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Chemical Composition of the Cashew Apple Bagasse and Potential Use for Ethanol Production

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ABSTRACT

On the world scene, the energy requirements are mainly based on fossil fuels, however, these compounds reserves are finite and their exploitation has caused serious environmental problems. As a consequence, the demand for alternative renewable sources has been intensified in substitution the rising demand for energy and raw materials. The biomass is emerging as one of the few sources that have potential to meet these challenges of sustainability, as is currently the largest energy resource in the world, and only carbon-rich material available on the planet, apart from fossils. Form, the cashew crop has great potential for technological development of alternative sources of energy, from its industrial waste processing cashew adding value to the product. In this sense, this paper aims to study the characterization of the cashew apple bagasse and to verify (by acid prehydrolysis) the potential of this material for ethanol production. Initially it was carried out physicochemical characterization of cashew bagasse used (pH, moisture content, soluble solids, sugars, cellulose, hemicellulose and lignin). Following it was carried prehydrolysis at 105˚C for 1 h to obtain fermentable sugars. Analyses of the samples were carried out on HPLC the results showed the saccharification of biomass with glucose (1537.49 mg/L), xylose (3823.22 mg/L) and arabinose (7131.11 mg/L) as well as the capacity of the biomass for ethanol production.

Keywords: Pre-Hydrolyze; Ethanol; Cashew Apple Bagasse

1. Introduction

The world's energy needs are based on fossil fuels, however, the impending shortage of fossil oil and environmental problems that its holding concerned, it has aroused in the scientific community interest in new alternative energy sources renewable and sustainable [1,2]. In this context, the biomass comes as one of the sources having this potential, because when produced sustainably, can dramatically reduce emissions of greenhouse gases compared to fossil fuels, as the only carbon-rich material available on the planet [3,4], which can be used for energy, heat, liquid and gaseous fuels, and also serves as a raw material for chemicals and materials.

Brazil is enjoying a comfortable position in the world with the technology of ethanol production. In this sector, the United States is currently the largest producer, except that the bioethanol produced from corn (cost three times higher than derived from cane sugar), followed by Brazil which uses cane sugar, with an ethanol production of 27.7 billion liters, respectively, in the harvest of 2008/2009 [5].

The lignocellulosic biomass represent an abundant source of sugars by biotechnological processes can be converted to products of industrial interest such as ethanol. This biofuel is currently produced from virtually raw beet and starch, cane sugar and maize, respectively. However, researchers are developing new processes for the most economically viable use of the component of lignocellulosic biomass such as agricultural residues (straw and bagasse of sugar cane, wheat straw and corn stover) and forest residues (dust and waste wood), for production of fuel ethanol (second generation ethanol) [6,7].

In Brazil, the cashew nut harvest (2008/2009) accounted for 11% of world production, which represents more than 6 million tons of cashew [8]. However, in the Northeast, cashew agroindustry has an outstanding role in the local economy, because, in industrial processes 40% (w/w) of bagasse is normally discarded by the industry [9]. So sustainably this culture has great potential for technological development of alternative energy sources, from their industrial waste processing, besides being used as a support for cells in alcoholic fermentation of juice cashew [10].

The cashew bagasse is a lignocellulosic waste that is composed mainly of cellulose, hemicellulose and lignin. For these residues are bioconverted it is necessary to subject them to physical pretreatments and/or chemicals prior to hydrolysis in order to produce ethanol. Such pretreatment aimed at removing lignin and hemicellulose, reducing the crystallinity of the cellulose and increasing the porosity of these materials so as to make the pulp more susceptible to hydrolysis. Among the various options for pre-treatment, the use of dilute acid in addition to removing the selective hemicellulose produces liqueurs (prehydrolysis) with high content of pentoses and reduced lignin content [8,11].

This liquor resulting from the pre-hydrolysis is constituted by compounds such as pentoses (xylose and arabinose) at high concentrations and hexoses (glucose, mannose, galactose, etc.) components of the hemicellulose. During the pretreatment the acids used as catalysts in the process release protons that act on glycosidic bonds between the monomers polymeric sugar chains, causing the breaking of these bonds releasing a number of undesirable compounds in the fermentation process, leading to partial degradation of pentoses and hexoses, generating furfural and 5-hydroxymethylfurfural (5-HMF) [12].

In this context, this work was to study the characterization of the cashew apple pomace and by acid hydrolysis pre-determine their potential for ethanol production.

2. Materials and Methods

The investigation was conducted at the Laboratories of Porous Media, Particulate Systems and Biochemical Engineering at the Chemical Engineering Academic Unit in the Science and Technology Center of the Universidade Federal de Campina Grande—Paraíba state.

2.1. Obtaining a Raw Material

Fresh cashew apple bagasse was used, obtained from FRUTNAT, a fruit juice production company located in the city of Campina Grande/Paraiba/Brazil.

2.2. Preparation of Raw Material

The cashew apple bagasse was washed twice in water at 60˚C, and then water at room temperature until reaching ˚Brix 0. After washing, it was placed into aluminum trays and dried in an air circulating oven at 55˚C for 48 hours, depending (**Figures 1(a)-(c)**). It was then immediately ground in a knife mill, sieved through 40 mesh sieves and stored in polypropylene bags for subsequent use.

2.3. Acid Prehydrolysis of Cashew Apple Bagasse

Dried cashew residue was treated with a dilute acid solution (95% pure sulfuric acid—VETEC/PA), and prehydrolysis liquor was obtained at 105˚C for 1 h in a pressurized 700 mL stainless steel reactor, using a weight ratio of 1:6 (100 g of sample/600 g of H_2SO_4 at 3%v/v).

2.4. Characterization of Cashew Apple Bagasse: Physicochemical Analysis

Samples of cashew bagasse dry and prehydrolysis were taken to be its characterization, which was to analyze (moisture, pH, soluble solids, reducing sugars, cellulose, hemicellulose and lignin). **Table 1** gives the references of the methodologies used for physicochemical characterization.

2.5. Characterization of Prehydrolysis Liquor

Levels of sugars and furan compounds (HMF and Furfural) were determined by high performance liquid chromatography (HPLC) equipped with a ProStar 210 pump (Varian); Manual injector with a 20 µL loop; ProStar 356 refractive index detector (Varian) and 284 nm UV-visible (aldehydes); Hi-Plex H stainless steel analytical column (300 mm × 7.7 mm; Varian), applying the following operating conditions: Column temperature of 40˚C; Mobile phase: 0.005 M H_2SO_4 with a flow rate of 0.6 mL/min; Analysis time: 15 and 60 minutes for

(a) (b) (c)

Figure 1. Cashew apple bagasse: (a) In nature; (b) Drying at 55˚C; (c) Dry.

Table 1. Methods used in the characterization of cashew apple bagasse.

Parameters Analyzed	Methodology
Moisture	[13]
pH	[13]
Soluble Solids	[13]
Cellulose	[14]
Lignin	[14]
Hemicellulose	[14]
Reducing Sugars	[15]

sugar and aldehyde content, respectively. Internal standard solution for sugars: glucose, xylose, arabinose and sucrose (Sigma 99.99% HPLC grade), congeners 5-hydroxymethylfurfural—HMF (Aldrich 99.98%) and furfural (Vetec 99.9 UV/HPLC) were used to quantify the components of liquor.

3. Results and Discussion

The physicochemical characterization of cashew bagasse dry and prehydrolyzed shown in **Table 2**, aims to analyze its composition with respect to nutrient content and for future comparison with the bagasse hydrolyzate.

According to the results shown in **Table 1** shows that the analysis of dry bagasse resulted in 9.29% ± 0.07% moisture, however, [16] analyzing the cashew stalk residue dried in a vacuum oven at 65˚C found 6.99% moisture. For the analysis of the pH value of 4.23 ± 0.01 was found no significant difference with the values reported by [16,17] at pH 4.01 and 4.52. For soluble solids was found to be the result of 0, this is because the pulp was well washed to remove the remaining sugar prior to drying. Now for the AR value was higher than that reported by [18] who studied the efficiency of solvents in the extractives content in pulp of the cashew apple, finding the dry bagasse at 55˚C the value 0.31%.

Analyzing prehydrolyzed the bagasse it is found that the values of moisture, pH, Brix and AR found for dry pomace cashew are similar to those found in [19] to study the acid hydrolysis of bagasse from the stalk of the cashew, which was reported at 14.51% moisture, pH 1.77 and 0.10% of ˚Brix.

A comparison of the chemical composition of dry bagasse cashew pre-treated is shown in **Table 3**.

In terms of cellulose, hemicellulose and lignin, the pulp of the cashew apple dry values were similar to that found by [8] 19.21% ± 0.35%, 12.05% ± 0.37% and 38.11% ± 0.08% for the cashew apple bagasse in nature, [20] 38.4%, 10.2% and 2.8% for soybean hulls, however, [21] studied the same residue found 36%, 12.5% and 18.2%.

It was observed for wheat straw 31, 26 and 24%, respectively [22]. The values related to lignin were higher than those found by different authors. As can be seen the cashew bagasse dry compared to other residues mentioned, appears to be quite promising for bioconversion products of high added value such as ethanol.

Bagasse from cashew stalk when subjected to pre-hydrolysis with dilute acid changes most of the hemicellulose fraction monosaccharides by hydrolysis (xylose, arabinose, and others). Consequently, the pulp prehydrolyzed has a browning in relation to the dry material due to the formation of degradation products of carbohydrates under acid catalysis [23] as shown in **Figure 2(b)**. It can be seen in **Table 3**, values for cellulose, hemicellulose and lignin. Compared to the straw marabout 39.5%, 15.9% and 31.6% of cellulose, hemicellulose and lignin, respectively [24] can be observed that the amount of pulp was higher, however, hemicellulose and lignin were similar.

As can be seen in **Table 4**, the pre-hydrolysis with dilute acid not only solubilizing hemicellulose, but also has the power to convert it into fermentable sugars, the resulting liquor is composed of sugars (glucose, xylose and arabinose), making it an important residue which can be used for producing ethanol, as shown in **Figure 3** as a percentage.

4. Conclusion

Depending on the results presented here, we can conclude

Table 2. Physicochemical characterization of the cashew apple bagasse in natura and after pretreatment.

Parameters analyzed	Cashew bagasse dry	Bagasse of cashew prehydrolyzed
Moisture (%)	9.29 ± 0.07	23.85 ± 0.05
pH	4.23 ± 0.01	1.70 ± 0.04
Soluble solids (˚Brix)	0.00 ± 0.00	0.00 ± 0.00
Reducing Sugars (%)	0.56 ± 0.02	1.80 ± 0.08

Table 3. Comparison between the chemical composition of dried and crushed cashew pretreated.

Parameters analyzed	Cashew bagasse dry	Bagasse of cashew prehydrolyzed
Cellulose (%)	18.31 ± 0.07	31.50 ± 0.02
Hemicellulose (%)	27.18 ± 0.01	19.30 ± 0.09
Lignin (%)	23.91 ± 0.02	32.21 ± 0.07

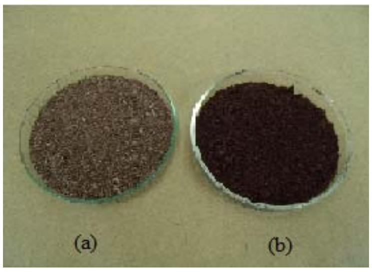

Figure 2. Peduncle of cashew bagasse (a) dry and (b) prehydrolyzed.

Table 4. Concentration (mg/L) and sugar compounds toxic liquor bagasse prehydrolyzed of the cashew apple.

Component	Content (mg/L)
Glucose	1758.66
Xylose	5458.70
Arabinose	7640.72
Acetic acid	5.66
HMF	49.17
Furfural	0.04

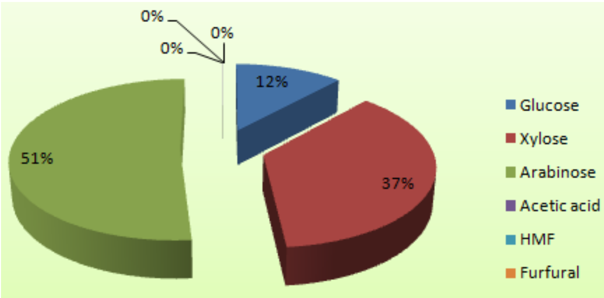

Figure 3. Percentage of sugar in the liquor prehydrolyzed bagasse peduncle of cashew.

that the cashew bagasse biomass has great potential for bioprocess after prehydrolysis, is a promising raw material for bioethanol production, with 12% of hexoses, and 88% pentoses.

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