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Isolation and Characterization of Sugarcane *(Saccharum officinarum* L.) Bagasse Cellulose Hydrolyzed with Acid Variation

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ABSTRACT

The acid-based approach has been used to successfully isolate natural cellulose from sugarcane (*Saccharum officinarum* L.) bagasse. This research was aimed at investigating the effects of different acids and concentrations on the physical characteristics and powder properties of sugarcane bagasse cellulose (SBC). From sugarcane bagasse, cellulose was isolated. The optimization parameters; acid types (nitric, sulfuric, or hydrochloride acid), concentrations (3, 4, and 5%, respectively), the ratio of acid to sugarcane bagasse, and the concentration of bleaching agent (hydrogen peroxide) were evaluated. The isolated celluloses were characterized using FTIR Spectroscopy and X-Ray Diffraction analysis. The physical properties and powder properties of SBC were determined. The results showed that the optimum condition for the isolation process was 4% HNO_3 with a percentage yield of 44.200±0.004%. The optimum ratio of acid: sugarcane bagasse was obtained at 8 mL: 1 g, and bleached with 15% hydrogen peroxide. The colour and form of SBC obtained at optimum conditions were appropriate compared to the standard. The coefficient of the Pearson correlation test shows that acid type (-0.246) and concentration (-0.087) correlated with the percentage yield. Bagasse (6.6%) and cellulose (6.27%) powders have moisture contents that meet the requirements of simplicia (10%). The FTIR spectra of SBC were similar to the standard. The bulk and tapped densities (0.071 and 0.077, respectively) of SBC were found to be significantly lower than the standards (0.227 and 0.250). The findings of this study reveal that different acid types and concentrations influence the characteristics of sugarcane bagasse cellulose.

Keywords: *Saccharum officinarum* L., Cellulose, Bagasse, Powder properties.

Introduction

Cellulose is the most abundant renewable polymer source in nature. It is one of the major sources of materials in the cosmetic and pharmaceutical industries. Ethyl cellulose, methyl cellulose, microcellulose, nanocellulose, cellulose esters, cellulose ethers, and other cellulose derivatives are all useful in the pharmaceutical industry[1,2] Cellulose can be found or isolated from many sources, such as natural materials, semi-synthetic or synthetic products. Natural resources that contain cellulose, such as plant cell walls, acetic acid bacteria, animals (tunicates), algae, and oomycetes, can be obtained as raw materials. Therefore, cellulose can be extracted from waste pineapple peel juice to produce bacterial cellulose,[3] palm oil mesocarp fiber,[4] potato peel waste,[5] palm sugar fiber,[6] sago,[7] palm bunches oil,[8] banana residue,[9] wheat straw,[10] cassava pulp,[11,12]borassus flabellifer,[13] and sugarcane bagasse.[14,15] Sugarcane bagasse is fibrous residue from sugarcane that is obtained after juice extraction process.[16] It is a waste obtained from the sugar mill and alcohol industry. Sugarcane bagasse contains 40-50% cellulose (crystalline and amorphous structure), 25-35% hemicellulose (amorphous polymers usually composed of xylose, arabinose, galactose, glucose, and mannose), 15-20% lignin, and minor amounts of minerals, wax, as well as other compounds.[17]

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The large percentage of cellulose makes sugarcane bagasse a promising candidate for the production of cellulose and its derivatives. Production of cellulose can be processed by several methods, such as sonication,[15] extrution,[18] acid hydrolysis,[19] base hydrolysis, using toluene as an organic solvent,[15] and enzymatic hydrolysis.[18]Toluene is a well-known toxic solvent and as such, it might cause irreversible diseases such as neurotoxicity and teratogenicity.[15,20] Enzymatic hydrolysis is very expensive and requires a long process of approximately 72 h.[21] From the several methods, acid-base hydrolysis is most widely used for cellulose isolation due to its shorter reaction time compared to other methods.[22,23]Several studies have reported the isolation of cellulose by using acid or base hydrolysis. The optimized the isolation of cellulose with various nitric acid concentrations, reaction times, and temperatures. His objective was to determine the optimal process conditions for converting sugarcane bagasse to cellulose through the delignification process. The result shows that the optimal yield was achieved with 3-5% HNO_3 for 5 hours reaction time at 80ºC. In the study, cellulose was not analyzed for physicochemical properties.[24]Nanocellulose is produced by isolating sugarcane bagasse cellulose with sulfuric acid. Isolation works at various concentrations, temperatures, and reaction times. The best results were obtained using 60% sulfuric acid at 40°C for 5 minutes of hydrolysis time. Then, it was characterized by Fourier Transform Infrared Spectroscopy and X-Ray Diffraction.[14] The extraction method was also used to isolate cellulose using a toluene: ethanol (2:1) solution. In the physical characterization of the cellulose, morphological tests using a scanning electron microscopy, analysis of infrared spectra, and X-ray diffraction (XRD) analysis were used.[15]
The aim of this research was to investigate the effects of different acids and concentrations on the physical characteristics and powder properties of sugarcane bagasse cellulose (SBC).

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Materials and Methods

Source of plant materials
Sugarcane bagasse samples were obtained from the sugar industry at Slumbung, Kediri, East Java, Indonesia in September 2018. The fresh sugarcane bagasse waste was identified using the morphological characteristics at the Technical Implementation Unit of the Herbal Material Medika Laboratory, Batu, Malang, East Java, Indonesia.

Sources of chemicals
The reagents used were nitric acid, hydrochloric acid and sodium hydroxide (Merck), sulfuric acid (Mallincordt, USA), hydrogen peroxide and α-cellulose (Sigma).

Sample preparation
A 5 kg of sugarcane bagasse was washed to remove any leftover soil or other contaminants before being dried in the sun. The dried bagasse was cut into small pieces (approximately 1-2 cm), crushed, and the fraction that passed through a 100 mesh sieve was chosen as the raw material for the next step. The bagasse powder samples were stored in closed containers at room temperature.

Isolation of sugarcane bagasse cellulose
The powder of sugarcane bagasse was hydrolyzed in the acid solution for 2 hours at 80°C. The residue was neutralized with distilled water and heated with sodium hydroxide for 1 h at 80°C. Then, it was washed with distilled water and bleached with hydrogen peroxide. The residue was dried at 60°C for 24 h. Physical tests, characterization of infrared spectra, and X-ray diffraction analyses, powder properties, as well as percentage of yield in various acids and concentrations were used to assess sugarcane bagasse cellulose. In this study, three types of acid (nitric, sulfuric, or hydrochloride acid) in different concentrations of 3, 4, and 5%, respectively, were used for hydrolysis.

Analysis of physical properties
Moisture content, color, and cellulose form were the physical properties analyzed. The moisture content was measured by evaporating 0.5 g of sample in the moisture content analyzer (Mettler Toledo HE 53).Then, the moisture content was recorded.[25] Measurement of moisture content was carried out for sugarcane bagasse and sugarcane bagasse cellulose. Standard cellulose from Sigma was used to determine the color and shape of cellulose.

Analysis of powder properties
Powder properties of sugarcane bagasse cellulose such as bulk densities, tapped densities, Hausner ratio, Carr's index, and angle of repose were calculated. The formula for each of the properties are given below.

Bulk densities
Bulk density is the mass of bulk solid that involves a unit volume of a bed, including the volume of all interparticle voids. Given that a powder is a molecular gas mixture with both interparticle and intraparticle gaps.[26] Cellulose (2 g) was placed in a sterile 100 mL measuring glass. The bulk volume of the sample was obtained and recorded.

$$\rho \text{ bulk} = \frac{massa\ (g)}{volume\ (mL)}$$

Tapped densities
Tapped density is the proportion of the mass of the powder to the volume involved by the powder after it has been tapped for a specified timeframe. The tapped density of a powder addresses its arbitrary thick packing.[27] The estimating glass containing the sample was tapped at a height of 2.5 mm until the logical equilibrium was reached. In addition, the tapped volume was recorded.

$$\rho \text{ tapped} = \frac{massa\ (g)}{volume\ (mL)}$$

Hausner ratio
The Hausner ratio is the proportion of the bulk density to the tapped density. In the less free-streaming powders had a proportion of less than 1.2 compared with more durable powders, and less free-streaming powders had higher qualities (> 1.5).[28] The Hausner ratio of the sample was obtained and recorded.

$$\text{Hausner ratio} = \frac{\rho\ tapped}{\rho\ bulk}$$

Carr's index
Carr's index is an immediate proportion of the propensity of a curve or extension arrangement and its solidarity. In addition, it is a convoluted fraction of the powder's stream qualities. A free-streamed powder would have a value of less than 15, while an inadequately streamed powder has a file esteem higher than 32.[29] The compressibility index was also recorded.

$$\text{Compressibility Index} = 100 \times \frac{\rho\ tapped - \rho\ bulk}{\rho\ tapped}$$

Angle of repose
Through the decent channel and unattached cone strategy, the static point of rest was obtained. A chart paper was raised on a flat surface with the tip of a pipe, 2 cm away from the paper. The sample powder was fed through the channel until the apex of one reached the tip of the funnel.[30] The height (h) and radius (r) of the cone were recorded.

$$\Theta = \tan\text{-}1 \frac{h}{r}$$

Infrared spectra analysis
The FTIR spectra of sugarcane bagasse and sugarcane bagasse cellulose were recorded on the Fourier Transform Infrared (FTIR) Spectrophotometer Shimadzu in the wavelength range from 4000 to 500 cm^{-1}.[31]

X-ray diffraction analysis
XRD X'pert PRO PANalytical was used to collect the X-ray diffraction data The crystallinity index (CI) was calculated using the equation by measuring the peak height of the crystalline region (I_{002}) and the amorphous region (Iam).[32] The I_{002} is the intensity value for the crystalline cellulose (2θ = 22.5° for cellulose I and 2θ = 20.1° for cellulose II), and Iam is the intensity value for the amorphous cellulose (2θ = 18° for cellulose I and 2θ = 16.3° for cellulose II).[33]

$$C_I(\%) = \frac{I_{002} - I_{am}}{I_{002}} x100\%$$

Statistical analysis
The simple correlation test (Pearson correlation),[34] was used to determine the correlation between the type of acid and the variation in concentration with the percentage of cellulose obtained. This test can use either a positive linear correlation or a negative linear correlation as the form of correlation. The value of the correlation coefficient that is close to or away from one determines the form of correlation of the analyzed data. Descriptive analysis was used to process the moisture content data of sugarcane bagasse and sugarcane bagasse cellulose.

Results and Discussion

Determination and sample preparation of sugarcane bagasse
PS 862 sugarcane types have green leaves with a curving end less than half the length of the leaf blade. The sugarcane stem is divided into portions that are straight rather than conical in shape until it reaches a coil with a round cross-section. The segments are yellowish-green. The bar is covered with wax, which can affect the colour of the segment. It has cork stains, cork cracks, and no growing cracks. The flow of the eye is narrow, shallow, and does not reach the middle of the segment; the root eye consists of 2-3 rows, with the top row not passing through the top of the eye. The porch is rather large (Figure 1a and Figure 1b). Fresh bagasse (Figure 1c) can produce bagasse powder of almost 40% of its initial weight. The bagasse is ground to expand the surface of the particles so that it can expand the contact

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area between the bagasse and the solvent during isolation. The larger the surface, the easier the penetration and the more optimal the hydrolytic process. Bagasse powder is creamy and fibrous (Figure 1d).

Isolation of sugarcane bagasse cellulose

The isolation process of cellulose from sugarcane bagasse was started by acid hydrolysis. The effect of acid variations and concentrations on color, form, and cellulose yields in percent is shown in Table 1 and figure 2. Sugarcane bagasse is mainly a cellulosic material. Acid addition to sugarcane bagasse powder cleaved the intrachain bonds between cellulose, hemicellulose, and lignin contained in bagasse.[16] The colour changed from brown to orange or rust after heating at 80^{o}C for 2 hours. Hemicellulose and lignin are soluble in alkali and can be released. In this study, sodium hydroxide was employed to remove hemicellulose and delignify the procedure. The cellulose colour changed from dark brown to cream. A hydrogen peroxide solution was added in the last step to bleach the cellulose. The white cellulose was obtained from the isolation process using nitric acid, while the cream cellulose was obtained by employing both sulphuric acid and hydrochloric acid. Using 4% nitric acid throughout the hydrolysis process yielded the highest cellulose yield (44.20%).

The isolated cellulose of sugarcane bagasse was impacted by changes in acid solutions and concentrations. According to the Pearson correlation test (Table 2), acid type and concentration exhibit negative type linear correlation coefficients of -0.246 and -0.087, respectively, to the percentage of yield. Compared to the type of acid, the concentration of acid has a more significant effect on the percentage yield. Changes in acid concentration cause the value of the percentage of yields to fluctuate. The highest amount of yield was obtained for isolates hydrolyzed with nitric acid. The presence of nitric acid is intended to convert the lignin in pulp into nitro lignin, which can be dissolved in the base.[35] During the hydrolysis process, electrons influenced the nucleus of the guasil group from lignin, causing the electrophile to strongly point to the para or ortho position of the OH group, causing the bond with the propyl side chain to break. This results in the lignin end unit splitting from the remaining lignin macromolecule and becoming a dissolved form.[21]. Sodium hydroxide is used to remove hemicellulose and replace it with cellulose.[14] After washing and bleaching with peroxide, lignin, and other matrices are released. The formation of dangerous organochlorine compounds is not caused by hydrogen peroxide. During the process, there was no possibility of chlorine gas being formed. It is more environmentally friendly because it decomposes with water and oxygen.[24]

The effect of the ratio of acid (mL) to sugarcane bagasse isolated (g) was observed on the amount of cellulose yield obtained. With 4% nitric acid as a hydrolysis agent, the ratios employed were 15:1, 8:1, 6:1, and 4:1. The highest yield was obtained at a ratio of 8: 1. At this ratio, nitric acid can work optimally in hydrolyzing sugarcane bagasse (Table 1). Hydrolysis treatment, or the addition of an acid solvent, is most widely used in the isolation of cellulose from natural materials because it only requires a shorter reaction time than other processes. Hydrochloric acid and its derivatives, as well as peroxide acid are often used in acid treatment because, in addition to optimizing the delignification process, it also functions as a bleach or assists in the bleaching process.[36] The white powder was produced through the bleaching process using peroxide acid. The colour and form of standard cellulose were white powder. At a concentration of 10%, the colour of sugarcane bagasse cellulose was incompatible with standard cellulose; however, at a concentration of 15-30%, the cellulose was inappropriate with standard cellulose (Table 3).

Sugarcane bagasse powder moisture content

During storage, the moisture content of sugarcane bagasse powder was less than 7% (Figure 2). Bagasse powder had a moisture content of 6.843% at the beginning. Then it drops and stays steady between the fourth and sixth month, which was around 6.6 ±0.175%. Moreover, the moisture content of cellulose powder was 6.27±0.28%. During the storage period, the moisture content of dry bagasse powder can evaporate more easily due to the larger surface area of the powder.

Because the moisture content of bagasse and cellulose powder during storage met the specified requirements, namely <10%, the risk of bacterial, fungal, and other contamination is minimal.[25]

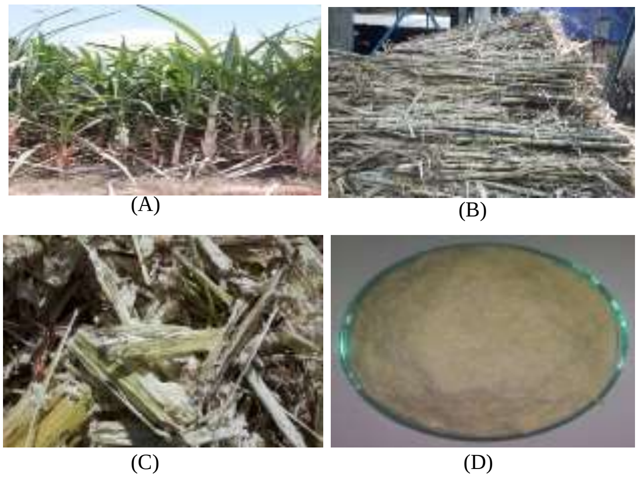

Figure 1: Processing of sugarcane bagasse **(**A) *Saccharum officinarum* L (B) *Sugarcane* stalks before the juice was squeezed (C) Wet bagasse after the juice was collected (D) Prepared bagasse powder

Table 1: The effect of different acid on cellulose organoleptic characteristics

Acid variation	Changes after adding acid	Changes after adding NaOH	Changes after adding H_2O_2	Colour		Cellulose yield
H_2SO_4 (3%)	Brick red	Dark brown	beige	Fiber	beige	32.770±0.068
HCl (3%)	Brick red	Dark brown	beige	Fiber	beige	32.423±0.127
HNO_3 (3%)	Orange	Red brown	White	Powder	White	38.930±0.024
H_2SO_4 (4%)	Brick red	Dark brown	beige	Fiber	beige	34.410±0.314
HCl (4%)	Brick red	Dark brown	beige	Fiber	beige	31.008±0.566
HNO_3 (4%)	Orange	Red brown	White	Powder	White	44.200±0.004
H_2SO_4 (5%)	Brick red	Dark brown	beige	Fiber	beige	32.500±0.074
HCl (5%)	Brick red	Dark brown	beige	Fiber	beige	26.905±0.004
HNO_3 (5%)	Orange	Red brown	White	Powder	White	41.400±0.012

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Analysis of powder properties

The quality of the dried powder was determined by bulk and tapped densities, Carr's index, Hausner ratio, and angle of repose.[37] Cellulose has a bulk density of 0.15-0.39 g/cm^3 and a tapped density of 0.21-0.48 g/cm^3.[3,26,27,38] The bulk and tapped densities of sugarcane bagasse cellulose were found to be significantly lower than the standard, with values of 0.071 and 0.077, respectively (Table 4). The residual moisture content of the powder during the isolation process affects bulk and tapped densities. The remaining solids after moisture removal have higher densities than water, and the overall solid density tends to increase as the moisture is removed.[39] The flowability of powder is a measure of the free flow characteristics.[39] The flowability and cohesiveness properties of cellulose powder in terms of Hausner ratio, Carr's index, and angle of repose were evaluated. The results were 1.080, 8,450, and 50.201, respectively. According to the index classification of powder flowability (Tables 4-7), sugarcane bagasse cellulose is categorized as excellent powder based on the Hausner ratio and Carr's index and medium flowability based on the angle of repose.

Infrared spectroscopic analysis

Based on the characteristics of the components contained in sugarcane bagasse, a pre-treatment step is required to facilitate the structure of the lignocellulosic matrix of sugarcane bagasse. Pre-treatment can be the addition of acid to open the disposal of lignin and hemicellulose to produce cellulose.[40,41] The reaction is complex and heterogeneous. Acid breaks ester bonds between hemicellulose and lignin, and disrupts hydrogen bonds between the hemicellulose and cellulose.[42] The addition of alkali optimizes the delignification process by breaking the ester bond between cellulose lignin-acid-sensitive cellulose. Alkalis and lignin can form soluble compounds that are easily washed away.[21] The FTIR spectra of cellulose from sugarcane bagasse formed by acid variation (Figure 5 and Table 8)showed two main absorbance regions in the range of 700–1650 cm^{-1} and 2900–3400 cm^{-1}.[43] A broadband around 3200-3500 cm^{-1} indicated the presence of stretching O-H groups in cellulose, lignin, and hemicellulose. Absorption in this range was found in all the samples. Stretching of the C-H group was also found in all the samples at 2900 cm-^{1}. Lignin showed a typical band around 1500 cm^{-1} which represents the presence of guacil and ring lignin (Figure 5a, d, and e). Meanwhile, in the cellulose samples of Figure 5b and c, absorption was not found in this area. The absorption band is correlated with the typical band of lignin in the area around 1750 cm^{-1} which indicates the presence of C=O groups in lignin, hemicellulose, and acetyl esters.
The absorption band at 1750 cm^{-1} was found in the sample (untreated sugarcane bagasse) as displayed in Figure 4a.There was no absorption band in that area for sugarcane bagasse cellulose samples from all the acid treatments.
Absorption bands around 1500 cm^{-1} to 1600 cm^{-1} appeared in all the samples indicating the presence of C=O stretching of lignin. The absorption band that appeared in the 890 cm^{-1} indicates the formation of cellulose glycosidic bonds. This absorption band only appeared in the acid-treated samples to produce the cellulose from sugarcane bagasse. The typical absorption band for COO vibrations of the hemicellulose acetyl group is shown to be around 1270 cm^{-1}.[44] This absorption can also be represented as an aryl C-O stretching of lignin.[43] The absorption band only appeared in the untreated sugarcane bagasse samples. Bagasse cellulose absorption of around 1630 cm^{-1} indicates the presence of water absorption in the cellulose.[15,36,43] This is related to the space left by hemicellulose and lignin (empty) so that it allows the cellulose to absorb moisture. Based on the description above, the process of delignification of sugarcane bagasse to cellulose sugarcane bagasse is not perfect with sulfuric acid and hydrochloric acid solvents. This result is in accordance with the shape and colour of the cellulose obtained, which is different from the standard.

X-ray diffraction analysis

Sugarcane bagasse samples and cellulose from sugarcane bagasse samples showed a similar and unique crystal peak profile around 15^o; 22^o and 34^o, according to the value of 2θ that is required (Figure 5).

Table 2: Pearson correlation test of different acid type and concentration in relation to cellulose yields.

Parameter	Pearson Correlation	Sig.	Covariance	N
Acid type	-0.246	0.524	-1.167	9
Concentration	-0.087	0.824	-3.310	9

Table 3: The effect of H_2O_2 consentration on cellulose organoleptic characteristics.

Concentration	Colour	Type
10%	Ivory	powder
15%	White	powder
20%	White	powder
30%	White	powder

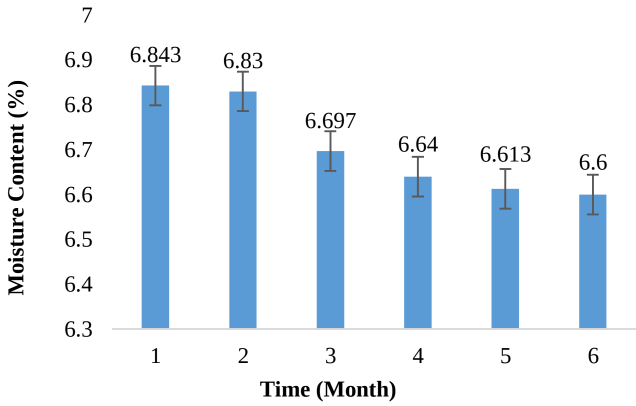

Figure 2: Moisture content of sugarcane bagasse powder

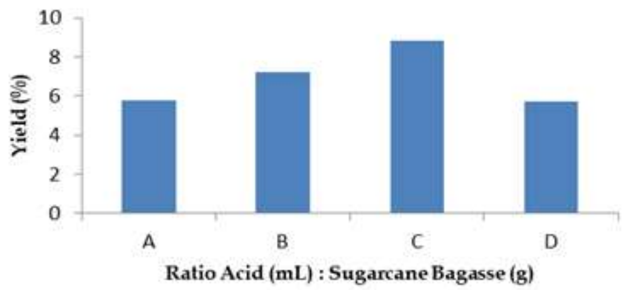

Figure 3: Effect of acid (mL) : sugarcane bagasse (g) ratio on yield (%) (A) 4:1 (B) 6:1 (C) 8:1 (D) 15:1

Table 4: Physical properties of sugarcane bagasse cellulose powder

Characteristics	Sugarcane bagasse cellulose	Standard cellulose
Bulk Density	0.071	0.227
Tap Density	0.077	0.250
Hausner Ratio	1.080	1.101
Carr's Index	8.450	9.2
Angle of Repose	50.201	53.9

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This result is in agreement with the research of Rahimiet al.[15] The difference between the three peaks lies in the intensity, which indicates the crystallinity of the two different samples. Sugarcane bagasse has a lower crystallinity index than cellulose from sugarcane bagasse because there are still amorphous areas in its structure. The termination of amorphous regions in cellulose from sugarcane bagasse can increase the crystallinity index. The crystallinity values of bagasse (Figure 5A) and bagasse cellulose (Figure 5B) were 42% and 59.3%, respectively.

Table 5: Hausner ratio of sugarcane bagasse cellulose powder.

Compressibility index (%)	Flow Character	Hausner Ratio
1-10	Excellent	1.00-1.11
11-15	Good	1.12-1.18
16-20	Fair	1.19-1.25
21-25	Passable	1.26-1.34
26-31	Poor	1.35-1.45
32-37	Very poor	1.46-1.59
>38	Very, very poor	>1.60

Table 6: Carr's index of sugarcane bagasse cellulose powder.

Consolidation Index (Carr's %)	Flow
5-15	Excellent
12-16	Good
18-21	Fair to passable
23-35	Poor
33-38	Very poor
>40	Very, very poor

Table 7: Angle of repose of sugarcane bagasse cellulose powder

Angle of Repose	Flowability
≤31	Excellent
32-45	Good
46-56	Medium
≥57	Poor

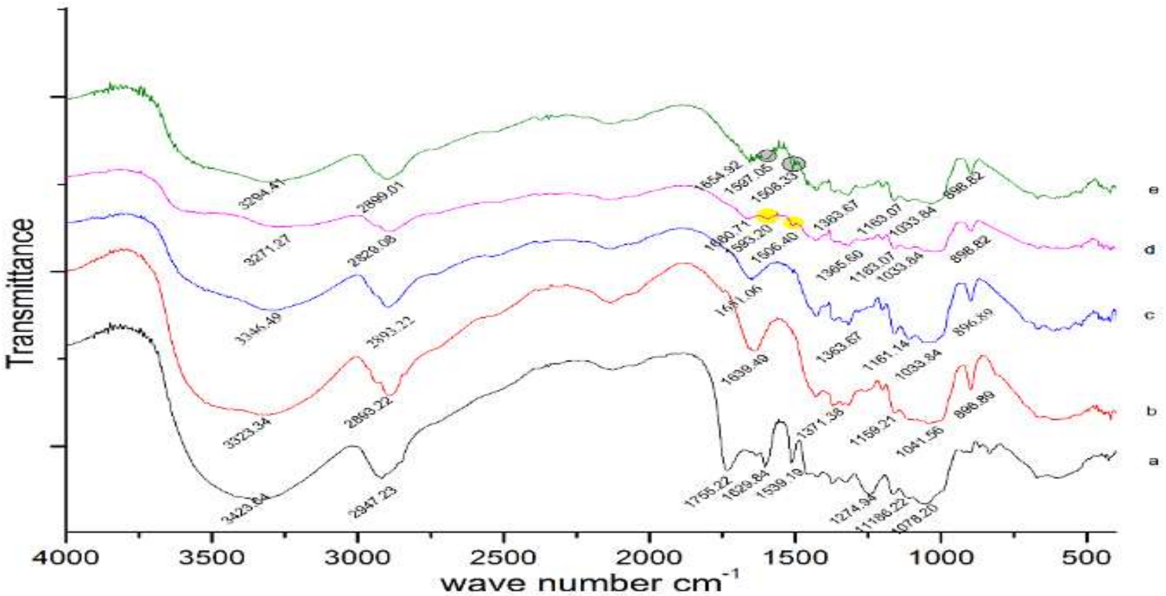

Figure 4: FTIR spectra of isolated cellulose (a) Sugarcane bagasse (b) Standard cellulose (c) Treatment with nitric acid (d) Treatment with sulphuric acid (e) Treatment with hydrochloric acid

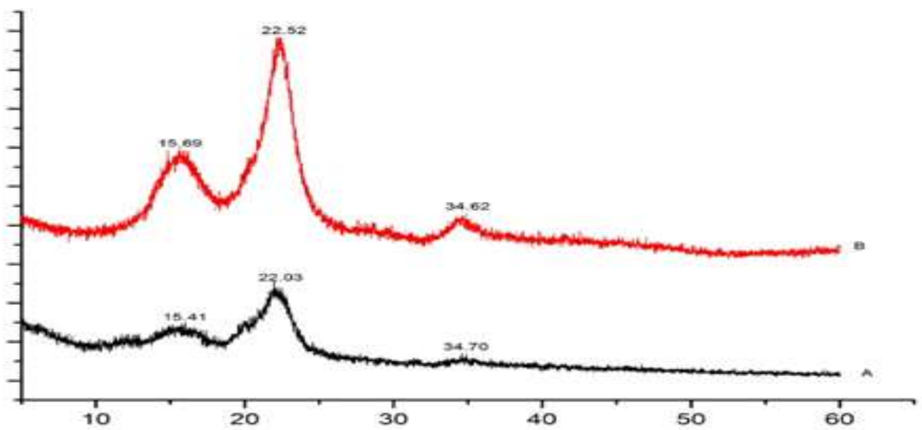

Figure 5: The XRD spectra of the sugarcane bagasse (A) and sugarcane bagasse cellulose (B).

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Table 8: The effect of acid on functional group of cellulose.

Code	O-H 3500-3250 (cm^{-1})	C-H 3000-2750 (cm^{-1})	O-H absorbs water 1700-1650 (cm^{-1})	C-H and C-O bond 1400-1300 (cm^{-1})	C-O-C pyranose ring 1200-1000 (cm^{-1})	Glycosidic bond 900-880 (cm^{-1})	C=O lignin and lignin/hemicellulose carboxylate groups 1734 and 1602 (cm^{-1})	C=C from the aromatic ring of lignin 1512,19 (cm^{-1})	Cyrillic groups in lignin 1240,22 (cm^{-1})	C-H bond in lignin 867,96 (cm^{-1})
A	√	√	-	-	√	-	√	√	√	√
B	√	√	√	√	√	√	-	-	-	-
C	√	√	√	√	√	√	-	-	-	-
D	√	√	-	√	√	√	√	√	-	-
E	√	√	-	√	√	√	√	√	-	-

Code Stands: A. Untreated Sugarcane Bagasse; B. Standard cellulose; C. Sugarcane bagasse cellulose (HNO_3 4%); D. Sugarcane bagasse cellulose (HCl 4%); E. Sugarcane bagasse cellulose (H_2SO_4 4%)

Conclusion

The hydrolysis of lignin and bagasse may be affected by changes in acid and concentration of solvents used in cellulose isolation. In this study, the cellulose isolated with nitric acid is suitable for the standard sigma cellulose. Meanwhile, the results of the cellulose isolation with sulfuric acid and hydrochloric acid showed discrepancy with the standard cellulose. The lignin peak still appears at the IR spectra of cellulose isolated with sulfuric acid and hydrochloric acid, which was consistent with the standard IR spectra. The bulk and tapped densities of sugarcane bagasse cellulose were found to be significantly lower than the standard. The flowability of powder is a measure of the free flow characteristics. According to the index classification of powder flowability, sugarcane bagasse cellulose was categorized as excellent powder based on the Hausner ratio and Carr's index and medium powder in flowability, based on the angle of repose.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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