microbiology and Biotechnology*, v. 98, n. 22, p. 9473–9481, 2014.

TECHNOLOGICAL QUALITY OF SWEET SORGHUM BROTH SUBMITTED TO ETHYIL-TRINEXAPAC CHEMICAL RIPENER

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Abstract
Plant growth regulators, such as Glyphosate, Sulfumeturon-methyl, Ethephon and Ethyl-trinexapac, are usually applied to energetic crops to improvement feedstock quality. The aim of this paper was to evaluate technological quality of sweet sorghum cv. CMSXS 646 broth submitted to Ethyl-trinexapac chemical ripener. Field experimentation was carried on São Paulo Technology and Agrobusiness Agency, located at Andradina, Brazil. It was applied a randomized block design, considering four commercial product levels (0.0, 0.4, 0.8 and 1.6 L c. p. ha^{-1}), with four replications. Chemical ripener was applied before crop flowering period by sprayer (CO_2 pressurized). After 30 days plants were harvested and stalks samples were intended to laboratory for °Brix, Pol, Purity, Reducer Sugars (RS), Total Reducer Sugars (TRS), Fibers and Recoverable Theoretical Sugars (RTS) evaluation. Data set was subjected to regression analyze ($P<0.01$ and $P<0.05$). Quadratic regressions rejected nullity hypothesis to every technological parameters. Ethyl-trinexapac levels (0.4 and 0.8 L c. p. ha^{-1}) had negative effects on Pol (15 and 13 %), Purity (75 and 65 %), TRS (12 and 11 %) and RTS (109 and 98 Kg t^{-1}), respectively; keeping it bellow standard limits preconized by to sugar-energy industry. In addition, similar situation was checked to total soluble solids; however °Brix (20 and 20.5 %) percentages, respectively, stayed above to standard limit desirable to bioethanol industrialization from sugarcane and sweet sorghum. It was concluded that Ethyl-trinexapac levels (0.4 and 0.8 L c. p. ha^{-1}) are not indicated to sweet sorghum cv. CMSXS 646 treatment, because decreased broth technological quality.

Keywords: bioenergy, chemical ripener, biofuel

Introduction

In Brazil, sugar and bioethanol are basically obtained from sugarcane industrialization. However, along of-season this energetic crop, there is little alcohol supply to biofuel markets livestock. In this context, development and research institutes are searching others feedstocks able to bioethanol production, such as maize and sweet sorghum (VIANA et al., 2015).

Sweet sorghum (*Sorghum bicolor* L. Moench) is a C_4 plant from African continent. This grass is characterized by short commercial cycle (90 to 120 days) high photosynthetic potential, genetic rusticity to pest and diseases, and large adaptation ability to climatic adverse conditions; moreover, allow mechanization in all agricultural and industrial process (HAN et al., 2011; MAY et al., 2011; STEDUTO et al., 2012).

Sweet sorghum broth technological quality is less than sugarcane, but this problem can be overcome by use of chemical ripeners, synthetic products usually applied to agricultural crops to enhance feedstock quality (CAPUTO et al., 2008; LEITE et al., 2009).

Nationally, Glyphosate, Sulfumeturon-methyl, Ethyl-trinexapac and Thiadizuron are plant growth regulators examples widely used on sugar-energy industry, principally, in sugarcane crop. For this reason, there are little scientific informations about to application these active ingredients to *Sorghum spp*. complex (MESCHEDE et al., 2012; HEERDEN, 2012; VIANA et al., 2016).

So, the aim of this paper was to evaluate technological quality of sweet sorghum cv. CMSXS 646 broth submitted to Ethyl-trinexapac chemical ripener.

Materials and methods

The field experiment was carried on São Paulo Technology and Agrobusiness Agency, located at Andradina, Brazil. According to Alvares et al. (2014), regional climate is classified as Aw, characterized by dry winter and summer rainy.

It was applied a randomized block design, considering four levels of commercial product (0.0, 0.4, 0.8 and 1.6 L c. p. ha^{-1}), with four replications.

Soil acidity and natural fertility were corrected by dolomitic limestone (2 t ha^{-1}) and NPK (0.6 t ha^{-1}) fertilizer. After 60 days from soil preparation, sowing was done distributing fifteen sweet sorghum cv. CMSXS 646 seeds by linear meter at plots with five plantation lines (10 m length) spaced at 0.5 m (DURÃES, 2011).

Before flowering period (60 days from tillage sowing), Ethephon was applied by sprayer (CO_2 pressurized) containing with six flat spray nozzles (AXI 11002). Application was done morning period under temperature and air relative humidity corresponding to 27.5 ± 2.5 °C and 70 ± 10 %, no subsequence rainfall (VIANA et al., 2016).

After 30 days from chemical ripener application, plants were harvested and stalk samples were intended to laboratory for °Brix, Pol, Purity, Reducer Sugars (RS), Total Reducer Sugars (TRS), Fibers and Recoverable Theoretical Sugars (RTS) evaluation. Data set was subjected to regression analyze (P<0.01 and P<0.05), using *Software R* Version 3.3.1. (R Core Team, 2018).

Results and discussion

Quadratic regressions rejected nullity hypothesis and adjusted significantly to every parameters, explaining at least 84.36 % of variations checked (Figure 1).

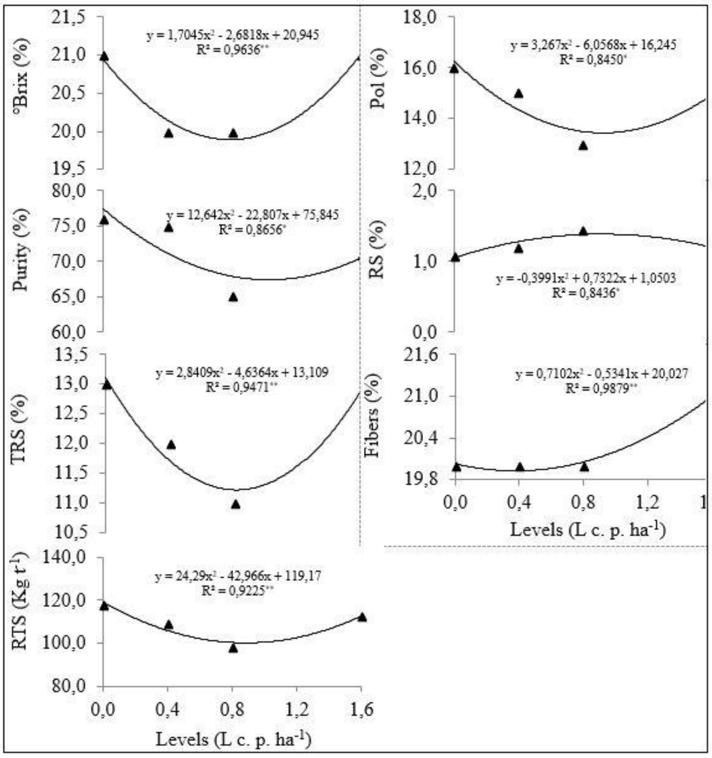

Figure 1. Ethyl-trinexapac effects on sweet sorghum cv. CMSXS 646 broth technological parameters; significance: ** (P<0.01); * (P<0.05).

Ethyl-trinexapac levels (0.4 and 0.8 L c. p. ha^{-1}) reduced broth °Brix in one percentage point regarding to control, which reached same performance that 1.6 L c. p. ha^{-1}. So, Ethyl-trinexapac no had positive effect on feedstock total soluble solids. The general average overcome results from Viana et al. (2015), that obtained 16.27 and 16.97 °Brix applying 0.4 and 0.8 L c. p. ha^{-1} of Ethyl-trinexapac to sweet sorghum cv. BIOMATRIX, respectively. °Brix is most important to bioethanol production. This technological parameter can be influenced by several biotic and abiotic factors, such as genotype, soil fertility, plant age and chemical ripener types and concentrations (KUMAR et al., 2008; VIANA et al., 2015). Sugarcane and sweet sorghum broths are considered able to alcohol sustainable industrialization when reach about to 15.5 – 18.0 °Brix (PRASAD et al., 2007; ALMODARES; HADI, 2009). So, was verified that every treatments this research presented °Brix values above to standard preconized.

Similar pattern was checked to sucrose: broth from plants subjected to 0.4 and 0.8 L c. p. ha^{-1} dosages presented one and three Pol percentage points less than control, respectively. Moreover, there is no a significant difference between control and 1.6 L c. p. ha^{-1} treatments. Viana et al. (2015) checked positive relation between Ethyl-trinexapac levels (0.2, 0.4 and 0.8 L c. p. ha^{-1}) and Pol rate, corroborating results this paper. In addition, Leite et al. (2009) and Silva et al. (2010) verified plant growth regulators positive effects on sugarcane Pol, unlike this research.

About to Purity, control and 0.4 L c. p. ha^{-1} showed similar yield, whereas 0.8 and 1.6 L c. p. ha^{-1} decreased it in about to eleven and five percentage points regarding to natural broth, respectively. This fact is undesirable a lot to bioethanol industrialization, because feedstocks with low purity difficult sugar extraction (VIANA et al., 2015). In general, results this study were highest than Viana et al. (2015); those researchers verified Purity percentage of 52.91, 52.94 and 55.14 % to 0.0, 0.4 and 0.8 L c. p. ha^{-1} Ethyl-trinexapac levels, respectively.

Unlikely °Brix, Pol and Purity, was verified that 0.4 and 0.8 L c. p. ha^{-1} increased RS percentage regarding to control, suggesting that largest Ethyl-trinexapac level was less favorable to glucose and fructose accumulation on stalks laconic parenchyma. The RS percentages were similar to the observed by Viana et al. (2015). As Audilakshimi et al. (2010) sugarcane and sweet sorghum juices with high RS rate are desirable a lot to sugar-energy industry, because improvement reducer sugars fermentation.

Ethyl-trinexapac levels (0.4 and 0.8 L c. p. ha^{-1}) depreciated TRS in about to one and two percentage points regarding to control, which presented similar performance that 1.6 L c. p. ha^{-1}. As checked to °Brix, Pol, Purity and RS, Ethyl-trinexapac dosages no provided positive effects on sweet sorghum cv. CMSXS 646 broth TRS. Viana et al. (2015) obtained TRS percentages same to the verified in this paper.

Regarding to Fibers, broths from control, 0.4 and 0.8 L c. p. ha^{-1} Ethyl-trinexapac levels presented similar yields, whereas 1.6 L c. p. ha^{-1} showed one percentage point more than these treatments. Therefore, Ethyl-trinexapac application no influenced a lot broth Fibers, however increased stalk lignification process, corroborating Viana et al. (2015). Feedstocks with high fibers percentage not are indicated to alcohol commercial production, because limit milling process (CAPUTO et al., 2008).

The treatments (0.0 and 1.6 L c. p. ha^{-1}) reached similar TRS yields, whereas 0.4 and 0.8 L c. p. ha^{-1} decreased it in about to 9.0 and 10.0 Kg t^{-1} contrasted to control, respectively. This fact is most undesirable to bioethanol production from sugarcane and sweet sorghum, because TRS is directly related to feedstock price paid to producers (VIANA et al., 2015).

Conclusion

Ethyl-trinexapac levels (0.4 and 0.8 L c. p. ha^{-1}) are not indicated to sweet sorghum cv. CMSXS 646 treatment, because decreased broth technological quality.

References

Almodares, A.; Hadi, M. R. Production of bioethanol from sweet sorghum: a review. *African Journal of Agricultural Research*, v. 4, n. 9, p. 772-780, 2009.

Alvares, C. A.; Stape, J. L.; Sentelhas, P. C.; Gonçalves, J. L. De M.; Sparovek, G. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, vol. 22, n. 6, p. 711–728, 2014.

Audilakshmi, S.; Mall, A. K.; Swarnalatha, M Seetharama, N. Inheritance of sugar concentration in stalk (Brix), sucrose content, stalk and juice yield in sorghum. *Biomass and Bioenergy*, v. 34, p. 813820, 2010.

Caputo, M. M.; Beauclair, E. G. F.; Silva, M. A.; Piedade, S. M. S. Resposta de genótipos de cana-de-açúcar à aplicação de indutores de maturação. *Bragantia*, v. 67, p. 15 – 23, 2008.

Durães, F. O. M. Sorgo sacarino: desenvolvimento de tecnologia agronômica. *Agroenergia em Revista*, p. 7 – 8, 2011.

Han L. P.; Wang X.; Guo X.; Rao M. S.; Steinberger Y.; Cheng X.; Xie G. H. Effects of plant growth regulators on growth, yield and lodging of sweet sorghum. *Research on Crops*, v. 12, n. 2, p. 372 – 382, 2011.

Heerden, P. D. R. Evaluation of Moddus® as a new chemical ripener for the South African sugar industry: preliminary finding. *South African Sugarcane Research Institute*, v. 85: 193 – 195, 2012.

Kumar, S. R.; Shrotria, P. K.; Deshmukh, J. P. Characterizing nutrient management effect on yield of sweet sorghum genotypes. *World Journal of Agricultural Sciences*, v. 4, n. 6, p. 787 – 789, 2008.

Leite, G. H. P.; Crusciol, C. A. C.; Silva, M. de A.; Venturini filho, W. G. Technological quality of sugarcane uppon application of ripeners during the cropping season. *Bragantia*, v. 68, n. 2, p. 527-534, 2009.

May, A.; Albuquerque filho, M.R.; Rodrigues, J.A.S.; Landau, E.C.; Parrella, R.A.C.; Massafera, R. Cultivares de sorgo para o mercado brasileiro na safra 2011/2012. *Documentos*, v.117, n.1, p.05-28, 2011.

Meschede, D. K.; Velini, E. D.; Tonin, F. G.; Carbonari, C. A. Alterações no metabolismo da cana-de-açúcar em função da aplicação de maturadores. *Planta Daninha*, v. 30, n. 1, p. 113-119, 2012.

Prasad, S.; Anoop S.; Jain, N.; Joshi, H. C. Ethanol production from sweet sorghum syrup for utilization as automotive fuel in India. *Energy and Fuels*, v. 21, p. 24152420, 2007.

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URLhttps://www.R-project.org/.

Silva, M. A.; Gava, G. J. C.; Caputo, M. M.; Sorrilla, P. F.; Bassetto, S. C. Productivity of stalk and sucrose in sugarcane in relation to cultivar and ripener interaction. *Scientia Agraria*, v. 11, n. 4, p. 323 - 329, 2010.

Steduto, P.; Hsiao, T.C.; Fereres E.; RAES D. *Crop yield response to water*. Roma: FAO, 2012, v. 66, cap. 3, p.144-154.

Viana R. S.; Figueiredo, P. A. M; Lisboa, L. A. M.; Assumpção, A. C. N. D; Sá, M. E.; May, A. Aplicação de maturadores químicos na qualidade tecnológica do sorgo sacarino cv. Biomatrix 535. *Revista Brasileira de Milho e Sorgo*, v. 14, n. 3, p. 326 – 334, 2015.

Viana R. S.; Figueiredo, P. A. M; Lisboa, L. A. M.; Magalhães, A. C. Morpho-anatomical aspects and technological quality of saccharine sorghum submitted to planta regulators. *Revista Brasileira de Herbicidas*, v. 15, n. 2, p. 175 – 183, 2016.

THEME: GASIFICATION AND PYROLYSIS

CATALYTIC PYROLYSIS OF MYRISTIC ACID: IMPACT OF CATALYST NATURE ON KETONES FORMATION

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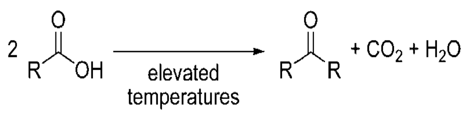
Abstract
Catalytic pyrolysis of fatty acids appears as an interesting process for ketones formation, through partial decarbonylation. This process doesn't need solvents or complex reagents, and therefore can be considered as a green one. The present work studied the influence of two catalysts, γ-Al_2O_3 and Nb_2O_5 together with different pyrolysis methods, for the production of ketones using myristic acid as reagent. For this objective, an experimental plan was followed, with two parameters: temperature (450 and 600°C) and pyrolysis thermal method (*Single-Shot*- SS *and Heart Cut* - HC). Myristic acid and catalysts were mixed in a weight ratio of 1:10 before use. Micro-pyrolysis experiments were performed in a set-up with "on-line" analysis (GC-MS). In the best experimental conditions, the ketone fraction varied between 3 - 30 % of products with γ-Al_2O_3 and from 2 - 90 % with Nb_2O_5, this latter showing high selectivity for 14-heptacosanone symmetrical ketone. Some mechanisms are discussed.
Keywords: pyrolysis, catalysis, ketones, myristic acid

Introduction

Long chain ketones, also named fatty ketones, symmetric and aliphatic, are used in various industries as fabric softeners, corrosion inhibitors, and flotation agents. They appear as main components in emulsifiers for dermatologic creams and lotions. They can also be transformed to power-full surfactants, after quaternization or sulfonation. Fatty ketones can be obtained by ketonic decarboxylation of fatty acids by a reaction known as ketonization. This reaction route is also useful for synthesis of simpler ketones such as propanone, 3-pentanone and cyclopentanone, also synthesized by processes in liquid phase, in presence of strong base catalysts, under non-stoichiometric conditions, with high yields (RENZ, 2005). Ketonic decarboxylation reaction route is also recognized as intermediate pathway during fatty acid deoxygenation in conditions allowing formation of hydrocarbon-like liquid fuels (SANTILLAN-JIMENEZ, 2012). Equation 1 presents theoretic transformation of two molecules of fatty acid, at elevated temperature, to three products i.e. symmetrical ketone, water and carbon dioxide. The reality is always more complex.

Heterogeneous catalysis was applied with success for fatty acids pyrolysis when Vavon (1928) sent adipic vapors on MnO at 350 °C, obtaining a 80 % yield in cyclopentanone. Pyrolysis on an environmentalist point of view can be seen as a modern process, relatively safe, free from solvent or complex reagent, allowing obtaining ketone families (RENZ, 2005). However, catalytic pyrolysis of fatty acids to ketones formation still presents problems including choice of catalyst and definition of the best operating conditions as well as the comprehension of intermediate pathways and identification of all products. Table 1 shows a variety of conditions, with different catalysts systems, and how these parameters affect the product yield.



Equation 1. Ketones formation schema (RENZ, 2005)

Table 1 - Transformation of fatty acids into fatty ketones through ketonic decarboxylation

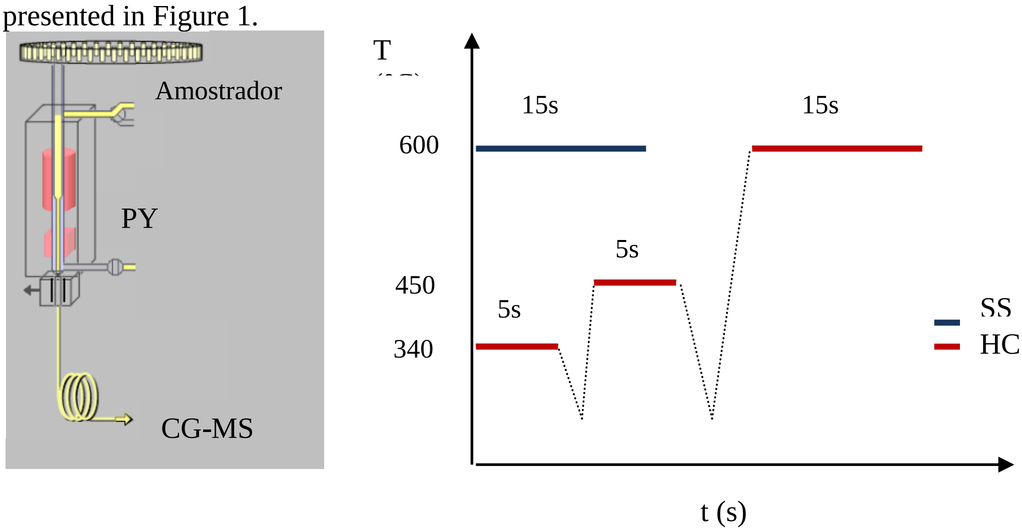
Substrate	T[ºC]	Reaction Conditions	Catalyst	Yield [%]
octanoic acid	420	[a]	MgO	76[b]
octanoic acid	398	WHSV = 1.2 h $^{-1}$	Al-Zr-oxide	88
monanoic acid	398	WHSV = 1.66 h $^{-1}$	ZrO_2	70
decanoic acid	420	WHSV = 2.0 h $^{-1}$	ZrO_2	91
dodecanoic acid	380	distillation	bauxite Fe-Al-Si-Ti	89
dodecanoic acid	330	[a]	MnO_2 on pumice	95
octadecanoic acid	340	semicont.destillation	bauxite Fe-Al-Si-Ti	70
octadecanoic acid	360	[a]	MnO_2 on pumice	95
octadecanoic acid/hexadecanoic acid (90:10)	380	distillation	Bauxite Fe-Al-Si-Ti	82[d]

[a] Continuous reactor; weight hourly space velocity (WHSV) not reported. [b] At a conversion of 82%. [c] Hydrocarbons were detected at 22%. [d] Mixture of ketones (RENZ, 2005).

In the present work, the catalytic micro pyrolysis of a model fatty acid, tetradecanoic or myristic acid – C14:0, preadsorbed on the surface of metal oxides with moderate surface acidity was performed. Niobia (Nb_2O_5) and alumina ALCOA A1 were used. These catalysts were retained as they are rather low-cost materials, non-toxic, and because literature reports that catalysts able to promote important ketonization are often base catalysts (RESASCO, 2013). The pyrolysis was performed using various thermal sequences to study the effect of such parameter on the ketone production.

Materials and methods

Pyrolysis reactions occurred in a Multi-shot Pyrolyzer Model EGA/PY-3030d (Frontier Laboratories LTD), connected *on-line* with a GC-MS 5799A (Agilent) (see Figure 2.a). Chromatographic analysis used a HP-5MS column, with a heating ramp comprising an initial temperature 40 °C for 2 min, followed by heating at 20 °C min^{-1} up to 320 °C, and a stabilization at this temperature for 10 min. The ion source was maintained at 320 °C, the interface at 320 °C, in scan mode, with mass interval between 40 and 400 m/z. The set-up scheme of PY-GC-MS is presented in Figure 1.



(a) (b)

Figure 1– Pyrolysis set-up (a) and heating ramps for SS and HC pyrolysis methods (b)

Pyrolysis followed two different thermal methods: I- Single Shot (SS) at 450 e 600°C for 15s; and II- Heart Cut (HC) with final temperatures of 450 and 600°C, for 15s (see Figure 2.b).

For the analysis of products, only pyrogram's peaks with an area greater than 0.5% of the total area were considered. The peaks were identified through the NIST Library, and only compounds with identification probability higher than 80 % were considered. To estimate the effects of experiment variables on answers (conversion of the fatty acid to ketones and hydrocarbons) a 2^3 factorial experimental plan was designed, with 95% confidence, using the *Statistica* software.

Nb_2O_5 was obtained by thermal treatment of solid niobic acid (HY-340 – from Companhia Brasileira de Metalurgia e Mineração – CBMM) at 700 °C with air for 2 h. Al_2O_3 (A1 – Alcoa Alumínio S/A) is a transition alumina containing 0.013 wt% of silica and 0.48 wt% of sodium oxide. Before adsorbing C14:0 on the catalysts surface, the solid catalysts were previously treated at around 600 °C, in order to decrease the amount of adsorbed water and potential impurities. After this thermal treatment, C14:0 (MA) was adsorbed on the solids under permanent manual mixing with glass rod, at some 90 °C. Once the mixture came back to room temperature, 0.002 g of each sample was introduced in a titanium sample holder and covered with a quartz wool plug. The sample holder was then transferred to the pyrolysis chamber, under helium flow, and quickly introduced in the oven of the equipment, preheated at the desired pyrolysis temperature.

Results and discussion

The full factorial experimental plan (2^3) was performed aiming at identifying some parameters having an important effect on fatty acid conversion to ketones and hydrocarbons. Generally, literature doesn't describe extensively the pyrolysis methodology regarding the thermal treatments of the samples, being limited only to parameters such as final pyrolysis temperature and heating rate (ASOMANING, 2014; FRÉTY, 2014; EVERSHED, 1997). Table 2 presents the myristic acid conversion to ketones and hydrocarbons of the runs, evidencing the conditions where ketones are formed with higher yields for both catalysts.

Table 2 - Myristic acid conversion to ketones and hydrocarbons

Experiments	Catalyst	Temperature (°C)	Method	Ketone	HC's
1 [- - -]	NB	450	SS	1,9%	0,0%
2 [+ - -]	AL	450	SS	3,2%	0,2%
3 [- + -]	NB	600	SS	15,0%	1,2%
4 [+ + -]	AL	600	SS	18,2%	24,0%
5 [- - +]	**NB**	**450**	**HC**	**90,6%**	**0,4%**
6 [+ - +]	AL	450	HC	27,0%	17,3%
7 [- + +]	NB	600	HC	35,3%	31,8%
8 [+ + +]	**AL**	**600**	**HC**	**30,0%**	**36,4%**

Figure 2 shows the pyrograms obtained for the experiments 5 and 8 respectively. The distribution of products is very different between both situations, but clearly shows that ketones are intermediate in fatty acid pyrolysis products, in agreement with some literature observations (BILLAUD et al., 2001 SANTILLAN-JIMENEZ, 2012).

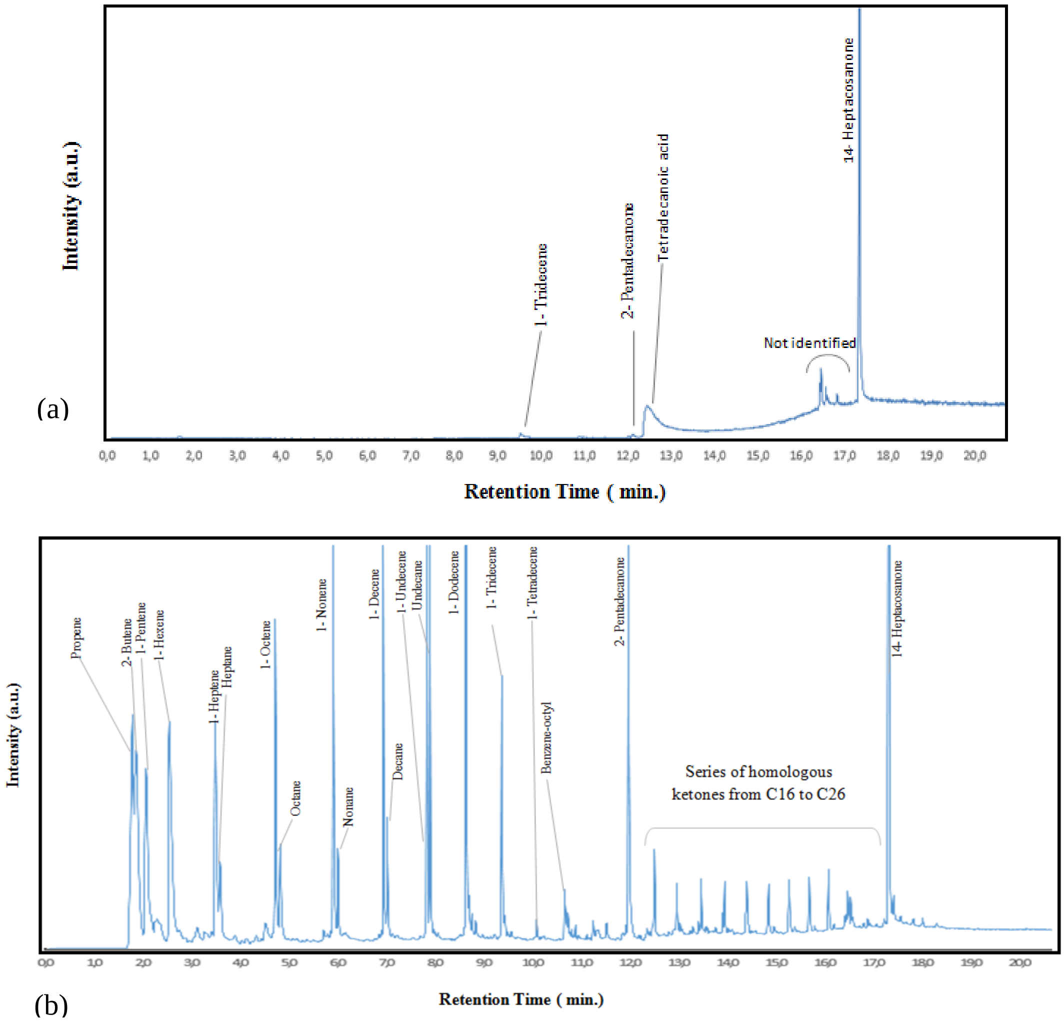


Figure 2. Pyrograms of C14:0 products after pyrolysis at (a) 450 °C (Nb_2O_5) and (b) 600°C (Al_2O_3)

The results of Figure 2 show that Nb_2O_5 is very efficient in forming the symmetrical ketone, 14-heptacosanone, together with a tiny amount of 1-tridecene. However, a complete transformation of C14:0 was not obtained. On the other hand, Al_2O_3 allowed a complete conversion of C14:0 and showed a very more complex pyrogram than Nb_2O_5. 14-heptacosanone, 2-pentadecanone, and many other ketones with total carbon number increasing for higher retention times, together with a shift in C=O position. Moreover, an important number of terminal olefins, and a lower amount of n-alkanes are observed, result in agreement with the pyrolysis of other saturated fatty acids (MAHER et al, 2008). It is important to note that a perfect family of homologous alkenes and alkanes is formed in the present conditions.

Data in Table 2 were treated in a statistical way. Results showed that for ketones formation change of variables from lower level to higher level resulted in a negative effect. On the contrary, the same variations induced a positive effect in the formation of hydrocarbons, i.e. of deoxygenated products. Renz, in its review article (RENZ, 2005) described comparative works for decanoic acid pyrolysis in which residence time (TR) appeared as an important parameter affecting both ketones and hydrocarbons formation. With TR = 15 s, 10-nonadecanone was the major product, followed by 2-undecanone (and small amounts of other molecules of the same family) together with n-nonane, the more abundant hydrocarbon. With TR= 300 s, the composition of products changed to 2-undecanone as the more abundant ketone, in parallel with n-alkanes and alkenes (C4-C9) and aromatics. In that work, it was observed that for small TRs, pyrolysis of carboxylic acid induces the formation of symmetric ketone: 10-nonadecanone. For pyrolysis with major TRs, the cracking of the ketone alkyl chain led predominantly to the formation of 2-undecanone, for which a β-hemolysis mechanism, favored by resonance stabilization was suggested (MARCH,1985; RESASCO, 2013). In the present work, the results of the pyrolysis method can be linked to the time during which the sample is submitted to thermal effect: 15 s no SS, but a time close to 5 + 5 + 15 s no HC, considering all heating ramp (see Figure 1.b). In that way, the cracking of the alkyl chain in the initially formed ketone is more intense.

It is also important to discuss some differences in catalyst properties. The specific surface area of the present Al_2O_3 is 71 m²/g whereas that of Nb_2O_5 is close to 10 m²/g (FLORENTINO, 1992). A larger surface area may favour a higher contact time between products and surface sites promoting therefore higher secondary cracking and higher deoxygenation. In fact, Al_2O_3 showed better deoxygenation potential for myristic acid than do Nb_2O_5, and therefore intermediate ketones are quickly cracked, with formation of hydrocarbons in all experimental conditions of the present study. The actual results are in qualitative agreement with the observations of BILLAUD et al., 2001, during their pyrolysis of octanoic acid (C8:0), in presence of activated alumina, between 300 and 500 °C. On the other hand, it is known that two other mechanisms are advocated to explain hydrocarbon formation starting from fatty acids, in parallel to ketonization: a decarbonylation route, producing CO, H_2O and terminal alkenes, and a decarboxylation one leading to CO_2 and linear alkanes. Although the difference in specific area between both catalysts of the present study is significant, this property doesn't appear sufficient to explain the higher ketone formation in the case of niobia. Lu et al. , 2018, studied the ketonisation on metallic oxides with different redox properties. They observed that an increase in the redox properties favoured ketones formation. Whereas alumina is not known for redox properties, niobia can, up to a certain degree, in presence of reducing atmosphere, present a partial transformation of $Nb^{5+} \rightarrow Nb^{4+}$ at around 400-500°C (WACHS, 1996). Then, niobium oxide would be able, in a specific temperature range to stabilize ketones, limiting their cracking, once formed.

Finally, Kumar, 2018, suggested that catalysts having neighbour acid and basic sites are active in symmetric ketones formation. Acidity characterization of the present catalysts is under way.

Conclusions

Ketones production via catalytic pyrolysis is dependent on variables such as temperature, pyrolysis method and catalyst nature. Results showed that Nb_2O_5 is more efficient than Al_2O_3, in the synthesis of symmetrical 14-heptacontanone, mainly at pyrolysis temperature of 450°C, after quick heating for 5 sec at 340 °C. Pyrolysis method affects the cracking of C14:0 in parallel to temperature, both for ketones and for hydrocarbons products formation. Obtained results confirmed that ketones are intermediate products during thermal cracking of fatty acids in the formation of deoxygenated products.

References

Fréty, R; et al. Flash Pyrolysis of Oleic Acid as a Model Compound Adsorbed on Supported Nickel Catalysts for Biofuel Production. *J. Braz. Chem. Soc.* v. 25, n. 12, p. 2433-2443, 2014.
RENZ M. Ketonization of Carboxylic Acids by Decarboxylation: Mechanism and Scope. *Eur. J. Org. Chem.* p. 979–988, 2005

Santillan-jimenez, E.; Crocker, M. Catalytic deoxygenation of fatty acids and their derivatives to hydrocarbon fuels via decarboxylation/decarbonylation. *J. Chem Technol Biotechnol; v.*87; p. 1041–1050. 2012

Vavon, G; Apchie, A. *Bull. Soc. Chim.* v. *43*, p. 667–677, 1928.
BILLAUD, F. *et al*. Catalytic cracking of octanoic acid. *J. Anal. Appl. Pyrolysis*. v.58–59; p. 605–616, 2001

Kumar, R *et al*. Ketonization of oxygenated hydrocarbons on metal oxide based catalysts. *Catal. Today***.** v. 302; p. 16-49, 2018

March, J. Advanced Organic Chemistry: Reactions, Mechanisms, and Structures, third ed., Wiley, USA, p. 442. 1985

Lu, F; *et al.* Insights into the improvement effect of Fe doping into the CeO_2 catalyst for vapor phase ketonization of carboxylic acids. *J. Mol. Catal.*, v. 444, p. 22–33. 2018

Florentino, A; *et al*. Textural, acidic and catalytic properties of niobium phosphate and of niobium oxide: Influence of the pretreatment temperature. *Appl. Catal, A. General*, v.89, p.143-153. 1992

Resasco, D; et al. Ketonization of Carboxylic Acids: Mechanisms, Catalysts, and Implications for Biomass Conversion. ACS Catalysis, v. 3, p. 2456−2473. 2013
Asomaning, J; et al. Thermal deoxygenation and pyrolysis of oleic acid. J. Anal. Appl. Pyrolysis .v. 105; p 1-. 2014

Evershed, R.; et al. Formation of long-chain ketones in archaeological pottery vessels by pyrolysis of acyl lipids. J. Anal. Appl. Pyrolysis .v.40-41 ; p 267-285. 1997
Maher, K.D., Kirkwood, K.M., Cray, M.R, Bressler, D.C., Ind. Eng., Chem. Res., v. 47, 15, p. 5328-5336, 2008.

Simakova, I.; et al Transformation of bio-derived acids into fuel-like alkanes via ketonic decarboxylation and hydrodeoxygenation: Design of multifunctional catalyst, kinetic and mechanistic aspects . J. Ener. Chem., v.25; p.208–224. 2016

Wachs, I.E. et al.; Redox properties of niobium oxide catalysts, Catal. Today, v. 28, p. 198-205, 1996

EVALUATION OF THE ANATOMICAL PROPERTIES OF *Eucalyptus urophylla IN NATURA* AND TORREFIED WOOD

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Abstract
A technology capable of modify wood properties and enhance its energetic potential is the torrefaction process. The torrefaction or pre-carbonization is a thermal treatment that occurs in a low oxygenation and moderate temperatures, which may vary from 200 to 300°C, capable of accumulate carbon in the wood, transforming it in a material with a greater energetic density and lower hygroscopicity. This work has as an objective to evaluate the torrefaction temperature influence in the anatomical properties of *Eucalyptus urophylla'*s wood chips. To perform this study, wood chips were sieved and dried dried in an oven until reaching a constant mass. Afterwards, they were torrefied for periods of 20 minutes at 180, 220 and 260°C temperatures in an endless-thread roaster, being executed 3 torrefaction per treatment and using approximately 2 kilograms of chips per cycle. After the torrefaction process, the anatomical properties of the chip's fibers were analyzed in comparison with *in natura* and torrefied samples. It was also observed a smaller wall thickness and fiber width in the torrefied wood chips at higher temperatures.

Keywords: heat treatment, torrefaction, biomass energy.

Introduction

Brazil is a country that presents a great potential of wood use to energy means expansion due to its high energetical demands and its climatic and terrain conditions which favors the fast growth of some species such as *Eucalyptus* (PREVEDELLO et al., 2013; CUNHA et al., 2015).

However, when destined to energy production, the wood displays some disadvantages such as high humidity levels, low specific calorific power and low fix carbon content, besides being a heterogeneous and hygroscopic (BRAND et al., 2013; NONES, et al., 2014; ZANUNCIO et al., 2015). Thus, a great deal of those characteristics can be enhanced with the material's torrefaction process.

The torrefaction process is a thermal treatment, also known as pre-carbonization, which consists of heating the biomass in an inert or low-oxygen atmosphere, between temperatures of 200°C and 300°C, promoting the homogenization and enhancement of the biomass' energetic properties (VAN DER STELT et al., 2011; BATIDZIRAI et al. 2013; SHANG et al., 2014).

It differentiates of carbonization due to its milder temperatures and its displays of high gravimetric yield, with energy conservation and partial removal of volatile materials in the biomass (MATALI et al., 2016). In a typical torrefaction, 70% of the mass remains in a solid state, conserving 90% of the initial energy, and the other 30% are constituted by gases which contains only 10% of the biomass' energetic content (VIDAL e HORA, 2011).

In the torrefaction, either residence time and final process temperature carry influence on the biomass' final characteristics, normally, as greater those variants' values, the greater the calorific power (STRANDBERG et al., 2015). Among the benefits brought by the torrefaction process, it can be highlighted the increase in the energetic density and the decrease in the humidity rate, resulting in a material with chemical and physical properties the potentialize energy production and allows a long-range transport and a long-term storage (NA et al., 2013; 16 CHEN et al., 2014; SHANG et al., 2014, PEREIRA et al., 2016).

Besides the torrefaction process being study in France since the 1930's, this technique is considered only a “promising technology”, requiring studies that determine better torrefaction conditions in order of potentialize the wood use as a fuel and the commercialization of this biomass (VAN DER STELT et al., 2011; BATIDZIRAI et al. 2013).

Hence the facts displayed, the objective of this study was the evaluation of the *Eucalyptus urophylla* in natura and torrefied form energetic potential.

Materials and methods

This experiment was conducted with wood chips from *Eucalyptus urophylla* wood of approximately 7 years of age stemming from experimental plantations of the Federal University of Viçosa. The wood chips were sieved, being effectively used in the experiment only those that were retained in the 16 mm sieve and passed through the 31.5 mm sieve. After the classification, the wood chips were dried in a hothouse at 103±2ºC until reaching a constant mass, in other words, 0% humidity in dry base. Afterwards, the chips were torrefied for 20 minutes in temperatures of 180, 220 and 260°C.

For the torrefaction it was used an endless screw reactor, developed in the Panels and Wood Energy Laboratory (LAPEM/UFV), as described by Magalhães (2016). The reactor consists of four basic components; a biomass transport system; a gas heating, cooling and exhaustion system. The torrefaction temperature was monitored via a *Gulton* digital thermometer model *700-10S*, using 8 type J- thermocouples.

To determine the gravimetric yield, which is the final material (torrefied) in relation to its initial mass, presented in percentage, the wood chips were weighted before and after the process, to determine the mass loss during the process.

To study the fibers' anatomical properties, it was first made the macerated material, were slim fraction were removed from a proof-body and inserted in a hydrogen peroxide and glacial acetic acid solution in a test tube, as descripted by Dadswell (1972). The mixture was kept in a 60°C hothouse for seventy-two hours until the wood's complete dissociation. The fibers were individualized and colored with the blue astra dye and afterwards the material was stored in distilled water. Afterwards, there were organized temporary microscope slides to fiber-mensuration.

There were determined the length (mm), width (mm) and wall thickness (μm) of thirty different treatment fibers using the Axio-Vision®. Using a light-microscope the length was measured through the 5X lens, the width and wall thickness were determined via the 20X lens. The wall thickness was calculated through the Equation 1, which relates the half of the difference between the width and diameter of the lumen:

$$WT = \frac{(FW-LD)}{2} \qquad \text{Equation 1}$$

Where: WT = Fiber' Wall thickness (μm); FW = Fiber width (μm); LD = Fiber Lumen Diameter (μm).

This experiment was installed by a total casual lining containing the witness plus 3 treatments (temperatures), in three repetitions, totaling 12 sample units: Witness, 180, 220 and 260°C

The results were submitted through a variance analysis (ANOVA) and when the significant differences were established, it was applied the Tukey test, at 5% significance using STATISTICA 8.0 software (STATSOFT, 2007).

Results and discussion

In the Table 1, there are displayed the average values of the fibers' anatomical properties of in natura and torrefied wood.

Table 1– Average length, width, lumen diameter and fiber wall thickness values of the in natura and torrefied wood

Analysis	*In natura*	Torrefaction temperature		
		180ºC	220ºC	260ºC
Length (mm)	0.93 a	1.00 a	0.98 a	0.99 a
Width (µm)	24.07 a	22.16 ab	21.13 b	20.42 b
Lumen Diameter (µm)	8.25 a	8.34 a	11.39 b	11.67 b
Wall thickness (µm)	7.91 a	6.91 b	5.38 c	4.38 d

Measures followed by the same letter, in the same line, don't statistically differ (Tukey p > 0,05)

It can be observed that the fiber properties were modified with the thermal treatment, except the length.

It can be noted that the fiber width was decreased with the increase of torrefaction temperature, being reduced in 12.2 and 15.2%, respectively, in the 220°C and 260°C treatments when compared to the witness. The same can be observed for the wall thickness that contracted with the temperature increase, observing significant educations in the already treated chips at 180°C, where it was observed a 12.6% contraction in relation to the witness. In the 220°C and 260°C treatments, this retraction was even larger, 31.9% and 44.6%, respectively, compared to the witness. Pereira et al. (2016b) also observed a reduction on the fiver wall thickness when submitted to heat.

According to Silva et al. (2016a), the plant's cellular wall is a complex structure composed by lignin, cellulose, hemicellulose and others. It is known that the torrefaction process degrades the cellular wall constituents, mainly the hemicelluloses and cellulose, which explains the cellular wall reduction because of torrefaction temperature increase. Besides that, cellulose suffers the drying process, the chains of the amorphous region close in into each other and make strong bonds, decreasing the cellular wall thickness.

The lumen's diameter had opposite behavior, expanding in relation to the witness in 38.1 and 41.5% in the fibers of the treated chips, at 220°C and 260°C, respectively. This is associated, mainly, with the decrease of the width and wall thickness of the fibers.

According to Silva et al. (2007), the larger the lumen's diameter, the emptier spaces are found in the wood, therefore, the lower the material' specific mass. In this way, it is expected that the witness has a lower specific mass than the torrefied chips.

Conclusion

In higher torrefaction temperatures, the fiber's wall thickness and width are decreased, however, the lumen's diameter and fiber length are increased.

References

Batidzirai, B.; Mignot, A. P. R.; Schakel, W. B.; Junginger, H. M.; Faaij, A. P. C. Biomass torrefaction technology: techno-economic status and future prospects. *Energy,* v. 62, p. 196–214, 2013.

Brand, M. A.; Cunha, A. B.; Carvalho, A. F.; Brehmer, D. R.; Küster, L. C. Análise da qualidade da madeira e do carvão vegetal produzido a partir da espécie *Miconia cinnamomifolia* (De Candolle) Naudin (Jacatirão-açu) na agricultura familiar, em Biguaçu, Santa Catarina. *Scientia Forestalis*, v. 41, p. 401-410, 2013.

Chen, W. H.; Lu, K. M.; Lee, W. J.; Liu, S. H.; Lin, T. C. Non-oxidative and oxidative torrefaction characterization and SEM observations of fibrous and ligneous biomass. Appl. *Energy*, v. 114, p. 104–113, 2014.

Cunha, A. B. D.; Brand, M. A.; Simão, R. L.; Martins, S. A.; Anjos, R. A. M. D.; Surdi, P. G.; Schimalski, M. B. Determination of yield of raw material of *Eucalyptus benthamii* Maiden & Cambage by different sawing methods. *Revista Árvore*, v. 39, n. 4, p. 733-741, 2015.

Dadswell, H. E. The anatomy of eucalypt wood. Melbourne: *Forest Products Laboratory*, CSIRO, n. 66, p. 1-28, 1972.

Matali, S.; Rahman, N. A.; Idris, S. S.; Yaacob, N.; Alias, A. B. Lignocellulosic biomass solid fuel properties enhancement via torrefaction. *Procedia Engineering*, v. 148, p. 671-678, 2016.

Na, B.; Kim, Y.-H.; Lim, W.-S.; Lee, S.-M.; Lee, H.-W.; Lee, J.-W. Torrefaction of oil palm mesocarp fiber and their effect on pelletizing. *Biomass Bioenergy*, v. 52, p. 159–165, 2013.

Nones, D. L.; Brand, M. A.; Cunha, A. B.; Carvalho, A. F.; Weise, S. M. K. Determinação das propriedades energéticas da madeira e do carvão vegetal produzido a partir de *Eucalyptus benthamii*. *Floresta*, v. 45, p. 57-64, 2014.

Pereira, B. L. C.; Carvalho, A. M. M. L.; Oliveira, A. C.; Santos, L. C.; Carneiro, A. D. C. O.; magalhães, M. A. D. Effect of wood carbonization in the anatomical structure and density of charcoal from Eucalyptus. *Ciência Florestal*, v.26, n.2, p.545-557, 2016b.

Prevedello, J.; Kaiser, D. R.; Reinert, D. J.; Vogelmann, E. S.; FontanelA, E.; Reichert, J.M. Manejo do solo e crescimento inicial de *Eucalyptus grandis* Hill ex Maiden em Argissolo. *Ciência Florestal*, Santa Maria, v. 23, n. 1, p. 129-138, 2013.

Shang, L.; Ahrenfeldt, J.; Holm, J. K.; Bach, L. S.; Stelte, W.; Henriksen, U. B. Kinetic model for torrefaction of wood chips in a pilot-scale continuous reactor. In: *Journal of analytical and applied pyrolysis*. v. 108, p. 109-116, 2014.

Silva, V. L.; Borges, I.; Araújo, A. R.; Costa, H. H. A.; Alves Filho, F. M.; Frutuoso, F. I. A.; Silva, R. H. P.; Ancântara, P. B. X. Efeito do tratamento químico sobre a digestibilidade de volumosos e subprodutos agroindustriais. *Acta Kariri Pesq. e Des. Crato*/CE, v.1, n.1, p.29-37, 2016.

Statsoft, I.N.C. Statistica data analysis software system version 8.0. Tulsa, USA 2007.

Strandberg, M.; Olofsson, I.; Pommer, L.; Wiklund-Lindström, S.; Åberg, K.; Nordin, A. Effects of temperature and residence time on continuous torrefaction of spruce wood. *Fuel Processing Technology*, v. 134, n. 4467, p. 387-398, 2015.

Van Der Stelt, M. J. C.; Gerhauser, H.; Kiel, J. H. A.; Ptasinski, K. J. Biomass upgrading by torrefaction for the production of biofuels: A review. *Biomass and Bioenergy*, v. 35, p. 3748-3762, 2011.

Vidal, A. C. F.; Hora, A. B. Perspectivas do setor de biomassa de madeira para a geração de energia. *BNDES Setorial*, Rio de Janeiro, v. 33, p. 261-314, 2011.

Zanuncio, A. J. V.; Carvalho, A. G.; Silva, E. M. G. C. S.; Monteiro, T. C.; Lima, J. T.; Silva, J. R. M. Propriedades energéticas da madeira e carvão de *Corymbia* e *Eucalyptus* em diferentes condições de secagem. *Agrária,* v. 10, n. 3, p. 432-436, 2015.

RESISTANCE OF THE EUCALYPTUS WOOD *IN NATURA* AND TORREFIED EXPOSED TO THE ATTACK OF *Cryptotermes brevis*

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Abstract

Overall, the eucalyptus wood presents a low natural durability and some characteristics limits its use in energy generation, among which, its low energetically density can be highlighted. An alternative to overcome these characteristics is the roasting process. The roasting, or pre-carbonization, is a thermal treatment executed in low oxygenated environments and moderate temperatures that may vary between 200 and 300°C, capable of concentrate lignin in the wood, reducing its hygroscopicity and elevating its energetic potential and natural durability. Therefore, this work had as its main goal to study the influence of the roasting temperature on the endurance of the *Eucalyptus urophylla* wood *in natura* as well as roasted, both exposed to the attack of dry-wood termites. To the execution of this study, *in natura* wood chips and torrefied chips (torrefied for 20 minutes at the following temperatures: 180, 220 and 260°C) were submitted to the dry-wood termite resistence test, following the Insituto de Pesquisas Tecnológicas do Estado de São Paulo’s guidelines and standards, with some adaptions. In this experiment, were used termites of the *Cryptotermes brevis* species. After 45 days of exposure, it was possible to observe that the torrefied process provided a greater resistance which consequently increased the endurance when exposed to the termite’s attack, observing that the control sample, loss 5 times more mass than the chips torrefied at 260°C. Besides that, in the treatment with *in natura* chips, was observed less mortality of the termites and greater visual damage, confirming the lower durability of such material when compared to torrefied chips.

Keywords: thermal treatment, biomass, durability, dry-wood termite.

Introduction

In Brazil the *Cryptotermes brevis,* belonging to the Kalotermitidae family, is considered the most relevant due to it easy spread and ability to attack multiple lignocellulosic objects such as books, furniture, firewood and even wood structures, once it survival depend on materials with humidity levels inferior to 30% (FOELKEL, 2008).

To enhance the usage of the biomass energetic potential, the wood chips pass through a drying process in an apron, for at least 90 days. During this period the wood it is exposed to air, therefore allowing the possibility of a termite attack. The termites, due to its ability to degrade the organic material, decrease the woody mass destined to the burn subsequently decreasing the amount of energy liberated at the biomass combustion. The resistance of the material to the termite’s attack is related with the density and chemical properties, such as resin content, lignin, extractives and others. (OLIVEIRA et al. 1986).

Besides the attack, another issue to be dealt with by the forest industries of the energetic field are the presence of unwanted characteristics in the wood that may limit its potential to energy production. According to Pereira et al. (2016) and Shang et al. (2014), the torrefaction is a thermal process with controlled temperature and low-oxygenation (200-300 °C), capable of accumulate lignin, lower hygroscopicity and potentialize energy production from lignocellulosic biomass.

Highlights that the natural resistance to deterioration depends, amongst other factors, on the lignin percentage (GONÇALVES et al., 2013). Thus, it is believed that the torrefaction, by concentrating lignin, may, besides increasing the biomass energetic potential, increase the wood’s resistance to the xylophage insects like the dry-wood termite *Criptotermes brevis.*

Hence the facts herein displayed, this work had as an objective to evaluate the effect of the torrefaction in the *Eucalyptus urophylla* wood resistance to the attack of dry-wood termites.

Materials and methods

The experiment was realized at the Panels and Wood Energy Laboratory – LAPEM and at the Wood Properties Laboratory – LPM, both incorporated to the Federal University of Viçosa, city of Viçosa, MG. Via the method described by the Technological Research Institute of São Paulo state (IPT) No. 1157 (IPT, 1980), with some adaptions, it was determined the resistance of the torrified and in natura wood chips when exposed to the attacks of the dry-wood termite *Cryptotermes brevis*.

Material Torrefaction

This experiment was conducted with wood chips from *Eucalyptus urophylla* wood of approximately 7 years of age stemming from experimental plantations of the Federal University of Viçosa. The wood chips were sieved, being effectively used in the experiment only those that were retained in the 16 mm sieve and passed through the 31.5 mm sieve. After the classification, the wood chips were dried in a greenhouse at 103±2 ºC until reaching a constant mass, or 0% humidity in dry base. Afterwards, the chips were torrefied for 20 minutes at 180, 220 and 260 °C.

For the torrefaction it was used an endless screw reactor, developed as described by Magalhães (2016). The reactor consists of four basic components; a biomass transport system; a gas heating, cooling and exhaustion system. The torrefaction temperature was monitored via a *Gulton* digital thermometer model *700-10S*, using 8 type J- thermocouples.

Durability to the dry-wood termites Test

The termites were manually released from four different school chairs colonized by *Criptotermes brevis* that were opened with a machete. To put together the experiment, there were used young (no signs of wings) and apparently healthy individuals.

It was also used in this experiment, in natura and torrified wood chips that were dried in greenhouse at 103°C ± 2°C until reaching constant mass, in other words, 0% humidity at dry base and afterwards were weighted. Then, they were put in a climatic chamber for 2 weeks for acclimation.

Petri dishes were assembled containing 40 *Cryptotermes brevis* termites, in the rate of 39 worker to 1 soldier. It was added approximately 5 grams of wood chips, dried and weighted, in each plate, totaling 6 repetitions to each treatment.

The petri dishes were drilled at the top of the lid, to allow gas exchange with the ambient. The experiment was kept in laboratory condition (25 ± 2 °C e 65 ± 5% of relative humidity) as specified by the used method. After 45 days, the mass loss and mortality values were gauged, and the termites graded from 0 to 4, by four examiners, to the damage caused by the termites as criteria shown on Table 1. It was considered the average of the grade of each examiner and treatment to evaluate the wear (damage) caused by the termites.

Table 1 – Wood wear and damage grades caused by the termites.

Grade	Damage
0	None
1	Superficial damage
2	Moderate Damage
3	Accentuated Damage
4	Deep Damage

Source: Adapted from Pessoa et al. (2006).

Experimental design and statistical analysis

The experiment was installed according to a total casual design, containing the witness and 4 treatments (180 ºC, 220 ºC, 260 ºC and the witness mix 180 ºC, 220 ºC and 260 °C), with 6 repetitions totalizing 30 sample units.

The mass loss and mortality values were transformed to arcsen [squared root (mass loss or mortality/100)], and the wear grades transformed into squared root (wear grade + 0.5), to permit normality amongst data (Lilliefors Test) and homogeinity of the variance (Cochran Test), as described by Steel & Torrie (1980).

The results were submitted to variance analysis (ANOVA) and when the significant differences among the treatments were established, it was applied Tukey Test, at 5% significance using STATISTICA 8.0 software (STATSOFT, 2007).

Results and discussion

On Table 2, there are displayed the average value of mass loss, mortality and wear grade of the *Eucalyptus urophylla* in natura and torrified wood chips after exposure to the *Cryptotermes brevis* termite.

Table 2 – Average value of mass loss, mortality and wear grade of the in natura and torrified wood chips.

		Torrefaction Temeperature		
Parameters	***In natura***	**180ºC**	**220ºC**	**260ºC**
Mass Loss (%)	1,69 a	0,68 b	0,63 b	0,33 b
Mortality (%)	60,0 a	67,0 a	65,5 a	68,3 a
Wear Grade	2,65 a	2,25 a	2,18 a	1,89 a

Averages followed by the same letter, in the same line, don no differ amongst themselves in the Tukey test at 5% probability.

Notice that the torrefaction made the wood chips more resistant to the dry-wood termites' attack, hence the mass loss was reduced in the chips thermally treated, being 59.8% lower on the wood torrified at 180 °C.

Besides the treatments at 180, 220 and 260 °C do not significantly differ among themselves, dully noting that numerically the torrefaction temperature increase significantly raised the wood's resistance. It is noted that, even, the torrefaction at 260 °C was numerically the most efficient to raise the materials' durability to the *Cryptoterme brevis* attack, once the witness' mass loss was five times bigger than the loss on this treatment.

The resistance of some wood species, according Silva et al. (2004) and Paes et al. (2007), is related to the concentration and properties of its chemical components, establishing a direct connection between the quantity and extractives class and wood natural durability.

In addition, Silva et al. (2008) and Pereira et al. (2016) explain that when the wood when exposed to high temperatures, like the ones in the torrefaction process, is chemically altered, which may occasion new extractives and accumulate lignin, corroborating with what has been found in this work and justifying the lower mass loss of the wood chips torrified in higher temperatures when submitted to the attack of dry-wood termites.

Ribeiro (2011) also states that the lignin groups alongside the phenolic extractives may harm the insects feeding process and, even if it does not cause the death of the individuals, reduces the intensity of the attack, prompting low mass loss.

Based on the mortality rate of the termites, it was verified that the *Eucalyptus urophylla wood* presents high resistance to the termites' attack, hence the mortality rate had an average equal to 65.2%, value greater than the one found by Gonçalves e Oliveira (2006) whom submitted 7 forest species to the attack of dry-wood termites (58.6%), and also above what observed by Pessoa et al. (2006) that working with *E. grandis* termoretified wood also found an average mortality of 32.3%.

Notice that the termites' mortality was significantly equal to all treatments, therefore, it tends to raise with the increase of torrefaction temperature, being numerically larger on torrified chips, mainly on the thermally treated at 260 °C. Pessoa et al. (2006), also observed that tendency and explained that the presence of organic composites resultants from the thermal degradation may also harm the termites, such as the case of phenolic composites, that, according to Brito (1992), may remain in the solid product.

It was also observed, in every Petri dishes, wood chips damaged by termites. For the wear grades it was not observed significant effect of treatments, indicating that, visually, the torrefaction was not efficient to minimize the resultant effect of the termites' attack.

It is noticed, however, that the wear grade on the in natura treatment comes closer to the equivalent accentuated damage classification, whilst the other treatments have approximated to the moderate damage. It is observed that, even if that the wear grades tended to decrease with the torrefaction temperature raise, agreeing with the lower mass losses in the torrified treatment.

The *Cryptotermes brevis* termite attack on the wood chips occasioned mass losses inferior to 1.7%. Besides this low figure, it is important to highlight that this attack was only conduced for 45 days and by only 40 individuals. Dry-wood Termite colonies contain an average of 300 individuals, which would prompt an expressively bigger mass loss.

Conclusion

From the work it was possible to conclude that the torrefaction increased the durability of the *E. urophylla* wood chips; and the higher the torrefaction temperature, the lower the damage and mass loss occasioned by termites, however, the bigger the termite mortality.

References

Foelkel E. A madeira dos Pinus e sua susceptibilidade ao ataque por cupins-de-madeira-seca e por cupins subterrâneos. Ed. n. 5, 2008.

Gonçalves, F. G.; Oliveira, J. T. S. Resistência ao ataque de cupim-de-madeira seca (*Cryptotermes brevis*) em seis espécies florestais. *Cerne,* v. 12, n. 1, p. 80-83, 2006.

Gonçalves, F. G.; Pinheiro, D. T. C.; Paes, J. B.; Carvalho, A. G.; Oliveira, G. L. Durabilidade Natural de Espécies Florestais Madeireiras ao Ataque de Cupim de Madeira Seca. *Floresta e Ambiente,* v. 20, n. 1, p. 110-116, 2013.

Instituto de Pesquisas tecnológicas. *IPT***.** Métodos de ensaios e análise em preservação de madeira: ensaio acelerado de laboratório da resistência natural ou de madeira preservada ao ataque de térmitas do gênero *Cryptotermes* (Fam. Kalotermitidae). (Publicação IPT, 1157). São Paulo: 1980. 1 p.

Magalhães, M. A. *Tratamento térmico de partículas e pellets de madeira em reator tipo rosca sem fim.* 2016. 55f. Dissertação (mestrado) – Universidade Federal de Viçosa, Viçosa, MG, 2016.

Oliveira, J. T. S. *Caracterização da madeira de eucalipto para a construção civil.* 1997, 429 p. Tese (Doutorado) – Universidade de São Paulo, São Paulo, 1997.

Paes, J. B; Melo, R. R.; Lima, C. R. Resistência natural de sete madeiras a fungos e cupins xilófagos em condições de laboratório. *Cerne*, v. 13, n. 2, p. 160-169, 2007.

Pereira, M. P. C. F.; Costa, E. V. S.; Pereira, B. L. C.; Carvalho, A. M. M. L.; Carneiro, A. C. O.; Oliveira, A. C. Torrefação de cavacos de eucalipto para fins energéticos. *Pesquisa Florestal Brasileira*, Colombo, v. 36, n. 87, p. 269-275, 2016.

Pessoa, A. M. C.; Filho, E. B.; Brito, J. O. Avaliação da madeira termorretificada de *Eucalyptus grandis*, submetida ao ataque de cupim de madeira seca, *Cryptotermes brevis*. *Scientia Forestalis*. n. 72, p. 11-16, 2006.

Ribeiro, M. X. *Resistência de painéis aglomerados a cupins de madeira seca (Cryptotermes brevis)***.** 2011, 92 p. Dissertação (Mestrado), Universidade Federal de Lavras, 2011.

Shang, L.; Ahrenfeldt, J. Holm, J. K.; Bach, L. S.; Stelte, W.; Henriksen, U. B. Kinetic model for torrefaction of wood chips in a pilot-scale continuous reactor. In: *Journal of analytical and applied pyrolysis.* v. 108, p. 109-116, 2014.

Silva, J. C.; Lopes, A. G. C.; Oliveira, J. T. S. Influência da idade na resistência natural da madeira de *Eucalyptus grandis* w. HILL ex. Maiden ao ataque de cupim de madeira seca (*Cryptotermes brevis*). *Revista Árvore***,** v. 28, n. 4, p. 583-587, 2004.

Silva, M. R. Mahado, G. O.; Alil Junior, C. Efeito do tratamento térmico nas propriedades mecânicas de *Pinus elliotti*. In: ENCONTRO BRASILEIRO EM MADEIRA E ESTRUTURAS DE MADEIRA, 11, 2008, Londrina. *Anais*... Londrina: UEL - EBRAMEM, 2008.

TORREFACTION OF EUCALYPTUS CHIPS FOR ENERGY PURPOSES

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Abstract
Wood in the innate condition presents undesirable characteristics for its use as an energy source when compared to fossil fuels, such as high moisture content, low calorific value and heterogeneous character. It can reduce the economic competitiveness of this source in front of the others and even make it unviable. Therefore, torrefaction appears as an opportunity to improve the energy properties of biomass, and to add value to the final product. The present study aimed to evaluate the energy properties of chips of Eucalyptus sp. submitted to the torrefaction process. Was used semi-continuous flow reactor by endless thread to torrify the chips of Eucaliptus sp. The variables analyzed in the process were residence time in the reactor (10, 15 and 20 minutes); torrefaction temperature (250 and 300 °C); and initial moisture of the chips (~ 14% b.s and ~ 0% b.s.), totaling 12 treatments and more the control treatment. The data were submitted to ANOVA and when a significant effect of the treatments was observed, the means were compared by the Scott Knott and Dunnet tests, at 5% probability. The increase in temperature and torrefaction time generally improved the energetic properties of wood chips, as well as the lower initial moisture content of the wood for roasting. It was observed an increase in initial bulk density in the treatments at 250 ºC and 300 ºC, at 10 and 15 minutes, with decrease in more intense treatments; significant reductions in hygroscopic moisture equilibrium values; decrease of volatile materials contents, with consequent increase in fixed carbon concentration; and finally, increase in calorific value and energy density. It is concluded that torrefaction is a technically feasible alternative because it promotes increases in the energy quality of eucalyptus chips.

Keywords: Biomass; wood; semi-continuous flow reactor; energy quality**.**

Introduction

Biomass is still part of the world energy matrix, however on a smaller scale and with greater expressiveness in countries with lower levels of development. In general, energy consumption from renewable sources accounts for about 14.2% of the world energy matrix, compared to 41.2% in Brazil. Approximately 28.9% of the Brazilian matrix is related to biofuels, characterizing itself as one of the countries with the highest biomass utilization in the world for energy generation. Although the apparent high consumption of biomass fuels, the use of this source is relatively low compared to non-renewable energy sources such as petroleum and its derivatives (BRASIL, 2016).

In this scenario, the search for sources that are energetically compatible and viable, replacing the current dominant source becomes important for contemporary society. Therefore, renewable sources, such as forest biomass, reappear as excellent alternatives, as they are sources of clean energy, do not influence the thermal balance of the planet and present high potential for job creation (PROTÁSIO et al., 2015).

Wood chips are widely used by the pulp and paper, panel and power generation industries by direct firing. The greater surface area of the chips associated to smaller dimensions of the same, acts in a positive way in the efficiency of the burning process and in the final quality of the product (PIRRAGLIA et al., 2012).

However, the biomass in the natural condition presents undesirable physical and chemical characteristics for its use as an energy source, therefore, it is justified the search for technologies that improve the properties of the biomass and add energy value to the final product (MODES, 2010).

Thermal treatments such as carbonization and torrefaction are examples, which present some advantages such as the increase in the energy value of the biomass and calorific value and the reduction of hygroscopicity (LORA et al., 2013).

Thus, the objective of the work was to evaluate the energy properties of small *Eucalyptus* sp. chips submitted to the torrefaction process.

Material and methods

Raw material and the torrefaction process

The experiment was developed at the Madeira Panels and Energy Laboratory, linked to the Forestry Engineering Department of the Federal University of Viçosa (DEF / UFV), in Viçosa, State of Minas Gerais. The biomass used was small *Eucalyptus* sp. chips donated by Biofogo company. The material presents dimensions of 1.97 x 8.89 x 12.88 mm (length x width x thickness), and granulometry of 8.82 mm. The chips were torrified in a semi-continuous flowless screw type reactor, which was developed in the Panels and Energy Laboratory of Madeira.

Physical and chemical properties

The bulk density was determined according to the standard DIN EN 15103 (2010). The hygroscopic equilibrium moisture was calculated on a dry basis (d.b.) according to DIN EN 14774-1 (2010) using a greenhouse with constant air circulation oven at 103 ± 2 ° C.

The immediate chemical composition of the chips was determined following the procedures established by ABNT NBR 8112 (1983), to obtain the content of volatile materials, fixed carbon and ash. The High Calorific Power of the chips was determined in an IKA300 adiabatic calorimeter pump following the standards of DIN EN 14918 (2010b), using samples under the same conditions.

The energy density (MJ/m^3) was estimated by multiplying the upper calorific value (MJ/kg) by the bulk density (kg/m^3) of the samples of each treatment.

Experimental design

The experiment was performed according to a completely randomized design, with twelve treatments. The treatments were compared by the Analysis of Variance at 5% of significance and, when obtained significant difference, were submitted to the Scott Knott Means Test at 5% probability level. Moreover, each treatment was compared to the control by the Dunnett Test of Means, also at 5% probability.

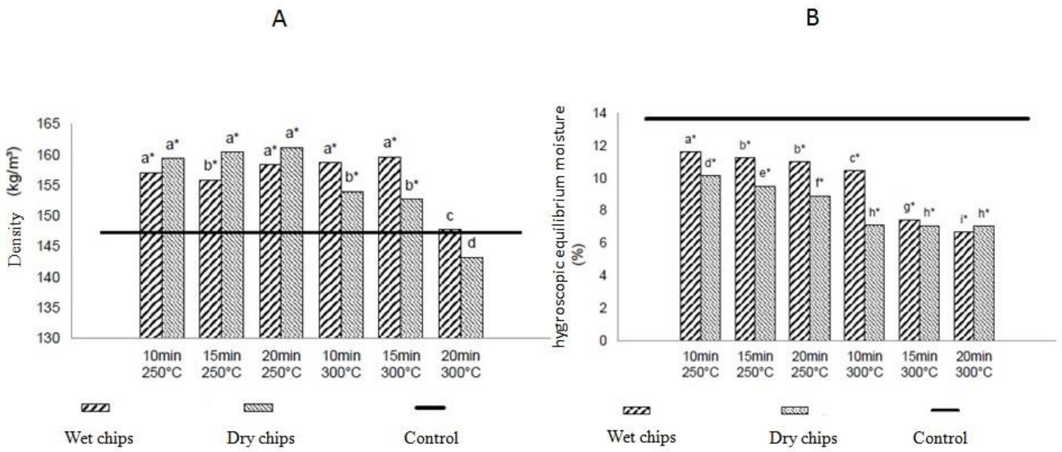
Results and discussion

Physical and Chemical Properties

Figure 1 shows the mean values of bulk density and hygroscopic equilibrium moisture of eucalyptus chips submitted to the torrefaction.

It can be seen in Figure 1-A that only the treatments at 300 °C for 20 minutes differ statistically from the others and did not present difference when compared to the control. The other treatments presented statistical difference when compared to the control, and the increase in temperature promotes greater difference between dry and wet chips.

In the more intense treatments, submitted to 300 ºC for 15 and 20 minutes, the density reduced due to greater mass loss in relation to the volumetric reduction, resulting in a lower mass / volume ratio and consequently lower bulk density.



Means followed by the same letter do not differ from each other by the Scott-Knott Test at 5% significance. Means followed by an asterisk (*) differ significantly from the control by the Dunnett Test.

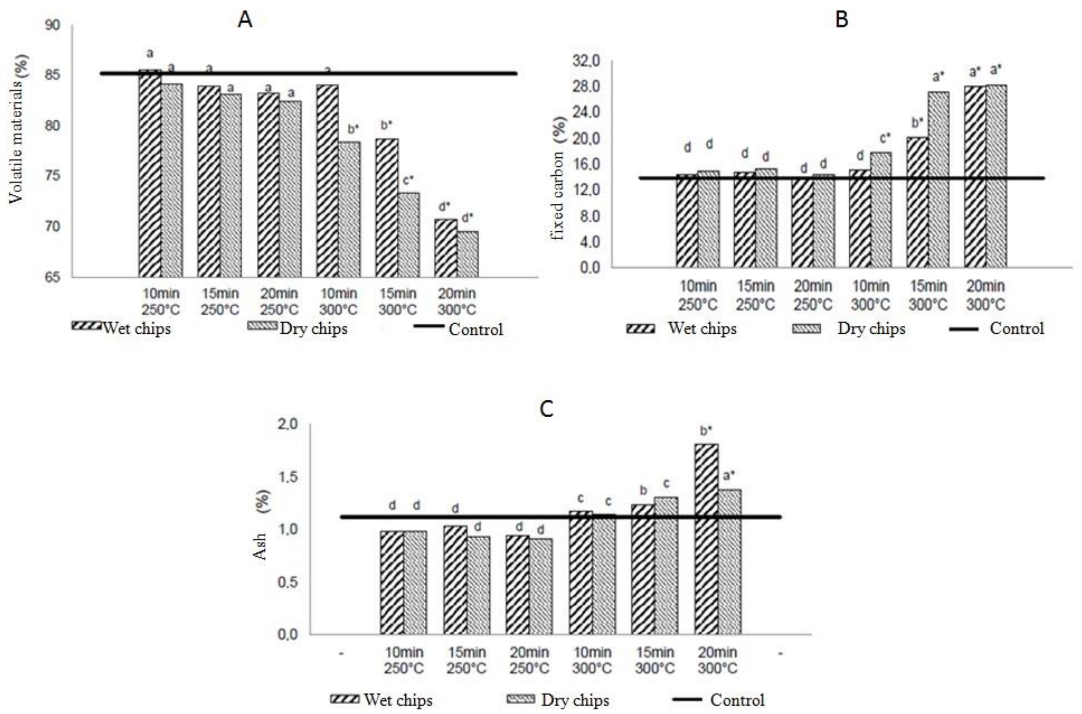
Figure 1A - Mean values of bulk density and **Figure 1B -** hygroscopic equilibrium moisture, of eucalyptus chips submitted to torrefaction in different treatment conditions.

There were significant reductions in the hygroscopic equilibrium humidity of the chips compared to the control in the Figure 1B. The increase of the temperature and the torrefaction time promoted the reduction of the hygroscopic moisture, and the previously dried chips were the ones that presented lower values, and therefore, they were more stable.

The reduction of hygroscopic equilibrium moisture can be attributed in large part to the degradation of more thermally unstable components, such as hemicelluloses (MELLO et al.,2013). Such compounds are rich in hydroxyl groups, facilitating the adsorption of water, and thus conferring hydrophilic character to the material (GOMES, et al. 2015). The ability to absorb moisture from the surrounding environment of the chips decreased, resulting in increased resistance to biological degradation, as well as facility of storage and transport (KYMÄLÄINEN et al., 2014).

Is possible to verify the average values of the immediate chemical composition of eucalyptus chips submitted to torrefaction in different treatment conditions in the Figure 2.

It is observed that the increase of the temperature of the torrefaction time of the dry and wet chips, resulted in significant changes in the chemical composition of the same, due to the greater thermal degradation of the wood constituents, resulting in a greater loss of mass, promoting the reduction in the concentration of volatile materials (Figure 2A) and increase of fixed carbon (Figure 2B) and ash (Figure 2C) (BATES e GHONIEM, 2014).



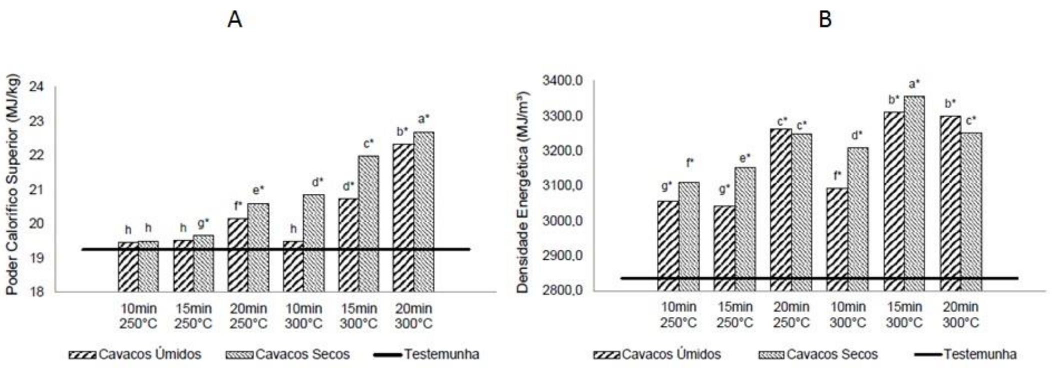
Means followed by the same letter do not differ from each other by the Scott-Knott Test at 5% significance. Means followed by an asterisk (*) differ significantly from the control by the Dunnett Test.

Figure 2A - Mean values of the content of Volatile Materials, Figure 2B - Fixed Carbon, and **Figure 2C** - Ash of eucalyptus chips submitted to torrefaction in different treatment conditions.

The reduction of volatile material contents in the final torrefaction product can be explained by the fact that most of the volatile fractions in the wood are generated from cellulose and hemicelluloses (VITAL et al., 2013). The ash contents increased in the most intense treatment (300 °C for 20 minutes), differing statistically from the others.

In Figure 3A and 3B, the average values of the upper calorific value and energy density of eucalyptus chips submitted to torrefaction in different treatment conditions.

A significant difference between the treatments is observed in the Figure 3A, indicating an increase in the higher calorific value following increasing in treatment time and temperature. This increase in energy is associated with the concentration of components with higher carbon content, which in turn has a higher energy potential (VITAL et al., 2013), as observed in Figure 2. The lower increase in the calorific value of the torch chips with initial moisture is associated with the requirement of energy and time to heat and evaporate the water in the wood.



Means followed by the same letter do not differ from each other by the Scott-Knott Test at 5% significance. Means followed by an asterisk (*) differ significantly from the control by the Dunnett Test.

Figure 3A - Mean values of higher calorific value-PCS, and **Figure 3B** - energy density (B), of the eucalyptus chips submitted to torrefaction in different treatment conditions.

It can be seen in Figure 3B that all treatments were significantly different from the control, presenting higher energy density values. The torch chips at 300 ºC showed the highest increase in energy density. The energy density is the amount of potential energy in a given volume of fuel, directly influencing the energy potential of the material and also in the cost of transportation and logistics (VITAL et al., 2013).

Conclusions

It is concluded that the increase in temperature and roasting time can generate gains in the physical and chemical properties of the chips, such as the reduction of hygroscopic equilibrium moisture and volatile materials, and increase in fixed carbon content, higher calorific value and energy density. The best results were found in the samples previously dried (0% moisture), and heat treated at 300 ºC for 15 and 20 minutes.

Acknowledgment

The Foundation for Research Support of the State of Minas Gerais (FAPEMIG), the Coordination of Improvement of Higher Education Personnel (CAPES), and National Council for Scientific and Technological Development (CNPq).

References

Brazilian Association of Technical Standards - NBR 8112: Charcoal - Immediate Analysis. Rio de Janeiro, 1983. 5p.

Agar, D.; Wihersaari, M. Bio-coal, torrefied lignocellulosic resources – Key properties for its use in co-firing with fossil coal – Their status. *Biomass and Bioenergy*, v.44, p.107-111, 2012.

Bates, R. B.; Ghoniem, A. F. Modeling kinetics-transport interactions during biomass torrefaction: The effects of temperature, particle size, and moisture content. *Fuel*, v.137, p.216-229, 2014.

Brasil. Ministry of Mines and Energy. Brazilian Energy Review: year of exercise 2015. Brasília: MME, 2016. 29p.

DIN - Deutsches Institut fur Normung. EN 14774-1: Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method. Berlim: CEN, 2010. 10 p.

DIN - Deutsches Institut fur Normung. DIEN 15103**:** Solid biofuels **-** Determination of bulk density. Berlim: CEN**,** 2010. 14p.

DIN - Deutsches Institut fur Normung. DIEN 14918**:** Determination of calorific value. Berlim: CEN**,** 2010. 63p.

Gomes, V. J.; Longue Junior, D.; Colodette, J. L.; Ribeiro, R. A.; Braun, H. Influence of xylan content on bleachability, hygroscopic, physico-mechanical and optical properties of bleached eucalyptus pulps. *Química Nova*, v. 38, p. 221-226, 2015.

Kymäläinen, M.; Havino, M.; Kerio, S.; Kemell, M.; Solio, J. Biological degradation of torrefied wood and charcoal. *Biomass and Bioenergy*, v.71, p.170-177, 2014.

Lora, E. E. S.; Venturini, O. J.; Andrade, R. V. Torrefaction wood. In: SANTOS, F.; COLODETTE, J.; QUEIROZ, J. H. de. *Bioenergia e biorrefinaria: cana-de-açúcar & espécies florestais,* Viçosa: Ed. UFV, p. 401– 428, 2013.

Luengo, C. A.; Felfli, F. E. F.; Bezzon, G. Pyrolysis and torrefaccion of biomass. In**:** CORTEZ, L. A. B.; LORA, E. S. *Biomassa para energia***.** Campinas: Ed. UNICAMP, 2008. p.333-351, 2008.

Mello L. R. P. F.; Vergílio, R. M.; Mali, S. Chemical and Functional Characterization of the Fibrous Waste of the Brewery Industry. *Biochemistry and Biotechnology Reports*, v. 2, n. 3, p. 191- 194, 2013.

Modes, K. S. *Effect of thermal rectification on the physical-mechanical and biological properties of Pinus taedae and Eucalyptus grandis*. 2010. 99p. Dissertação (mestrado em Engenharia Florestal) – Universidade Federal de Santa Maria, Santa Maria, 2010.

Pirraglia, A.; Gonzalez, R.; Denig, J.; Saloni, D.; Wright, J. Assessment of the most adequate pre-treatments and woody biomass sources intended for direct co-firing in the U.S. *BioResources*, v.7, n.4, p.4817-4842, 2012.

Protásio, T. P.; Trugilho, P. F.; Siqueira, H. F. de; Melo, I. C. N. A. de; Andrade, C. R.; Guimarães Junior, J. B. Energetic characterization of natural and torrified pellets produced with Pinus residual wood. *Pesquisa Florestal Brasileira*, v. 35, p. 435-442, 2015.

Vital, B. R.; Carneiro, A. C. O.; Pereira, B. L. C. Quality of wood for energy purposes. In: Santos, F.; Colodette, J.; Queiroz, J.H. (Ed.). *Bioenergia e Biorrefinaria - Cana-de-açúcar & Espécies Florestais*. Viçosa, MG: Ed. UFV, p. 321 – 354, 2013

THEME: SOLID BIOFUEL

CHARACTERIZATION OF *Eucalyptus urophylla* X *Eucalyptus grandis* QUALITY OF WOOD FOR ENERGY PURPOSES

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Abstract
The use of wood is related both to economic issues and to the low technological level of some segments, especially the industrial ones, where the ceramics of the state of Rio Grande do Norte (RN) use wood in the direct burning, without a previous study for such use. Considering this demand for wood biomass and the development of cultures of the genus Eucalyptus in Brazil, the present study aimed to characterize the wood properties of *Eucalyptus urophylla* X *Eucalyptus grandis* clones and to indicate, based on the results, the material with the best potential for energy purposes. Three clones were evaluated in the fourth year of age, AEC0144 (T1), AEC0224 (T2) and GG100 (T3), from a planting in the Forest Experimentation Unit of the Specialized Academic Unit in Agricultural Sciences (UAECIA) of the Federal University of Rio Grande do North (UFRN). The analyzes were carried out at the Wood and Energy Laboratory (LAPEM) of the Federal University of Viçosa (UFV), where the wood was evaluated for determination of the basic density ($g.cm^{-3}$), superior calorific value ($Kcal.kg^{-1}$), as well as components of the immediate chemical analysis (AQI) of wood: volatile materials (%), fixed carbon (%) and ash (%). For the variable basic density, the test found that treatment 1 and treatment 2 were statistically the same and differed from treatment 3, which obtained a higher average in relation to the others. On the other hand, for the variable calorific value, it was verified that the 3 treatments did not differ statistically. For AQI, the treatments did not differ statistically when comparing volatile materials and fixed carbon, but it was observed that T3 obtained a lower value than the others for the ash content. Thus, it was concluded that the clone GG100 (T3) presents better characteristics for its energy properties.

Keywords: High calorific value, Basic density, Energy from wood.

Introduction

In the northeastern semi-arid region, wood is consumed as a source of energy, especially by the sectors (residential, industrial and commercial) and this source comes from the Caatinga Biome. Thus, this biome has supported negative environmental impacts, mainly due to the unsustainable exploitation of this resource (SANTOS et al., 2013). In the Northeast, such use is estimated at thirteen million tons per year, where eight million refers only to residential use (cooking procedures), and the industrial and commercial sectors consume about five million in production of energy for use in ceramics, plaster factories, potteries, bakeries, among others (PAREYN et al., 2013).

In the state of Rio Grande do Norte (state of Rio Grande do Norte), the significant use of wood is related, both to economic issues, and to the low technological level of some segments, as observed in the red ceramic industry that uses wood for direct burning in the pre-drying and, mainly, sintering of the products, without, however, having a previous study of the properties of interest for such use (SANTOS et al., 2013), nor about the origin of the energy source.

Thus, the high consumption of wood, coupled with the low efficiency of the burning systems, are the main factors responsible for the high production costs in the activities of the industrial sector (SEBRAE, 2013), resulting in environmental, social and economic problems.

Ferreira (2015) reports that rapid growth of the material and the possession of the technological properties desirable for the final use of wood will contribute to the reduction of Caatinga exploitation and can become a substantial factor in the reduction of costs, in order to competitiveness of the regional forestry sector.

The implementation of commercial plantations with species of the genus *Eucalyptus* is a technical and economically feasible alternative in the short term to supply the consumer market where they have the possibility of generating energy at low cost in order to stand out in the current national energy matrix (DINARDI, 2014).

Eucalyptus urophylla X *Eucalyptus grandis,* in general, is considered the most viable because it provides good quality biomass for energy, since it has good characteristics regarding the basic density and calorific value (NOGUEIRA; BISPO; FRANCO, 2014).

In this context, the present study aimed to characterize the wood properties of *Eucalyptus urophylla* X *Eucalyptus grandis* clones implanted in the state of Rio Grande do Norte and to indicate the genetic material with the best potential for energy purposes.

Material and methods

Study area

The study was developed with three genetic materials, hybrids of *Eucalyptus urophylla* S.T. Blake x *Eucalyptus grandis* (Hill) Maiden, as follows: AEC0144 - treatment 1 (T1), AEC0224 – treatment 2 (T2) and GG100 – treatment 3 (T3), at four years of age, implanted under spacing of 3 m x 3m (1,111 ha^{-1} trees), in the Forest Experimentation Area of the Specialized Academic Unit in Sciences (UAECIA) of the Federal University of Rio Grande do Norte (UFRN), located in the municipality of Macaíba / RN. The average annual temperature of the site is 26°C with an average annual rainfall of 1,200 mm (CESTARO; SOARES, 2004; MACÊDO et al., 2007). It presents soil of the Yellow Latosol type with sandy texture (86% sand, 7% clay and 7% silt at depths of 0-60 cm) and a flat topography (BELTRÃO et al., 1975).

Collection of material and preparation of samples

Within the 6 plots (2 plots for each clone), four trees were selected, by genetic material, which represented the mean height of each population, excluding those that visually presented defects. From these, 5 cm thick discs were removed at four longitudinal points of the shaft: 0% (base at 10 cm from the ground); 25%; 50% and 75% of the total height of the tree.

Removed from the shells of the discs, these were divided into opposing wedges, with a cut incising the marrow. Part of these was sent for determination of the basic density of wood and another for determinations of the superior calorific value and the immediate chemical composition of the wood. All analyzes were performed on composite samples.

The basic wood density was determined according to the water immersion method described by Vital (1984). The calorific value of the wood was determined according to the methodology described by ABNT NBR 8633 (ABNT, 1984), with the aid of an IKA C 200 calorimetric pump and the immediate chemical analysis of the wood in accordance with ABNT NBR 8112.

The data were submitted to the Lilliefors tests to test normality, and Cochran to test the homogeneity of the variances, followed by the analysis of variance by the F test, and the means were compared by the Tukey test, with a significance level of 5%. Statistical analyzes were performed with the aid of program R version 2.13.1.

Results and discussion

Figure 1 shows the mean values of the basic wood density of each genetic material.

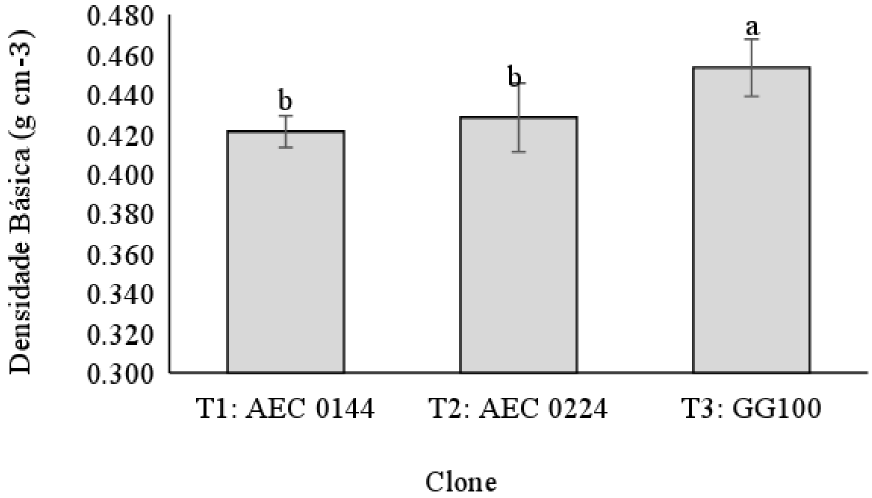

Figure 1. Basic density (g.m-³) of the wood in function of the clone

It was observed values between 0.420 g.cm^{-3} and 0.460 g.cm^{-3} for this variable. When evaluating the effect of age (between 3 and 7 years) on different clones of *Eucalyptus sp*. for the production of coal, Castro (2011) obtained value around 0.450 g.m^{-3}, for basic density of the wood of one of the hybrids, a value close to that found for clone GG100.

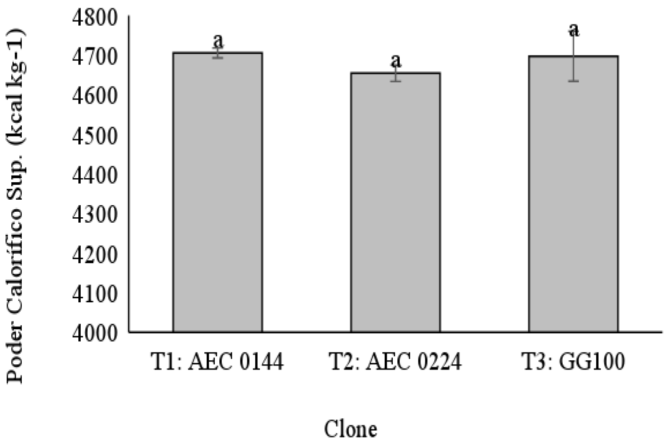

Figure 2. Calorific power (Kcal.kg^{-1}) of the wood in function of the clone

For the calorific power value of the wood, it was verified that there was no significant difference (Figure 2). The values found in this study (4696 Kcal.kg^{-1} and 4705 kcal.kg^{-1}) are consistent with those reported in the literature for the wood of Eucalyptus sp. at 7 years of age (SANTOS et al., 2016).

For immediate chemical analysis, as can be observed in Table 1, only the ash content of clone GG100 was statistically inferior to the others. Since the ash content is a property that affects the energy conversion of the biomass, so that the available energy of the fuel is reduced in proportion to the amount of ash content (SANTOS, 2012), the lower the ash content the lower the energy to be produced.

The GG100 clone obtained a much lower ash value compared to the others, such information can be corroborated by other authors, such as Pereira et al. (2013), which also found values below 0.5% for ash content when studying the wood of *Eucalyptus sp.* with 5.5 years of age, coming from commercial plantations of the company Suzano Energias Renováveis, in the State of Maranhão.

Table 1. Immediate chemical analysis of wood in function of the clone

Clone	MV	CZ	CF
AEC0144	14.76 A	0.56 A	84.68 A
AEC0224	13.43 A	0.56 A	86.01 A
GG100	14.34 A	0.21 B	85.45 A

In what: MV = Volatile Materials (%); CZ = Ash content (%); CF = Fixed Carbon (%)

About 70-80% of the dry matter is transformed into volatiles during the combustion process of biomass, and its importance is linked to ignition, because it is faster the higher the volatile content due to the reactivity of the fuel. (KLAUTAU, 2008). According to Santos (2012), the volatile materials are the components released at the beginning of the combustion, being composed mainly by hydrocarbons. In this way, the fixed carbon content depends on the volatile content that in this study presented very low values. This can be corroborated by the values found for fixed carbon, which has a standard interval of 14% to 25% (TEIXEIRA et al., 2016), but we can observe (Table 1) that for the present study carbon showed significantly higher levels than the standard. Also, according to the aforementioned authors, this inconstancy may also be due to heterogeneity between the clones and external influences, such as soil and climate.

Conclusion

The evaluated parameters allowed to conclude that all the treatments of this study present high potential for energy purposes. Among the evaluated materials the clone GG100 (T3) presented superior characteristics as to its energetic properties, being therefore the most indicated.

References

Alves, A. P. L. A.; Paula N. F. de.; Paula R. C. de.; Wood density in clones of hybrids eucalyptus. *Ciência & Tecnologia*: Fatec-JB, Jaboticabal, v. 6, p. 183-186, 2014.

Carneiro, A. C. O. et al. Caracterização energética das madeiras de clones de Eucalyptus cultivados em diferentes localidades. *Revista Ciência da Madeira - Rcm*, [s.l.], v. 8, n. 3, p.127-135, 23 ago. 2017.

Castro, A. F. N. M. Efeito da idade e de materiais genéticos de Eucalyptus sp. na madeira e carvão vegetal. Viçosa, MG, 2011. Dissertação (Mestrado) Universidade Federal de Viçosa.

Dinardi, A. J. Viabilidade técnica e econômica de povoamentos de Eucalyptus spp. sob diferentes espaçamentos visando a produção de biomassa para energia. 2014. 102 f. Tese (Doutorado) - Curso de Ciência Florestal, Universidade Estadual Paulista, Botucatu, 2014.

Klautau, J. V. P. Análise Experimental de uma Fornalha a Lenha de Fluxo Co-corrente para Secagem de Grãos**.** 2008. Dissertação (Mestrado em Engenharia Ambiental) – UFP, Curitiba, PR, 2008.

Nogueira, E. W.; Bispo, C. J. C.; Franco, D. S. Potencial de utilização do eucalipto para geração de energia no município de Paragominas/PA, Brasil. In: Congresso Internacional de Tecnologias Para o Meio Ambiente, 4. Anais... Bento Gonçalves: Fiema, 2014.

Pareyn, F. et al. (Org.). Cuidando da Caatinga. Associação Plantas do Nordeste (APNE) & Royal Botanic Gardens, Kew, 2013.

Pereira, B. L. C. et al. Estudo da degradação térmica da madeira de *Eucalyptus* através de termogravimetria e calorimetria. *Revista Árvore*, v. 37, n. 3, p. 567-576, 2013.

Pereira, M. P. C. F. et al. Torrefação de cavacos de eucalipto para fins energéticos. *Pesquisa Florestal Brasileira*, [s.l.], v. 36, n. 87, p.269-275, 30 set. 2016. Embrapa Florestas.

Santos, R. C. et al. Influência das propriedades químicas e da relação siringil/guaiacil da madeira de eucalipto na produção de carvão vegetal. *Ciência Florestal*, Santa Maria, v. 26, n. 2, p.657-669, 20 jun. 2016.

Santos, R. C. et al. Potencial energético da madeira de espécies oriundas de plano de manejo florestal no Estado do Rio Grande do Norte. *Ciência Florestal*, Santa Maria, v.23, n.2, p.491-502, 2013.

Santos, J. R. S. Estudo da biomassa torrada de resíduos florestais de eucalipto e bagaço de cana-de-açúcar para fins energéticos. 2012. 86 f. Dissertação (Mestrado) - Curso de Recursos Florestais, Escola Superior de Agricultura "Luiz de Queiroz", Piracicaba, 2012.

Sebrae. Serviço de apoio às micro e pequenas empresas do Rio Grande do Norte. Diagnóstico da indústria de cerâmica vermelha do Rio Grande do Norte. Natal: SEBRAE-RN, 2013.

Ferreira, M. C. Propriedades da madeira de Eucalyptus urophylla x Eucalyptus grandis e projeção de biomassa e energia em plantios de curta rotação localizados no município de Macaíba-RN. 2015. 49 f. Dissertação (Mestrado) - Curso de Ciências Florestais, Universidade Federal do Rio Grande do Norte, Macaíba, 2015.

Tabarés, J. L. M. et al. Feasibility study of energy use for densificated lignocellulosic material (briquettes). *Fuel*. 2009.

Teixeira, C. M. et al. Chemical Characterization of Eucalyptus sp. Residues from Short- Rotation Forests for Bioenergy Production. *Revista Virtual de Química*, [s.l.], v. 8, n. 5, p.1693-1701, 2016. Sociedade Brasileira de Quimica (SBQ).

EFFECT OF THE CULTIVATION METHOD ON THE TECHNOLOGICAL CHARACTERISTICS OF WOOD OF FOREST SPECIES, AIMING AT THE PRODUCTION OF ENERGY

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Abstract
Wood is a traditional resource that has long been used by man for a variety of purposes and, in particular, is the scope of studies and research focused on the production of renewable energy. In order to determine the energy potential of the wood, it uses the analyses of the technological properties of this source of biomass and energy, such as moisture content, basic density and superior and useful calorific power. In this context, the objectives of this work were to evaluate the effect of cultivation methods on basic density, on the superior and useful calorific value of the wood of *Acacia mangium* (Acacia), *Azadirachta indica* (Nim) and *Mimosa caesalpiniaefolia* (Sabiá); to evaluate the moisture effect in the values of density and superior and useful calorific value in response to silvicultural treatments. The planting is located in the forest experimentation area of the Federal University of Rio Grande do Norte, in the municipality of Macaíba - RN. Two trees were harvested per treatment, T1 (less intensive) and T2 (more intensive), discs were withdrawn along the trunk at 0%, 25%, 50%, 75% and 100% of commercial height and, and the characteristics determined, were: moisture content, basic density, superior and useful calorific value of the wood, being the useful calorific value determined by means of a mathematical equation, besides the influence of the humidity of the wood on the density and the superior and useful calorific value. The experimental design was completely randomized in a 3x2 factorial scheme. The data were submitted to analysis of variance by the F test, and the average of the treatments were compared by the Tukey test at 5% probability. The linear correlations were Pearson's at 5% of significance. Statistics analyses were performed in program R, version 2.13.1, ExpDes package. It is concluded that the cultivation method did not influence the energy production of the species by the parameters used. There was interaction between the species factor and useful calorific power, highlighting the highest values observed for the species *Azadirachta indica* and *Mimosa caesalpiniaefolia.* It was verified that the highest values for the basic density were for the wood of *Mimosa caesalpiniaefolia*, independent of the silvicultural treatment. The values of humidity influenced negatively the data of density and calorific power inferior and useful.

Keywords: forest species, wood quality, silvicultural treatments.

Introduction

Interest in renewable and clean energy sources has grown, especially in Brazil, in recent years as a result of economic and, especially, environmental pressure on fossil fuels. Biomass is a low-cost energy resource, in addition to being abundant in Brazil (ALMEIDA; BRITO; PERRÉ, 2010). Studies describe a biomass capacity for a clean energy production, such as those performed by Protásio et al. (2013), Caron et al. (2015) and Eloy et al. (2016).

When compared to other renewable sources, biomass has the advantage of being able to store the raw material (FOWLER, 2009), thereby reducing transportation and freight, and may even be marketed in times of lower supply and higher demand. (MENEZES, 2013). In addition to a traditional energy resource been used for a long time, and an important fuel in all regions of Brazil, biomass is also a strong source of studies (MIRANDA et al., 2017).

In the analysis of the potentiality of biomass to provide energy, takes into consideration the productivity and technological characteristics of the same, ocurring about these parameters, influence of some factors there is example method of cultivation. In the case of wood, the idea is to look for to produce energetic forests under ideal conditions for to supply demand, by means of short-term fast-growing florest with high energy supply (FERREIRA et al., 2017), the so-called energy forests.

In the state of Rio Grande do Norte, the consumption of wood as a source of energy reaches values between 25 and 30 stereo of wood per year and is a main source of the industries, especially the ceramic industry (RIEGELHAUPT, PAREYN, 2010). The wood used by this origin, in your majority, of the illegal exploitation of the Caatinga (PAUPITZ, 2010). To reduce the pressure on the biome, study species species and the factors that influence the productivity and characteristics of the wood, including exotic ones, which will enable more information on the energy potential in the State.

In view of the above, the objective of this work was to evaluate the influence of cultivation methods, of three different species, on the wood energy potential, as well as the isolated effect of the species factor.

Materials and methods

For the accomplishment of the present work three forest species were used, *Acacia mangium* (Acacia), *Azadirachta indica* (Nim) and *Mimosa caesalpiniaefolia* (Sabiá), were used, originating from experimental planting located in the Forest Experimentation Area of the Specialized Academic Unit in Agricultural Sciences (UAECIA). of the Federal University of Rio Grande do Norte (UFRN), *campus* Macaíba - RN.

According to the classification of Köppen, the local climate characterized by a transition between the types As', which is characterized by having a well defined dry season in the summer period and the BSh ', which is characterized by low humidity and low rainfall, with average temperatures of 27ºC, mean annual relative humidity of 76% and rainfall ranging between 863.7 and 1070.7 mm per year (IDEMA 2013). The soil is classified as Yellow Latosol with sandy texture and flat topography as cited by Silva (2017).

The seeds of *Acacia mangium*, *Azadirachta indica* and *Mimosa caesalpiniaefolia* were obtained from an orchard of the São Clemente farm (Macaíba, RN), Agricultural Research Company (EMPARN in Natal, RN) and the Agricultural School of Jundiaí (EAJ) respectively. The seedlings were produced in polyethylene bags, 15 cm in diameter and 18 cm high, containing 1: 1 substrate (cattle manure: sand). The seedlings were kept during the period of two months in the EAJ nursery, the seedlings remained during the period of two months in the EAJ nursery, being conducted to the planting when they presented in average 30 cm of height (NOBRÉGA, 2014).

At the planting site, was carried out, initially, the combat an ants, using Chlorpyrifos (Klorpan - trade name) together with mineral oil (Assist) in the proportion of 50 mL / L in thermoweller. Soon afterwards, for cleaning and preparation of the soil for the planting, were carried out two crushing of the soil throughout the area.

The treatments were classified as treatment "A" referring to the absence of silvicultural treatments and, treatment "B" with silvicultural treatments which refer to the addition of bovine manure and triple superphosphate in the grooves of the parcels B.

After the furrows were closed, was carried out the openings of pits with 20 cm of depth were made for both treatments and done planting the seedlings. Next, only in the cultivation plots B were applied 100 g/plant of NPK in the ratio 6-30-6 in two lateral covetas situated 15 cm away from each plant. After two months, the soil was corrected in the B plots, with application of limestone (2 t). It is worth noting that the "A" crop plots were not fertilized.

The trees are distributed in plots subdivided into bands with four replicates for each species studied. Each plot has 576 m², totaling approximately 1.4 ha of planting. Each plot has 64 plants per plot, 36 plants in the useful plot and 28 plants in the border, with spacing of 3 x 3m.

Wood samples were collected 5 years after planting, being slaughtered 4 trees of the most intensive treatment (B) and 4 trees of the less intensive treatment (A), of each species. Discs were removed from the base (10 cm of soil), 25%, 50%, 75% and 100% of the commercial height of the tree. To characterize the wood properties, analyzes of basic density, moisture content and higher calorific value power superior (PCS) were performed. To do so, the discs were initially divided into four wedges, and two opposite wedges were used to determine the basic density of the wood according to ABNT NBR 11941 (ABNT, 2003). The remaining were ground and a small fraction served as a sample to determine the moisture content and the remainder was passed in the 40 MESH sieve and used to determine theupper power calorific value according to the methodology described by ABNT NBR 8633 (ABNT, 1984). This analysis was performed in composite sampling at the biomaterials and biomass energy laboratory of the Federal University of Lavras.

The experimental design for the data analysis was completely randomized, in a 3x2 factorial scheme formed by the three-forest species submitted to two different silvicultural treatments (A - less intensive and B - more intensive). Four replicates were used, each experimental unit being composed of 1 tree of medium diameter of the trees. Data were submitted to analysis of variance by the F test, and the means of the treatments were compared by the Tukey test at 5% of significance. A análise estatística foi realizada no programa R, versão 2.13.1, pacote ExpDes.

Results and discussion

Table 1 shows the mean values of the moisture content of the three species under study.

Table 2. Mean values of the moisture content (%) of the woods of the species *Acacia mangium*, *Azadirachta indica* and *Mimosa caesalpiniaefolia*, according to the silvicutural tracts.

Species	Silvicultural Treatment		Average Overall
	Less Intensive (A)	More Intensive (B)	
Acacia mangium	14.87	12.86	13.87 A
Azadirachta indica	8.70	7.57	8.13 B
Mimosa caesalpiniaefolia	7.14	7.31	7.22 B
Average Overall	10.23	9.25	

CV = 22.76%. There was no interaction (p = 0.616). There was an isolated effect of the Species factor (p = 0.00002) and there was no Silvicultural Treatment effect (p = 0.61645). * average followed by the same capital letters between species do not differ in 5% of significance by the Tukey test.

The moisture content is one of the characteristics that directly alter the energy yield of the wood during the conversion process. As quoted in a study of the annals of the UNISC Scientific Initiation Seminar; (2014), the ideal moisture of wood to be converted into energy without further losses in the energy balance and it's below 20%. It was observed among the silvicultural that there was no statistical difference, probably due to the uniform soil type present in the planting area, since the samples had an equal drying period. Among the species, it was identified that the *Acacia mangium* presented a higher moisture content among the species, Braz et al. (2015) in his work says that the wood of *Acacia mangium* loses water slowly, due to the high concentration of resin inside.

The mean values of the basic wood density of the species *Acacia mangium*, *Azadirachta indica* and *Mimosa caesalpiniaefolia*, according to the silvicultural treatments, can be observed in Table 2.

Table 3. Mean valuesof the basic density (g / cm³) of the Wood of the species of *Acacia mangium*, *Azadirachta indica* and *Mimosa caesalpiniaefolia*, according to silvicultural tracts.

Species	**Silvicultural Treatment**		**Average Overall**
	Less Intensive (A)	**More Intensive (B)**	
Acacia mangium	0,466	0,468	0,467 C
Azadirachta indica	0,644	0,658	0,651 B
Mimosa caesalpiniaefolia	0,887	1,077	0,982 A
Average Overall	0,666 b	0,734 a	

CV = 11.36%. There was no interaction (p = 0.052). There was an isolated effect of the Species factor (p = 0.00001) and the Silvicultural Treatment effect (p = 0.048). * Average followed by the same capital letters between species and lowercase among silvicultural treatments, do not differ to 5% of significance by the Tukey test.

As can be observed in the Table 2 above, there was a significant effect both in the general average of the density, according to the silvicultural tract, and among species, with emphasis on the values of the wood density of *Mimosa caesalpiniaefolia*. Gonçalves, Lelis and Abreu (2010) found for this same species an average value of 0.87 g / cm³ for wood with seven years, resulting inferior to the one found in this study.

As one of the main indicators of wood quality for energy purposes (COSTA et al., 2014), higher values in basic wood density infer that the fiber walls are moderately thick (Paula, 1980) and, therefore, there will be greater mass per unit volume, which will produce greater energy per unit volume. In this work the highest value was for the species with the most intensive treatment, indicating that the nutrient supply in the soil influences the growth of the species studied, the same happens in the study of Assis et al. (2017) with different nitrogen dosages in an Eucalyptus plantation, and consequently in the quality of the wood.

The lowest values of the basic density were found in *Acacia mangium* wood. According to the results observed in relation to the higher moisture content for this wood, there is an indication of the presence of more empty spaces when compared to the others, since, generally, wood with high moisture content has low density and, low density is not a desirable feature for wood energy production.

Table 3 presents the mean values for the power calorific superior of the woods of the species *Acacia mangium*, *Azadirachta indica* and *Mimosa caesalpiniaefolia*, according to the silvicultural treatments.

Tabela 4. Mean values of the power calorific superior (PCS), in Kcal / kg, of the wood of the species *Acacia mangium, Azadirachta indica and Mimosa caesalpiniaefolia*, according to the silvicultural treatments.

Species	**Silvicultural Treatment**		**Average Overall**
	Less Intensive (A)	**More Intensive (B)**	
Acacia mangium	4726.00	4673.25	4699.63
Azadirachta indica	4598.75	4629.75	4614.25
Mimosa caesalpiniaefolia	4657.50	4645.75	4651.63
Average Overall	4660.75	4649.58	

CV = 1.42%. There was no interaction (p = 0.46474) and no isolated effect of the Species factor (p = 0.058) and Silvicultural Treatment (p = 0.684).

There was no significant effect in silvicultural treatments on this parameter, in all treatments. The literature mentions that PCS is influenced, among other aspects, by the moisture content of wood. The higher the moisture present in the wood, the longer the time spent to evaporate the water present in the wood, thus reducing the available energy balance from the conversion of wood to heat (COUTO, 2014). This association was not observed in the present study. In general, the mean values for PCS of the woods of the species under study are compatible with those observed in the literature, with studies focused on Eucalyptus (FERREIRA et al., 2017; MIRANDA et al., 2017; ELOY et al., 2016; CARNEIRO et al.; 2014; ALMEIDA, 2014; PROTÁSIO et al., 2013).

Conclusion

In general, we can conclude that the cultivation method used in this study did not directly influence wood quality for energy purposes. And that the wood of *Acacia mangium* for having relatively high humidity may not present adequate energetic yields when compared with the other evaluated species. Therefore, other analyzes are recommended to have a more detachable result for this site, since the superior calorific power did not differ between species, and between in the silvicultural treatments.

References

Almeida, G.; Brito, J.o.; Perré, P.. Alterations in energy properties of eucalyptus wood and bark subjected to torrefaction: The potential of mass loss as a synthetic indicator. *Bioresource Technology***,** [s.l.], v. 101, n. 24, p.9778-9784, dez. 2010.

Almeida, Carolane de Macêdo. Aproveitamento energético da biomassa eucalyptus a partir da gaseificação para utilização na geração de energia**.** 2014. 65 f. TCC (Graduação) - Programa de Graduação em Química Tecnológica, Universidade de Brasília, BrasÍlia, 2014.

ABNT - Associação Brasileira de Normas Técnicas. NBR 11941: Madeira - Densidade Básica da Madeira. Rio de Janeiro, 2003. 6 p.

ABNT - Associação Brasileira de Normas Técnicas. NBR 8633: carvão vegetal: determinação do poder calorífico. Rio de Janeiro, 1984. 13 p.

Assis, Claudinéia Olímpia et al. Efeito da Aplicação de Nitrogênio na Produção e Qualidade da Madeira e Carvão Vegetal de um Híbrido de *Eucalyptus grandis* x *Eucalyptus urophylla*. *Floresta e Ambiente***,** [s.l.], v. 25, n. 1, p.1-8, 11 dez. 2017
Braz, Rafael Leite et al. Curva Característica de Secagem da Madeira de Tectona grandis e Acacia mangium ao Ar Livre. *Floresta e Ambiente*, [s.l.], v. 22, n. 1, p.117-123, mar. 2015.

Carneiro, Angélica de Cássia Oliveira et al. Potencial energético da madeira de Eucalyptus sp. em função da idade e de diferentes materiais genéticos. **Revista Árvore,** Viçosa - Mg, v. 38, n. 2, p.375-381, abr. 2014.

Caron, Braulio Otomar et al. Quantificação da Biomassa florestal em plantios de curta rotação com diferentes espaçamentos. *Comunicata Scientiae***,** Bom Jesus, v. 6, n. 1, p.106-112, jan./mar. 2015.

Costa, Tattiane Gomes et al. Qualidade da madeira de cinco espécies de ocorrência no cerrado para produção de carvão vegetal. *Cerne***,** Lavras, v. 20, n. 1, p.37-46, mar. 2014.

Couto, Carolina Meincke. Estimativa do poder calorífico de madeira de acácia-negra e eucalipto do Município de Pelotas - RS. 2014. 56 f. TCC (Graduação) - Curso de Engenharia Ambiental e Sanitária, Universidade Federal de Pelotas, Pelotas, 2014.

Eloy, Elder et al. Effect of planting age and spacing on energy properties of *Eucalyptus grandis* W. Hill EX Maiden. *Revista Árvore***,** Viçosa, v. 40, n. 4, p.749-758, ago. 2016.

Ferreira, Maraísa Costa et al. Biomass and energy production at short rotation eucalyptus clonal plantations deployed in Rio Grande do Norte. *Revista Árvore***,** Viçosa, v. 41, n. 5, p.1-7, 30 nov. 2017.

Fowler, Pat et al. Modeling the energy potential of biomass – H2RES. *International Journal Of Hydrogen Energy***,** [s.l.], v. 34, n. 16, p.7027-7040, ago. 2009.

Instituto de Desenvolvimento Econômico e Meio Ambiente do Rio Grande do Norte (IDEMA). Perfil do seu município: Macaíba. IDEMA: Natal, 2013. 21 p. Disponível em http://adcon.rn.gov.br/ACERVO/idema/DOC/DOC000000000016679.PDF. Acesso em: 21 dezembro 2017.

Gonçalves, Celso de Almeida; Lelis, Roberto Carlos Costa; Abreu, Heber dos Santos. Caracterização físico-química da madeira de sabiá (*Mimosa caesalpiniaefolia* Benth.). *Revista Caatinga***,** Mossoró, v. 23, n. 1, p.54-62, jan/mar. 2010.

Menezes, Marta Juliana Schmatz. Poder calorífico e análise imediata da maravalha de pinus (pinus sp) e araucária (araucaria angustifolia) de reflorestamento como resíduos de madeireira. 2013. 65 f. Dissertação (Mestrado) - Programa de Pós-graduação em Energia na Agricultura,, Universidade Estadual do Oeste do Paraná, Cascavel, 2013.

Miranda, Marcos Antonio da Silva et al. Eucalyptus sp. WOODCHIP POTENTIAL FOR INDUSTRIAL THERMAL ENERGY PRODUCTION1. *Revista Árvore***,** Viçosa, v. 41, n. 6, p.1-8, 30 nov. 2017.

Nóbrega, Camila Costa da. Crescimento, produção de biomassa e desrama artificial de espécies florestais em resposta ao método de cultivo em Macaíba, RN. 2014. 34f. Dissertação (Mestrado em Ciências Florestais), Universidade Federal do Rio Grande do Norte, Natal, 2014.

Oliveira, Aylson Costa et al. Parâmetros de qualidade da madeira e do carvão vegetal de Eucalyptus pellita F. Muell. *Sci. For***,** Piracicaba, v. 38, n. 87, p.431-439, set. 2010.

Paula, José Elias de. Madeiras que produzem álcool, coque e carvão. Atualidades do Conselho Nacional do Petróleo, Rio de Janeiro, ano 12, n. 72, p. 31-45, jun./jul./ago. 1980.

Paupitz, Júlio. ELEMENTOS DA ESTRUTURA FUNDIÁRIA E USO DA TERRA NO SEMI-ÁRIDO BRASILEIRO. In: GARIGLIO, Maria Auxiliadora et al. Uso Sustentável e Conservação dos Recursos Florestais da CAATINGA. Brasília/df 2010: Serviço Florestal Brasileiro, 2010. p. 49-65.

Seminário de Iniciação Científica, 20., 2014, Santa Cruz do Sul, RS. *Anais do XX Seminário de Iniciação Científica da UNISC.* Santa Cruz do Sul, Rs: Unisc, 2014. 235 p.

Protásio, Thiago de Paula et al. Seleção de Clones de Eucalyptus para a produção de carvão vegetal e bioenergia por meio de técnicas univariadas e multivariadas. *Sientia Forestalis*, v. 41, n. 97, p.15-28, 2013.

Riegelhaupt, Enrique Mario; Pareyn, Frans Germain Corneel. A QUESTAO ENERGÉTICA. In: Gariglio, Maria Auxiliadora et al. Uso Sustentável e Conservação dos Recursos Florestais da

CAATINGA. Brasília/df 2010: Serviço Florestal Brasileiro, 2010. p. 77-76. Disponível em: <http://www.mma.gov.br/estruturas/sfb/_arquivos/web_uso_sustentvel_e_conservao_dos_recursos_florestais_da_caatinga_95.pdf>. Acesso em: 20 jan. 2018.

Silva, Mileny Galdino da. Crescimento, produção e distribuição de biomassa de espécies florestais em resposta ao método de cultivo. 2017. 73 f. Dissertação (Mestrado) - Programa de Pós-graduação em Ciências Florestais, Universidade Federal do Rio Grande do Norte, Macaíba, 2017.

ESTIMATES OF ENERGY PROPERTIES OF TORREFIED PELLETS BY COLORIMETRIC PARAMETERS

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Abstract

Torrefaction and pelletization of biomass can improve their energy properties and increase their competitiveness in relation to fossil fuels. The post pelletization torrefaction is one the routes used to obtain wood pellets with high energy density. Colorimetric properties are an important tool to predict the quality of torrefied products quickly and accurately, as well as assist in decision making in torrefaction process. Considering the importance of torrefaction control and the quality of torrefied products for obtaining an energetic and competitive biomass. The present work had as objective to correlate and adjust models between colorimetric and energetic properties of pine pellets torrefied in a screw type reactor. Pellets were produced and submitted to torrefaction at temperatures of 210, 250 and 290 °C and at residence times of 10, 20 and 30 minutes. Were determined the colorimetric parameters *L* (lightness), *a* (red-green coordinate) and *b* (blue-yellow coordinate), the hygroscopic equilibrium moisture, bulk density, net calorific value and estimated the energy density. The correlation between colorimetric parameters and properties of pellets was determined, after which models were adjusted to estimate the properties considering the parameters with significant correlation. The parameters *L* and *b* showed a significant correlation with all properties of pellets, and the parameter *a* only with the bulk density. Adjusted equations considering the significant parameters obtained determination coefficients (R^2) between 0.89 and 0.98. The results showed the feasibility of using equations to estimate energetic properties of torrefied pellets based on colorimetric parameters, allowing precise estimations that help in a decision making to control the torrefaction process and to know pellets quality.

Key words: torrefaction, CIELab system, pelletization

Introduction

The pellets obtained from compaction of vegetal biomass are used in the generation of thermal energy for residences heating or use in industrial processes. Pelletization makes biomass a more homogeneous fuel, reduces its volume and increases energy density, optimizing the storage and transportation (KALIYAN; VANCE MOREY, 2009; WARAJANONT; SOPONPONGPIPAT, 2013).

Although there is an increase in quality, the pellets retain some of the characteristics of biomass that gave rise to them, such as low calorific value in relation to non-renewable fuels and high hygroscopic equilibrium moisture, properties that contribute negatively to thermal generation (LAM et al., 2012). Torrefaction can significantly reduce these problems, performed at temperatures between 200 and 300 °C and in a low oxygen environment, promotes the degradation of less energetic and more hydrophilic compounds contained in biomass, its main effect is the increases in energy density (VAN DER STELT et al., 2011; SHANG et al., 2012; NHUCHHEN et al., 2014).

Torrefied pellets can be obtained through two routes. The first consists in torrefaction of particles and producing pellets. The second is production of pellets and subjecting them to torrefaction (GHIASI et al., 2014; PENG et al., 2015). In torrefaction post pelletization, pellets must have a high mechanical strength to support the process without disintegrating and generating fines, considering that the equipment keeps the biomass in constant movement. This route involves less overall cost and dispenses the steam conditioning to facilitate pelletization (GHIASI et al., 2014).

The control of torrefaction variables is extremely important for production of high quality torrefied pellets. The evaluation of conventional properties of material such as hygroscopic equilibrium moisture, bulk density and calorific value can predict the potential for energy use and help in decision making for specific interventions in torrefaction process. However, the determination of these properties during torrefaction is impracticable due to time demanded and cost of analyzes.

An alternative to mentioned problem is the properties estimation of torrefied pellets by means of variables correlated to them. The first effect of torrefaction is the darkening, which becomes more gradual with increasing in time or temperature (ZANUNCIO et al., 2014). The evaluation of colorimetric properties of torrefied pellets can be made repeatedly during torrefaction, being fast and quite accurate, and their correlation with certain properties of biomass allows to obtain information in real time for control of process.

The objective of present work was to evaluate the correlation and adjust models between colorimetric properties of torrefied pellets of pinus and its energetic properties.

Materials and methods

Production and torrefaction of pellets

The wood of Pinus sp. was preformed into particles using a hammer mil. The particles were classified in overlapping sieves, collecting the fraction that passed through the 3 mm sieve and was retained in the 0.5 mm sieve. Were dried in a forced circulation oven at 103 ± 2 °C until reaching approximately 16% moisture. The pellets were produced in a laboratory pelletization press of brand Amandus Kahl, model 14-175, at an average temperature of 106 °C.

For torrefaction, the pellets were initially oven dried at 103 ± 2 °C until 0% moisture. Approximately 5 kg were used for each heat treatment. Three temperatures (210, 250 and 290 °C) and three residence times (10, 20 and 30 minutes) were used. The reactor used is of screw type (Figure 1), developed at the Laboratory of Panels and Energy of Wood in Federal University of Viçosa, MG.

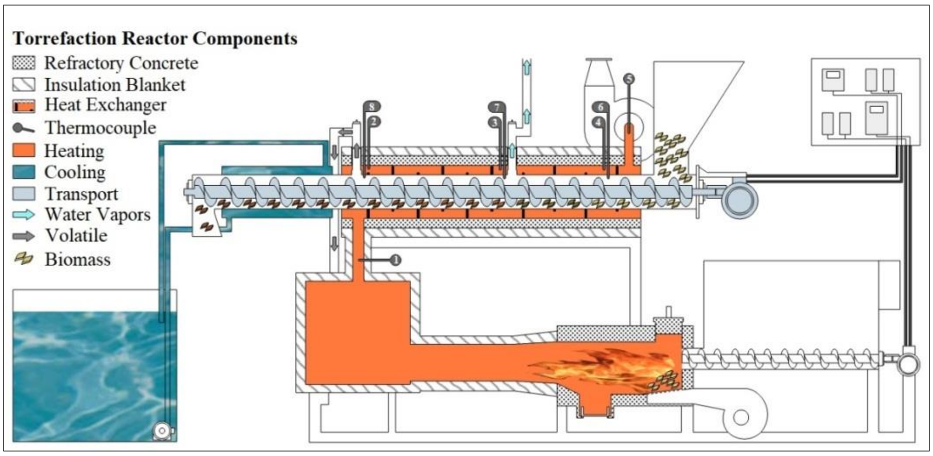

Figure 1 - Scheme of the biomass torrefaction system. Required Patent - BR 10 2016 010484 0.

Pellets properties

For determination of hygroscopic equilibrium moisture, samples were placed in a climatic chamber at 20 °C and 65% of relative humidity until reaching constant mass. The determination of the moisture content, on wet basis, was made according to the standard EN 14774-2 (DIN, 2009). The bulk density was obtained according to EN 15103 (DIN, 2010), in samples conditioned at 20 °C and 65% of relative humidity. The net calorific value was estimated from the higher calorific value determined in dry samples, according to standard EN 14918 (DIN, 2010). The energy density was obtained by the product of net calorific value by bulk density.

Colorimetric analysis

The colorimetric analysis was performed by measuring the lightness (*L*), the red-green coordinate (*a*) and the blue-yellow coordinate (*b*), also called CIELab (Figure 2), using a Konica Minolta CM-2500D spectrophotometer. For each treatment, five measurements were made on samples of homogenized and milled pellets.

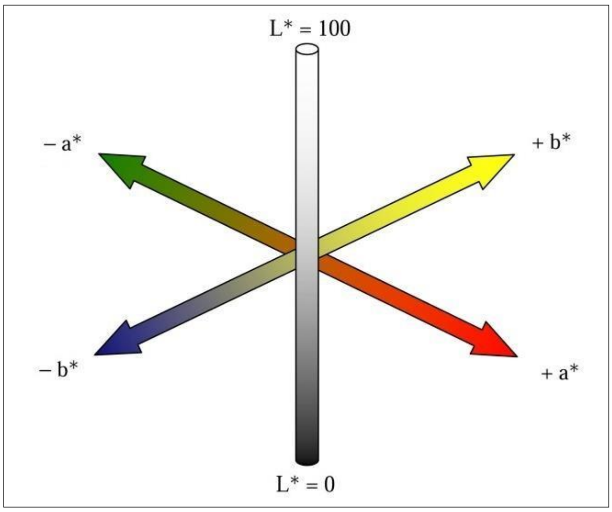

Figure 2 - CIELab three-dimensional color scheme. Adapted from Liew et al. (2008).

Correlations and adjust of models

The experiment was set up in a completely randomized design, with nine treatments (three temperatures and three times) and three replicates, totaling 27 sample units, more three control sample (non-torrefied pellets).

Correlations were obtained between the colorimetric parameters (*L*, *a* and *b*) and the properties of the pellets (hygroscopic equilibrium moisture, bulk density, net calorific value and energy density). For each property, when significant correlations were observed with colorimetric parameters, they were used to adjust the model described below.

$Y = \beta 0 + L^*\beta 1 + a^*\beta 2 + b^*\beta 3 + \varepsilon$
Being:
Y = property to be estimated;
β0, β1, β2, and β3 = coefficients generated;
L, *a* and *b* = colorimetric parameters;
ε = estimation error

Results and discussion

Table 1 shows mean values of CIELab color coordinates of pine pellets.

Table 1 - Mean values of colorimetric parameters as a function of treatments.

Treatment	*L*	*a*	*b*
1 - Control	70.0 (0.67)	8.0 (0.44)	24.5 (0.59)
2 - 210 °C / 10 min	68.1 (0.79)	8.9 (0.20)	24.8 (0.19)
3 - 210 °C / 20 min	64.2 (0.80)	9.5 (0.38)	24.3 (0.44)
4 - 210 °C / 30 min	64.4 (0.34)	9.8 (0.36)	24.9 (0.37)
5 - 250 °C / 10 min	62.9 (0.22)	10.0 (0.23)	24.9 (0.14)
6 - 250 °C / 20 min	44.2 (0.49)	11.6 (0.11)	21.1 (0.22)
7 - 250 °C / 30 min	32.5 (0.46)	10.8 (0.35)	15.7 (0.20)
8 - 290 °C / 10 min	61.6 (0.24)	9.7 (0.18)	23.9 (0.32)
9 - 290 °C / 20 min	36.5 (0.29)	11.0 (0.06)	17.9 (0.16)
10 - 290 °C / 30 min	21.6 (0.47)	4.8 (0.14)	5.1 (0.17)

Values in parentheses correspond to standard deviation.

The lightness values (*L*) decreased with increasing torrefaction time or temperature, indicating that there was a darkening of pellets. The values of red-green hue (*a*) tended to increase to intermediate times or temperatures and reduce with the intensification of heat treatment. The values of blue-yellow hue (*b*) presented a tendency of reduction, mainly, in greater times and temperatures of torrefaction.

Among the changes in color of wood due to heat treatment, the main one is the darkening (ZANUNCIO et al., 2014). Resulting from the reduction of lightness (*L*) combined with variations in individual colors, the hues.

Darkening is a consequence of degradation and oxidation of structural components less thermally stable, especially hemicelluloses, or oxidation of more stable ones, such as lignin. In addition, the extractives present in wood can undergo modifications during the heat treatment, changing their color patterns (CONTE et al., 2014; GARCIA et al., 2014; ZANUNCIO et al., 2014).

Table 2 presents the values of correlations between color coordinates CIELab and hygroscopic equilibrium moisture, bulk density, net calorific value and energy density.

Table 2 - Correlations between colorimetric parameters (L, a, and b) and hygroscopic equilibrium moisture (HEM), bulk density (BD), net calorific value (NCV) and energy density (ED).

Parameter	HEM	BD	NCV	ED
L	0.97	0.78	-0.96	-0.92
a	0.20	0.67	-0.41	0.03
b	0.91	0.93	-0.98	-0.78

Significant correlation at 5% probability is identified in bold.

For hygroscopic equilibrium moisture, only *L* and *b* parameters showed a significant and positive correlation, indicating a reduction of moisture together with the values of these parameters. All three parameters obtained a significant and positive correlation with bulk density. As for moisture, the net calorific value and the energy density presented significant correlation only with parameters *L* and *b*, being negative for both.

Based on significant correlations obtained between colorimetric parameters and the properties of pellets, the following regression equations were adjusted.

Hygroscopic equilibrium moisture = 3.707 + 0.086*L + 0.024*b ($R^2 = 0.94$) (1)

Bulk density = 444.756 + 3.421*L + 16.719*a - 7.963*b (R^2 = 0.91) (2)
Net calorific value = 21.560 - 0.024*L - 0.125*b (R^2 = 0.98) (3)
Energy density = 11.917 - 0.031*L + 0.030*b (R^2 = 0.89) (4)

The highest determination coefficient (R^2) was observed for net calorific value and the lowest for energy density. The coefficients obtained for the four properties of pellets can be considered satisfactory. Indicating that colorimetric parameters considered in the study can be used to estimate the properties of torrefied pellets.

Figure 3 presents mean values observed and estimated by respective equations for hygroscopic equilibrium moisture, bulk density, net calorific value and energy density.

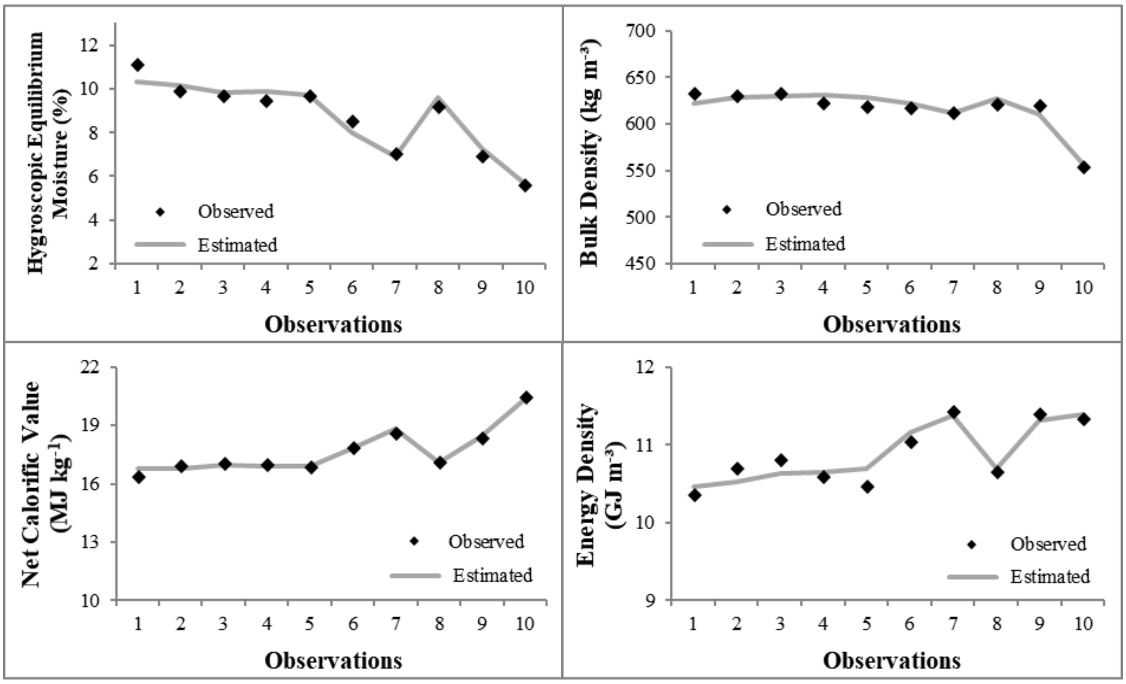

Figure 3 - Values observed and estimated by equations for hygroscopic equilibrium moisture, bulk density, net calorific value and energy density of pellets.

It is observed in Figure 3 that equations allow estimating satisfactorily the properties of wood pellets. The highest variation was observed for values of energy density, which obtained the lowest determination coeficiente. On the other hand, there is a smaller variation between observed and estimated results for the net calorific value, which presented higher determination coefficient.

Conclusion

The results showed that it is possible using equations to estimate the properties of pine wood pellets. Providing accurate estimates that to support the decision making to control the torrefaction process in real time.

It is emphasized that each biomass type when torrefied presents a different colorimetric behavior, being necessary the adjustment of equations for each situation.

References

Conte, B.; Missio, A. L.; Pertuzzatti, A.; de Cademartori, P. H.; Gatto, D. A. Propriedades físicas e colorimétricas da madeira termorretificada de Pinus elliottii var. elliottii. *Scientia Forestalis*, v. 42, n. 104, p. 9, 2014.

DIN - Deutsches Institut fur Normung. EN 14774-2: Solid biofuels - Determination of moisture content - Oven dry method - Part 2: Total moisture - Simplified method. Berlim: CEN**:** 9 p. 2009.

______. EN 14918: Determination of calorific value. Berlim: CEN**:** 63 p. 2010.

______. EN 15103: Solid biofuels - Determination of bulk density. Berlim: CEN**:** 14 p. 2010.

Garcia, R. A.; Lopes, J. D. O.; Santos, W. A. Modificação da cor original da madeira de Eucalyptus grandis através de tratamentos termorretificadores. *Cerne*, v. 20, p. 449-457, 2014.

Ghiasi, B.; Kumar, L.; Furubayashi, T.; Lim, C. J.; Bi, X.; Kim, C. S.; Sokhansanj, S. Densified biocoal from woodchips: Is it better to do torrefaction before or after densification? *Applied Energy*, v. 134, p. 133-142, 2014.

Kaliyan, N.; Vance Morey, R. Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy*, v. 33, n. 3, p. 337-359, 2009.

Lam, P. S.; Sokhansanj, S.; Bi, X. T.; Lim, C. J.; Larsson, S. H. Drying characteristics and equilibrium moisture content of steam-treated Douglas fir (Pseudotsuga menziesii L.). *Bioresource Technology*, v. 116, p. 396-402, 2012.

Liew, O.; Chong, P.; Li, B.; Asundi, A. Signature Optical Cues: Emerging Technologies for Monitoring Plant Health. **Sensors**, v. 8, n. 5, p. 3205, 2008.

Nhuchhen, D. R.; Basu, P.; Acharya, B. A Comprehensive Review on Biomass Torrefaction. *International Journal of Renewable Energy & Biofuels*, v. 2014, p. 1-56, 2014.

Peng, J.; Wang, J.; Bi, X. T.; Lim, C. J.; Sokhansanj, S.; Peng, H.; Jia, D. Effects of thermal treatment on energy density and hardness of torrefied wood pellets. *Fuel Processing Technology*, v. 129, p. 168-173, 2015.

Shang, L.; Nielsen, N. P. K.; Dahl, J.; Stelte, W.; Ahrenfeldt, J.; Holm, J. K.; Thomsen, T.; Henriksen, U. B. Quality effects caused by torrefaction of pellets made from Scots pine. *Fuel Processing Technology*, v. 101, p. 23-28, 2012.
Van der Stelt, M. J. C.; Gerhauser, H.; Kiel, J. H. A.; Ptasinski, K. J. Biomass upgrading by torrefaction for the production of biofuels: A review. *Biomass and Bioenergy*, v. 35, n. 9, p. 3748-3762, 2011.

Warajanont, S.; Soponpongpipat, N. Effect of particle size and moisture content on cassava root pellet fuel's qualities follow the acceptance of pellet fuel standard. *International Journal of Renewable and Sustainable Energy*, v. 2, n. 2, p. 74-79, 2013.

Zanuncio, A. J. V.; Farias, E. D. S.; Silveira, T. A. D. Termorretificação e colorimetria da madeira de Eucalyptus grandis. *Floresta e Ambiente*, v. 21, p. 85-90, 2014.

PROXIMATE ANALYSIS AND HIGHER HEATING VALUE OF WOOD PELLETS MANUFATURED IN THE STATES OF SANTA CATARINA AND PARANÁ

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Abstract
Wood pellet is a solid fuel formed from the densification of sawdust, it is used to replace fossil fuels due to low CO_2 emissions. Today Europe is the largest consumer and producer of this product, mainly due to policies to encourage the reduction of CO_2 emissions. In recent years, the biofuel Brazilian industry has been growing to meet the pellet supply needs in Europe. One way to analyze the performance of wood pellets was evaluated the highest calorific value (HHV) and proximate analysis that was determined as moisture, volatile matter, fixed carbon and ash contents. In this way, the present work aimed to analyze and compare the proximate analysis and higher heating value of four commercial wood pellets samples from companies located in the states of Santa Catarina and Paraná. The pellets were produced from sawdust of *Pinus spp*. of sawmills in the same region. The proximate analysis was performed according to the standard ASTM 1762/84 and HHV was determined according to ASTM D240/2017. It was verified that the higher ash content was 0.81% of the wood pellets manufactured for company C because this fact the sample of company C is not in according witch *Enplus* classification A1. All the samples analyzed don't have variation statistically significant and they are in accord witch *Enplus* standard; however, the higher HHV found was in sample A (20,03 $MJ.kg^{-1}$) in consequence of the low moisture wet basis and lowest ash content (0,37%). In conclusion, excepting the ash content of company C, the wood pellets manufactured in the studied region are in agreement to Enplus standard for parameters analyzed.

Keywords: Biofuel, *Pinus*, Densification.

Introduction

In 2015, agreements in the Climate Change Conference in Paris (COP21) support the use of renewable sources of energy, causing an increase in the demand of those in substitution to the fossil fuels (GARCIA *et al.*, 2017). Due to the low tenor emissions of carbon dioxide originated to the combustion (approximately 6 g of CO_2 MJ^{-1}) in relation to fossil fuels (approximately 100 g of CO_2 MJ^{-1}), the pellets are qualified to substitute the current energy needs in way economically viable and with a smaller environmental impact (MAGELLI *et al.*, 2009; CARASCHI, 2012). Pellets can be obtained with raw materials such as sawdust, peel of rice, corn, straw, sugarcane pulp, cotton peel, coffee and the others (QUIRINO, 2012).

By definition, the pellets are combustible solid, formed starting from triturated wood and compacted, in a cylindrical way from 6 to 8 mm diameter and 3.15 to 40 mm length. It is a fuel produced by humidity content same or less them 10% (SILVA *et al.*, 2012). They can be produced by the use of residues of the wood industry, forest residues and of the urban pruning or plantations destined for energy use (ESCOBAR, 2014).

However, when produced from wood, they have a percentage of ash and calorific value, favorable to energy use (FERREIRA, 2015). The wood as raw material varies thoroughly in his chemistry and physics composition because this fact, this material can influence the final product. Variations in the moisture (M), volatile matter (VM), fixed carbon (FC) and ash (A) contents are due to you differentiating in the ages of the trees, anatomical differences, crop methods, climatic conditions and the others. These have an effect on the quality parameters and in the gross calorific of the pellets (GILLESPIE *et al.*, 2013).

Materials and methods

The Enplus is the most used standard for certified the wood pellets. In this standard the wood pellets are classified for raw material and quality parameters. In this work, the standard parameters analyzed were the Moisture content dry basis, ash content and LHV (Lower Heating Value). Table 1 shows the threshold values for these parameters.

Table 1 - Parameters analyzed according to *Enplus* standard

Parameter	Unit	Enplus A1	Enplus A2	Enplus B
Moisture content wet basis	%		≤ 10	
Ash content	%	≤ 0.7	≤ 1.2	≤ 2.0
Lower Heating Value	MJ kg^{-1}		≥ 16.5	

Source: *Enplus* Handbook, 2015

The materials analyzed were coming off four located industries in the states of Santa Catarina and Paraná. The samples were denoted as A, B, C and D (Figure 1). All of the samples were originating from commercial lots produced starting from residues of sawmills without bark, the fact this that hinders the exact determination of the characteristics of the raw materials. However, it is known that are manufactured from *Pinus spp*. According to the classification of the standard for the raw material of manufacture, the samples belong to the classification A1.

All of the samples were stored a dry place and room temperature. The moisture content was used Brazilian standard ABNT NBR 14929/2003. The proximate analysis was performed according to the American standard ASTM 1762/84 and the higher heating value was determined according to ASTM D240/17 with a calorimeter IKA C5000.

Figure 1 Samples of commercial wood pellets

Statistical analyses were performed using statistical software R Core Team (2017) version 3.4.3. Previously, the dataset were submitting a Bartlett's test for homogeneity analyses and then Analysis of variance at 95% of probability, both using the package Stats (R CORE TEAM, 2017). For analyses means comparative, the data were submited a Tukey's test at 5% of significant using the package agricolae (DE MENDIBURU, 2017).

Results and discussion

The properties of commercial wood pellets were tested regarding proximate analysis and heating value. Results are shown in Table 2.

Table 2 – Proximate analysis and higher heating value for the commercial wood pellets

Parameter	Sample A	Sample B	Sample C	Sample D
M wet basis (%)	6.26 d ± 0.13	7.75 b ± 0.07	8.61 a ± 0.07	7.11 c ± 0.07
M dry basis (%)	6.67 d ± 0.15	8.40 b ± 0.08	9.40 a ± 0.08	7.65 c ± 0.08
VM (%)	81.62 a ± 0.09	80.90 ab ± 0.44	80.54 b ± 0.33	80.38 b ± 0.19
FC (%)	18.00 b ± 0.03	18.61 ab ± 0.44	18.65 ab ± 0.42	19.17 a ± 0.24
A (%)	0.38 b ± 0.05	0.49 b ± 0.06	0.81 a ± 0.17	0.45 b ± 0.05
HHV (MJ kg^{-1})	20.03 ns ± 0.37	19.58 ns ± 0.17	19.57 ns ± 0.13	19.87 ns ± 0.03
LHV (MJ kg^{-1})	18.68 ns ± 0.37	18.23 ns ± 0.17	18.22 ns ± 0.13	18.51 ns ± 0.03

Note: M wet basis - Moisture content wet basis; M dry basis - Moisture content dry basis; VM - Volatile Matter content; FC - Fixed Carbon content; A - Ash content; HHV - Higher Heating Value; LVH - Lower Heating Value; ns - not significant. Means followed by the same letters do not differ statistically in the same column, 5% based on Tukey's test.

For moisture content analyses, the samples showed are in according to *ENplus* standard. The moisture content of the material is found to be the most important factor that affects the energy properties of wood pellets. The moisture content influences the efficiency of the fuel, therefore the higher moisture content of the wood pellets, more energy necessary to evaporate the water and consequently lower net calorific value in the samples (BRAND, 2010).

Though the HHV it is possible to project the amount of necessary fuel as well as the project of storage facilities and to guarantee the biomass optimal in the production of energy. The pellets with a lower HHV will demand a larger amount of product to assist the same demand for energy (GILLESPIE, 2013). In accordance with BRAND, the hydrogen content in wood is around 6%. In this work, this value is used for estimated LHV. Thus like as was observed to HHV, there is no statistically significant variation in the samples analyzed for LHV measurement.

The commercial wood pellets in the present study showed a high volatile matter content that contributes to the improvement of the point of ignition in according to Garcia (2010). As well as, the volatile matter contributes to the improvement of the quality of the biofuel, high fixed carbon content in their composition has a larger residence time inside of the burners. The fixed carbon content contributes to better particles connection during the pelletizing process (GILLESPIE, 2013).

The ash contents can vary in agreement with the raw materials used in the pelletization process, such as species, bark content, age, place of growth three (BRAND, 2010). In the present study, the ash content of the company C is not in agreement with classification Enplus A1, but the could be denoted as Enplus A2.

Conclusion

In this study, the commercial wood pellets manufactured in the states of Santa Catarina and Paraná were evaluated proximate analysis and higher heating value. In ENplus standard all properties for a certain quality class like A1, A2 and B should be fulfilled. According to the results, A, B and D samples fulfill A1 quality class requirements and sample C fulfill A2 quality class requirements and certification appears to be useful to guarantee a high quality of pellet sold in the market. The results confirm that ash content value is related to other parameters and very important to define a quality of pellet. In this sense, the ash content could be a good representative parameter for a first, rapid quality assessment.

References

Brand, M. A. Energia de biomassa florestal.Edition 1 Rio de Janeiro. Interciência, 2010, p.131.

Caraschi, J. C.; Garcia, D. P. A indústria de pellets no Brasil. Revista Madeira, Ed.133, 2012.

Escobar, J. P.. O Potencial da produção de pellets de Madeira no Brasil. Oportunidades, desafios e perspectivas futuras. Available in: <http://www.iee.usp.br/sites/default/files/Javier%20F.%20Escobar%20-%20woodpellets%20Brasil_2014.pdf > Accessed in: 08/08/16

Ferreira, F. B. Pellets compostos por resíduos da torrefação do café (Coffea arabica l.) e madeira de pinus. 2015. Monografia, Universidade Federal de Viçosa, Viçosa.

Garcia, D. P.. Caracterização Química, Física e Térmica de Pellets de Madeira Produzidos no Brasil. 2010, 101 f. Dissertação (Mestrado em Engenharia Mecânica), Faculdade de Engenharia de Guaratinguetá da Universidade Estadual Paulista, Guaratinguetá.

Garcia, D.P; Caraschi, J.C.; Ventorim, G.. O setor de pellets de madeira no Brasil. Ciência da Madeira, v.8 n.1, p.21-28, 2017.

Gillespie, G.D.; Everard, C. D.; Fagan, C.C.; Mcdonnell, K.P.; Prediction of quality parameters of biomass pellets from proximate and ultimate analysis. Fuel. v.111, p. 771-777,2013.

Magelli, F.; Boucher, K.; Bi, H. T.; Melin, S.; Bonoli, A.. An environmental impact assessment of exported wood pellets from Canada to Europe. Biomass and Bioenergy, v.33, p.434–441, 2012.

De Mendiburu, F.. Agricolae: Statistical Procedures for Agricultural Research. R package version 1.2-8. 2017. URL https://CRAN.R-project.org/package=agricolae

Quirino, W. F.; Vale, A. T.; Andrade, A., P., A.; Abreu, V., L., S.; Azevedo, A., C., S. Poder calorífico da madeira e de materiais lignocelulósicos. Revista da madeira, n. 89, p. 100-106, 2005.

R core team. R: A language and environment for statistical computing. Viena : R Foundation for Statistical Computing, 2017. Statistical Software. URL https://www.R-project.org/.

Serrano, D. M. C. Avaliação do Potencial de Produção e Exportação de Pellets Combustível no Polo Florestal da Região Sul do Brasil. 2009. 90 . Dissertação. (Programa de Pós-Graduação em Planejamento de Sistemas Energéticos) - Faculdade de Engenharia Mecânica da Universidade Estadual de Campinas, Campinas, 2009.

Silva, D. A.; Ribeiro R. M.; Simetti, R.; Sfeir, T.. Indústria de Pellet e Perspectivas de Mercado. 2012. Available in: <http://malinovski.com.br/CongressoFlorestal/Trabalhos/05-Silvicultura/SIL- Artigo-37.pdf>. Accessed in 26/08/2016.

THERMODYNAMIC MODELING FOR THE DRYING OF SLUDGE WITH THERMAL ENERGY OF LOW TEMPERATURE TO AIR BLOWER IN WASTEWATER TREATMENT PLANT

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Abstract
Biological sludge can be used as solid biofuel in industrial processes or raw material for the production of syngas in gasification. However, these uses remain limited due to several factors, among them the high cost to perform the drying of this type of biomass. Mechanical dryers are equipment that allows drying and sanitizing high rates of sludge and produce a biomass of considerable added value but remain linked to a high energy consumption for its operation. In view of the above, the present work developed a thermodynamic model to evaluate, in an activated sludge wasterwater treatment plant, the energy viability of the sludge drying from the low temperature thermal energy harvested from the air of the aeration system of the unit studied. The modeled conditions predicted the drying of 28,904 kg. d^{-1} wet sludge with 25% total solids (ST). The results showed that the site with the highest temperature in the air blower discharge was located in the region near the check valves and relief, registering a mean temperature of 112 °C. The mass and energy balance showed that it is possible, for the design conditions of the studied station, to dry approximately 59% of the sludge produced until reaching 90% ST at the temperature of 80 °C. The thermodynamic model of sludge drying that was developed showed to be consistent to evaluate the biological sludge drying from the use of thermal energy of low temperature, emphasizing the use of the heat regenerator 1 to realize the preheating of the mud that enters in the system from the thermal energy present in the exit air, reaching a gain of 28.98 °C and proving its importance within the model, while the heat regenerator 2 that preheats the air from the dry sludge presented a small gain of 0.41 °C in air temperature, indicating that its use may not be feasible for a real system. For the heat exchanger that performs the final heating of the air, it had a gain of 58.86 °C, reaching values of 97.78 °C in the air before entering the dryer. For air humidity, the increase of the mass transfer capacity, based on reference air, presented gains of more than 13,000% at the inlet and 689% at the outlet of the dryer, demonstrating that small heating in the drying air revealed high gains on the absorption capacity of water vapor, making the air an important element of drying when heated.

Keywords: Solid Biofuel; Drying at Low Temperatures; Activated Sludge.

Introduction

For Bidart *et al*. (2014) and Zhao *et al*. (2014) the use of sludge as fuel has gained importance through discussions on climate change and the energy crisis. In the case of Wastewater Treatment Plant (WTP), the main problem is the energy demand of the aeration system, since this is the highest cost in this type of unit (PANEPINTO *et al*., 2016).

Despite the good aeration efficiency in the oxygen transfer aspect in WTP, the aeration mechanism (blower) continues to be limited to the typical efficiency of electromechanical equipment, manifesting significant energy losses in the form of vibration, noise and, mainly, heat. The latter, which is dissipated by the blower housing and the discharged air, represents the loss of the thermal form, being produced during the air compression and movement of the internal components of the aeration equipment.

Authors such as Incropera et al. (2014), who work with thermal systems, claim that 60% of all energy consumed is rejected as heat. In the case of blowers the air discharge can vary up to 110 °C in relation to the environment, generating great heat dissipation and requiring, for some applications, forced cooling (OMEL, 2012).

The development of new technologies can allow the recovery of part of the losses and their subsequent application as energy in smaller and parallel processes. According to Defraeye (2014) and Mäkelä et al. (2014), this view can be applied to sludge dryers for the development of sustainable equipment. Therefore, the present work aims to present the thermodynamic feasibility to take advantage of the thermal energy dissipated in the blowers of a WTP to perform the drying of the sludge produced by the unit itself.

Materials and methods

The evaluation of the drying was carried out by the Thermodynamic Model of Sludge Drying (TMSD), which integrates the thermal energy of a hot source (WTP blower air) with the thermal energy demand to dry the wet sludge (sludge produced in the WTP itself).

<u>Thermography and temperature monitoring</u>

The thermal imaging was performed with a thermographic camera, Model Box 3 and Flir Systems brand, while the temperature measurement was performed with a digital thermometer of the Equitherm brand, model 315FM and accuracy of ±1 °C. Temperature measurements were carried out in two locations: Shed and air discharge from the blowers.

<u>Thermodynamic Model of Sludge Drying</u>

The TMSD is constituted in its base by mass and energy balances between the drying air and the wet sludge, the first one being used for drying the sludge and it is heated by the air in the discharge of the blowers of the Araçás WTP, while the second is the sludge originated in the centrifugation process of the station studied, as shown in Figure 1.

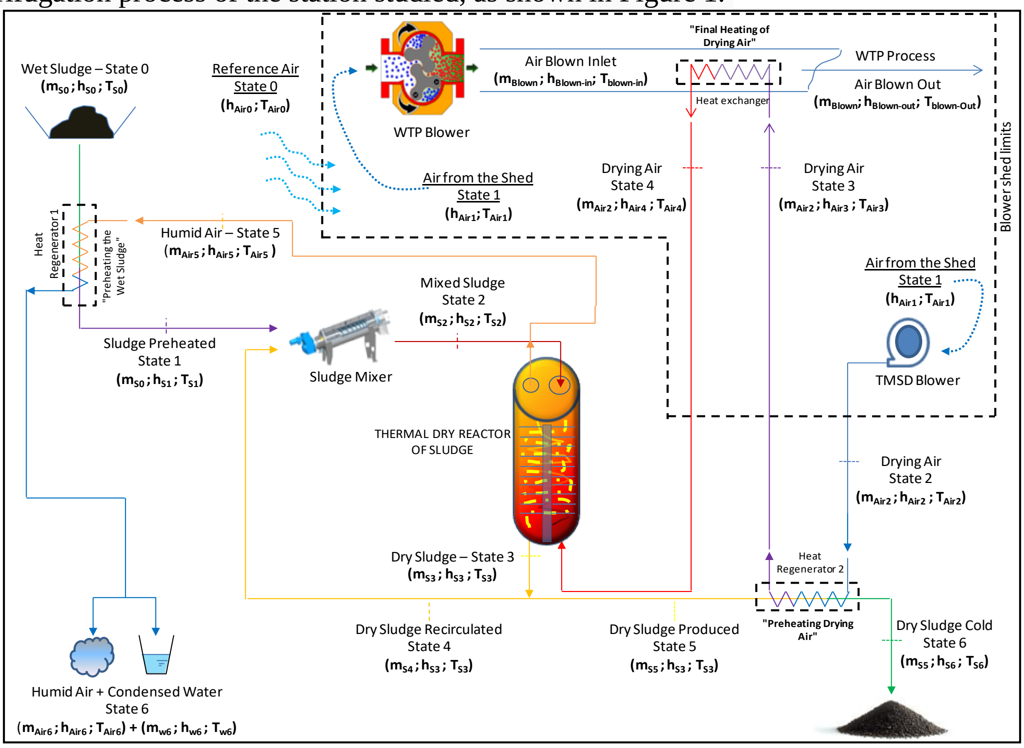

Figure 1: Flowchart of the steps provided in the TMSD.

Mass balance and sludge energy

Since sludge is a mixture of dry matter and water, the mass and energy balance was estimated for each plot, the water properties obtained from the Steam Table® software and the dry sludge enthalpy (Δh_{Sdry}) of Equation 1 of Arlabosse *et al*. (2005).

$$\Delta h_{S_{dry}} = \frac{1}{10^3}\int_{T_0}^{T_1}\left(c_{p_{S_{dry}}}\right)dT = \frac{1}{10^3}\int_{T_0}^{T_1}(1434 + 3{,}29T_0)\,dT \qquad (1)$$

Where:
Cp_{Sdry} : Specific heat at constant pressure of the dry sludge in $J.kg^{-1}.°C^{-1}$;
T_0 : Moist sludge temperature in reference in °C;
T_1 : Sludge temperature in state 1 in °C.

The Total Solids (TS) content and the reference flow of the wet sludge when entering the TMSD were 25% and 28,904 $kg.d^{-1}$, respectively, based on the average project values of Araçás WTP.

Balance of mass and energy of the air

The specific enthalpy of air (h_{Air}) was determined for each component of the mixture as a function of the variation of temperature in relation to reference (T_{air0}), as shown in Equation 2, which was adapted from Lozano and Valero (1986). The constants considered (A, B, C, D), as well as the fractions considered in the mixture, are described in Table 1.

$$h_{Air} = \frac{4{,}18}{\sum_{x=1}^{5} y'_x M_x}\sum_{x=1}^{5}\int_{T_{Airo}}^{T_{Air}}(A + BT + CT^2 + DT^3)_x\,dT \qquad (2)$$

Where:
y'_x : Corrected molar fraction of component x in the air mixture in %;
M_x : Mole mass of component x in the air mixture in $kg.kmol^{-1}$;
T_{Air}: Air temperature for a specific state in K.

Table 1: Components and constants employed.

X	Components	Constants ($kcal.kmol^{-1}$)				Molar Fraction	Molecular Mass
		A	B x 10^2	C x 10^5	D x 10^9	%	$kg.kmol^{-1}$
1	N_2	6,903	-0,03753	0,1930	-0,6861	78,09	28,013
2	O_2	6,085	0,36310	-0,1709	0,3133	20,95	31,999
3	CO_2	5,316	1,42850	-0,8362	1,7840	0,03	44,010
4	Air	4,964	-	-	-	0,93	39,948
5	H_2O	7,700	0,04594	0,2521	-0,8587	0,00	18,016

Sources of data: Henley, 1973, *apud* Lozano and Valero, 1986.

The conditions that were considered as reference for the work were 24.9 °C, 78% for relative humidity (RH) and 1,013 bar for atmospheric pressure.

Balance of mass and energy in heat exchanger and heat exchangers

The heat exchangers were modeled by the ε-NUT method, described by Incropera et al. (2014), according to Equation 3, and the effectiveness (ε) of 0.8 was adopted.

$$\dot{Q} = \varepsilon C_{min}(T_{h,in} - T_{c,in}) \qquad (3)$$

Where:
$\dot{Q}$: Amount of heat exchanged between sources/flows in kJ.s^{-1} or kW;
C_{min}: Lower thermal capacity of sources / flows in kJ.s^{-1}.°C or kW.°C^{-1};
$T_{h,in}$: Temperature of the hot source at the inlet in °C.
$T_{c,in}$: Temperature of the cold source at the inlet in °C.

Isentropic Efficiency

The temperature of the TMSD blower air was estimated based on the isentropic efficiency (η_{is}), according to Equation 4, where η_{is} is to 0.8 (MORAN, SHAPIRO, 2014)

$$\eta_{is} = \frac{T_{IS}-T_{Air1}}{T_{Air2}-T_{Air1}} \qquad (4)$$

Where:
T_{is}: Isentropic air temperature at TMSD blower discharge in °C;
p_1: Pressure inlet of the TMSD blower in bar
p_2: Pressure outlet of the TMSD blower in bar;
T_{Air2}: Drying air temperature at the outlet of the TMSD blower in °C.

Mass and energy balance in the sludge dryer

Considering the TMSD considerations, the dryer can be modeled by Equation 5.

$$H_{S2} + H_{Air4} = H_{S3} + H_{Air5} \qquad (5)$$

Where:
H_{S2}: Sludge energy rate in dryer inlet in kJ.s^{-1} or kW;
H_{S3}: Sludge energy rate in outlet in kJ.s^{-1} or kW;
H_{Ar4}: Air energy rate at dryer inlet in kJ.s^{-1} or kW;
H_{Ar5}: Air energy rate a outlet in kJ.s^{-1} or kW.

Dryer Thermal Index (DTI) and Dryer Energy Index (DEI)

The air temperature at the outlet of the dryer was used to evaluate the sludge drying capacity by the hot source in the TMSD, as shown in Equation 6. As a complement, the DEI was developed that relates the amount of heat exchanged by drying air to the maximum value (T_{Ar5}=T_{L2}), according to Equation 7.

$$DTI = \frac{T_{S2}}{T_{Air5}} \qquad (6)$$

$$DEI = \frac{T_{Air4}-T_{Air5}}{T_{Air4}-T_{S2}} \qquad (7)$$

Where:
T_{S2}: Sludge temperature at the dryer inlet in °C;
T_{Ar4}: Air temperature at the dryer inlet in °C.
T_{Ar5}: Air temperature at the dryer outlet in °C.

Results and discussion

The TMSD was developed specifically to work with mass and energy transfer at low temperatures, in addition to heat regeneration to increase overall process efficiency. In addition, the Araçás WTP was defined as a study site that presents an average flow of 400 L.s^{-1} and is located in the city of Vila Velha / ES, Brazil.

The thermography the Araçás WTP showed that the highest temperature region occurred after discharge of the blower, as shown in Figure 2. Since the thermography only shows the surface temperature, monitoring was started inside the tubing with the stem thermometer, the results being presented in Figure 3 and its simplified statistics in Table 2

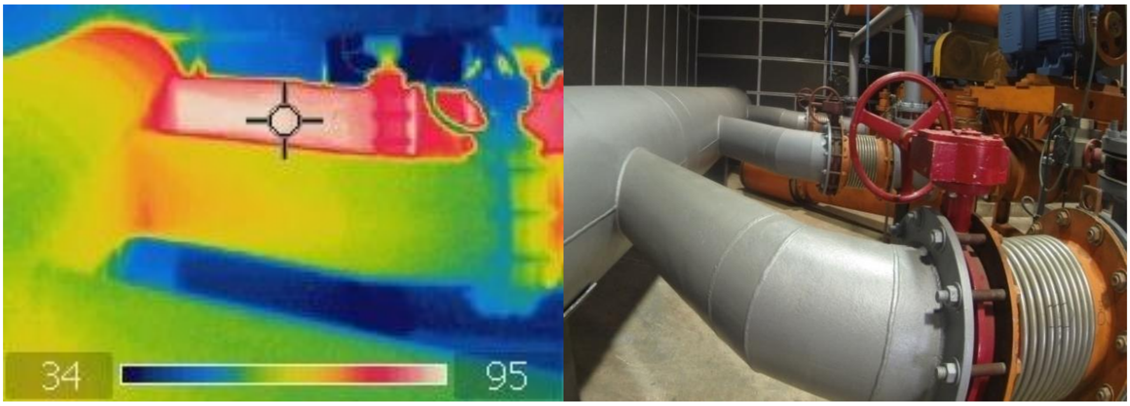

Figure 2: Thermography (left) and original image (right) of the blower shed.

Considering the reference temperature of 24.9 °C for atmospheric air outside the blower shed, the thermal variation was 13.1 °C in relation to the internal environment, a plausible variation because the shed has thermal insulation on the walls and ceiling.

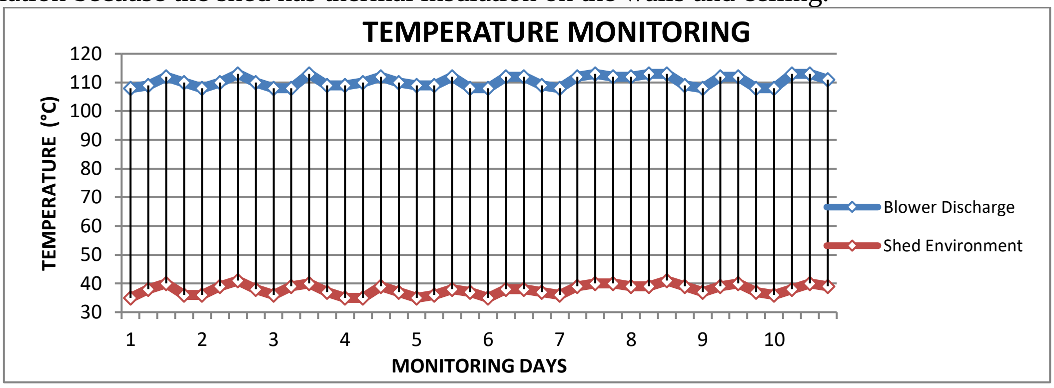

Figure 3: Distribution of monitored temperatures**.**

Table 2: Temperature monitoring statistics**.**

LOCAL	**MINIMUM**	**AVERAGE**	**MAXIMUM**	**STANDARD DEVIATION**
Blower Discharge (°C)	110	112	113	1.93
Shed Environment (°C)	35	38	41	1.79
Thermal Gradient (°C)	75	74	75	-

Sources: Own production.

The air temperature in the blower discharge showed a proportional variation to the ambient air of the shed on most monitored days, with an average increase of 74 °C, a consistent value for the operating pressure (0.710 bar) and rotation used in the blowers (72% of maximum speed), as OMEL (2012) describes.

<u>Numerical modeling results</u>

The results of the modeling indicate that it is possible to dry approximately 59% of the Araçá WTP sludge, as shown in Figure 4 when analyzing the DEI and DTI to the point that the process reaches the thermodynamic limit (close to 1). The optimization of the TMSD for the drying of 59% of the sludge was carried out with the aid of the Microsoft Excel® Solver tool, resulting in an air flow of 8.55 $kg.s^{-1}$ at the inlet of the dryer and outflows, of the evaporated water, of 8.70 $kg.s^{-1}$, as shown in Figure 5.

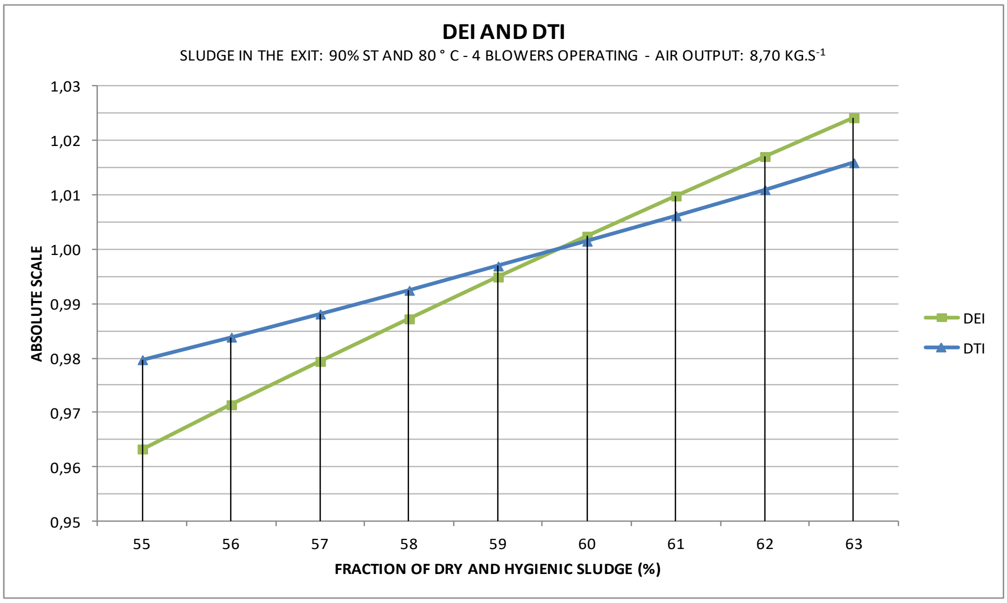

Figure 4: Variation of the DEI and DTI as a function of the variation of the sludge fraction.

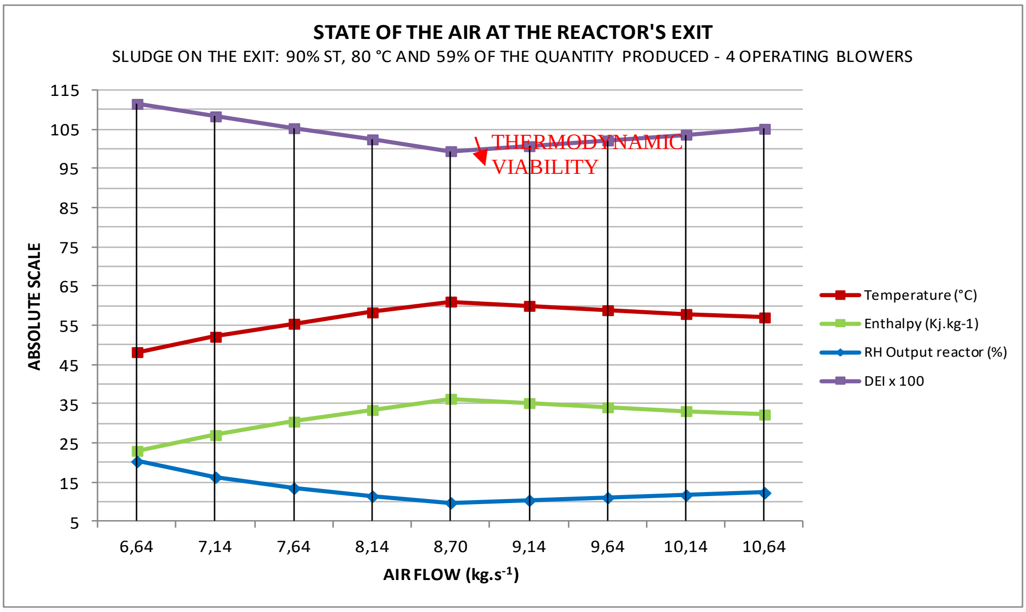

Figure 5: The variation of the control parameters as a function of the air at the dryer output.

The values of the DTI should vary between 0 and 1 for the modeling to be consistent, where the values tending to 1 (from the left) the process occurs near the thermal limit of the drying and higher the process is not thermodynamically viable, since the terminal temperatures exceeded the maximum limits allowed in the modeled conditions ($T_{Ar5} = T_{S2}$). While the DEI, similar to the DTI, varies from 0 to 1, the values tending to 1 (from the left) show that all available energy in the drying air was used, indicating that the process reached the limit of thermodynamic viability.

Figures 6 and 7 show the behavior, respectively, of air and sludge in the TMSD.

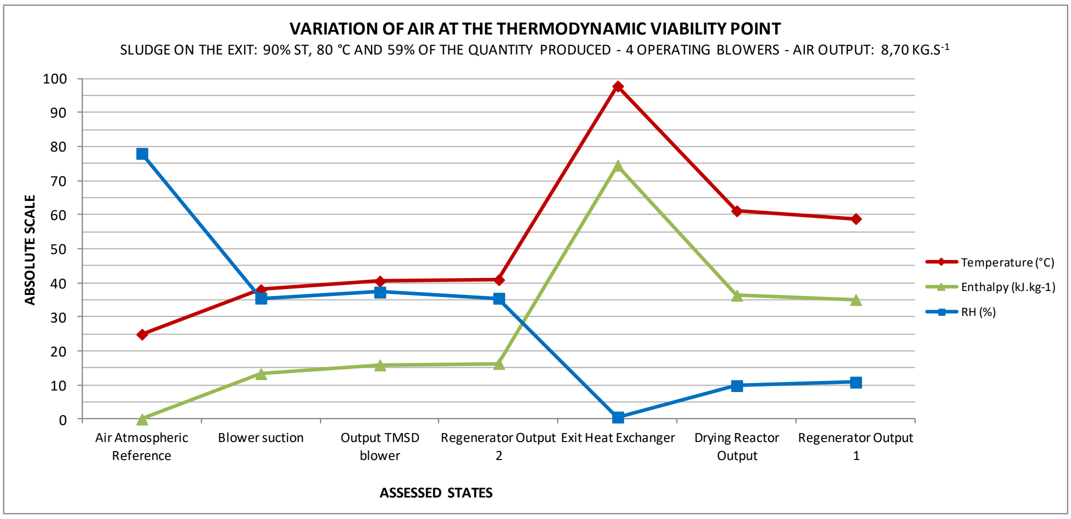

Figure 6: The variation of the air at the optimum thermodynamic point when processing 59% of the sludge produced and with air flow at the fixed output at 8.70 kg.s^{-1}.

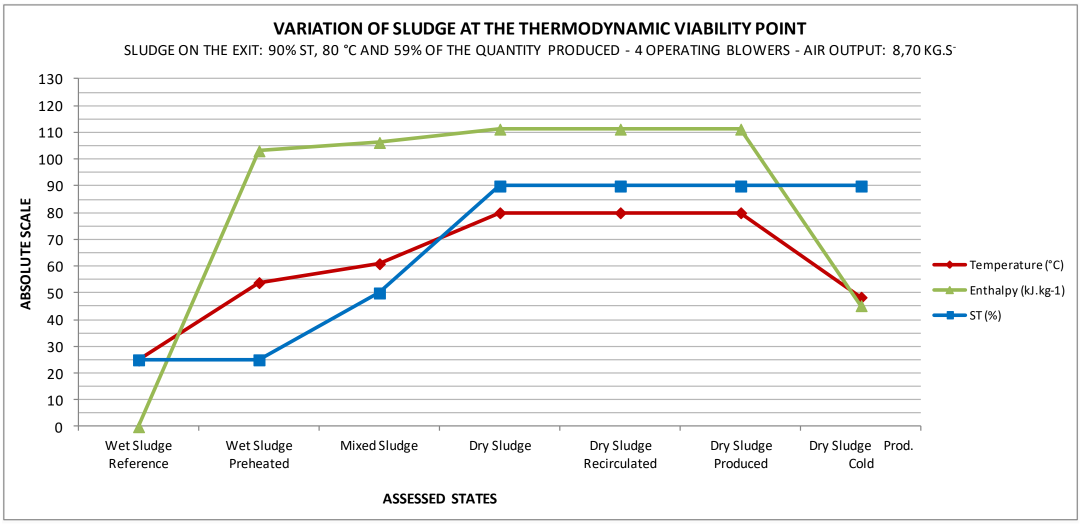

Figure 7: The variation of the sludge at the optimum thermodynamic point when processing 59% of the sludge produced and with air flow at the fixed output at 8.70 kg.s^{-1}.

It is observed that the air at the outlet of the regenerator 2, although reducing the sludge temperature by 31.59 °C, increased only 0.41 °C. While in the regenerator 1 a large energy gain is provided to the wet sludge, reaching 53.88 °C (28.98 °C) and still allowing the air to rise at elevated temperature (58.86 °C) before the reference.

The HR at the entrance of the dryer showed gains over 13,000% on the capacity to absorb water in relation to the reference, dropping in the output to 689% due to the reduction of air temperature. Proportional gains were observed by Louarn et al. (2014) which, when drying sludge, heated an air flow from 20 °C to 50 °C and reduced RH from 57% to 11%.

Modeling Considerations

Evidence of process viability for the actual scale is observed when comparing the values of this model with the results of actual drying processes at low temperatures, for example:

• Haralambopoulos et al. (2002) operated a solar dryer at temperatures of 54 °C and raised the ST content of the sludge from 0.2% to approximately 35.0%;
• Bux et al. (2002) showed variations from 3.0 to 93.0% ST in the sludge submitted to solar drying with the air temperature varying in the order of 50 °C in relation to the environment;
• Makela et al. (2014) operated a cyclone dryer by processing slurry of paper and cellulose at operating temperatures below 90 °C and obtaining ST levels of 60-70%.

Conclusion

In view of the modeled conditions, the partial thermodynamic viability was demonstrated to dry the sludge produced in an WTP from the thermal energy of the blowers themselves. This conclusion represents, within the aspects of sustainability, an important advance for the development of self-sustaining stations.

Although the results show that the sludge drying at temperatures of 80 °C and 90% TS does not allow the complete processing of the sludge produced in the Araçás WTP, the thermal energy utilization of the blowers can be used in combination with another thermal source, for example, solar or biomass, producing a hybrid process.

It was also possible to conclude that the heat regenerator 1 presented significant performance and proven importance for the present model. While regenerator 2 presented a low performance, compared to regenerator 1, it should be reevaluated.

Finally, it was observed that air heating proved to be of great importance to ensure the drying of all sludge at low temperature, since it allowed the evaporation of the water present in the material and did not make the humidity of the air a limiting factor for drying

References

Arlabosse P.; et al.. Drying of municipal sewage sludge. *Brazilian Journal of Chemical Engineering*, 22(2), Apr-June, 2005.

Bidart C.; et al.. Electricity and substitute natural gas generation from the conversion of wastewater treatment plant sludge. *Applied Energy*, 113, 404–413, 2014.

Bux M., et al.. Volume reduction and biological stabilization of sludge in small sewage plants by solar drying. *Drying Technology*, 20(4-5), 829– 837, 2002.

Defraeye T. Advanced computational modelling for drying processes – A review. *Applied Energy*, 131, 323–344, 2014.

Haralambopoulos D.A.; et al.. Dewatering of wastewater sludge through a solar still. *Renewable Energy*, 26, 247–256, 2002.

Incropera F.P. 2014. Fundamentals of Heat and Mass Transfer., New Jersey, 2014, 9 ed, p 819.

Louarn, S.; *et al*.. Experimental and Numerical Study of Flat Plate Sludge Drying at Low Temperature by Convection and Direct Conduction. *Drying Technology*: *Int. Journal*, 2014.

Lozano M. A.; Valero A.; Determinacion de la exergia para sustancias de interes industrial.

Ingenieria Química, 119-128, 1986.
Makela M.; et al.. Pretreatment of recycled paper sludge with a novel high-velocity pilot cyclone. *Applied Energy*, 131, 490–498, 2014.

Moran, M. J.; Shapiro, H. N.; Princípios de Termodinâmica para Engenharia. LTC, Rio de Janeiro, 7ª Ed, 819 p., 2014.

Omel, Bombas e Compressores LTDA. 2012. São Paulo, Brasil, p 14.

Panepinto D.; et al.. Evaluation of the energy efficiency of a large wastewater treatment plant in Italy. *Applied Energy*, 161, 404-411, 2016.

Zhao P.; *et al*.. Clean solid biofuel production from high moisture content waste biomass employing hydrothermal treatment. *Applied Energy*, 131, 345–367, 2014.

THEME: WASTES

AN ESSAY ON DRYING AND HYGIENIZATION THERMAL AT LOW TEMPERATURE: AN ALTERNATIVE FOR SANITARY SLUDGE

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Abstract
Within sanitation, sanitary sludge is a waste that has great potential for use, with emphasis on its use as raw material in production processes such as gasification or direct use as solid fuel for industrial heating. All mentioned uses are considered possible and plausible, however, to obtain the sludge in the appropriate conditions for these purposes, considered noble, it is necessary to carry out specific treatments. Among the existing treatments thermal drying is the most effective, drying and sanitizing the sludge even for use in the gasification and direct combustion, since both applications demand that the sludge is in very restricted conditions of humidity. However, the thermal drying of sludge does not present great permeability between the treatments used, because high temperatures are required in the operation of the dryers and this entails in a high energy cost that, in turn, limits its application and, consequently, the use of sanitation sludge. In view of the need to develop a technology with lower energy costs for the thermal treatment of sludge, the objective of this essay is to present the hypothesis that the sanitary sludge can be dried and sanitized with low temperature thermal energy. The drying hypothesis is based on the observation and study of the operating principles of evaporative cooling equipment, while the hygiene hypothesis is based on the observation of numerous experiments that resulted in the inactivation of microorganisms for exposures between 60-80°C for a few minutes. Therefore, the hypothesis of drying and sanitizing sludge at temperatures below 100°C could allow the development of a method that updates traditional mechanical sludge dryers, making them more efficient and viable energetically by making possible the use of alternative energy sources and low temperature. Depending on the direction of future developments, a self-sustaining energetically process can be achieved and that meets the principles of sustainability, being a viable solution economically, ecologically correct and socially just.

Keywords: drying at low temperatures; solid biofuel; sludge.

Introduction

The management of sludge in Wastewater Treatment Plant (WTP) is a problem that has been aggravating over time due to the increase in its production and high levels of quality that are required for its disposal (ZHEN *et al*., 2015).

The difficulty in determining the best and most efficient treatment for the sludge comes up against the great diversity of characteristics that it possesses, besides the innumerable possibilities for the final destination of the treated material. For Cano *et al*. (2015) and Andreoli (2006), in the thermodynamic aspect and in a simplified view, the organic matter present in the sewage, and in turn in the generated sludge, can be considered as a source of energy when observing the potential present in its chemical bonds , where it can be used as fuel in industrial processes, since the calorific value of the volatile fraction of the dry sludge can reach up to 11,880 $kJ.kg^{-1}$, similar to that of firewood.

For Zhen *et al*. (2015) and Zhao *et al*. (2014), the use of sludge as a fuel has gained great breadth and importance due to the energy crisis that has been reflected mainly in the constant increases in energy values, a scenario that reinforces the importance of developing sustainable technologies that allow energy to be obtained by processes cleaner and less impact. Also remarkable is the idea that the production of energy from the sludge reduces the primary energy demand for its own treatment.

All the mentioned uses are considered possible and plausible, however, to obtain the sludge in the suitable conditions for these purposes, considered noble, it is necessary to carry out specific treatments. Thermal drying has a higher consumption than traditional methods of treatment, however, this technique continues to be one of the most efficient and flexible processes to reduce the moisture content and to sanitize sludge, besides producing biosolids that can be easily manipulated, stored and recycled (ANDREOLI, BONNET, 2000; BENNAMOUN *et al.*, 2013).

Assays to sanitize biological sludge obtained satisfactory results from 60 ° C and with several exposure times (ANDREOLI, Bonnet, 2000; ARCE, 2009). However, high energy demand occurs during the process, since the amount of liquid present in the sludge and the latent heat of evaporation of the water are high, a context that reveals the high cost for the heat treatment and the need to develop energy efficient driers (HONG et al., 2013).

In view of the need to develop a technology with lower energy costs for heat treatment, this essay tries, although introductory, to present the hypothesis that sanitary sludge can be dried and sanitized with low temperature thermal energy.

Discussion

Mechanical sludge driers are based on the laws of thermodynamics and employ, in particular, the phenomenon of heat transfer and mass transfer between bodies. When the sludge is subjected to heating in order to reduce its moisture content, it receives a large amount of thermal energy to raise the temperature and generate a change in the physical state from liquid to vapor.

These drying equipments usually work with the principle of convective mode energy transfer in direct and conductive dryers in indirect dryers. Energy is transferred from the hot source (combustion gases or dryer walls) to the cold source (wet sludge) because of the high temperature gradient that is required for heat transfer to occur and allow the water present in the sludge to reach boiling temperature, vaporizing at 100°C when at sea level.

In this context, it can be considered that the first objective of conventional mechanical driers is to transfer energy, the mass transfer of water vapor into the air being a consequence of the process, also within the reach or not of the saturation state of the air at the outlet of the drying reactor.

On the other hand, the theory and method proposed by this study show that sludge drying can be carried out at low temperatures, provided that the main objective of the dryer is the transfer of mass and not of energy, seeking to transfer the liquid water present in the sludge to the drying air until the latter reaches the maximum water vapor pressure or saturation point.

The theory that dryers can operate at low temperatures, including sludge and drying air in equal thermal states, is part of the observation and study of the principles of operation of evaporative cooling equipment. These present in their main objective the transfer of mass between the water and the air, resulting, for the last substance, the reduction of temperature and increase of the relative humidity. However, when viewed from another point of view, such a method can also be applied in order to extract water present in a porous medium to reduce its moisture, becoming a drying process.

Applying the last concept described for the thermal drying of sludge and starting from the hypothesis that the main objective would be the transfer of mass and not of energy, it is observed that, by inducing a flow of unsaturated air through the wet sludge, transferring the mass of liquid water present in the solid to the air and leaving the latter to leave the limit of the saturated condition, such a process would allow the sludge to dry and in this case would become the porous medium of the classical evaporative cooling process and air only one drying agent.

Such a theory can be seen in Figure 1 which illustrates an adaptation of the evaporative cooling process to the sludge drying process at low temperatures.

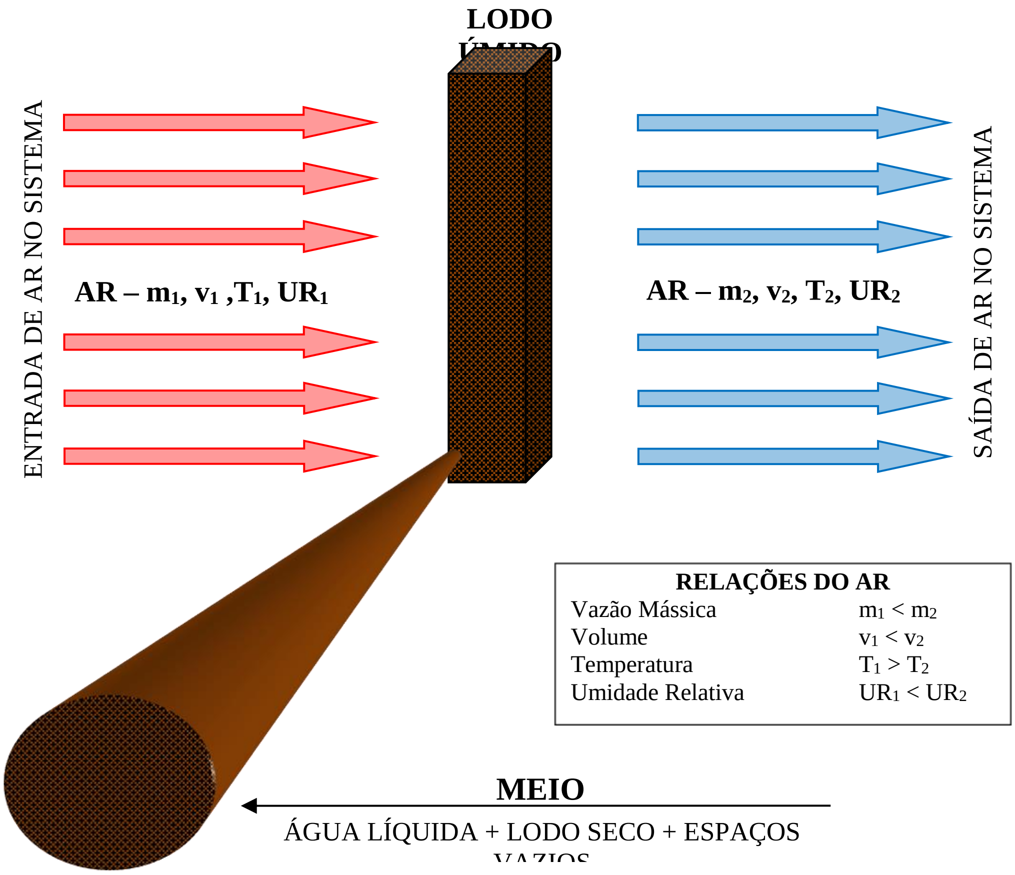

Figure 1: Didactic representation of sludge drying based on the evaporative cooling process.

Also, based on the theory of sludge drying at low temperatures, the use of a thermal source to raise the temperature of the drying air, slightly above the sludge temperature, can present two significant gains on the processing and, depending on the conditions of the source , to a third gain, as described below.

I. Increase the absorption capacity of water vapor in the drying air by raising the temperature;

II. Reduce the airflow necessary for sludge drying due to the increase in its absorption capacity which, consequently, reduces the size and costs of installation and operation of the equipment involved in the drying system;

III. Increasing the chances of obtaining, besides drying, the complete sanitation of the sludge when a thermal energy source is used, which allows the air temperature to rise to above 60 ° C.

For example, considering that the thermal drying process will be carried out at a rate of 1 kg.s-1 of dry air at sea level and with a temperature and humidity of 25 ° C and 80% RH, heating said air to temperature of 35 ° C there is an increase in its water vapor absorption capacity of 82% if the temperature were raised to 80 ° C this gain would reach 2,641%, reducing the initial relative humidity of 80% to respectively , 44% and 3% at the end of the two warm-ups, as shown in Table 1.

Table 1: Componentes e constantes empregadas.

Temperatura (°C)	**Capacidade de Absorção**[I] (g vapor/segundo)	**Variação Capacidade em Relação a Referência**	**UR**[II]
25°C*	20,169*	-	80%*
35°C	36,754	82%	44%
45°C	65,408	224%	25%
60°C	153,532	661%	11%
70°C	279,149	1.284%	6%
80°C	552,894	2.641%	3%

Nota: *: Referência; UR: Umidade Relativa. Source: Author's own production

The authors of Murthy (2009) and Dincer and Sahin (2004) describe that air heating, used in food drying systems, is used to accelerate the water evaporation process, achieving higher drying rates compared to the use of ambient conditions. Similarly, the drying assays of Deng *et al*. (2015) have shown that the higher the air temperature, the shorter the time required to dry the sludge.

Therefore, heating the air for thermal drying at low temperatures goes beyond the magnification of the absolute saturation humidity and in providing heat to the material to be dried. The heating also provides an expressive increase in the hygroscopic property of the air due to the exponential increase of the water pressure gradient between the air and the sludge, thus potentiating the efflorescence in the sludge, which is the characteristic that some hydrated substances have to release spontaneously the water into the air.

Figure 2 shows how the water vapor saturation pressure grows at an exponential rate, and as a consequence, the pressure gradient between the water that hydrates the sludge and the water vapor present in the air accompanies the same rate of change for stationary systems.

Deng et al. (2015) report that the sludge drying time and the evaporation rate are proportional to the humidity difference of the material and the air, and that difference is the driving force responsible for the diffusion of the water in the inner part of the sludge to the sludge. external part. Luboschik (1999) described a drying system for solar-powered sludge and stated that the best drying results are obtained with heated sludge and drier air, as it emphasizes the difference in the partial pressure of water vapor between the materials.

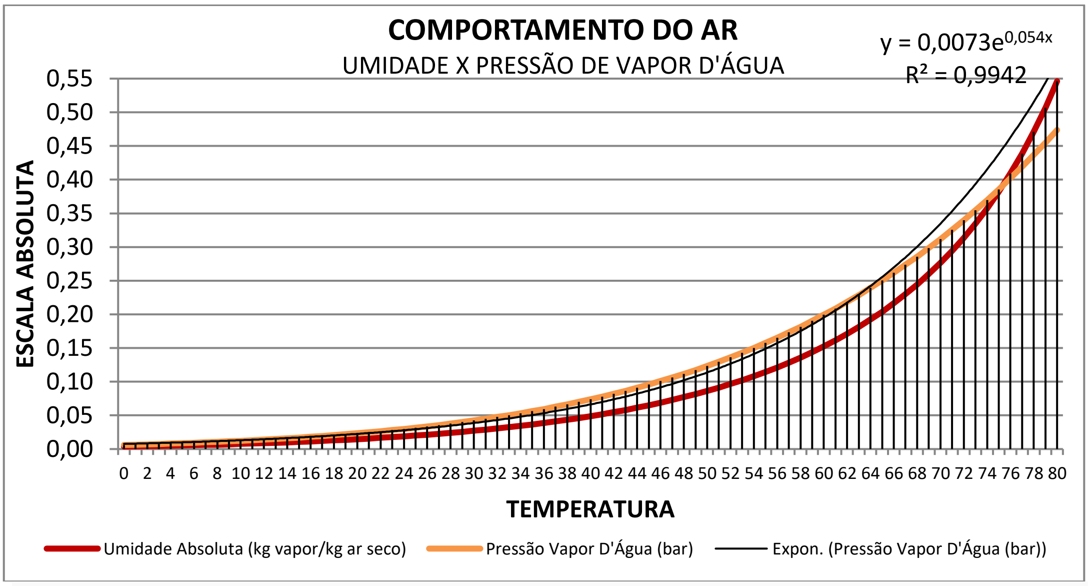

Figure 2: Curva de umidade absoluta e pressão parcial do vapor d'água em função da temperatura do ar.

Correlating the thermal drying in low temperatures with the hygienization, it can be affirmed that from the temperature of 60 ° C the complete elimination of pathogens in the sludge can be reached, becoming even more efficient when the temperature reaches 80 ° C, since the time required for the complete sanitization of the material is of the order of minutes. This relationship of temperature and exposure time was previously confirmed in the Sanitation Company of Paraná (SANEPAR) by Andreoli and Bonnet (2000). These authors submitted sludge of anaerobic origin in drying beds covered by greenhouse, achieving hygiene for viable eggs of Helminths with exposure of 50 ° C in 48 hours, 60 ° C in 6 hours and 80 ° C in 5 minutes. Also noteworthy are the results of Arce (2009) and Barés (2010), who observed a considerable reduction in the amount of microorganisms when analyzing samples of sludge that were submitted to thermal treatment at temperatures of 50, 60 and 70 ° C in time intervals , respectively, of 90, 60 and 30 minutes.

Other research has also identified good hygiene results at low temperatures, for example:

• Aroza and Kazmi (2015) investigated the treatment of sewage, through filtration in vermicompost systems, reaching the elimination of 96.9% of Salmonellas sp. and 99.3% Escherichia Coli for the temperature range of 38 to 40 ° C, hygiene not observed for the same experiment under temperatures of 25 to 27 ° C;

• Pecson et al. (2007) carried out experiments for the hygiene of biological sludge submitted to different temperatures, resulting in the elimination of the viability of 99% of the eggs of Ascaris sp. for the temperature of 50 ° C in 100 minutes of exposure, whereas for the temperatures of 40, 30 and 20 ° C the time for inactivation was in the order of days;

• Serenotti (2009) observed in sludge samples, similar to the above case, the elimination of microorganisms at temperatures of 60 ° C from 60 minutes;

• Passamani et al. (2002) report the complete elimination of the viability of helminth eggs in samples of anaerobic biological sludge for pasteurization at temperatures of 70 ° C.

Therefore, the drying and cleaning of sludge with low temperature thermal energy will allow the utilization of energy dissipated in the form of heat by productive processes of several genera, and this energy can be recovered and harnessed to maximize the drying properties of the air and, depending of the conditions, reach the sludge sanitation

Conclusion

The low-temperature sludge drying and sanitizing theory will allow the emergence of processes with reduced operating costs, since the method employed will inevitably make feasible the use of alternative energy sources and, depending on future developments, obtaining a self-sustaining process of drying and cleaning of sludge.

Finally, it is concluded that such a hypothesis could make possible the use of alternative sources of low-temperature thermal energy and, depending on future developments, the achievement of a self-sustaining process of drying and sanitizing sludge, leading to a new a proposal that will possibly allow the development of technologies that will update the traditional mechanical driers of sludge, making them more efficient and energy-efficient, in addition to meeting the principles of sustainability, which encompass economically viable, ecologically correct and socially just solutions.

References

Andreoli C.V. 2006. Biossólidos: Alternativas de uso de resíduos do saneamento. Rio de Janeiro: ABES (Associação Brasileira de Engenharia Sanitária e Ambiental), p 398.

Andreoli, C.V. and Bonnet B.R.P. 2000. Manual de métodos para análises microbiológicas e parasitológicas em reciclagem agrícola de lodo de esgoto. Curitiba, SANEPAR, p 80.

Arce E.B.M. 2009. Pretratamiento térmico y digestión anaerobia mesofílica de lodos residuales para la producción de biosólidos clase A. (Maestría en Ingeniería Ambiental) – Instituto de Ingeniería, Universidad Nacional Autónoma de México, México, p64.

Arora, S.; Kazmi, A. The effect of seasonal temperature on pathogen removal efficacy of vermifilter for wastewater treatment. Water Research, 74, (2015) p. 88-99.

Bares, M. E. Digestão e Higienização de Lodo de Estação de Tratamento de Esgotos Através de Processo Bifásico com Pré-Tratamento Térmico. Universidade Federal do Paraná. Dissertação. Curitiba, Paraná. 2010. 134 p.

Cano R., et al. 2015. Energy feasibility study of sludge pretreatments: A review. Applied Energy, 149, 176–185.

Bennamoun L., et al. 2013. Review on fundamental aspect of application of drying process to wastewater sludge. Renew. Sustain. Energy Rev., 28, 29–43.

Deng, S.; et al., Experimental and modeling study of the long cylindrical oily sludge drying process, Applied Thermal Engineering, vol. 91, 2015, p. 354-362.

Dincer, I.; Sahin, A.Z., A new model for thermodynamic analysis of a drying process, International Journal of Heat and Mass Transfer, vol. 47 (4), 2004, p. 645–52.

Hong S., et al. 2013. Process consideration of fry-drying combined with steam compression for efficient fuel production from sewage sludge. Applied Energy, 103, 468–476.

Luboschik, U., SOLAR SLUDGE DRYING - BASED ON THE IST PROCESS, Renewable Energy, vol. 16, 1999, p. 785-788.

Murthy M.V.R. 2009. A review of new technologies, models and experimental investigations of solar driers. Renew. Sustain. Energy Rev., 13, 835–844.

Passamani, F.R.F.; et al. Higienização de lodo utilizando caleagem e pasteurização em uma pequena estação de tratamento de esgoto combinando reator UASB e biofiltro aerado submerso. In: Aidis, D.F., Femisca, 2002, p.1-6.

Pecson, B.M., et al., The effects of temperature, pH, and ammonia concentration on the inactivation of Ascaris eggs in sewage sludge, Water Research, vol. 41, 2007, p. 2893 – 2902.

Serenotti, Fernando. A avaliação da secagem para redução de volume e inativação de microrganismos em lodo de ete. Campinas, São Paulo. 203 p. [s.n.], 2009. Tese (Doutorado) – Universidade Estadual de Campinas, Faculdade de Engenharia Química.

Zhao P., et al. 2014. Clean solid biofuel production from high moisture content waste biomass employing hydrothermal treatment. Applied Energy, 131, 345–367.

Zhen G., et al. 2015. Mesophilic anaerobic co-digestion of waste activated sludge and Egeria densa: Performance assessment and kinetic analysis. Applied Energy, 148, 78–86.

CHARACTERIZATION OF COCONUT BABAÇU RESIDUE FOR ENERGY ENHANCEMENT

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Abstract
Since the first oil shock in 1973, the search for the insertion of renewable sources in the energy matrix has been gaining prominence among nations and organizations worldwide. The generation and use of energy is one of the most delicate aspects of environmental problems, due to the excessive use of fossilsources. In this sense, biomass is a renewable source alternative whose use for energy purposes does not contribute to the generation of greenhouse gases. The use of this resource as an energy source can be achieved through waste from agricultural and / or agro-industrial crops. Babaçu is a palm tree whose fruit is found in large quantities in some Brazilian states, mainly in the Northeast Region. The almond is the constituent of the fruit that presents aggregated commercial valueand represents approximately 10% (by mass) of its composition. The remaining parts of the fruit make up the bark, which is considered as waste, which represents about 90% of the total. In the year 2013, the production of almonds was 89,739 tons (IBGE, 2014). Which is equivalent to a generation of 897,39 t/year of waste, an amount ten times the commercial production, considering the bark of representation in the fruit. One possibility of using this residual biomass is its use as a solid fuel. For this, it is of fundamental importance to know its physical and chemical properties. In view of the above, the main objective of this study was to characterize samples of bark of babaçu coconut, in order to evaluate their viability for solid fuel production. The waste characterization was carried out by analyzing immediate composition and the gross calorific value (PCS) for which we followed the methods described in the ABNT NBR 13999, ASTM E711-87 / 2004, ASTM D3172-13 / 2013, ASTM D3175-11 / 2011. The moisture content obtained was 11%, and the upper calorific value was 17,7185 MJ.kg^{-1}, values very close to the value of wood chips. And among the immediate analyzes 81,680% is of volatile material content, which represents high ignition power to biomass. The results indicate that biomass has similar properties to wood residues and is therefore suitable for use as solid fuel in thermochemical processes.

Keywords: Energy, Biomass, Waste, Characterization.

Introduction

Since the first oil shock in 1973, the search for the insertion of renewable sources in the energy matrix has been gaining prominence among nations and organizations worldwide. Water pollution, deforestation and climate change are examples of environmental impacts that characterize the devastating and disturbing magnitude risks of excessive use of fossil fuels. (VECCHIA, 2010). The generation and use of energy is one of the most delicate aspects of environmental problems due to the excessive use of fossil sources (GOLDEMBERG, 2009; BRAGA et al., 2005).

In that sense, biomass is a renewable energy source alternative that can help to minimize the environmental problems, and present high availability (ANEEL, 2005). Given the favorable conditions of production in the year 2016, the biomass was the third Brazil's most important generation source in the InnerSupply of Electric Power (BEN, 2017). However, for the efficient use of biomass energy, studies are required that involve everything from the choice of raw material to the definition of the best process for the energy utilization of the same.

Agricultural crops and agribusiness generate waste of great representativity, due to the significant production data from the agroindustry (HENRICHS; KLEINBACH; REIS, 2011). The 2012 National Solid Waste Plan estimates that the generation of waste from the agro-industry associated with Brazilian agriculture represents about 290,838,422 tons / year, which represents an installed energy potential of up to 23 GW / year (PNRS, 2012).

Specifically, the babaçu is a palm tree whose fruit is found in large quantities in some Brazilian states, mainly in the Northeast Region. The babaçu nut consists of the following components: epicarp (outermost layer is very resistant), mesocarp (rich in starch), endocarp (hard) and almonds (one to six per fruit). The fruit has extreme added value, with potential use in the cosmetics and food industries. Almonds, is extracted from the oil babaçu oil used in soap, soaps and cosmetics in general. On the other hand, the other constituents that make up the bark, which represent about 90% of the total, are considered as waste. (SOLAR; VITALI; MUTO, 2007).

A babaçu palm can produce 3 to 5 bunches of coconut and can have average yield of up to 400 fruits per cluster. The production of almonds, according to IBGE was 89,739 tons in the year 2013. Considering that 90% of the total fruit is residue, the quantitative generated of this part of the fruit are expressive. Considering the production of the year 2013, a generation of 897,39 can be estimated tonnes of waste per year. Currently, this residual biomass is partly used for handicrafts, with the rest being discarded in dumps. (CONAB, 2015). An alternative to the use of this residual biomass is its use as an energy source, which would allow the use of a solid fuel without the need to increase the planted area. However, it is fundamental to know its physical and chemical properties, either to define the most appropriate process or to correctly dimension equipment and operating conditions.

Thus, this study had as main objective to characterize samples of bark of babaçu coconut, in order to evaluate the viability of the same for solid fuel production.

Materials and methods

The biomass used is agricultural residues from the babaçu crop. Figure 1. The samples were collected in the municipality of Baturité, polo city of the Maciço of Baturité, micro region of the state of Ceará, Brazil.

The samples went through the particle size reduction step. In this process, a manual grinding was performed with scissors and / or table saw, in addition to the residential liquefying aid for a smaller particle size and a greater uniformity between them.

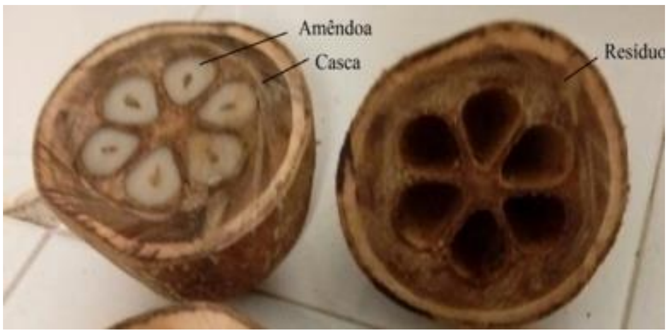

Figure 1 - Babaçu Coco Bark (CCB)

The analyzes were performed in quadruplicate, in order to give the results more reliability.

- Determination of the Moisture Content (U)

The method used met the standard NBR 14929 (ABNT, 2003). A DL-CBE model greenhouse was used. The temperature employed was 105°C, mass of 5 grams and a period of 30 minutes of each drying until stabilization of the weight of the sample. There was thus obtained dry mass in grams and moisture sample, on a wet basis.

- Determination of Calorific Power (PCS)

The analysis was performed according to ASTM E711-87 (ASTM, 2004) and using an IKA / C200 calorimeter pump. In the calorimetric pump, the procedure is carried out by means of a compression system, having the oxygen as element for combustion reaction, in a pressure of 30 bar. Returning the result of the analysis in MJ / kg.

Immediate Analyzes

Determination of Volatile Material Content (TV)

The methodology used was based on ASTM D3175-11 (ASTM, 2011). Was used as equipment for complete combustion of the samples QUIMIS a mufflefurnace, Q318M model. Used to sample 1 gram of mass at a temperature of 900ºC for a time of 10 minutes, 3 minutes in the oven lid and 7 minutes inside the oven lid closed.

Determination of Ash Content (TC)

The analysis to ascertain the ash content was performed based on standard NBR 13999. A muffle furnace QUIMIS, model Q318M. The procedure was performed on samples of 5 grams, for a time of 4 hours at 525°C temperature.

Determination of the Fixed Carbon Content (CF)

The determination of fixed carbon content in the samples was conducted based on ASTM D3172-13 (ASTM, 2013), according to Equation 1.

$$CF = 100 - (TC + TV) \tag{1}$$

In which:
CF = Fixed Carbon Content (%);
TV = Volatile content (%);
TC = Ash content (%).

Results and discussion

The results obtained for analyzes of moisture, immediate composition and higher calorific value are presented in Table 1.

Table 1 - Characterization analyzes of the Bark of Coco Babaçu (CCB)

		Quadruplicates	Average	Standard deviation
U in b.u (%)		11,306	11,005	0,19 0
		10,900		
		10,631		
		11,183		
PCS in b.u (MJ.kg-1)		17,906	17,718	0, 140
		17,739		
		17,508		
		17,721		
Immediate Analysis	**TV (%)**	82,000	81,680	0.290
		81,200		
		81,700		
		81,800		
	TC (%)	10,226	11,442	1,680
		14,244		
		10,082		
		11,214		
	CF (%)	7,774	6,554	1.41
		4.556		
		8,128		
		6,986		

Source: Authors (2016)

The value obtained for moisture of the babaçu coconut shell was 11,00%, on wet basis. This data represents a small amount of water contained in the sample, comparable to the wood chip, which has 15,7% moisture in the wet basis, as shown by Silva, Cardoso and Saiki (2004). Thus are energy use, enables the application of feedstock in thermochemical processes applications; for example, which suggest the lowest possible moisture content (FRANCISCO, 2012).

The Upper Calorific Power (PCS) of the babaçu coconut shell was 17,71 MJ. Kg^{-1}. The result is satisfactory when it relates to use as solid fuels. And compared to PCS wood chips, Silva, Cardoso and Saiki (2004), shows a value corresponding to 18,24 MJ. kg $^{-1}$.

The calorific value is termed higher when the combustion takes place at constant volume and the water formed in this process is condensed. Therefore, the moisture is inversely proportional to the fuel burning power (NOGUEIRA; LORA, 2003). In this sense there is a uniformity between data when the PCS and humidity of the CCB.

The results of the immediate composition of the babaçu coconut residue are shown in Figure 2.

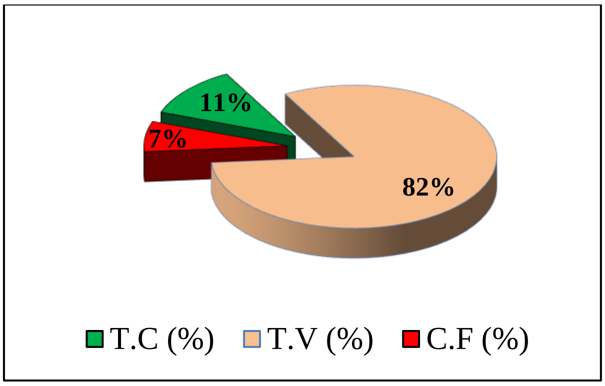

Figura 2 – Composition Babaçu Coco Bark (CCB)

The high content of volatile material, 82%, shows a large volume of combustible gases that can be released in a complete combustion process. In addition, the high value shows that the bark of babaçu coconut, represents a biomass with ease of ignition even at low temperatures.

For ashes, 11% is a very representative value when compared to the sugarcane bagasse, which according to Williams et al. (2012) has an ash content of 2,2 %. However, if compared to the Brazilian mineral coal, which presents 41.19%, according to FALLAVENA (2013), it is a biomass with low content of ash in the composition. It is believed that this quantitative refers to the form of collection, which despite being careful, creates a risk of contamination with inorganic materials, such as sand, earth, stones, among other substances. In this way, the cleaning platform before carbonization is a way to avoid such risks, and reduce possibilities of incrustations in the equipment, and could consequently increase the calorific value of the biomass.

In combustion processes, a high amount of ash can cause clogging and corrosion problems, for example. In this way, a complementary study is necessary to know the composition of these ashes.

In the case of fixed carbon content, the result was 7%, a value related to the amount of combustible material that can be oxidized in combustion processes.

Conclusion

The results obtained in the characterization study showed a high energetic potential added to the bark of babaçu coconut. We obtained significant data calorific power, comparable to that of wood chips, which are widely used in the energy sector, in addition to low humidity, which would enable their use in thermochemical processes such as combustion, gasification or pyrolysis . The content of volatile material, greater than 80%, enhances its high energy power, especially in application to obtain energy in the form of heat.

References

Goldemberg, J. *Biomass and energy*. New Chemistry, São Paulo, v. 32, n. 3, p.582-587, Mar. 2009. Available at: <http://www.scielo.br/pdf/qn/v32n3/a04v32n3.pdf>. Accessed on: 29 Jul. 2016.

Silva, J. N.; Cardoso, J. S.; Saiki, E. T. Use of Biomass in the Drying of Agricultural Products Via Gasification with Combustion Adjacent of the Gases Produced. *Agricultural Engineering*, Jaboticabal, v. 24, n. 2, p.405-411, Aug. 2004.

Soler, M. P.; Vitali, A. A.; MUTO, E. F. Breaking technology of babaçu coconut (*Orbignya speciosa*). *Science Food Technology*, Campinas, v. 27, n. 4, p.717-722, set. 2007.

Williams, A. et al. Pollutants from the combustion of solid biomass fuels. *Progress In Energy And Combustion Science*, v. 38, n. 2, p.113-137, abr. 2012. Elsevier BV.

Braga, B. et al. Introduction to Environmental Engineering: The challenge of sustainable development. 2. ed. São Paulo: Person, 2005. 317 p.

Nogueira, L. A. H.; Lora, E. E. S. Dendroenergy: fundamentals and applications. 2. ed. Rio de Janeiro: Interciência, 2003.

Fallavena, V. L.V. et al. Caracterização Detalhada de Material de Referência Certificado De Carvão Brasileiro. *Química Nova*, v. 36, n. 6, p.859-864, mar. 2013.

Hinrichs, R. A.; Kleinbach, M.; Reis, L. B. Biomass: From plants to waste. In: HINRICHS, Roger A.; KLEINBACH, Merlin; REIS,Lineu Belico dos. Energy and Environment. 4. ed. São Paulo: Cengace Learning, 2011. Chap. 623-652.

Vecchia, R. Renewable fuels: driving forces for a new energy civilization. In: VECCHIA, Rodnei. The Environment and Renewable Energy: Instruments of Visionary Leadership for sustainable society. São Paulo: Manole, 2010. Chapter 4. p.145-207

Francisco, R. P. Thermochemical Study of Fuel Burning in Boilers Using Energy Balances. 2012. 148 f. Dissertation (Master degree) - Energy Engineering Course, Federal University of São João Del- Rei, São João Del Rei, 2012.

BRAZIL. Ministry of the Environment. National Solid Waste Plan – PNRS. Brasília, 2012.

Brazilian Institute of Geography and Statistics - IBGE. Production of Plant Extraction and Forestry, base year 2013, Rio de Janeiro, v. 28, p.1-69, 2014.

Proposal of minimum prices: 2015/2016 crop Sociobiodiversity products. Brasilia: Conab, v. 2, sea. 2015. Available at: <http://www.conab.gov.br/OlalaCMS/uploads/arquivos/15_08_19_09_15_16_proposta_preco_minimo_-sociobiodiversidade.pdf>. Access in: April 17 2017.

ABNT -. Brazilian Association of Technical Norms (2003). NBR 14929. Wood - Determination of the moisture content of chips. Method by oven drying.

ABNT -. Brazilian Association of Technical Norms (2003). NBR 13999. Paper, paperboard, cellulosic pulps and wood - Determination of the residue (ash) after incineration at 525°C.

National Electric Energy Agency (ANEEL) (Brazil). Atlas of electric power in Brazil. 2. Ed.. Brasília, 2005. 243 p.

ASTM - American Society for Testing and Materials (1989). D 3172: Standard Practice for Proximate Analysis of Coal and Coke.

ASTM - American Society for Testing and Materials (2011). D 3175

Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke.

ASTM - American Society for Testing and Materials (2004). E 711-87. Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel by the Calorimeter Bomb.

Brazil. Ministry of Mines and Energy - MME. National Energy Balance (BEN), base year 2016. Energy Research Company (EPE). Rio de Janeiro, 2017. Available in: <https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2017.pdf>. Access in: 20 jan. 2018.

CHARACTERIZATION OF THE RESIDUE OF THE DESPOOLIZATION OF BLACK LIQUOR ORGANOSOLV DE *Eucalyptus paniculata*

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Abstract
Lignin is considered as a residue in pulp and paper pulp production processes. Therefore, it is a low value-added product, but it is a raw material with great potential where they could be developed for several interesting applications. With the new concepts of biorefinery, it is necessary to search for the use of industrial waste, with the obtaining of new products. The use of alternative lignocellulosic raw materials (straw, pruning residues, forestry, agricultural or industrial waste) and application of new green technologies are under intensive research for bio-refinery development processes. Operating under depolymerization conditions lignin can produce some phenolic components and other products (coke and residual lignin). In order to take advantage of these residues, this study aimed to evaluate the characterization of the coke and residual lignin from the depolymerization of the black liquor Organosolv of *Eucalyptus paniculata*, where they were introduced into the stainless-steel reactor (Parr 4836) equipped with a heating mantle, mechanical stirrer and gauge the 600 ml of the liquor obtained with constant reaction conditions at 215 ± 2 ° C at 36.5 ± 2 bar with stirring, with 3 times (30, 45 and 60 min). Was analyzed the yield of products produced and all were characterized by various analytical techniques, the residual solid by infrared spectroscopy (ATR-IR), gel permeation chromatography (GPC), the antioxidant activity of the analyzed by the radical ABTS (2,2-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)) assay. In addition, the total lignin content (soluble and insoluble) and the ash content were evaluated. The results will show that the longer the depolymerization time the lower the total lignin content and the ashes. The residue solid presented a slight decrease for the inhibition capacity of the radical ABTS with the treatment held in batch reactor.

Keywords: biorefinery, continuous reactor, batch reactor.

Introduction

The future generation biorefinery will include treatments leading to the preparation of compounds with high added value, such as extraction, fermentation and controlled pyrolysis, combined with traditional methods (Clark, 2007).

According to Fitz Patrick et al. (2010), the implementation of an industrial biorefinery, has great potential mainly because industries are the main sources of raw biomass. Specifically, lignocellulosic biorefinery to produce bio-fuels, chemicals and materials is presented as a solid alternative to the current petrochemical platform and a possible solution to the accumulation of greenhouse gases.

The pulp and paper industry is the largest conversion of existing biomass but still only produces as main products: pulp, paper and some specialty chemicals (Zhang et al., 2011). Today this reality is changing; it is very attractive to improve the profitability of forest products industry through integrated biorefinery to produce new structural products, fuels and other pulp (Heiningen, 2006). According to Zhang et al. (2011), existing infrastructure of pulp and paper can in principle be modified to develop modern biorefinery plants.

New methods of treatment of lignocellulosic materials, seeking better use of raw material, not only the production of pulp, but also lignin, sugars and other products in order to exploit the entire biomass component are emerging.

This is the reason, the present study aims to characterize the residue solid by base-catalyzed depolymerization obtained from black liquor Organosolv, produced by different routes in order to achieve a better performance of a bio-refinery with to use of various products obtained.

Materials and methods

In this work *Eucalyptus paniculata* Sm. Wood obtained in a homogeneous site located in the city of Charqueadas (29º 57 '17 "south latitude and 51° 37' 31" W); Rio Grande do Sul, Brazil was used, by Organosolv process described to García et al. (2010) using a solution of ethanol-water 60% (v / v), in a solid: liquid ratio of 1:10 at 180 ° C for 90 min. After reaction, solid fraction was separated from the liquid fraction by filtration, and liquid fractions obtained were concentrated without precipitating the lignin, about 20% of the ethanol was removed from the black liquor before promoting hydrolysis by base-catalyzed depolymerization where they were introduced into the stainless steel reactor (Parr 4836) equipped with a heating mantle, mechanical stirrer and gauge the 600 ml of the liquor obtained with constant reaction conditions at 215 ± 2 ° C at 36.5 ± 2 bar with stirring, with 3 times (30, 45 and 60 min).

Results and discussion

In order to know better the composition of this residual lignin and the changes in composition that has suffered in its own structure were characterized from FTIR, GPC.

FTIR analysis

In Figure 1 the FTIR analysis results of solid residue are shown. To better evaluate the effect of reactions of the structure of lignin in different conditions.

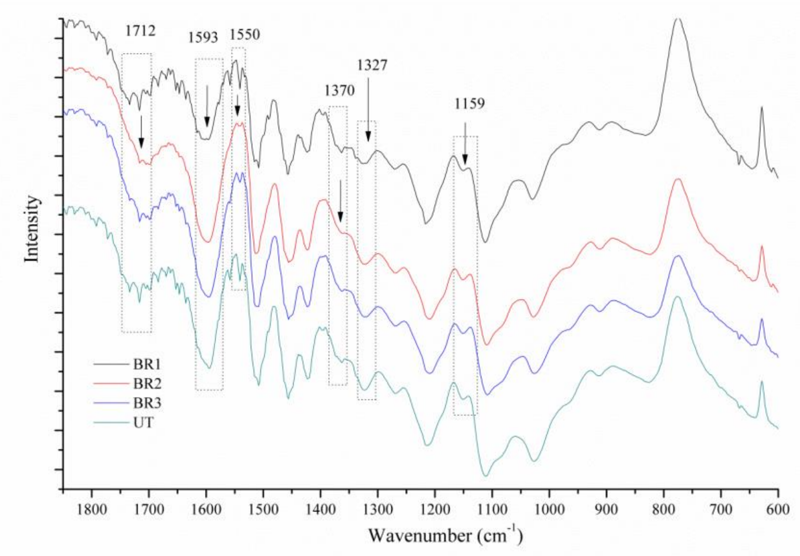

Figure 1. ATR-IR spectra (from 1850 to 600 cm^{-1}) of solid residue

Second Dos Santos et al (2014), the peak at 1712 cm^{-1} is referred to conjugated carbonyl vibration. All the spectra showed typical bands at 1593 and 1515 cm^{-1}, corresponding to aromatic ring vibrations. In peak 1593 cm^{-1} is possible look with a reduction in BR1 sample, compared with other samples. The BR2 present a modification of the 1550 cm^{-1} peak, second Tondi et al. (2014) refers to this modified lignin with a greater presence of asymmetric substituent.

The peak at 1370 cm^{-1} is due to the bending vibration of the phenolic OH groups. The more interesting change observed was the intensity of the peak at 1327 cm^{-1}, which according to Del Río et. al (2007) indicates the ring breaking of siringil (S) with a reduction in BR1 compared with other samples.

Moreover, a peak at a shoulder at 1159 cm^{-1} units represents S (Kline et al. 2010), a reduction in this work for the samples treated with longer times (BR2 and BR3) have been reported.

Molecular weight distribution

The results of gel permeation chromatography (GPC) showed that average molecular weight (M_w) of residual solids were very different for the analyzed samples and showed values between 7750 and 11262 g/mol (Table 1).

Table 1. Average values of Mw (weight-average), Mn (number-average) and Mw/Mn (polydispersity) of solid residue.

Experiment	Mn	Mw	Mw/Mn
UT	1409	10862	7.7
BR 1	1703	11262	6.6
BR 2	1372	7750	5.6
BR 3	1439	9232	6.4

It is possible to observe the results of residual solids (UT) has a high average Weight average (Mw) (10862) is similar results to previous studies (Dos Santos et al. 2014) for Organosolv lignin *Eucalyptus paniculata* with values 10193 molecular weight, the only sample that did superior presented results was the BR1 with (11262). Second to Erdocia et al (2014), the Mw of the residual solids after BCD is similar to natural lignin. Even after all the treatments applied, there are no major differences in Mn getting between (1372 and 1703) and polydispersity being among (5.6 and 7.7) and the BR2 that presented the greatest differences among the other samples.

Antioxidant behaviour of products solid (lignin and coke).

Table 2 shows the results for antioxidant properties analysis products solids and lignin untreated, where it can be seen that the antioxidant properties of all studied lignin revealed a high antiradical (ABTS) scavenging activity (>90%) furthermore, was compared with Trolox (ZHONG & SHAHIDI, 2015).

The residue solid showed a slight decrease for the inhibition capacity of the radical ABTS with the treatment held in batch reactor. Since the samples untreated presents an antioxidant capacity to radical ABTS very near to Trolox. The sample showed less capacity was the BR2.

Table 2. Average values of % ABTS inhibition, for the different solid residue compared to Trolox.

Experiment	ABTS inhibition (%)
Trolox	99.72 (0.1)
UT	97.22 (0.8)
BR1	96.69 (0.05)
BR2	94.06 (1.3)
BR3	95.82 (1.2)

The values in parentheses are SD.

The important thing that can be observed with the capability of inhibiting the ABTS that the solid waste could be utilized for other purposes due to its high antioxidant power, even with the extraction of phenolic compounds there was no significant loss in antioxidant capacity remains above 90 %. Use as the antioxidant, can be considered a good alternative to use of the waste generated in a Base-Catalyzed depolymerisation.

Conclusion

In FTIR analysis results of solid residue, all the spectra showed typical bands at 1593 and 1515 cm-1, corresponding to aromatic ring vibrations, with a reduction in BR1 in peak 1593 cm-1. The BR2 present a modification of the 1550 cm-1 peak, refers to this lignin asymmetric. The more interesting change observed was the intensity of the peak at 1327 cm-1 indicates the ring breaking of siringil with a reduction in BR1, compared with other experiments. Average molecular weight (Mw) for residual solids presented values between 7750 and 11262 g/mol, superior presented results were the BR1.

Acknowledgments

The authors would like to thanks to CNPq-Brazil for Phd scholarship DGE (246018/2012-7), the Federal University of Pará- UFPA, the Federal University of Pelotas-UFPel and the University of the Basque Country for financially supporting this research

References

Clark, J.H., Green chemistry for the second generation biorefinery—sustainable chemical manufacturing based on biomass. *Journal of Chemical Technology and Biotechnology* , v. 82, n.7,603–9, 2007.

Del Rio. J. C.. Gutiérrez. A.. Rodriguez. I. M.. Ibarra. D.. and Martinez. A. T. Composition of non-woody plant lignins and cinnamic acids by Py-GC/MS. Py/TMAH and FT-IR. *Journal of Analytical and Applied Pyrolysis*. v.79, n.1, 39-46,2007.

Dos Santos, P. S. B, de Cademartori, P. H. G., Prado, R., Gatto, D. A., & Labidi, J. Composition and structure of organosolv lignins from four eucalypt species. *Wood Science and Technology*, v.48, n.4, 873-885, 2014.

Erdocia, X., Prado, R., Corcuera, M. Á., & Labidi, J. Base catalyzed depolymerization of lignin: Influence of organosolv lignin nature. *Biomass and Bioenergy*, v. 66, 379-386, 2014.

FitzPatrick, M., Champagne, P., Cunningham, M. F.and Ralph A. W. 'A biorefinery processing perspective: treatment of lignocellulosic materials for the production of value-added products'.

Bioresource Technology v.101, n.23,8915–22, 2010.

García A., Toledano A, Andrés MA, Labidi J.Study of the antioxidant capacity of Miscanthus sinensis lignins. *Process Biochem*. V.45, 935–940,2010.

Heiningen, A.V. Converting a Kraft pulp mill into an integrated forest biorefinery. *Pulp and Paper Canada* v.107, n.6,38–43, 2006.

Kline L.M., Hayes D.G., Womac A.R. and Labbe. N. (2010) Simplified determination of lignin content in hardand softwood via uv-spectrophotometric analysis of biomass dissolved in ionic liquids. *Bioresources*. V.5, n.3, 1366–1383,2010.

Tondi G, Petutschnigg A. Middle infrared (ATR FT-MIR) characterization of industrial tannin extracts. *Industrial Crops and Products*, v.65, 422-428, 2014.

Zhang, X., Paice, M. G., Deng, J., Zhu, J. Y., and Pan, X. J. 2011., Modify existing pulp and paper mills for biorefinery operations. *Sustainable Production of Fuels, Chemicals, and Fibres from Forest Biomass*, 395–408.

Zhong, Y.; Shahidi, F. In: *Handbook of Antioxidants for Food Preservation*. Chapter 12: Methods for the assessment of antioxidant activity in foods., 2015. p. 287-333.

CHEMICAL, ELEMENTARY AND ENERGY CHARACTERIZATION OF BABASSU RESIDUES IN AMAZONIA

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Abstract

The palm tree known as babassu is a perennial and heliophite species. Studies have shown that there is a considerable supply of residues of babassu coconut in Brazil, including part of the state of Pará. The objective of this work was to determine the chemical, elemental and energetic characteristics of Orbignya speciosa, to verify its potential for the production of activated carbon. The residues were collected in the municipality of Castanhal-PA. The material was crushed, sifted and classified from a set of sieves with different granulometries. The granulometrically classified materials were conditioned in an air conditioning room. Part of the material in natura was only acclimatized for later carbonization. The carbonization was done in a muffle type oven, adapted to this function. Analysis of the molecular chemical composition of the biomass was carried out to quantify lignin, extractive, mineral and holocellulose contents. It was also carried out analysis of immediate chemical composition of the in natura and carbonized material and elemental analysis (CHNS) of both. From the analyzes performed, it was verified that the biomass presented average of 27.77% of lignin, 4.51% of extractives, 1.76% of minerals and 65.96% of holocellulose. For immediate chemical composition, averages of 9.14% of moisture, 79.61% of volatiles, 1.59% of ash and 9.79% of fixed carbon were found. In the analysis of elemental chemical composition, averages of 46.49% of carbon, 5.85% of hydrogen, 0.92% of nitrogen, 0.07% of sulfur and 45.08% of oxygen were obtained. The analyzes of the immediate chemical composition of the charcoal found averages of 5.58% of humidity, 21.77% of volatiles, 5.67% of ash and 66.98% of fixed carbon. The charcoal produced presented 30.67% yield at 450 ° C. From the elemental analysis of the coal produced with the studied biomass, it was verified a high carbon content in comparison to the other elements (70.28%). Low ash content (5.67%) and high fixed carbon content (66.98%) were obtained from the immediate analysis of the coal produced. The high lignin and carbon content and low ash content found represent a potential for the use of Orbignya speciosa waste for direct energy and activated carbon production.

Keywords: biomass, coal, lignin, residues.

Introduction

The palm tree known as babassu is a perennial and heliophite species, occurring naturally in Brazil and other countries of the Americas such as Mexico, Peru and Colombia (EMBRAPA, 1984). There are three distinct genera of the family *Arecaceae: Scheelea, Attalea* and *Orbignya*, being the *Orbignya phalerata Mart*., the most frequent species (TEIXEIRA, 2008).

According to studies carried out, about 12% of the fruit of babassu correspond to the epicarp, 23% to the mesocarp, 58% to the endocarp and 7% to the almonds, which shows that approximately 93% of the fruit is waste (EMBRAPA, 1984). For each ton of babassu coconut we have 930 kg of waste.

The exploitation of babassu occurs in order to use the oil present in the almonds for use in cosmetics and cooking, the shell being a residue of the manual breaking process. Regarding the current availability of babassu coconut residue, Dias et al., 2012 estimated, based on the production of almonds of 106,055 tons provided by IBGE, an amount of 1,409,016 tons of residues.

The residue presents an encouraging prospect for bioenergy use, mainly the production of charcoal for use in the steel industry. However, despite the large supply of waste, most of this biomass is improperly disposed of, which can negatively impact the environment (EMMERICH; LUENGO, 1996).

Faced with this considerable supply of coconut residues in Brazil, especially in the states of Maranhão and in part of the state of Pará, and its social importance for extractive communities, research related to its adequate energy utilization and the production of products with higher added value of this biomass are one of the viable options (TEIXEIRA, 2008; PORRO; VEIGA; MOTA, 2011).

In this context, the present work aimed to characterize the chemical, elemental and energetic characteristics of the *Orbignya speciosa* residue, in order to verify its potential for the production of activated carbon.

Material and methods

For this work, agroindustrial residues of *Orbignya speciosa* (babassu palm) were used, commonly generated from processing in agroindustries in the Amazon region. The material was collected in the city of Castanhal-PA, which is located in the northeast region of the State of Pará. The residues of Palmeira Babaçu are constituted of the endocarp and mesocarp obtained from the processing to obtain oil of coconut almonds.

Part of the material was stored in plastic bags, sealed and identified. Then the residues were ground and sieved in sieves with a grain size of 40, 60, 100, 200 and 270 mesh for analysis. The materials classified by granulometry were conditioned in an air conditioning room, with temperature conditions of 20 ± 2 ° C and humidity of 65 ± 3%, until reaching a constant mass, with humidity of 12%. The other part of the material (in natura) was only acclimated to after being charred.

The biomass was dried at 12% moisture and transformed into charcoal at a temperature of 450 ° C at a heating rate of 1.67 ° C.min-1 with residence time of 30 minutes, being cooled naturally and gradually to the oven reach the final carbonization temperature and time. For elemental analysis, the fraction that passed through the 200 mesh sieve was used and was retained in the of 270 mesh, immediate for the accomplishment of the analysis.

The molecular chemical composition analyzes for lignin quantification, total secondary components (extractives) and inorganic constituents (minerals) of the materials were carried out according to the Brazilian regulation standards – BRS norms of the Brazilian Association of Technical Norms- BATN (Table 1).

Table 1 – standards for the chemical analyzes of materials

Chemical tests	Standards ABNT
Total extractives – EXT. (%)	BRS 14853/2010
Insoluble lignina – LIG. (%)	BRS 7989/2010
Minerals – MIN. (%)	BRS 13999/2003

Source: Authors (2017).

The determination of the holocellulose content was performed by difference in relation to the other chemical constituents as total extractives, lignin and minerals.

The immediate composition analysis aimed at the determination of moisture, volatiles, ash and fixed carbon. This was performed with the 40 and 60 mesh fraction, according to BRS 8112: 1986 (BATS, 1986).

The quantification of the carbon, hydrogen, nitrogen, sulfur and oxygen contents (by difference) was performed in a universal analyzer of the Elemental brand, Vario Micro Cube. The analyzer uses, as drag and ignition gases, helium and oxygen, respectively. The 2 mg and three replicate samples for each biomass were packed in tin capsules and completely incinerated at 1200 ° C.

All chemical analyzes were performed in triplicates, in order to apply the descriptive statistics, from the arithmetic mean, standard deviation and coefficient of variation. This application was made in Excel 2016 software.

Results and discussion

Molecular Chemical composition

In the analysis of chemical composition, the lignin and holocellulose contents found were 27.7% and 65.96%, respectively (Table 02).

Table 2 – values obtained from the analysis of chemical composition

	Lignin (%)	Extractives (%)	Minerals (%)	Holocelllose* (%)
Average	27,77	4,51	1,76	65,96
SD	0,78	0,76	0,06	0,37
CV	2,81	16,90	3,77	0,57

* Values obtained by difference; SD: standard deviation; CV: coefficient of variation
Source: Authors (2017).

` The high lignin content in the biomass studied favors the production of activated carbon, since this substance is more resistant to thermal degradation when compared to cellulose and hemicelluloses. A lignin is a carbon-rich component with a concrete-like structure, a precursor material constituent ideal for the production of activated carbon (SUHAS et al., 2007).

The high content of holocellulose can influence the porosity characteristics of the activated carbon, since the cellulose promotes the production of predominantly microporous materials (AYGUN et al., 2003).

Chemical composition Immediately

From the analysis of immediate chemical composition, it was verified that the analyzed biomass presented a high index of volatile and low levels of ash, humidity and fixed carbon (Table 3).

Table 3- results of immediate chemical composition analyzes

	Moisture (%)	Volatile (%)	Ashes (%)	Fixed Carbon * (%)
Average	9,14	79,61	1,59	09,79
SD	0,11	0,82	0,05	0,82
CV	1,29	1,04	3,75	4,40

* Values obtained by difference; SD: standard deviation; CV: coefficient of variation
Source: Authors (2017).

In analyzes carried out by Protásio et al., 2014, similar values of moisture, volatiles, ash and fixed carbon were obtained for babassu residues. The amount of fixed carbon, ash and volatiles, directly affect the quality of activated carbon (APAYDIN-VAROL & ERÜLKEN, 2015). In addition to this factor, based on fixed carbon, it is possible to estimate the yield of coal that will be obtained (BOLIGON, 2015).

Elementary composition

From the analysis of elemental composition, it was found that the carbon content was the highest in comparison to the other elements (Table 4).

Table 4 – results of elemental composition analysis

	Elements					
	C (%)	**H (%)**	**N (%)**	**S (%)**	**-O (%)***	**O/C**
Average	46,49	5,85	0,92	0,07	45,08	0,97
SD	0,27	0,08	0,04	0,02	0,34	0,01
CV	0,58	1,30	4,54	26,47	0,76	1,32

* Values obtained by difference between the other constituents and also discounted the amount of minerals of the immediate composition (Table 3); SD: standard deviation; CV: coefficient of variation.

Source: Authors (2017).

Similar results were obtained in analyzes carried out by Protásio et al. 2014, by which the authors verified that the residue of babassu has 47.28% of carbon, 5.81% of hydrogen, 1.31% of nitrogen, 43.87% of oxygen and 1.73% of sulfur.

Carbonization yield and charcoal characteristics

The values obtained (arithmetic mean, standard deviation and coefficient of variation) for the mass yield of carbonization for the species Orbignya speciosa can be observed in table 05.

Table 5 - Gravimetric yield of carbonization of babassu waste

Temperature °C	**Rendimento**	(%)
450°C	Average	30,67
	SD	0,84
	CV	2,76

* SD: standard deviation; CV: coefficient of variation.
Source: Authors (2017).

The yield of the analyzed biomass was considerably within the normal range when compared to solid wood coal yield (28.27-30.21%) and to coal obtained from other biomass (32.31-34.35%) (SANTOS et al., 2017, PROTÁSIO et al., 2014).

This factor is due to the fact that the other species are high in lignin and carbon. This provides resistance to thermal degradation of the material during the carbonization process. Another important factor is the oxygen content, which also contributes to the coal yield. Low oxygen contents allow less combustion of the material during the carbonization process, since combustion occurs or is increased due to the amount of oxygen present in the material to be charred and in the furnace where it will be pyrolyzed (NOBRE, 2013).

Elemental analysis (CHNS-O) of charcoal produced

From the elemental analysis of the coal produced with the studied biomass, it was verified a high carbon content in comparison to the other elements (Table 6).

Table 6 - Values of the elemental analysis of the coal at a carbonization temperature of 450 ° C.

	C (%)	H (%)	N (%)	S (%)	-O (%)*	O/C
Average	70,28	3,26	2,31	0,32	22,24	0,26
SD	0,30	0,01	0,08	0,02	0,22	0,00
CV	0,42	0,35	3,37	4,83	1,00	1,43

* Values obtained by difference between the other constituents and also discounted the amount of minerals of the immediate composition (Table 3); SD: standard deviation; CV: coefficient of variation.
Sourcee: Authors (2017).

Pyrolysis makes it possible to obtain a product with high carbon content due to the volatilization of hydrogen, oxygen and nitrogen containing compounds (SEKIRIFA et al., 2013). The low oxygen / carbon ratio can promote greater mass yields after the next step which will be physical activation.

Immediate analysis of the coal produced

From the immediate analysis of the coal produced, it was found low ash content and high fixed carbon content (Table 7).

Table 7- Immediate chemical composition of charcoal produced

	Umidade (%)	Voláteis (%)	Cinzas (%)	Carbono fixo (%)
Average	5,58	21,77	5,67	66,98
SD	0,40	0,71	0,67	0,81
CV	0,07	0,03	0,11	0,01

* Values obtained by difference; SD: standard deviation; CV: coefficient of variation.
Source: Authors (2017).

The high carbon content and low ash content can directly influence the quality of activated carbon produced. The fixed carbon content helps in the development of the pores of the coal in the process of pyrolysis and activation. Raw materials with higher carbon content and lower ash content may be considered more suitable for the production of activated carbon (HAMZA, et al., 2017).

Conclusion

Babassu residues showed a gravimetric yield considered normal when compared to charcoal produced from wood. The immediate analysis shows the large amount of fixed carbon present in the residual biomass and charcoal, being indicative of a good precursor material for the production of charcoal and activated carbon.
The high content of lignin, elemental carbon and low ash content found in the analysis of molecular and elemental chemical composition represent the potential of using Orbignya speciosa residues for direct production of energy, charcoal, activated carbon and biochar.

References

Apaydin-Varol, E.; Erülken, Y. A study on the porosity development for biomass based carbonaceous materials. *Journal of the Taiwan Institute of Chemical and Engineers*, v. 54, n. 8 p. 37-44, 2015.

Aygun, A.; et al. Production of granular activated carbon from fruit Stones and nutshells and evaluation of their physical, chemical and adsorption properties. *Microporous and Mesoporous Materials*, v. 66, n.2-3, p. 189–195, 2003.

BATS. Brazilian Association of Technical Standards. BRS 13.999. Paper, paperboard, cellulosic pulps and wood - determination of the residue (ash) after incineration at 525 ° C. Rio de Janeiro, 2003.

BATS. Brazilian Association of Technical Standards. BRS 7.989. Cellulosic pulp and wood - Determination of acid-insoluble lignin. Rio de Janeiro, 2010.

BATS. Brazilian Association of Technical Standards. BRS 8.112 method for immediate analysis of charcoal. Rio de Janeiro. 1986.

BATS. Brazilian Association of Technical Standards. BRS 14.853. Determination of the material soluble in ethanol-boronene, dichloromethane and acetone. Rio de Janeiro. 2010.

Boligon, J. *Production and characterization of bodywork activated from soluble coffee grounds.* 2015. 87 p. (Dissertation). University of Technology Federal of Paraná, Londrina. 2015.

EMBRAPA. Brazilian company of agricultural research. *Babaçu: programa Nacional de Pesquisa*. 1984. Available in:< https://www.infoteca.cnptia.embrapa.br/bitstream/doc/51263/1/Doc2.pdf>. Accessed in: 18 jan. 2017.

Emmerich, F. G.; Luengo, C. A. Babassu charcoal: a sulfurless renewable thermo-reducing feedstock for steelmaking. *Biomass and Bioenergy*, v. 10, n. 1, p. 41-44, 1996.

Hamza, E. *et al*. Extraperitoneal abscess originating from an ischorectal abscess. *Bmj Case Reports*, New York, p.23-37, 22 mar. 2017. BMJ.

Nobre, J.R. *Production and quality of activated carbon from wood waste from species in the state of Pará.* 2013. 116 p. (Dissertation). Federal University of Lavras, Lavras. 2013.

Porro, N., Veiga, I. e Mota, D. Traditional communities in the Brazilian Amazon and the emergence of new political identities: the struggle of the quebradeiras de coco babaçu – babassu breaker women. *Journal of Cultural Geography*, v. 28, n. 1, p. 123-146, 2011.

Protásio, Thiago de Paula et al. Avaliação tecnológica do carvão vegetal da madeira de clones jovens de Eucalyptus grandis e Eucalyptus urophylla. *Scientia Forestalis***,** Goiás, v. 43, n. 108, p.801-816, 2015.

Santos, M.P.F, et al. Utilization of activated charcoal synthesized from agroindustrial waste and its study on the adsorption of β-lactoglobulin. *Brazilian Journal of Agricultural Sciences*, v. 9, n.3, p. 60-66, 2017.

Sekirifa, M.L., et al. Preparation and Characterization of an activated carbon from a date stones variety by physical activation with carbon dioxide. *J Anal Appl Pyrol*, v. 99, n.8, p. 155-160, 2013.

Suhas; Carrott, P.J.; Carrott, R.R.M. Lignin – from natural adsorbent to activated carbon: A review. *Bioresource Technology*, v. 98, n. 12, p.2301-2312, 2007.

Teixeira, M.A., Babassu: A new approach for an ancient Brazilian biomass. *Biomass and Bioenergy*, v. 32, n. 14. p. 857-86, 2008.

ELEMENTARY, CHEMICAL AND ENERGETIC CHARACTERIZATION OF WASTE FROM *Euterpe oleracea* MART, IN THE STATE OF PARÁ

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Abstract
The species Euterpe oleracea, popularly known as açaí, is a palm of the genus Euterpe, of Amazonian origin, and composes the vegetation of the forests of várzea or igapó and terra firme. The objective of this work was to perform the energetic characterization of this biomass, for indication of use. The residues were collected in the municipality of Castanhal-PA, obtained from the process of pulping in local trades. The cores were inserted in plastic bags, properly closed, identified and sent to the Biomaterials Laboratory at the Federal University of Lavras-MG for further analysis. The material was crushed, sieved and classified in sieves with a grain size of 40, 60, 100, 200 and 270 mesh. They were then conditioned in an air-conditioning room, with a temperature of 20 ± 2 ° C and humidity of 65 ± 3%, until reaching a constant mass, with a mean humidity of 12%. Part of the in natura material was also separated to be acclimated and then charred. The analysis of molecular chemical composition of biomass was carried out to quantify lignin, extractive, mineral and holocellulose contents, in accordance with NBR 14853/2010, 7989/2010 and 13999/2003. The elemental analysis (CHNS) was done on the in natura and carbonized material, using the fraction that passed through the sieve 200 and was retained in the of 270 mesh, indicated for the accomplishment of the analysis. The immediate chemical analysis was also carried out on the in natura and carbonized material. The carbonization was done in a muffle oven, adapted for this function, at a temperature of 450 ° C with a heating rate of 1.67 ° / min-1 and 30 minutes of residence time at the final temperature. According to the results obtained, the biomass presented a mean of 21.83% of lignin, 20.33% of extractives, 2.19% of minerals and 55.65% of holocellulose. For immediate chemical composition, averages of 11.21% of moisture, 75.65% of volatiles, 1.87% of ash and 11.27% of fixed carbon were found. In the analysis of elemental chemical composition, we found averages of 48.21% of carbon, 6.20% of hydrogen, 1.66% of nitrogen, 0.25% of sulfur and 41.81% of oxygen. For the immediate chemistry of charcoal, we found averages of 4.18% of moisture, 22.53% of volatiles, 3.04% of ash and 70.25% of fixed carbon. Due to the significant concentrations of lignin, structural carbon and fixed carbon, the biomass residue of açaí presented potential for use in direct energy production, activated carbon and biochar production.

Keywords: biomass. energy. use. carbon

Introduction

The species Euterpe oleracea, popularly known as Açaí, is a palm of the genus Euterpe, of Amazonian origin, found in the wild state and composing the vegetation of the terra firme, várzea or igapó forests (BACELLAR, 2006). Supplier of the main product of the vegetal extractivism of the Northern Region of Brazil, açaí, is of great socio-environmental and economic relevance to the region. According to the IBGE (2015), the production of açaí reached the mark of 216,071 tons / year, being the Pará national leader in the production of this fruit, with 58.3% of that of this total. To date, only t-he açaí pulp has been extracted from the fruit for the purpose of economic activity, some authors claim that the fruit has 30% of its composition while the other

70% result in residues: core and fibers (MATOS et al. 2006; SEYE et al., 2008). As a result, the large amount of waste generated becomes an environmental problem due to the lack of disposal. The objective of this work was to analyze the molecular chemical composition of the açaí stone for quantification of the lignin, extractive, mineral and holocellulose contents, in order to give a suitable destination to the generated residues

Material and methods

In order to carry out this work, agroindustrial residues commonly generated from processing in agroindustries in the Amazon region were used. The residues were collected in the municipality of Castanhal-PA, obtained from the process of pulping in local trades. Some of the material was stored in plastic bags, closed and identified, then crushed and screened in sieves with a grain size of 40, 60, 100, 200 and 270 mesh for analysis.

The materials classified by granulometry were conditioned in an air conditioning room, with temperature conditions of 20 ± 2 ° C and humidity of 65 ± 3%, until reaching a constant mass, with humidity of 12%. The other part of the in natura material was only acclimated to after being charred.

The biomass was dried at 12% moisture and transformed into charcoal at a temperature of 450 ° C at a heating rate of 1.67 ° C.min-1 with residence time of 30 minutes, being cooled naturally and gradually after reaching the final carbonization temperature and time. For the elemental analysis (CHNS), the fraction that passed through the 200 mesh sieve was used and was retained in the of 270 mesh, indicated for the accomplishment of the analysis.

The chemical analyzes for lignin quantification, total secondary (extractive) components and inorganic (mineral) constituents of the materials were carried out according to the standards listed in Table 1.

The determination of the holocellulose content was performed by difference in relation to the other chemical constituents as total extractives, lignin and minerals.

Table 1 - Standards used for chemical analysis of materials

Chemical Tests	ABNT Standards
Total Extracts - EXT. (%)	NBR 14853/2010
Insoluble lignin - LIG. (%)	NBR 7989/2010
Minerals - MIN. (%)	NBR 13999/2003

The analysis of the immediate chemical composition was aimed at the determination of moisture, volatiles, ash and physical carbon. This was done with the fractions 40 and 60 mesh, according to NBR 8112: 1986 (ABNT, 1986).

For the elemental analysis (CHNS), the fraction that passed through the 200 mesh sieve was used and was retained in the of 270 mesh, indicated for the accomplishment of the analysis. The quantification of carbon, hydrogen, nitrogen, sulfur and oxygen (by difference) was carried out in a universal analyzer of the Elemental brand, Vario Micro Cube model. The analyzer uses, as drag and ignition gases, helium and oxygen, respectively.

For the elemental analysis (CHNS), the fraction that passed through the 200 mesh sieve was used and was retained in the of 270 mesh, indicated for the accomplishment of the analysis. The quantification of carbon, hydrogen, nitrogen, sulfur and oxygen (by difference) was carried out in a universal analyzer of the Elemental brand, Vario Micro Cube model. The analyzer uses, as drag and ignition gases, helium and oxygen, respectively. The 2 mg and three replicate samples for each biomass were packed in tin capsules and completely incinerated at 1200 ° C.

All chemical analyzes were carried out in triplicates, to calculate the mean values, standard deviation and coefficient of variation and with that the values were obtained in the form of descriptive statistics.

Results and discussion

The results obtained in the chemical and elemental analyzes of the analyzed biomass are presented in Tables 2, 3 and 4.

Table 2 - Mean values of chemical composition, standard deviation (SD) and coefficient of variation (CV) of *Euterpe oleracea* residues.

Species		**Chemical composition**			
		Lignin (%)	**Extractives (%)**	**Minerals (%)**	**Holocellulose * (%)**
Açaí	**Average**	21,83	20,33	2,19	55,65
	SD	0,37	1,35	0,09	1,54
	CV	1,71	6,65	4,27	2,79

* Values obtained by difference; SD: standard deviation; CV: coefficient of variation;

The percentage of lignin found matches the results obtained by Ramos and Paula et. al (2011), for soybean residues with 21.64%, wood sawdust 21.88% and corn stalk 20.49% lignin. Suhas et. al (2007) states that lignin is an excellent precursor material for coal production because it is a carbon-rich component.

Santos (2008) says that there is an inverse relationship in lignin and holocellulose values, as observed in table 2, however, a high percentage of holocellulose in biomass is not considered ideal for energy purposes. For Aygun et. (2003) high levels of holocellulose influence the porosity of the coal, which can generate a low energy yield of the coal obtained through the biomass of this residue.

The amount of extractives found was considered high, and can be explained by processing conditions and by genetic factors. The almond present in the açaí stone that continues even after the pressing process also contributes to a high quantity of extractives. As for minerals, the residue also showed a higher value. For Castile (2004), the ideal for the production of activated carbon is a material with low ash content, since the mineral components cause an unfavorable effect on the adsorption process, preferentially adsorbing water, due to the hydrophilic character.
The values obtained for the contents of volatile materials, fixed carbon and ash (immediate chemical composition), are presented in Table 3.

Table 3 - Immediate chemical composition of *Euterpe oleracea* residues.

Species		**Composition**			
		Humidity (%)	**Volatiles (%)**	**Ash (%)**	**Fixed Carbon* (%)**
Açaí	**Average**	11,21	75,65	1,87	11,27
	SD	0,72	0,82	0,10	0,90
	CV	0,17	1,08	5,58	4,03

* Values obtained by difference; SD: standard deviation; CV: coefficient of variation;

The results obtained by Rangel (2015) with açaí stones presented values for immediate chemical composition similar to that of the present study, where it obtained 81.08% for volatile content, 1.79% for ash and 17.13% for fixed carbon content.
The volatiles content for biomasses that are used as fuel should be between 80-90% (DERMIBAS, 2004).

Therefore, we can observe that the volatile index is lower than expected. According to Santos and Júnior (2016), the higher the fixed carbon indices the better the energy potential of a biofuel, since the fixed carbon content is indicative that it more efficiently expresses the calorific value of a fuel. Chen et. al (2013) states that residues with higher carbon content and lower ash content are ideal for coal production.

The values obtained for the carbon, hydrogen, nitrogen and sulfur contents found for açaí biomass by elemental analysis are shown in Table 4.

Table 4 - Mean values of the elemental analysis, standard deviation (SD) and coefficient of variation (CV) for *Euterpe oleracea* biomass.

Species		**Elements**					
		C (%)	**H (%)**	**N (%)**	**S (%)**	**-O (%)***	**O/C**
Açaí	**Average**	48,21	6,20	1,66	0,25	41,81	0,87
	DP	0,42	0,08	0,06	0,11	0,60	0,02
	CV	0,87	1,27	3,31	44,43	1,44	2,31

* Values obtained by difference between the other constituents and also discounted the amount of minerals of the immediate composition (Table 3); SD: standard deviation; CV: coefficient of variation

Similar results were obtained authors who studied wood residues and wood sawdust (RAMOS and PAULA et al., 2011; SEYE, CORTEZ, GOMEZ, 2003). According to Ramos and Paula (2011) the presence of sulfur in fuels is undesirable because it causes problems such as erosion and release of SO2 gas after combustion. As for the ash content, Klatau (2008) states that in great quantity causes the reduction of calorific power, causing loss of energy.

The carbon content found is considered to be high, which characterizes great precursor material in the preparation of activated carbon.

The values of elemental analysis (CHNS-O) for the Euterpe oleracea biomass coals produced at a temperature of 450 ° C can be seen in Table 5.

Table 5 - Mean values of elemental analysis, standard deviation (SD) and coefficient of variation (CV) of the carbons at a carbonization temperature of 450 ° C.

Species		**Elements**					
		C (%)	**H (%)**	**N (%)**	**S (%)**	**-O (%)***	**O/C**
Açaí	**Average**	48,21	6,20	1,66	0,25	41,81	0,87
	DP	0,42	0,08	0,06	0,11	0,60	0,02
	CV	0,87	1,27	3,31	44,43	1,44	2,31

* Values obtained by difference between the other constituents and also discounted the amount of minerals of the immediate composition (Table 3); SD: standard deviation; CV: coefficient of variation

It can be observed that in the coals the carbon contents are higher and the hydrogen contents are smaller when compared to the original biomasses (Table 4). The biomass combustion allows to obtain a product with high carbon content due to the volatilization of compounds containing hydrogen, oxygen and nitrogen (SEKIRIFA et al., 2013).

As well as the low oxygen / carbon ratio, it can promote greater mass yields of coal. The values found for analysis of the immediate chemical composition of charcoal produced can be observed in Table 6.

Table 6 - Immediate chemical composition of charcoal produced from *Euterpe oleracea* biomass.

Carvão Vegetal		**Composition**			
		Humidity (%)	**Volatiles (%)**	**Ash (%)**	**Fixed Carbon* (%)**
Açaí	**Avegare**	4,18	22,53	3,04	70,25
	SD	0,72	1,35	0,80	1,22
	CV	0,17	0,06	0,26	0,01

* Values obtained by difference; SD: standard deviation; CV: coefficient of variation;

It can be observed an increase in the amount of fixed carbon compared to the chemical composition of the biomass, this is due to the fact the pyrolysis enables a product with a high carbon content to be generated. As for the ash content, Klatau (2008), states that in great quantity causes the reduction of power calorific power, causing loss of energy.

Conclusion

The analyzes of chemical composition and immediate, higher values of moisture and less marked lignin were found when compared with other biomasses seen in the literature. However, the results of the elemental composition are considered good for coal production, due to the high carbon content of biomass and coal.

The high carbon content helps in the development of the pores of the coal in the process of pyrolysis and activation, directly influencing the quality of the activated carbon produced.

Therefore, the high lignin, elemental carbon and fixed carbon content of charcoal demonstrate that *Euterpe oleracea* residue has good potential for use in direct energy production, activated carbon and biochar production.

References

Aygun, A. et. al. Production of granular activated carbon from fruit stones and nutshells and evaluations of their physical, chemical and adsorpition properties. Microporous and Mesoporous Materials, vol. 66, cap. 2-3, p. 189-195, dez. 2003.

Bacellar, A. A. et al. Geração de renda na cadeira produtiva do açaí em projeto de abastecimento de energia elétrica em comunidades isoladas no município de Manacapuru – AM, Manaus. Centro de Desenvolvimento Energético Amazônico, Universidade Federal do Amazonas – UFAM, 2006.

Castilla, M. C. Eliminación de contaminantes orgânicos de las aguas mediante adsorción em materiales de carbón. Granada: Universidade de Granada, 2004.

Chen, W. et. al. Activated carbon powders from wool fibers. Powder Technology. v. 234, p. 76-83, 2013.

Dermibas, A., Dermibas, A. H. Estimating the Calorific Values of Lignocellulosic Fuels. Energy Exploration & Exploitation, vol. 22, cap. 2, pp. 135-143, 2004.

Ibge - Instituto Brasileiro de Geografia e Estatística, 2015**.** Disponível em: <https://agenciadenoticias.ibge.gov.br/agencianoticias/agenciadenoticias/releases/16981-pevs-2016-producao-da-silvicultura-e-da-extracao-vegetal> Acesso em: 18 de janeiro de 2018.

Klatau, J. V. P. Análise Experimental de uma fornalha a lenha de fluxo co-corrente para a secagem de grãos. 2008. 192f. Dissertação (Mestrado) - Pós-Graduação em Engenharia de Recursos Hídricos e Ambiental, Universidade Federal do Paraná, Curitiba, 2008.

Matos, A. C., et al. Quadro político, jurídico e técnico da gestão de resíduos sólidos nos países do BRICS. Revista Tecnologia e Sociedade, 2016.

Ramos e Paula, et. al. Characterization of residues from plant biomas for use in energy generation. Revista Cerne, Lavras, v. 17, n. 2, p. 237-246, abr./jun. 2011.

Santos, E. C. S., Júnior, L. D. Caracterização química de resíduos agroindustrais e de extrativismo na Amazônia. In: CONGRESSO TÉCNICO CIENTIFICO DE ENGENHARIA E DA AGRONOMIA, 1., Foz do Iguaçu, 2016.

Seye, O., Cortez, L. A., Gómez, E. O**.** Estudo cinético da biomassa a partir de resultados termogravimétricos. In: ENCONTRO DE ENERGIA NO MEIO RURAL. Campinas – SP, 2003. Disponível em: < www.proceedings.scielo0.br/scielo.php?pid> Acesso em: 20 de Janeiro de 2018.

Seye, O., Souza, R. C. R., Bacellar, A. A., Morais, M. R. Caracterização do caroço de açaí como insumo para geração de eletricidade via gaseificação. VII AGRENER, 2008.

Shekirifa, M. L. et al. Preparetion and characterization of and activated carbon from a date stones pyrolysis/activation from apricot stones. Micropor mesopor mater, 2013.

Suhas, P. J. E., et. al. Lignin – From Natural Adsorbent To Activated Carbon: A Review. *Bioresource Technology*, vol. 98, cap. 12, p. 2301-2312, 2007.

ENERGETIC POTENCIAL OF THE RESIDUE OF *Tectona grandis* WOOD

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Abstract
The teak is a noble wood, used mainly for furniture and floors, and its culture of thinning can provide diverse uses to teak wood throughout the production cycle. So, the objective of the study was to evaluate the energetic potential of the residue of teak (*Tectona grandis*) wood at juvenile growth provided by thinning. The wood used in this study, from seminal origin, was donated by a forest company, located in the city of Nova Maringá (MT) at 10, 14 and 17 years old, using 4 trees for each age. The samples were taken from longitudinal direction of the log and transformed into sawdust and later making a composed sample. Were evaluated the content of fixed carbon and elementary carbon, volatile matter; extractives; ashes and calorific value throughout the age. The volatile matter increased according to the aging. The ashes content increased aswell and the fixed carbon decreased, but the extractives content, elementary carbon and the calorific power increased, which justifies its energetic potential.

Keywords: teak, energy, Wood

Introduction

The increasing demand for consumer goods is creating constant worries about de present way of development, based on the indiscriminate use of the finite resources. As an alternative for the consumption of non-renewable materials, the usage of wood, especially from short rotation culture, are gaining prominences, because it's a renewable source, abundant, versatile and attractive. Therefore, the implication of wood species from faster growth can be related not just with the market necessities, but aswell as a substitute for the non renewable material and ensure the decreasing of the devastation of native forests.

According to Ramos et al. (2011) and Bonduelle et al. (2015), the wood of *Tectona grandis* has many purposes, due the physical stability and natural durability. Because of the properties of teak wood, it has a great use such for furniture as for production of chemical components provided by its extractives. Thanks to the large use of the specie, Pelissari et al. (2014) emphasize that it must not discard the possibility of extract the wood with different technological properties throughout the plantation growth. These authors says that the use of thinning and wood removal from the forest at lower ages assure the usage diversification and add value to the reminiscent trees. Therefore, thinning made on teak plantations guarantee income anticipation made during all the productive cycle.

By the possible uses for the teak wood in younger age, there is the energetic purpose. So the objective of this study was to evaluate the energetic potential of the residue fo teak wood provided by thinning.

Materials and methods

This study used wood from seminal origin, donated by a forest company, located in the city of Nova Maringá (MT) at 10, 14 and 17 years old, using 4 trees for each age. The samples were taken from longitudinal direction of the log and transformed into sawdust and later making a composed sample.

The volatiles, fixed carbon and ashes matter were done by de standards of NBR 8112 (ABNT. 1986).

The higher calorific value was determined using an adiabatic calorimeter in accordance to the NBR 8633 (ABNT, 1981) standard.

The elementary carbon was determinate according to EN 15104 (DIN, 2011a) standard. The equipment used was Vario Micro Cube CHNS, Elementar®.

The regression analysis was conducted with 5% of significance.

Results and discussion

The Figure 1 represents, graphically, the variation of extractive content. At the age of 10, the extractive content was 4,97%, at 14, 7,38 and at the age of 17 the content was 8,62%. Despite numerical increase, the variation wasn´t statistically significant.

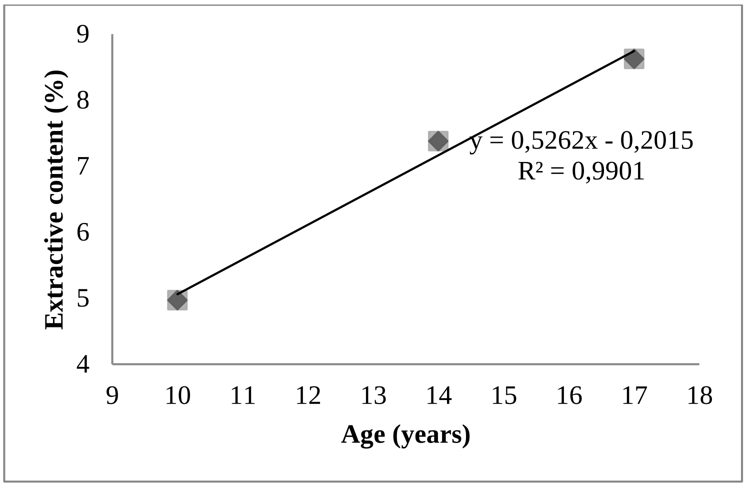

Figure 3- Values of extractive content according to the age.

At the Figure 2 there is the variation of volatile matter through the years. At 10 years, the volatile matter was 81,46%, 83,37% for 14 years and 85,43% for 17 years. Besides the increase, it wasn’t statistically significant.

Figure 4- Values of extractive content according to the age.

The Figure 3 represents the fixed carbon value throughout the age. Values as 17,56%, 16% and 13,95% are from the ages 10, 14 and 17, respectively. The fixed carbon decrease wasn’t statistically significant.

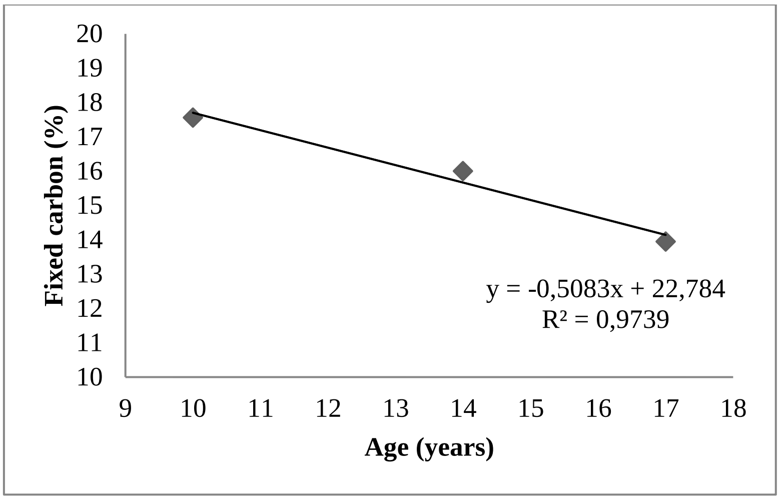

Figure 3- Values of fixed carbon according to the age.

The Figure 4 presents the decreasing of the ashes content throughout the ages, with 0,98% at 10, 0,62% at 14 and 0,62% at 17 years.

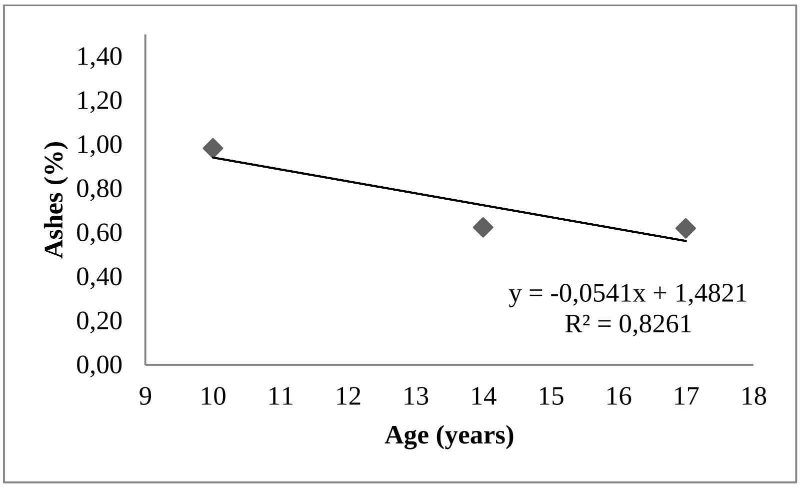

Figure 4- Values of ashes content according to the age.

The Figure 5 shows the increasing of de higher calorific value, with 4878 Kcal/kg at the age 10, 4904,5 Kcal/kg at the age 14 and 5063 Kcal/kg at 17.

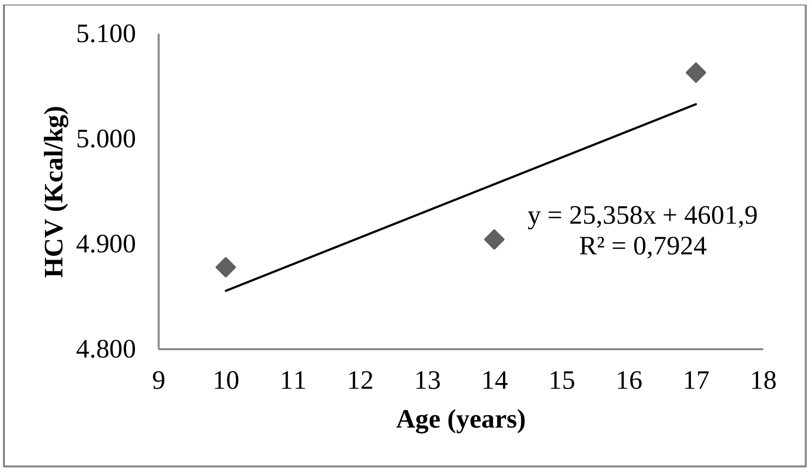

Figure 5- Values of high calorific value according to the age.

At the Figure 6, the graphic shows the increase of the elementary carbon throughout the tree's growth. At 10 years the elementary carbon present in the wood was 50,8%, at 14 years 51,3% and 51,7% at 17 years. These values weren't statistically significant.

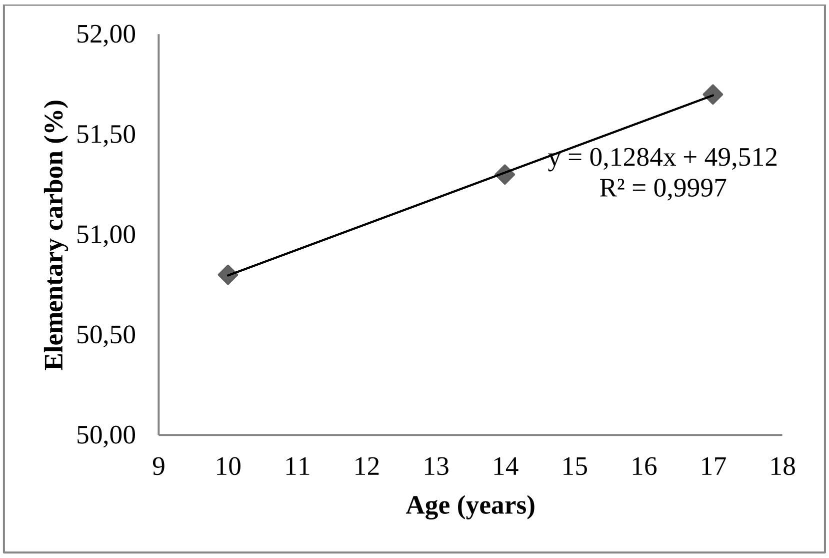

Figure 6- Values of elementary carbon according to the age.

Despite the decreasing of fixed carbon (non significant), the higher calorific value increased significantly. Even if the values of elementary carbon and extractive content weren't significant, it may have contributed for the HCV.

According to Bufalino et al. (2012) and Castro et al. (2013), mentioned by Moutinho et al. (2016) the presence of high extractive content is a great characteristic for energy production, due to the higher calorific value of its components.

For Medeiros et al. (2014), the extractive present in the wood is an important point when it comes to coal production because it increases the density of the wood and, consequentially, the density of the choal produced.

The use of this material as biofuell is considerate satisfactory once Santos (2008) determinate that the percentages of ashes under 1% are satisfactory.

Conclusion

The residue of teak wood, provided by thinning in juvenile growth has energy potential due do the higher calorific value and ashes content. The wood at the age of 17 has the higher value of HCV and lower value of ashes.

References

Associação Brasileira De Normas Técnicas. NBR 8633: Carvão vegetal: determinação do poder calorífico. Rio de Janeiro, 1984. 13 p.

Associação Brasileira De Normas Técnicas – ABNT NBR 8112 – Análise química imediata do carvão vegetal.Rio de Janeiro, 1981.

Bonduelle, G.M.; Iwakiri, S.; Trianoski, R.; Prata, J. G.; Rocha, V. Y. Análise da massa específica e da retratibilidade da madeira de *Tectonagrandis* nos sentidos axial e radial do tronco. *RevistaFloresta*, Curitiba, v.45, n.04, p.671-680, 2015.

Deutsches Institut Fur Normung – DIN EN 15104: Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods. Berlim: CEN: 15 p. 2011a.

Medeiros, P. N. D., Oliveira, E. D.; Paes, J. B. (2014). Relações entre as características da madeira e do carvão vegetal de duas Espécies da Caatinga.

Moutinho, V. H. P., da Rocha, J. J. M., do Amaral, E. P., de Medeiros Santana, L. G., & de Águiar, O. J. R. (2016). Propriedades Químicas e Energéticas de Madeiras Amazônicas do Segundo Ciclo de Corte. Floresta e Ambiente, 23(3), 443-449.

Pelissari, A. L., Figueiredo Filho, A., Caldeira, S. F., & Machado, S. D. A. Geoestatística aplicada ao manejo de povoamentos florestais de teca, em períodos pré-desbaste seletivo, no estado do Mato Grosso. *Revista Brasileira de Biometria*, p. 430-444, 2014.

Ramos, L. M. A.; Latorraca, J. V. De F.; Pastro, M. S.; Souza, M. T. De.; Garcia, R. A.; Carvalho, A. M. De. Variação radial dos caracteres anatômicos da madeira de *Eucalyptus grandis* W. Hill ExMaiden e idade de transição entre lenho juvenil e adulto. *ScientiaForestalis*, Piracicaba, v.39, n.92, p.411-418, 2011.

Santos, M. A. S. Parâmetros de qualidade do carvão vegetal para uso em alto-forno. In: FÓRUM NACIONAL SOBRE CARVÃO VEGETAL, 1, 2008, Belo Horizonte. Anais... Belo Horizonte: UFMG, 2008.

PYROLYTIC SYSTEM IN FIXED BED REACTOR FOR THE PRODUCTION OF BIO-FUEL FROM THE AGRO-RESIDUE OF SOYBEAN

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Abstract

Worldwide, it is essential appropriate forms of treatment and disposal of waste, from anthropic and industrial demands. Thermal/thermochemical processes are promising concepts to add value to biomass as agro-industrial residues, increasing the energy matrix. A pyrolytic system is an innovation that involves different technologies that allows to obtain bio-fuels with intrinsic characteristics through the degradation of biomass. Soybeans residues have ideal characteristics for use in these processes, according to their physical and chemical composition and availability; for each hectare of soybeans produced, about 3.0 to 4.0 tons of waste is generated. The main objective of this work is to evaluate the operation of a fixed bed reactor during the pyrolysis process of soybean agro-residues in order to maximize the production of solid and liquid fuels. Methods of collecting, sampling, refinement and drying were performed to guarantee homogeneity of the sample, in addition, a method for producing handmade briquettes. The pyrolysis tests were developed in the system composed of a fixed bed reactor, from which the briquettes were inserted. The reactor is composed of a bipartite heating chamber in which holds the quartz tube which contains two flanges at its ends, which allow a passage of nitrogen, which has a carrier gas function. In addition, the pyrolytic system is composed of a condensation system and a cooling system. The 2^{k-1} factorial experimental planning was defined so as to visualize different experimental parameters.

Keywords: biomass; thermochemical process; yields.

Introduction

Currently, the production of bio-fuels is generating great importance for the global scenario, the generation of energy through the combustion of fossil fuels, such as oil and coal, produce a large emission of greenhouse gases, as well produce waste that pollute the environment and is improperly discarded (BIODISELBR, 2017).

In addition, the extraction of these fossil fuels is a process that harms the environment, contaminating groundwater, rivers, soils and oceans, making the recovery process of the affected areas difficult and the investment costs of this extraction even greater (FREITAS; SILVA, 2008). Another disadvantage in relation to fossil fuels is the fact that they are exhaustible resources, and the growing consumption of oil and coal in recent years has made them increasingly scarce in nature (INTERNATIONAL ENERGY AGENCY, 2017).

In view of these factors, investigating alternatives for the production of renewable energy is essential to reduce these impacts in nature. Bio-fuels emerge as a viable alternative to replace these fossil fuels (FREITAS; SILVA, 2008), and therefore research in this area has been growing in recent years, and one of the processes that has demonstrated efficiency in the production of bio-fuels is the use of waste through the pyrolysis of biomass.

The use of residues from agricultural production has taken a large part of the study of the use of biomass, since agriculture is one of the main bases in the country's economy so it becomes more feasible and advantageous these studies directing to agricultural residues. According to EMBRAPA, Brazil is the second largest soybean producer in the world, having base that in the harvest of 2015/2016, 95.63 tons of soybeans were harvested in Brazil, where most of them are grown in states such as Bahia, Pernambuco, Rio Grande do Sul among other states, producing its derivatives such as oil, milk, flour and etc. (EMBRAPA, 2017). It is estimated that for each hectare of soybeans produced, about 3.0 to 4.0 tons of waste is generated. Therefore, the use of soy residues in the production of new industrial products provides the country with technological, economic and environmental benefits (GUIMARÃES, 2017).

The production processes of these derivatives, such as milling drying and pelletizing produce, besides a clean soybean for commercialization, a series of residues such as bran, which can be well used in the study of biomass and energy (SILVIA et al, 2004). The agricultural residues of the soybean present in its constitution great fibers that can be used in thermal processes like the pyrolysis, producing high quality bio-fuels.

In thermal processes, pyrolysis is defined as the process of thermochemical conversion of a carbon chain, in which the decomposition of matter occurs by an increase in the temperature of the system. It is able to convert materials into highly renewable products such as coal, bio-oil and biogas; during pyrolysis, biomass undergoes a very complex set of chemical reactions such as: cracking, elimination, addition, substitution and polymerization of the substances (PEDROZA et al., 2010).

Therefore, investigating the different equipment and systems for the pyrolysis process is of great importance to develop and model a technology that is capable of overcoming the different equipment and techniques available in the current market. Chemical reactors are the main technology for the application of thermochemical conversion of biomass. They are designed to contain chemical reactions of interest on an industrial scale and are able to process chemical reactions more efficiently, generating a high yield of the product (BROSSARD et al., 2003). The main objective of this work is to evaluate the operation of a fixed bed reactor during the pyrolysis process of soybean residues in order to maximize the production of bio-fuels.

Materials and methods

The soybean bran sample was collected in the month of April 2017 in the agro-industrial sector of Porto Nacional - TO. About 6 kg of soybean bran was collected (Figure 1), which was transported to the LARSEN (Laboratório de Inovação e Aproveitamento de Resíduos e Sustentabilidade Energética) at the Federal Institute of Tocantins-Campus Palmas.

Figure 1 - Temporary storage of soybean bran (In-Natura Sample).

The characterization and identification of the biomass was determined through NBR 10.004, which classifies the solid waste. According to the Brazilian Standard soybean bran is classified as Class II-A, a non-hazardous and non-inert residue.

The methodology for sampling and storage of the waste was determined by NBR 10.007, the solid waste should be disposable in polyethylene containers that need to provide a good seal, so to store the sample were used hermetic and transparent polyethylene bags 15 cm x 25cm, with a capacity of 2 liters (Figure 2). For the storage of the packaged samples, a plastic box with dimensions 30cm x 40cm x 30cm was used, with a lid for sealing (Figure 3).

Figure 2 - Samples properly packed, sealed and identified.

Figure 3 – Plastic box for storage of packaged samples.

In order to obtain the desired particle size of the samples, TYLER/MESH 8 sieves (Figure 4) were used, as well as TYLER/MESH 14 (Figure 5). The sieving of the sample guarantees its homogeneity, in addition, favors the procedural analyzes guaranteeing better results.

Figure 4 - Sieving with MESH 14.

Figure 5 – Sieving with MESH 9.

In order to achieve more efficient results in the pyrolytic process and to concentrate the available biomass energy, the soybean bran sample was briquetted. The briquettes were produced handmade, guaranteeing more control and autonomy in the production process. 250 grams of the sample was measured (Figure 6), then the biomass was transferred to a 9-liter basin, and 500 mL of distilled water was added to the sample. To reach the optimum point of homogeneity of the compound, the mass was mixed using the gloved hands, making circular movements and checking its alloy.

In order to obtain the shape of the briquettes, a PVC tube 30 mm in diameter and 20 cm in length was used, in which the mass was inserted inside the tube, and with the help of a wooden rod, the sample was compacted inside the PVC in order to of concentrating more biomass to make it denser. Finally, the mass was pressed out of the tube with the wooden rod generating the briquette (Figure 7). Soon after the briquettes were weighed next to a polyethylene container and were taken to a drying oven where it was maintained at 50 °C until the constant weight of the sample was obtained.

Figure 6 - Weighing of soybean bran.

Figure 7 - Production of handmade briquette.

The pyrolysis system consisted of two fundamental parts: the fixed bed chemical reactor and the condensation system. The reactor was designed and developed in the LARSEN. It is composed of a heating chamber located over on a partition containing the electric system and the reactor automation system (Figure 8).

The heating chamber holds the quartz tube which contains two flanges at its ends, they have the function of sealing the inside of the tube. In addition, flanges have outlets that allow the passage of gas. Nitrogen gas was used as the carrier gas for vapors in the system. The quartz tube holds the sample and guarantees the inert atmosphere required for the pyrolysis process. The briquette is weighed together with an aluminum barge and then inserted into the tube.

The condensation system (Figure 9) is composed of a Graham condenser, which condenses the gas that is released during the pyrolysis of the biomass in the quartz tube, and a Kitassato (1000 mL), which stores the bio-oil that flows through the coolant-jacketed spiral and expels the carrier gas. An aquarium water-pump has the function of performing the circulation of the cooling water in the condenser; the pump is submerged in a gallon with a capacity of 1 liter.

Figure 8 – Bipartite Fixed Bed Reactor.

Figure 9 - Condensation system implemented in the fixed bed chemical reactor.

The pyrolysis tests were performed during the 3-week period, in June and July 2017. In order to simultaneously evaluate several control parameters in the pyrolysis process, and also to reduce the number of experiments, a tool of static model was used, denominated: Factorial Design 2^{k-1}. Four parameters were established in order to evaluate different conditions in the experimental analyzes: Temperature; Heating rate; Inert Flow; Pyrolysis time. According to Factorial Design 2^{k-1}, 8 experimental tests must be performed considering 4 different parameters.

Results and discussion

The pyrolysis tests were performed according to Table 1. Solid yields of the products generated in the fixed bed reactor were analyzed according to the mass which was not carried by the nitrogen gas and remained inside the quartz tube, liquid yields are counted from the condensed mass that remained in Kitassato. The gaseous yields are composed of the gases which were also carried by nitrogen, but were not condensed during the process, and thus, were expelled along with the carrier gas. The non-condensable gases were not analyzed for yield purposes; however, they were counted from the difference of the solid and liquid products.

The biochar consists of ash content and non-degraded organic matter, the results indicate an average of 28.34% with a variation of 1.7%, that is, independently of the conditions in the pyrolysis tests, solid yields are practically constant. For the liquid yields: bio-oil and lignocellulosic volatile material (extract-acid), an average of 47.932% with a variation of 20.769% was obtained. Gaseous yields have an average of 23.728%.

Table 1 - Results of Factorial Design 2^{4-1} obtained for solid and liquid fractions.

Test	**Parameters**				**Yields (%)**	
	Temperature (ºC)	**Heating rate (ºC/min)**	**Inert Flow (mL/min)**	**Pyrolysis Time (min)**	**Solids**	**Liquids**
1	500	10	1	30	28.22	43.48
2	550	10	1	60	**28.86**	46.33
3	500	20	1	60	28.62	57.09
4	550	20	1	30	**27.19**	53.71
5	500	10	4	60	28.41	**66.60**
6	550	10	4	30	28.13	42.19
7	500	20	4	30	28.76	**32.92**
8	550	20	4	60	28.48	41.13

Source: Fabricio Machado Silva (2017).

Conclusion

The main products obtained during this heat treatment are bio-oil (liquid), coal (solid) and gas fraction, products with higher energy density and better properties than those of the initial biomass. Due to their energy powers, these products obtained have different potential uses, being able to be used in their own process and for the industrial sector, besides contributing to the diversification of the Brazilian energy plan. In addition, such products as coal can be used for chemical adsorption, removing impurities and contaminants from fluids and gases, acting in filtration systems allowing their use in various branches.

According to the results obtained, heating rate of 10ºC/ min and reaction time of 60 minutes showed higher production of liquid products when comparing the tests with lower and higher yield. As a suggestion for future work, a statistical analysis of the data obtained should be performed using quality tools such as the Pareto diagram, allowing to identify the parameters that effectively influence the pyrolysis process. In addition, immediate analyzes such as: ash content, volatile solids and soybean bran moisture, as well as elemental analyzes are important to determine the physicochemical characterization of the products obtained, ensuring a detailed analysis of the potential of bio-fuels.

References

ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 10.007. Amostragem de Resíduos. Rio de Janeiro, 1987.

ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 10.004. Resíduos sólidos – Classificação. Rio de Janeiro, 1987.

Biodiselbr. Greenhouse Effect. 2006. Available in: <https://www.biodieselbr.com/efeito-estufa/co2/efeito-estufa-dioxido.htm>. Accessed in: 08/11/17.

Brossard, L. E. P.; et al. PIRÓLISE RÁPIDA EM LEITO FLUIDIZADO: UMA OPÇÃO PARA TRANSFORMAR BIOMASSA EM ENERGIA LIMPA. Analytica, Bela Vista - São Paulo, v. 1, n. 4, p. 32-36, 2003.

EMBRAPA. Soja. Available in: <https://www.embrapa.br/soja/cultivos/soja1>. Accessed in: 09/11/17.

Freitas, T. F. S.; Silva, P. R. F. Biodiesel: o ônus e o bônus de produzir combustível. Ciência Rural, Santa Maria, v. 38, n. 3, p. 843-851, 2008.

Guimarães, I. L. Aproveitamento de Resíduo de Soja para Produção de Painéis MDP (Medium Density Particleboard) (2017). Universidade Federal de Goiás Regional Jataí.

International Energy Agency. Oil Market Report: World Oil Demand. Available in:<https://www.iea.org/oilmarketreport/omrpublic/#search=%22%22world%20oil%20supply%20and%20demand%22%22>. Accessed in: 08/11/17.

International Energy Agency. Global coal demand to reach 9 billion tonnes per year by 2019. Available in:<https://www.iea.org/newsroom/news/2014/december/global-coal-demand-to-reach-9-billion-tonnes-per-year-by-2019.html>. Accessed in: 08/11/17.

Pedroza, M. M., et al. Balanço energético da pirólise de lodo de esgoto: uma abordagem das propriedades termodinâmicas do processo. In: CONGRESSO BRASILEIRO DE ENGENHARIA QUÍMICA, 18., Foz do Iguaçu: Anais... Foz do Iguaçu: ABEP, 2010. p. 1-8.

Silvia, R. M. P.; et al. Estudo de caso: gerenciamento de resíduos sólidos industriais em uma indústria processadora de soja. Anais - XI SIMPEP, Bauru, SP, v. XI, n. XI, p. 1-7, 2004.