EVALUATION OF PHYSICAL AND CHEMICAL PROPERTIES OF BRIQUETTES FROM SISAL SOLID WASTE

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ABSTRACT

Sisal waste, a secondary agricultural waste from Agave sisalana, promotes environmental impact by generating waste in several areas in the northeast of Brazil. Potential waste-to-energy technologies can be used in the valorization of sisal waste. Solid biofuel is a proven way of generating energy from waste by direct combustion. Thus, this research aims to produce briquettes from solid waste to store energy for further use by the semi-arid region population of Brazil. Sisal waste briquettes were made with or without lignin and characterized to determine their physical and chemical properties. Moisture content found is favorable to the production of briquettes, which demand values between 5% and 12%. The briquettes obtained densities ranging from 1.01 to 1.10 g.cm $^{-1}$. The highest calorific value was 17.7 MJ/kg. The results indicated the potential for direct burning and conversion by thermochemical processes.

Keywords: Biorefinery. Circular economy. Biomass. Agave.

1 INTRODUCTION

Agave sisalana or sisal, as it is popularly known in Brazil, is cultivated mainly in the northeastern region of Brazil due to its adaptability to semi-arid climates. Its cultivation and processing are labor intensive and provide a livelihood for the population of one of the poorest regions in the country. The product from this crop is a longer fiber that represents only 4% of the weight of the leaves processed, whereas co-products from this operation can be separated into pulp, sisal tow (short fibers), and juice (chlorophyllous sap). Thus, 96% of the leaves are left on the ground. According to IBGE (2024)[1], Brazil produced 91,923 tons of sisal fiber in 2022, generating a high amount of solid and liquid residues[2].

Several efforts have been made to find ways to utilize sisal wastes (SSW) to obtain valuable products. Using co-products and residues represents an opportunity to ensure additional income to the sisal farmer, employment and income generation, and a guarantee of sustainability for the sisal productive chain. For instance, some studies have demonstrated that the solid and liquid residues have the potential not only for ethanol 2G production but also as an organic fertilizer, feeding ruminants, and raw material to produce extracts with important biological activities, such as larvicidal, antimicrobial, ovicidal and antiparasitic [2,3,4].

The short fiber or sisal solid waste can be used to produce briquettes which can be burned in boilers and industrial furnaces substituting firewood as a fuel. In northeastern Brazil, firewood is typically produced clandestinely from scarce natural vegetation. Such deforestation constitutes an environmental problem and contributes to ecological unbalance in the region [2].

Briquette production from sisal solid waste may be practiced in locations with a minimum supply of water and electric energy. So, this research aims to produce briquettes from sisal solid waste to store energy for further use by the semi-arid region population of Brazil.

2 MATERIAL & METHODS

Raw materials: The sisal solid waste (short fiber) used in the study came from Valente/Ba, in the Northeast region of Brazil. Lignin was donated from Suzano / São Paulo state, Brazil.

Preparation process: Briefly, sisal solid waste (SSW) was ground in a knife mill with 1730 RPM and classified using a 20-mesh sieve. Biomass was inserted into a cylindrical stainless steel with a diameter of 4 cm and height of 2 cm. Then, it was pressed in an electric hydraulic press for 30 s under 5 N pressure at 25ºC.

Determination of physical and Chemical properties: Biomass in natura and briquettes were characterized by moisture content (EMBRAPA 236)[5], apparent density, holocellulose (TAPPI T257 om-85) and ash content (EMBRAPA 236), morphological properties, Fourier transform infrared spectroscopy, diametrical compression test (ABNT NBR 7222), crystallinity and calorific value (ASTM D2015-66).

3 RESULTS & DISCUSSION

The SEM analysis of the SSW and lignin is shown in the micrographs of Fig. 1. It is possible to observe the structure of the SSW fiber and the size of the particles used in the preparation of the briquettes (Fig. 2). The particles had a rougher surface layer, probably due to the presence of amorphous components of the fiber.

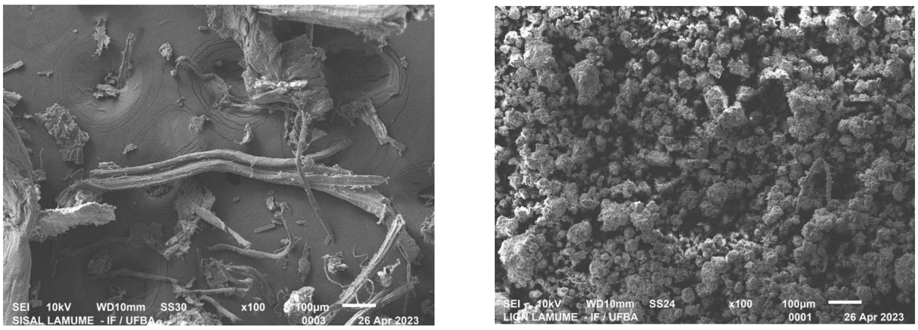

Figure 1 . SEM micrographs of SSW (left) and Lignin (right).

Figure 2 SSW before and after processing and briquettes composed of (a) SSW, (b) SSW: lignin 9:1, (c) SSW:liginin 8:2

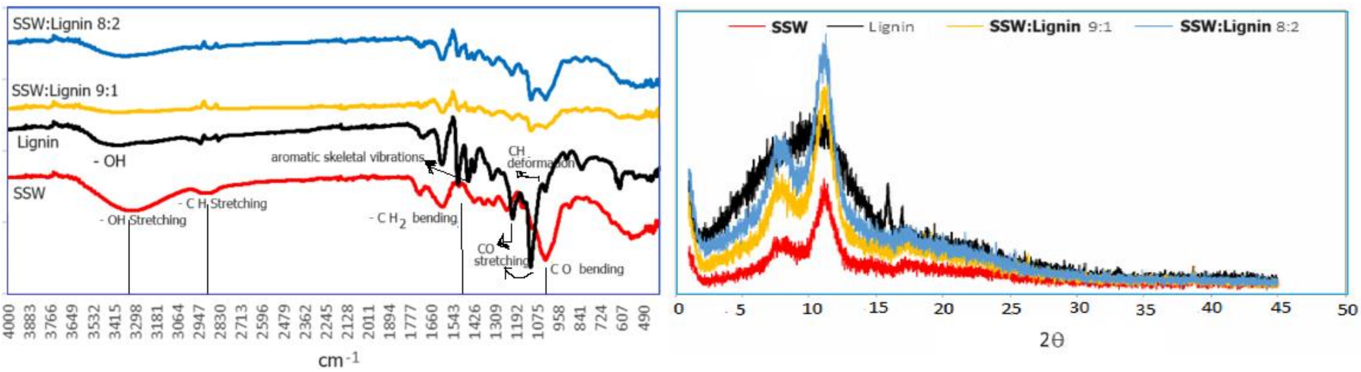

Figure 3 Characterization of biomass (SSW and lignin) *in natura* and Briquettes by FT-IR (left) and DRX (right)

The characterization of the SSW in natura shows that this lignocellulosic material has a high holocellulose content. (~70%) and low lignin fraction (~11%). The moisture content of SSW was approximately 11%. The results obtained about moisture content, ash compression strength and calorific power are summarized in Table 1. According to L. Chena[6] et al., the moisture content and ash are best to be low, in a range of 10–15% and <10%, respectively, when applied as fuel.

Fourier Transform (FTIR) analysis of biomass and briquettes showed the cellulose and lignin characteristic functional groups. The hydroxyl absorption band, between 3625-3000cm^{-1}, with a peak at 3300cm^{-1}; the peaks of 1424 cm^{-1} and 1027 cm^{-1}, correspond respectively to (-CH2) and (CO) bending. It is also observed the peak between 1309 cm^{-1} and 1075 cm^{-1} related to C-O stretching groups of lignin. The analysis of FTIR spectra indicated the absence of chemical interaction between SSW and lignin (without new peaks).

The SSW diffractograms show two characteristic peaks related to cellulose: the first around 8° and the second between 10° and 15°. Lignin has a non-crystalline (amorphous) structure due to its highly complex branched configuration.

Table 1 Biomass and briquettes characterization by moisture content, holocellulose, ash, density, diametral compressive strength, and calorific power.

Sample	Moisture Content (%)	Ash (%)	Hollocelullose (%)	Apparent density (kg/m³)	Compressive strength (MPa)	Calorific Power (MJ/Kg)
SSW	10.68 ± 0.26	6,66	70.77	1040.4 ± 11.4	1.43[a]	15.63
Lignin	5.97 ± 0.14	4,31	-	-	-	24.3
SSW:Lignin 9:1	9.41 ± 0.11	6,87	-	1076.2 ± 6.1	1.67[a]	16.84
SSW:Lignin 8:2	8.76 ± 0.13	6,36	-	1085.5 ± 9.8	1.70[a]	17.64

The dimensional stability of the briquettes is related to their mechanical strength and directly affects the transport and storage of the briquettes.[7] In this work, the briquettes were well formed, dry to the touch and with good adhesion (without fine particles during manipulation and transport). Briquettes made from SSW and lignin have a calorific value of ~17 MJ/kg or ~4200 kcal/kg. Those values were like sugarcane bagasse – var 7985 as reported by Silva and colleagues[8] (2021) and sisal solid residue as reported by Jambeiro and colleagues[9] (2018). The calorific value of SSW of 15.63 MJ/kg is comparable to landfill biogas (~12MJ/kg) and biodigester biogas (~20MJ/kg). These results allow us to state that these bio-briquettes have significant thermal properties compared to other mixtures of briquettes.

4 CONCLUSION

The briquettes produced with SSW:liginin presented satisfactory physical and energetic properties to store and use as fuel. Local raw materials (SSW: short fiber of sisal) in combination with lignin are suitable as an alternative source of fuel. This process is economical, environmentally friendly, cheap, and therefore affordable, and can be used by housing and municipal services, farms, and residents in rural areas with solid waste available.

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