Energy and Mechanical Characterization of Briquettes Made from Waste

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Abstract

The biomass briquettes can produce a higher quality solid biofuel than the residual biomass material. The objective of this work was to evaluate the use of paraffin as a binder in the sorghum briquettes formation. Three treatments were used: (T1) 100% sorghum + without heating; (T2) 96% sorghum + 4% paraffin + without heating and (T3) 96% sorghum + 4% paraffin + heating. Some biomass characteristics were observed such as: moisture content, bulk density and energy characteristics (fixed carbon, volatile, ashes and high heating value). The mechanical characteristics (expansion, maximum strength at the moment of rupture and friability) were also evaluated. The high heating value of the biomass without and with paraffin were 4446 kcal.kg^{-1} and 7.144,96 kcal.kg^{-1}, respectively. T3 provided better results with a size stabilization after 6 hours, 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.

Resumo

Os briquetes de biomassa podem produzir um biocombustível sólido de qualidade superior ao material de biomassa residual. O objetivo deste trabalho foi avaliar o uso de parafina como ligante na formação de briquetes de sorgo. Foram utilizados três tratamentos: (T1) 100% sorgo + sem aquecimento; (T2) 96% sorgo + 4% parafina + sem aquecimento e (T3) 96% sorgo + 4% parafina + aquecimento. Algumas características da biomassa foram observadas, tais como: teor de umidade, densidade aparente e características de energia (carbono fixo, volátil, cinzas e poder calorífico superior). As características mecânicas (expansão, resistência máxima no momento da ruptura e friabilidade) também foram avaliadas. O poder calorífico superior (PCS) da biomassa sem e com parafina foi de 4446 kcal.kg^{-1} e 7.144,96 kcal.kg^{-1}, respectivamente. O tratamento T3 apresentou melhores resultados com estabilização dimensional em 6 horas após a briquetagem, resistência mecânica de 0,75 MPa e índice de friabilidade de 0,96%. Todos os tratamentos foram classificados como materiais muito pouco friáveis. O processo de briquetagem aumentou a densidade do combustível (briquetes) e diminuiu o teor de umidade, minimizando os custos de transporte e armazenamento.

Palavras-chave: biomassa, biocombustível, aglutinante, compactação.

Resumen

Las briquetas de biomasa pueden producir un biocombustible sólido de mayor calidad que el material de biomasa residual. El objetivo de este trabajo fue evaluar el uso de parafina como aglutinante en la formación de briquetas de sorgo. Se utilizaron tres tratamientos: (T1) 100% sorgo + sin calentamiento; (T2) 96% sorgo

+ 4 parafina + sin calentamiento y (T3) 100% sorgo + 4% parafina + calentamiento. Se observaron algunas características de la biomasa, tales como: contenido de humedad, densidad aparente y características de energía (carbono fijo, volátil, cenizas y poder calorífico superior). También se evaluaron las características mecánicas (expansión, resistencia máxima en el momento de la ruptura y friabilidad). El poder calorífico superior de la biomasa sin y con parafina fue de 4446 kcal.kg^{-1} y 7.144,96 kcal.kg^{-1}, respectivamente. El tratamiento (T3) proporcionó mejores resultados con una estabilización de tamaño después de 6 horas de la compactación, una resistencia mecánica de 0,75 MPa y un índice de friabilidad de 0,96%. Todos los tratamientos se clasificaron como materiales muy poco friables. El proceso de fabricación de briquetas mejoró la densidad del combustible (briquetas) y disminuyó el contenido de humedad minimizando los costos de transporte y almacenamiento.

Palabras clave: biomasa, biocombustible, aglutinante, compactación.

INTRODUCTION

The use of biomass used for energy source supply represented about 10% of global annual primary energy consumption (GOLDEMBERG, 2017). Climatic instability, caused by global warming, already causes large variations in hydroelectric reserves. This may affect the energy security in hydroelectric dependent countries, such as in Brazil.

An alternative would be the generation of thermoelectric energy from biomass. This is a reality in sugar-alcohol industries taking advantage of the residual sugar cane bagasse to generate their own energy (SOUZA-SANTOS & CHAVES, 2012). In Brazil, there are 457 thermoelectric based on solids residual lignocellulosic (PEDROSO et al., 2018).

Residual biomass from agricultural, forestry or industrial sources is an alternative energy source for firewood and coal (DIAS JÚNIOR., 2016). Sorghum (*Sorghum bicolor* L. Moench) is a grain-filled grass. In the USA, South America and Australia, it is used in animal nutrition. In many countries, cereals can be used in human food, such as baking and biscuit production (QUEIROZ et al., 2009).

In Brazil, studies on the use of sorghum as a biofuel focus on the use of grains. The rest of the plant, which constitutes the largest mass, is discarded. Briquetting could provide the reuse of the same. The material compaction can produce a higher quality solid biofuel than the residual biomass material (DIAS JÚNIOR et al., 2016; HANSTED et al., 2016).

The presence of extractives in the sorghum residual biomass may interfere in the compaction (NAKASHIMA et al., 2017; OBERNBERGER & TREK, 2004). The extraction of these substances can result in the improvement of the physical qualities of the briquettes. Briquettes have lower expansion and higher mechanical resistance when extracting impurities and sugars from biomass residues. However, this procedure may incur costs in the briquetting process.

A binder can be used to improve the particles adhesion process. Briquettes produced from charcoal fines need a binder to be formed (Fernandez, 2018; Oliveira, 2013), because the moisture content is not enough to provide chemical interactions, such as hydrogen bonds.

Paraffin is a derivative of petroleum which often precipitates in the extraction pipes, harming its extraction. Thus, a residue is generated on the oil platforms (LAZAR et al., 1999). Because it is an oil derivative, it increases the calorific value. This characteristic is a positive factor for the fuel quality. Oliveira (2013) studied the use of paraffin as a binder in the production of coal fines briquettes. The result was the formation of a solid fuel with better energetic and mechanical characteristics.

In order to add a higher commercial value to the sorghum residual biomass, a briquetting study was carried out using the paraffin as a binder.

1 MATERIALS AND METHODS

The residual biomass of *Sorghum bicolor* was collected in Dracena. The geographic coordinates correspond to a latitude of 21° 28 '57 "S, longitude of 51° 31' 58" W, altitude of 421 meters and an area of 489.3 Km^2. The grains were benefited for the production of biofuel and the unused biomass was used for the study.

The experiment consisted of three treatments. The first treatment (T1) consisted of briquetting the biomass (100% sorghum) without paraffin. The second treatment (T2) consisted of briquetting the biomass (96% sorghum) mixed with 4.0% paraffin, without heating. The third treatment (T3) had 96% sorghum + 4.0% of paraffin and heating of 60 ° C. The statistical design was entirely randomized.

The volatile content, ashes content and fixed carbon content of the sorghum residual biomass were analyzed according to NAKASHIMA et al. (2017). The result was obtained by the difference of the initial mass and dry mass of each sample subjected to a temperature of approximately 103°C.

The biomass was subjected to pressing with a moisture content in the range from 10 to 12%. The press used was Marconi MA 098 and a stainless steel mold with 3.50 cm in diameter and 16 cm in height. The mass used to make each briquette was 20 g, which was compacted at a pressure of 61.48 kgf cm^{-2} for 30 seconds. A total of 10 briquettes were prepared.

The evaluation of the expansion of the briquettes was done longitudinally and transversally, the means were made in different stages (1, 3, 6, 12, 24, 72 and 96 hours) after the compaction. The heights and diameter of each briquette were observed.

After seven days from the briquettes production, the diametral compression traction test, according to Nakashima et al. (2017), and the briquettes longitudinal measurement were performed, using the universal test machine EMIC DL30000N. Five replicates were used and the results were obtained directly by the Tesc software version 3.04.

The friability index was performed with a friabilometer of 30 revolutions per minute (rpm) for 10 minutes. The friability was calculated from the mass of the remaining sample after the separation of broken particles.

2 RESULTS AND DISCUSSION

The combustion process depends on the chemical composition of the material. The immediate analysis of the sorghum material (table 1) provides ashes, volatile and fixed carbon content. The ashes represent the residues which damage the boiler. Volatiles can contribute to the material ignition by releasing flammable gaseous compounds at the beginning of the combustion. Fixed carbon is a variable that is associated with the high heating value of the fuel and determines the time of the material burning (DEMIRBAS, 2009).

Table 1. Data obtained from the immediate analysis and calorific value for each biomass

Material	Ashes (%)	Volatiles (%)	Fixed carbon (%)	High Heating Value (kcal.kg^{-1})
Sorghum	3.63(±0.24)	80.36(±0.42)	16.01(±0.55)	4,446.00
SPar 4.0*	2.61(±0.35)	85.82(±0.40)	11.57(±0.47)	7,144.96

* Sorghum with 4.0% of the paraffin

The volatile content was very close to those found by Nakashima et al. (2014) when working with residues of sugarcane bagasse, corn straw, elephant grass and garden pruning. And higher values to the ashes when compared to corn straw and sugarcane bagasse (Nakashima et al., 2014) and lower when compared to Leucaena (HANSTED et al., 2016).

According to Nakashima et al. (2017) the fixed carbon content for lignocellulosic materials ranges from 11% to 27%. The residual biomass of sorghum exhibited results within the literary range.

The mechanical analysis can be observed in table 2. The stability reflects in the accommodation of the fibers inside the briquettes. This variable can be measured as the expansion stabilizes. After stabilization, the solid fuel maintains a uniform size, as it is not affected to relative humidity variations (SILVA et al., 2015, NAKASHIMA et al., 2014, OLIVEIRA, 2013).

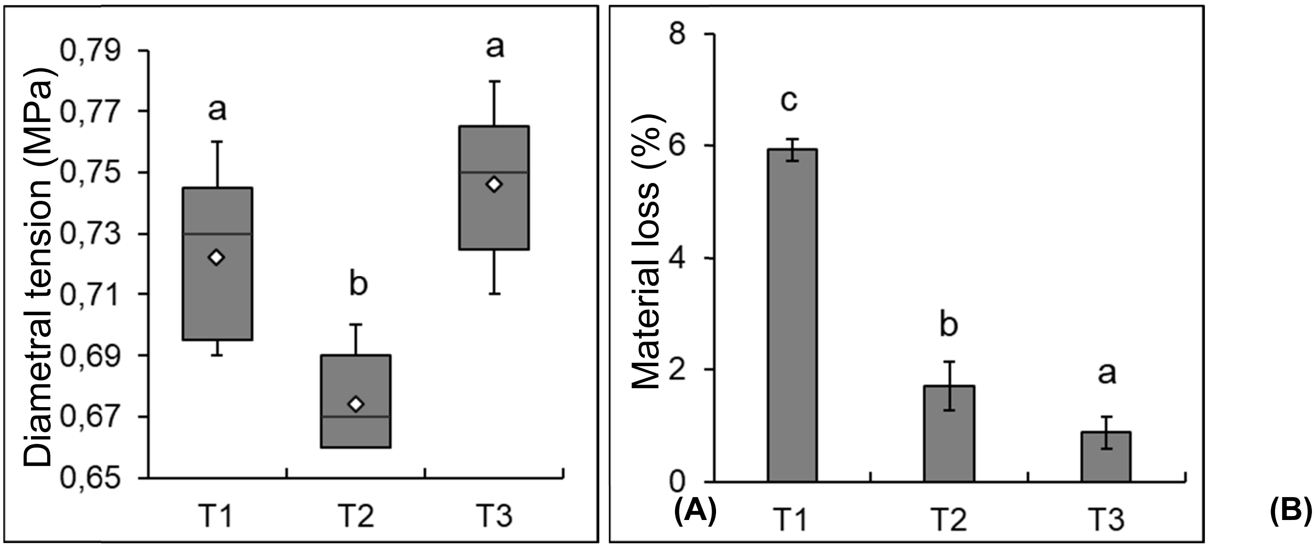
Table 2. Summary of the mechanical results: stability, mechanical strength e friability. Different letters imply significant difference among the treatments (significance level of 0.05%)

Treatment	Stability (hours)	Mechanical strength (MPa)	Friability (%)
T1	72	0.72 a	5.90 c
T2	12	0.67 b	1.79 b
T3	06	0.75 a	0.87 a

Treatment 3 provided a shorter stability time. Thus, the use of paraffin with temperature provides a saving of six hours in relation to T2 and two and a half days in relation to T3. All treatments showed differences among them for the stability response, at a 5% level of significance by the Tuckey test.

Regarding the briquettes resistance, the best response was for T3 (figure 1A). Only T2 presented statistical difference for the diametral tension response. Thus, the best product resistance was evidenced by T1 and T3. This result is important to gauge the maximum stacking height that the material can withstand without deformation that would endanger its quality (HANSTED et al., 2016; SILVA et al., 2015; NAKASHIMA et al., 2014; NAKASHIMA et al., 2017; OLIVEIRA, 2013).

Figure 1 – Maximum tensions (A) and tumbling test (B) for each treatment of the briquettes. Different letters imply significant difference among the treatments (significance level of 5%)



The material friability was evidenced by the tumbling test (Figure 1B). The more compact the material the less particles are released (NAKASHIMA et al., 2017; TABARES et al., 2000). All treatments presented statistical differences among them. It was observed that the use of a binder allowed the formation of a material of lower friability (T2 and T3), that is, a more compact material. This feature is important for briquettes handling and transportation (NARITA et al., 2018; SILVA et al., 2015; KARUNANITHY et al., 2012; TABARES et al., 2000).

CONCLUSION

The paraffin provided differences to the briquettes mechanical properties. The treatment T3 (Paraffin + heating) produced the best briquettes (stability and mechanical properties). The use of paraffin as a binder may be an alternative for improving the briquettes quality.

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