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REVISTA BRASILEIRA DE ENERGIAS RENOVÁVEIS

USE OF CASTOR OIL PLANT PIE FOR SOLID BIOFUEL PRODUCTION[1]

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Abstract

The objective of this study was the characterization, analysis and compaction of residues from castor oil plant pie extraction to verify its potential as solid biofuel. The chemical analysis, the mechanical test and the gross calorific value had satisfactory results. With the extraction of residual oil of the material there was a decrease on the high heating value. The produced briquettes presented good longitudinal expansion as well as mechanical strenght, however the presence of residual oil had influence on their strenght. In conclusion, the castor oil plant pie possesses energetic characteristics suitable for solid biofuel production, in addition it contributes with the reduction of industrial waste amount.

Keywords: Biomass, Bioenergy, Castor plant, Residue, Oil.

USO DA TORTA DE MAMONA PARA PRODUÇÃO DE COMBUSTÍVEL SÓLIDO

Resumo

O objetivo deste estudo foi a caracterização, análise e compactação de resíduos da extração de torta de mamona para verificar seu potencial como biocombustível sólido. A análise química, o teste mecânico e o poder calorífico bruto tiveram resultados satisfatórios. Com a extração do óleo residual do material houve uma diminuição no alto valor de aquecimento. Os briquetes produzidos apresentaram boa expansão longitudinal e resistência mecânica, porém a presença de óleo residual influenciou a sua resistência. Em conclusão, a torta de mamona possui características energéticas adequadas para a produção de biocombustível sólido, além de contribuir com a redução da quantidade de resíduos industriais.

Palavras-chave: Biomassa, Bioenergia, Mamona, Resíduo, Óleo.

INTRODUCTION

Brazil has a wide range of development, research and production of biofuels like ethanol, biodiesel and briquettes and has contributed with innovations for a sustainable energy matrix. Bioenergy is generated through all animal or plant non-fossil material and used as source to generate heat, electricity and transport fuel (COSTA; PRATES, 2005).

Biomass is the only renewable energy source that can provide solid, liquid and gaseous fuel and is obtained from crop residues, forest, sewer, urban solid, food processing and energetic crops (INTERNACIONAL ENERGY AGENCY – IEA, 2012). It is known that Brazil has climate and soil varieties, and a large territory, thus facilitating the diversity of raw material for bioenergy production. There are several plantations for energy purposes in the country, such as sunflower, castor, soybean, jatropha, cotton, peanuts, and palm oil (IEA, 2012). In addition, biomass has great potential as a source of income and benefit to farmers (COSTA; PRATES, 2005).

After castor oil beneficiation, the residue, also called co-products, as pie and bran, could be exploited for the briquettes production in order to eliminate or mitigate negative environmental impacts like waste accumulation through innovative alternatives and adding value to biofuel (ROSA et al., 2011).

The briquettes efficiently concentrate the energy available in biomass to generate electricity or heat and the process of briquetting is accomplished by adjustment of moisture, crushing and pressing waste (ROCHA; SOUSA; DAMASCENO, 2009), applying pressure on the particles, using or not addition of heat and/or binder.

According to Quirino and Brito (1991) in the same volume of briquettes there are five times more energy than in unmanaged residue and theirs production allows the optimum use of resources leading to reduced environmental impact, while reducing the volume. Also the values of apparent density of the briquettes notify the volume reduction of the materials, which is an important aspect to industries as it relates to the transport and storage system (CHRISOSTOMO, 2011).

This study aimed to characterize the co-products generated from the extraction of vegetable oil from castor bean, to study its chemical and mechanical characteristics, viability for compaction and for solid biofuel production.

MATERIALS AND METHODS

Vegetable residue of Riccinus communis L. (castor bean) was obtained in the form of pie after extraction of oil for production of biodiesel of Fauna and Flona corporation in the municipality of Vista Alegre do Alto - SP, Brazil.

In order to obtain the bulk density, the methodology prescribed in the regulation NBR 6922:1981 was used. Particles were classified applying the particle size analysis, based on the ABNT NBR 7217:1987 regulation, with mechanical sieving. The sieves with mesh opening phase used were: 20 mesh (0.85 mm) and 40 mesh (0.42 mm) and 60 mesh (0.25 mm) and 100 mesh (0.15 mm) and the bottom (<0.15 mm), installed on an orbital shaker, model MA 750, with intermittent strikes and orbital mechanical agitation system fixed at 250 rpm.

The chemical analysis where the ash content, volatile matter, and fixed carbon materials were obtained followed the regulation ABNT NBR 8112:1986.

The analysis of extractive content in cyclohexane and dichloromethane was performed, following TAPPI T204-cm97:1997 standard, to determine the percentage of residual oil. It was used 01 g of moisture-free sample with smaller than 35 mesh particle size, placed in a known mass filter paper and sealed. The samples were placed in a Soxhlet system with cyclohexane and then dichloromethane over a period of 8 h. Finally, the samples were removed from the extractor and dried at (105 ± 2 ° C) for 24 h or until they reached constant weight. The samples were then cooled in a desiccator with silica gel. This procedure was carried out in triplicate.

The calorific value was carried out applying the ABNT NBR 8633:1984 standard. A calorimeter IKA- C200 was used.

15 briquettes were produced with 20 g with particles smaller than 0.50 mm. The moisture content was adjusted to 12%. For the compaction process, a metallic mold of 3.5 cm diameter in a MA Marconi - hydraulic press capacity of 30 t was used. The process was performed under pressure of 1247.25 $kgf.cm^{-2}$ for a period of 30 s without heating or use of binders, for the formation of briquettes. The longitudinal and diametrical expansion of briquettes was analyzed using a digital caliper with a capacity of 15 cm and an accuracy of .0001 cm, on the intervals of 0, 1, 2, 4, 6, 12, 18, 24, 48, 72 and 96 h. The briquettes were kept in a climatic chamber (22 ° C and 65% relative humidity) during the test.

The mechanical behavior of the briquettes was evaluated by means of tensile test by diametrical compression. Thus, 10 samples were subjected to the test of compression loads after 96 hours of compression. The compressive force produced a tensile stress parallel to the loading plane (with consequent crack perpendicular to the center of the sample). The apparatus used for the test was the universal testing machine EMIC – DL30000. The speed used for this assay was 3 $mm.min^{-1}$. The bulk density of the solid biofuel has been determined with the mass and volume of the briquettes, where the measurements were recorded 96 hours after compaction.

To analyze the strength of the briquettes during handling and transport, a test was held according to the ABNT NBR 8740:1985 regulation, 96 h after briquetting. 5 samples were used. The procedure was adapted and the index was measured by the percentage of mass of five samples, after being subjected to 35 rpm for 5 min in a standard drum, and later weighting the residues of material retained on the 20 mesh sieve.

RESULTS

The particle size distribution of the material showed a higher percentage (53.57%) in the 20 mesh sieve(larger than 0.085 mm). For sieves 35, 60, 100 mesh and background the results were 21.75; 10.89; 6.84 and 6.95%, respectively. A high amount of peel was observed.

The chemical analysis is shown in Table 1.

Table 1: Results from the physicochemical characteristics of castor bean.

Analysis	[%]
Moisture content	12.00
Ash	5.05
Volatile matter	74.18
Fixed carbon	20.77

Costa et al. (2004) and Oliveira, Pereira and Alvarenga (2005) found levels of ash for the castor bean residue of 12.13 and 5.71%, respectively. These values may have been affected due to contamination of materials or treatment in which they were subjected . Ashes content for other residues of oil seeds such as sunflower and peanut were found by Oliveira, Pereira and Alvarenga (2005) of 4.14 and 13.54%, respectively

The volatile matter content (Table 1) is similar to the value found by Sant'Anna et al. (2012) of 74.04%. According to Santos et al. (2011) the volatiles represent the energy supply in the combustion, promoting a slow burning and tough ignition. Therefore, the volatile matter has great importance for the combustion of the briquette, since its release in the form of a flame, causes the spread of the heat through the burning region. According to Morais (2017) fuels which have high volatile contents can burn quicker.

If the amount of ash content and volatile matter are known, it is possible to obtain the fixed carbon content, since this is related to the mass present in the material after its output (VIEIRA, et al., 2013). The fixed carbon is the energy content of the material and high levels of it are desireble, due to the greater amount of energy supplied and thermal resistance of the fuel, promoting a slower burning (SANTOS et al., 2011).

It is emphasized that the calorific value is directly related to the fixed carbon, a larger amount of fixed carbon implies a longer time in the firing unit (CHAVES et al., 2013).

The oil content and the calorific value checked before and after extraction of the residual oil is presented in Table 2.

Table 2: Analysis of calorific value and castor bean residual oil content.

Calorific value *in natura* material [kcal.kg^{-1}]	Calorific value after oil extraction [kcal.kg^{-1}]	Oil content [%]
4589.19	4360.13	6.64

Silva et al. (2013) found 13.10% of residual oil into the castor oil plant pie. This e percentage is significantly higher than the one found in this study. This discrepancy may be related to the procedures performed and/or origin of the material.

With the data obtained on the energy evaluation, the calorific value of castor bean in natura and after oil extraction, it is noticed that the oil content had influence on the calorific value (6,64%).

Quirino et al. (2005) shows that in ideal burning conditions, in the wood, free of moisture, the calorific value is influenced by extractives (resins, oils, grease materials) and raise its potential.

The briquettes had an expansion of 4.41% in height and 0.64% in diameter. In a period of 96 h after compression, the volumetric expansion was 6%. The expansion of the briquettes is related to atmospheric moisture that each material is able to absorb even in controlled conditions and because of its anatomical and chemical properties of the plant specie. The smaller the enlargment of the briquette is, the most advantageous for producing it will be. Thus, it occupies less space and avoids changes in the physiognomy.

The briquettes mechanical resistance test (friability) produced less than 10% of fines. It can be considered relatively friable according to the classification of friability of Cetec described by Oliveira (1982), which is a positive aspect when it comes to the briquettes transportation.

The results of the tensile test by diametrical compression showed the average of maximum strain tension, elastic modulus and maximum tension of 619.78 N, 511.49 kgf.cm^{-2} and 6.83 kgf.cm^{-2}, respectively. Thus, the compacted material exhibited good resistance.

The briquettes density was 1180 kg m^{-3}. The bulk density found for castor bean was 292 kg.m^{-3}, with a moisture content of 11.4%. The increase in the briquettes density was 404.10% compared to the castor bean bulk density. Thus, with the compaction of the material there was an increase in its density, showing that the briquetting process is capable of producing a fuel with a higher energy content per volume unit.

According to Yamaji et al. (2013), the briquettes storage environment influences its characteristics of density due to hygroscopicity (water absorption) of the material; therefore, the briquettes should be kept under controlled temperature and humidity conditions.

The material compression secured a decrease in occupancy due to the higher mass per unit area, with a benefit for storage of industries waste.

CONCLUSIONS

It was possible to produce briquettes employing castor oil plant pie as raw material, without the addition of binders or temperature.

The briquettes made with castor oil plant pie presented adequate physical, chemical and mechanical properties for use as a solid biofuel. The materials compaction contributed to a reduction in the volume occupied by waste, ensuring a smaller footprint area.

Despite the oil content in castor oil pie had influenced the calorific value, the residues from the extraction of castor oil can be used for the production of solid biofuel, presenting features of good calorific value, low friability and good compression suitable for firing and transport.

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