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RESEARCH ARTICLE

Comparative evaluation of xylan extraction methods and product characterization from sugarcane bagasse

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Abstract:
Sugarcane bagasse is a rich source for Hemicelluloses. Xylan is a major type of hemicellulose represented as glucurono-arabinoxylans (GAX) in sugarcane. In the present study, comparative analysis of different xylan extraction methods namely sodium borohydride treatment, dimethyl sulfoxide (DMSO) extraction; dilute acid treatment, sonication, hydrogen peroxide and hot water treatment methods have been carried out for extraction and purification xylan from the bagasse of sugarcane genotypes Co 86032, Co 2001 -15, SES 159, and SES 18. The results showed that alkaline extracted sugarcane bagasse yielded significantly highest xylan yield and recovery in the range of 23.85-32.35% and 72.37%-97% respectively as compared to the rest of the pretreatment methods. Moderate xylan yield (7.68-17.43%) and recovery (22.49-52.89%) was observed using hot water, sodium borohydride and hydrogen peroxide pretreatment methods with significantly highest xylan recovery of 52.89% in hydrogen peroxide pretretated bagasse. Among all the pretreatment methods studied, DMSO, dilute acid and sonication pretreated bagasse samples yielded significantly very low xylan recovery in the range of 1.21-4.89%. Fourier Transmission Infra-Red (FT-IR) spectroscopic analysis of alkali extracted xylan showed similar spectral profile of commercial Beechwood xylan and indicated the presence of hemicellulose structures. These results evidenced the simple economically feasible xylan extraction technology and provided much more scope for using sugarcane bagasse as potential xylan source to produce industrially important value added products.

Keywords: Hemicellulose; Xylan; Sugarcane Bagasse; Pretreatment; Value added product

Introduction

Sugarcane bagasse is an important byproduct of sugar and alcohol industries. Bagasse is a fibrous product remained after sugar extraction from sugarcane. Bagasse is a rich source for lignocellulose contributing about 98% on dry weight basis. One tonne of sugarcane generates about 280 kg of bagasse and approximately 54 million dry tons of bagasse is produced annually throughout the world (Canilha et al. 2012). Sugarcane bagasse is being mainly used to generate heat and power to run the sugar mills and ethanol plants. Therefore, large amount of biomass is available for converting into value added chemicals and fuels. Chemically, bagasse comprised of about 40–50% of the dry residue is the glucose polymer cellulose, much of which is in a crystalline structure. Another 25–35% is hemicelluloses, an amorphous polymer usually composed of xylose, arabinose, galactose, glucose, and mannose. The remainder is mostly lignin plus lesser amounts minerals, waxes, and other compounds (Rezendee et al. 2011; Jaypal et al. 2013, Guilhermee et al. 2015).

Hemicelluloses, which occur in the cell wall, are hetero polysaccharides. Xylan is the most abundant of the hemicelluloses found in the cell walls of land plants, of which they can constitute more than 30% of the dry weight. It is also a second most abundant polysaccharide after cellulose. Hemicellulose has been used to produce higher value-added products such as prebiotic xylo oligosaccharides or polymers and composites for chemical and pharmaceutical applications. Hemicelluloses

are known as valuable in pulp additives, natural barrier for packaging films and as components of skin substitutes in case of damage of superficial epidermal layers. Xylan has drawn considerable interest due to its potential for packaging films and coating food, as well as for its use in biomedical products (Li et al. 2011). Because, it is referred to as a corn fiber gum with a sticky behavior, xylan has been used as an adhesive, thickener, and additive to plastics. It increases their stretch and breaking resistance as well as their susceptibility to biodegradation (Unlue et al. 2009). Xylan has also been studied because of its significant mitogenic and comitogenic properties, which enable it to be compared to the commercial immunomodulator, Zymosan (Ebringerova et al. 1995). Another interesting application for xylan may be found in the food industry as an emulsifier and protein foam stabilizer during heating (Ebringerova et al. 1995). Previous papers have investigated the suitable use of xylan in paper making (Ebringerova et al. 1994) and textile printing (Hromadkova et al. 1999). In the drug delivery field, xylan extracted from birch wood has been used for the production of nanoparticles after structural modification by the addition of different ester moieties, namely those with furoate and pyroglutamate functions (Heinze et al. 2007). On the other hand, the esterification of xylan from beech wood via activation of the carboxylic acid with *N,N"*-carbonyldiimidazole has been carried out in order to produce prodrugs for ibuprofen release (Daus and Heinze 2010).

Depending on composition of sugar units and type of plant and extraction process, hemicelluloses are classified as xylans (β-1,4-linked D-xylose units), mannans (β -1,4-linked D-mannose units), arabinans (α-1,5-linked L-arabinose units), and galactans (β -1,3-linked D-galactose units) (Jeffries 1994; Ebringerova and Heinze 2000; Belgacem and Gandini 2008). Different treatments have been applied to hemicellulose extraction, and heat treatment is often combined with addition of chemicals such as alkali, acid or hydrogen peroxide. Alkaline peroxide is an effective agent for both delignification and solubilisation of hemicelluloses. In these conditions carbohydrates are less damaged and delignification is more efficient (Sun et al. and 2004). Various pre-treatment methods have been reported to extract hemicellulosic components from sugarcane bagasse. These include dilute acid pre-treatment, hot water pre-treatment and alkaline/peroxide treatment (Lie et al. 2010). Dilute acid hydrolysis mostly generates oligomeric and monomeric hemicellulose derived sugars, mainly xylose which can be the platform for the production of chemicals such as ethanol, furfural and xylitol. On other hand, alkaline treatment originates high molecular weight hemicellulose derived polymers in particular xylan which might be used for the production of biopolymers.

However, fractionation of these individual lignocellulosic components in pure form is always challenging. Several pretreatment methods are available to fractionate lignocellulosic components and use them in chemical conversion or bioconversion to fuels and chemicals. In this study, we report the comparative evaluation of different extraction methods for xylan from sugarcane bagasse and derived product has analyzed for various physical and chemical characteristics. Unlike previous reports, the present study report simultaneous comparison of different pretreatment methods to extract xylan from sugarcane bagasse. In this study, we have investigated the optimization of xylan extraction processes from sugarcane bagasse by various pre-treatment methods like sodium borohydride treatment, DMSO extraction, dilute acid treatment, sonication, hydrogen peroxide and hot water pretreatments.

Materials and Methods

Plant material

Sugarcane genotypes namely Co 86032, Co 2001 -15, SES 159, and SES 18 were grown in the field of ICAR- Sugarcane Breeding Institute, at Coimbatore. Matured canes of 12th month age plants were harvested and juice was extracted. Bagasse remained was dried in sunlight and ground to a fine powder. Powdered bagasse samples were sieved (mesh size of 0.85 mm) and used for the extraction of xylan.

Compositional analysis of sugarcane bagasse:

Powdered Sugarcane bagasse samples of genotypes Co 86032, Co 2001- 15, SES 159 and SES 181 were oven dried at 60°C till constant weight. The total ash content were estimated by igniting the samples at 550°C for 3 hr in BTI-36 (BIO-TECHNICS INIDA^{TM}) muffle furnace (AOAC, 2000). Cellulose, hemicelluloses and lignin content in the samples was analyzed using National Renewable Energy Laboratory (NREL) method (Sluiteret al. 2011).

Pretreatment methods:

In this study, xylan was extracted from sugarcane bagasse using methods namely sodium borohydride method, hot water pre-treatment method, hydrogen peroxide pre-treatment method, alkaline pre-treatment method, dilute acid method, sonication method, and di-methyl sulfoxide method. Sequential steps involved in the pretreatment methods are depicted in figure 1.

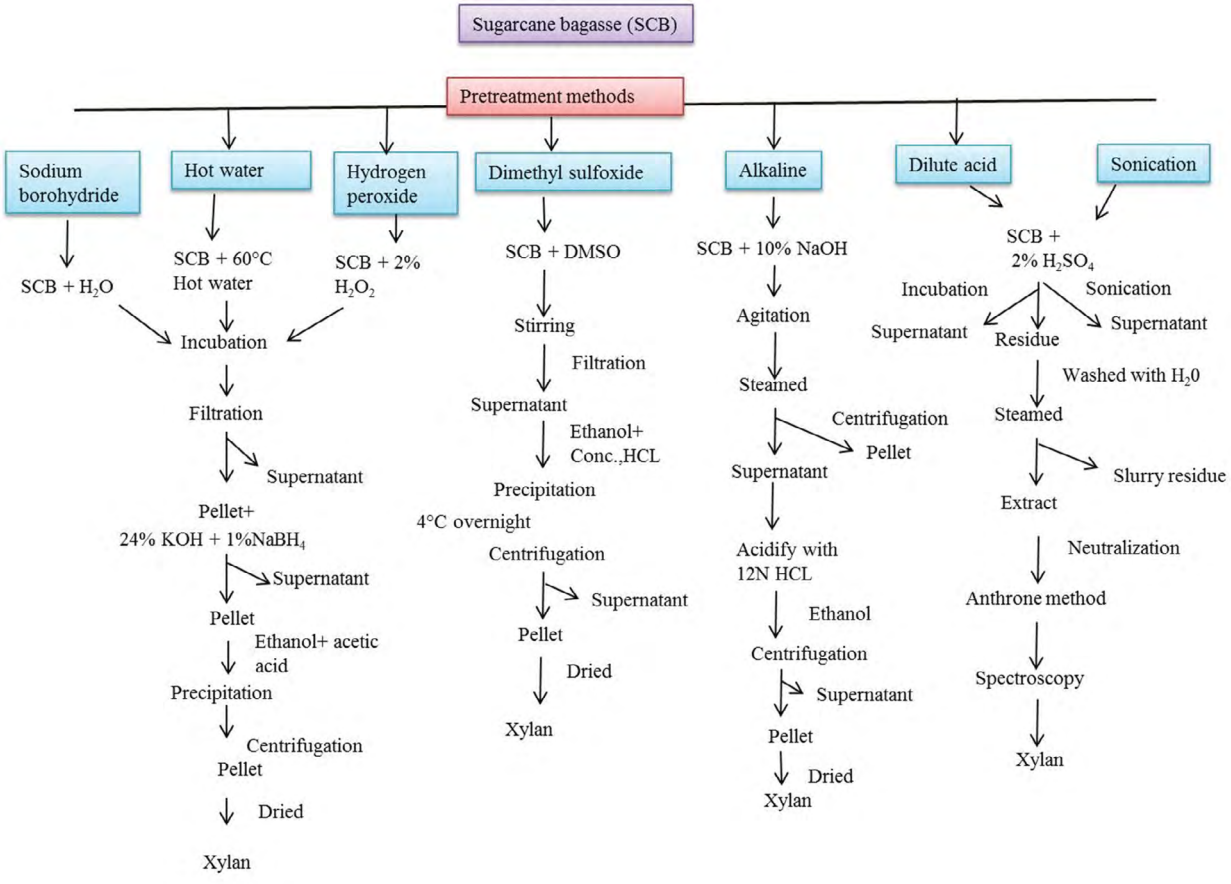

Figure 1: Flow chart showing sequence of steps involved in extraction of xylan from sugarcane bagasse using different pretreatments method.

i. Sodium borohydride, hot water and hydrogen peroxide pretreatment methods

Sodium borohydride method was carried out as per the method described previously by Zillox and Debeire (1998) with some modifications. Ten grams of sugarcane bagasse from each variety was suspended in 200 ml of distilled water and allowed for swelling at 60°C for 16 hr. The swollen sample was filtered using Whatman filter paper. Thus, obtained soild residue was stirred in 50 ml of 24% w/v potassium hydroxide and 1% Sodium borohydride solution for 3 hr at room temperature. Then the suspension was filtered using Whatman filter paper and resulting filtrate was mixed with 5 ml cold ethanol and 0.5 ml acetic acid solution. This mixture was kept for shaking for 1 hr, and it was kept at -20°C for overnight for complete precipitation of xylan. The resulting solution was centrifuged at 10000 rpm for 30 min, and the pellet was collected. This step was repeated by adding ethanol until no pellet remained after centrifugation. The resulting pellet was allowed to dry at 50°C and used as xylan source. Similar procedure was followed for hot water and hydrogen peroxide pretreatment methods except initial step where bagasse samples were suspended in hot water and 2% hydrogen peroxide respectively.

ii. Alkaline pretreatment method

Alkaline extraction of xylan from bagasse samples was performed as per the method described by Hauli et al.(2013). Ten grams of sugarcane bagasse sample was soaked in 100 ml of 10% sodium hydroxide (with ratio of 1:10) and incubated overnight with constant agitation at 60°C. Samples were then steamed at 100°C for 3 hr. After alkaline treatment the supernatant was recovered by centrifugation at 10000 rpm for 15 min, and acidified with 12 N hydrochloric acid to pH 5. During acidification the black colour supernatant was turned into milky tea colour. Then the resulting solution was precipitated using 1.5 volume of 95% ethanol and centrifuged at 10000 rpm for 20 min. Xylan pellet was recovered and allowed to air dry for overnight at 55°C. The pellet was weighed and stored at room temperature for further analysis.

iii. Dilute acid pretreatment and sonication methods

Ten gram of sugarcane bagasse sample was soaked in 100 ml of dilute sulphuric acid (2%, 1:10 w/v ratio) at 50°C for 24 hr. After incubation, the extract was separated by filtration. The residue was washed with distilled water before being subjected to steaming. This pre-treatment helps in breaking the covalent bonds between lignin and xylan present in the sugarcane bagasse, thus resulting xylan. The pre-treated samples were subjected to steaming using autoclave. This process was carried out for 30 min at 121°C as per the method described by Yang et al., (2005). After steaming, the samples were blended with 100 ml of water at 16000 rpm for 2 min. For chemical analysis, the slurry obtained after the extraction was filtered by Whatmann filter paper. Then the liquid fraction was neutralized by adding 1.5% sodium hydroxide and chemically tested for the presence of xylan as described in the section iv. Similar procedure was followed for sonication method where acid pretreated bagasse samples were sonicated followed by steaming.

iv. Chemical analysis of xylan obtained from dilute acid and sonication pretreatment methods.

Xylan resulted from dilute acid and sonication was quantified using the following formula.

Percentage of xylan present in the extract = Total soluble sugar (glucan and xylan) in the extract/ hemicelluose in raw material×100

Analysis of total soluble sugar by anthrone method:

Analysis of the total soluble sugars was carried out using standard anthrone method. Absorbance of the extracted samples at 630 nm was determined using an UV-Visible Spectrophotometer. According to the anthrone method, a standard curve was developed using glucose and xylose as standards (Sigma chemicals, St. Louis, MO), and a pre-determined factor was considered when plotting the absorbance values at concentrations of 20µg ,40µg, 60µg, 80µg and 100µg to yield the standard curve. Anthrone reagent used in the measurement was prepared by dissolving 0.2g of anthrone in 100 ml of cold 95% sulphuric acid. 5ml of ice-cold anthrone reagent was added to standards and test samples and boiled at 100°C for 10 minutes in water bath and cooled down quickly to 0°C on ice. Absorbance of standard and test sample were recorded at 630 nm using reagent blank and TSS was calculated by adding glucans and xylans content using the glucose and xylose standard curves.

Dimethyl sulfoxide method

The extraction of xylan from sugarcane bagasse was performed as per the method described by Ebringerova and Heinze (2000) with some modifications. Ten grams of sugarcane bagasse from each variety was mixed with 100ml of ethanol and it was allowed to evaporate overnight for delignification process. Then to the delignified sample, DMSO was added (14ml/g of biomass) at room temperature with stirring at 200 rpm for 2 hr. The solid residue obtained after filtration process was again pretreated with DMSO. This step was repeated two times. Then the solid residue was filtered and washed thoroughly with ethanol to remove the residual DMSO and xylan. The ethanol filtrate was reversed for the precipitation step. The DMSO extracted was combined with absolute ethanol (3.8ml/ml of extract). Concentrated hydrochloric acid was added in a ratio of approximately 0.66 ml hydrochloric acid/l of ethanol/DMSO solution to precipitate the xylan from the DMSO/ethanol mixture. The solution was cooled at 4°C overnight for complete precipitation. The cold solution was centrifuged at 10000 rpm for 30 min.

Calculation of xylan recovery

The true recovery of xylan was calculated using the formula

True recovery (%) = Dry weight of extracted xylan (g/100g)/ Hemicellulose content in the bagasse (g/100g) × 100.

Analysis of xylan by FT-IR spectroscopy

FT-IR analysis of xylan extracted from sugarcane bagasse was analyzed as per the method described by Chandel et al. 2014. The sieved sample of extracted xylan was dried at 60°C overnight and stored in hot air oven. One milligram of each extracted xylan sample was homogenized with ten milligram of potassium bromide for 1 minute and spectra was recorded between 400 and 4000 cm-1 in IR Prestige-21 FT-IR spectrometer using several scans. The baseline was corrected to the regions near 4000 to 500 cm-1. The results obtained were represented as graph along with transmission peaks. Commercial Beechwood xylan (Sigma Aldrich, USA) was used as reference for comparison of FT-IR data.

Results and Discussion

Sugarcane is the most potential source for lignocellulosic biomass and it is composed of 40-45% cellulose, 25-35% hemicellulose and 18-25% lignin (Rezende et al. 2011; Jaypal et al. 2013, Guilherme et al. 2015). Compositional analysis of sugarcane bagasse is prerequisite for subsequent analysis of individual lignocellulosic fractions using various pretreatment methods. Considering the potential applications of hemicelluloses in

pharmaceutical, cosmetics, biofuels, paper and food industries (Ebringerova and Heinze 2000; Ebringerova and Hromadkova 1999; Ebringerova et al. 1998; Garcia et al. 2000; Kayserilioglu et al. 2003; Oliveira et al. 2010; Sedlmeyer 2011; Yang et al. 2005), present investigation was undertaken to identify suitable method for extraction of xylan from sugarcane bagasse. Sugarcane bagasse of genotypes Co 86032, Co 2001- 15, SES 159, and SES 181was treated with various pretreatment methods. The xylan extracted was characterized and yield and recovery were analyzed (Fig. 1 and 2).

Cellulose, hemicellulose and lignin content in the bagasse samples were estimated and results are shown in table1. Cellulose content in bagasse samples did not show much variation among the genotypes and accumulated in the range of 40-43% on dry weight basis. Cellulose content in the commercial hybrids namely Co 86032 and Co 2001 -15 was 40.14 % and 41.37 % which was slightly low compared to wild *S. spontaneum* genotypes SES 159 and SES 181 having cellulose content of 43.19 % and 43.15 % respectively. Total lignin content in the bagasse samples of genotypes Co 86032, Co 2001- 15, SES 159, and SES 181 was 21.93%, 21.87%, 19.61% and 20.08% respectively. Whereas, hemicellulose content was 33.35%, 33.04%, 32.95% and 32.99% in the bagasse derived from Co 86032, Co 2001-15, SES 159, and SES 181 respectively. Total ash content in the bagasse samples varied from 3.5 % to 4.0 % (Table1).

Based on the compositional analysis of sugarcane bagasse, hemicellulose content was used as reference for comparative evaluation of xylan yield and recovery. Sugarcane bagasse was subjected for different pretreatment methods namely sodium borohydride method, hot water pre-treatment method, hydrogen peroxide pre-treatment method, alkaline pre-treatment method, dilute acid method, sonication method, and di-methyl sulfoxide method for extraction of xylan (Fig. 1). Comparative analysis revealed that there was a significant variation in the yield of xylan between the pretreatment methods. Highest xylan yield of 32.35 %, 29.33%, 23.85 % and 30.26 % was observed in the alkaline pretreated sugarcane bagasse samples of genotypes Co 86032, Co 2001 15, SES 159 and SES 181 respectively, which was significantly high as compared to other pretreatment methods (table2). Also, a significant variation in the xylan yield between sugarcane genotypes was observed. The methods namely hot water, sodium borohydride and hydrogen peroxide pretreatment methods were having similar extraction process except initial step of treating bagasse samples with hot water, sodium borohydride and hydrogen peroxide. Therefore, these three methods have yielded xylan in the narrow range of 7-17 %,

Table 1: Compositional analysis of untreated sugarcane bagasse before xylan extraction

Sl No.	genotypes	Components (g//100 g of sample dry weight basis)		
		Cellulose (%)	Lignin (%)	Hemicellulose (%)
1	Co 86032	40.14 ± 1.71	21.93 ± 1.20	33.35 ± 1.76
2	Co 2001- 15	41.37 ± 0.79	21.87 ± 1.88	33.04 ± 1.33
3	SES 159	43.19 ± 2.02	19.61 ± 2.22	32.95 ± 1.08
4	SES 181	43.15 ± 1.79	20.08 ± 2.02	32.99 ± 1.30

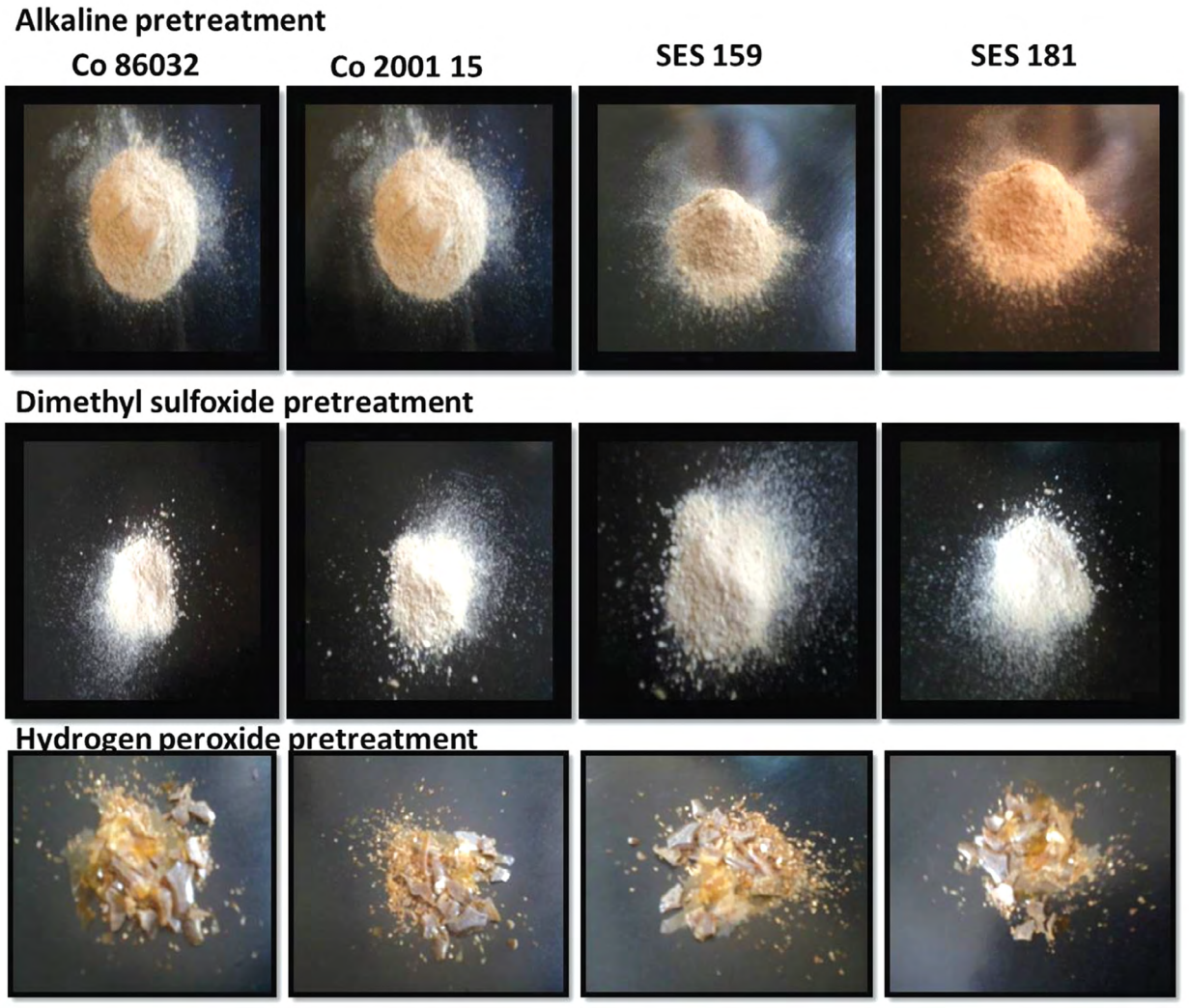

Figure 2: Crude xylan obtained from sugarcane bagasse using different pretreatment methods.

although variation was observed between the genotypes. Among these three methods, hydrogen peroxide treated bagasse samples yielded highest xylan of 14.69 %, 10.87 %, 17.43 % and 16.54 % against hot water (14.50 %, 10.41 %, 9.13 % and 9.94 %) and sodium borohydride treated (11.45%, 9.35%, 7.68% and 7.42%) bagasse samples in the genotypes Co 86032, Co 2001- 15, SES 159 and SES 181 respectively (Table 2). Other two similar pretreatment methods were dilute acid pretreatment and sonication. Both the methods involved steaming before treating bagasse with dilute acid and sonication. However these two pretreatment methods produced significantly very low xylan yield of 1.34 %, 1.06 %, 1.54 % and 1.58 % (dilute acid method) and 1.31 %, 1.55 %, 1.42 % and 2.02 % (sonication method) in the bagasse samples of genotypes Co 86032, Co 2001 -15, SES 159 and SES 181 respectively as compared to alkaline, hydrogen peroxide, hot water and sodium borohydride pretreated methods. Among all the pretreatment methods, DMSO pretreated bagasse sample yielded significantly very low xylan of 1.08 %, 0.73 %, 0.45 % and 0.41 % in the bagasse samples of genotypes Co 86032, Co 2001-15, SES 159 and SES 181 respectively (Table 2).

Table 2: Comparative analysis of crude yield of xylan extracted from sugarcane bagasse through different pre-treatment methods

S. No	Genotype	Yield (% dry weight)						
		Pre-treatment methods						
		Alkaline	Hot water	Sodium borohydride	Hydrogen peroxide	DMSO	Dilute acid	Sonication
1	Co 86032	32.35 ± 1.92	14.15 ± 1.91	11.45 ± 1.39	14.69 ± 1.72	1.08 ± 0.29	1.34 ± 0.16	1.31 ± 0.14
2	Co 2001-15	29.33 ± 1.13	10.41 ± 2.71	9.35 ± 1.84	10.87 ± 2.08	0.73 ±0.28	1.06 ± 0.21	1.55 ± 0.17
3	SES 159	23.85 ± 2.08	9.136 ± 1.08	7.68 ± 1.78	17.43 ± 1.84	0.45 ± 0.07	1.54 ± 0.12	1.42 ± 0.06
4	SES 181	30.26 ± 2.04	9.94 ± 2.04	7.423 ± 1.11	16.54 ± 1.18	0.41 ±0.08	1.58 ± 0.19	2.02 ± 0.33

True recovery of xylan was calculated using the original hemicellulose content in the bagasse samples. The recovery of crude xylan in the alkaline bagasse samples was 97% (Co 86032), 88.78 % (Co2001 15), 72.39 % (SES 159) and 91.72 % (SES 181) which was significantly highest as compared to all the pretreatment methods (Table 3). Therefore, alkaline treatment is the best method for obtaining high xylan yield and recovery from sugarcane bagasse.

Table 3: Recovery of xylan extracted from sugarcane bagasse using different pre- treatment methods

S. No	Genotype	Xylan Recovery percentage						
		Pre-treatment methods						
		Alkaline	Hot water	Sodium borohydride	Hydrogen peroxide	DMSO	Dilute acid	Sonication
1	Co 86032	97.00	42.42	34.33	44.06	3.26	4.02	3.94
2	Co 2001-15	88.78	31.51	28.29	32.91	2.21	3.22	4.69
3	SES 159	72.39	27.72	23.30	52.89	1.36	4.67	4.31
4	SES 181	91.72	30.12	22.49	50.13	1.24	4.80	6.12

Among the pretreatment methods employed in this study, alkaline pretreatment has yielded significantly higher xylan yield and recovery in the range of 23.85-32.35% and 72.37%-97% respectively as compared rest of the pretreatment methods (Table 2 & Table 3). Recent study on alkaline extraction of xylan using alkaline-sulfite chemi -thermomechanical process yielded up to 55% recovery (Sporcket al. 2017). Many studies have been reported previously on hemicellulose extraction methods. Delignification using sodium chlorite pre-treatment followed by alkaline extraction yielded high xylan recovery (Hoijiet al. 2005). Similar to the present study of alkaline extraction followed by ethanol precipitation provided lower xylan yield (De Lopez et al. 1996; Hauliet al. 2013; Guilherme et al. 2015) and also, highest xylan recovery of 85% was achieved using combination of alkali and steam application (Jayapal et al. 2013). However, use of these methods on delignified bagasse yielded high xylan recovery but 16-18% residual lignin impurity was observed in the extracted xylan (Chimpango et al. 2012). Other studies employed combination of enzymatic treatments with alkaline extraction to remove xylan and xylo-oligosaccharides from lignocellulosic materials (Remond et al. 2010; Hakkala et al. 2013; Aguedo et al. 2014). However, use of xylanase resulted in low molecular weight xylans and lower yield of high molecular weight xylans. Glucurono-arabinoxylans (GAX) are the main xylan types present in sugarcane bagasse (Sun et al. 2004; Brienzo et al. 2009; Costa et al. 2016). Similar GAX contents of 29–31% were observed in the pretreated and untreated sugarcane bagasse. GAX extraction using combined alkaline and enzymatic methods using Lopez (45%) and Hoije (53%) procedures yielded higher xylan recovery in sugarcane bagasse (Spork et al. 2017).

Other pretreatment methods employed in our study yielded low xylan recovery as compared to alkaline pretreatment method (Table 2 & Table 3). Moderate xylan yield (7.68-17.43%) and recovery (22.49-52.89%) was observed using hot water, sodium borohydride and hydrogen peroxide pretreatment methods (Table 2 & Table 3). Among these three methods, hydrogen peroxide pretretated bagasse showed higher xylan recovery of 52.89% which is similar to the previous study where 44-72% hemicellulose recovery was reported from Rye straw (Fang et al. 2000). Among all the pretreatment methods attempted in the present study, DMSO, dilute acid and sonication pretreated bagasse samples yielded very low xylan recovery in the range of 1.21-4.89%. Previous study on xylan extraction using dilute acid hydrolysis has removed around 95% of xylan from sugarcane bagasse which is contradicting with our results where we observed very low xylan yield and recovery (Jiang et al. 2016).

FT-IR spectroscopy has been widely employed to identify polysaccharides, to analyze purity, to investigate functional properties, to determine the structure, and to study the molecular interactions. Xylan extracted from different bagasse samples were characterized using FT-IR. The transmission spectra of alkali pretreated bagasse samples exhibited a maximum vibration at 678.94 cm^{-1},1043.49 cm^{-1}, 1647.21 cm^{-1}, 2355.08 cm^{-1} and 3444.87 cm^{-1} in the variety Co 86032; 426.27 cm^{-1}, 1043.49 cm^{-1}, 1641.42 cm^{-1},2355.08 cm^{-1}, 3448.72 cm^{-1} and 3736.2 cm^{-1} in the variety Co 2001- 15; 650.01 cm^{-1},1043.49 cm^{-1},1637.56 cm^{-1} and 2304.94 cm^{-1} in the variety SES 159; 478.35 cm^{-1},1043.49 cm^{-1},1637.56 cm^{-1} and 2314.58 cm^{-1} in the variety SES 181. The band 1043.49 cm^{-1} was observed to be uniform which is due to the backbone of cellulose and hemicellulose. It is also more prominent due to C-O stretching in the cellulose and hemicellulose structures. The vibration in the band around 1641 cm^{-1}, 1647

cm-1and 1637 cm^{-1} is due to the C=C and C=O stretching of aromatic ring in lignin which indicated the small amount of lignin is present as impurity in the extracted xylan. The band in the range of 3444.87 and 3736.2 cm^{-1} is due to the crystalline structure of cellulose. FT-IR profiles of alkaline treated bagasse samples were compared with the FT-IR profile of standard Beechwood xylan. The transmission spectra of commercial xylan showed maximum vibration at 426.27 cm^{-1}, 1041.56 cm^{-1}, 1523.76 cm^{-1}, 1685.79 cm^{-1}, 2310.72 cm^{-1}, 3604.96 cm^{-1} and 3736.12 cm^{-1}. These results confirmed that the extracted sugarcane bagasse xylan was more comparable to the commercial Beechwood xylan showing the similar vibrations 1043.49 cm^{-1}, 1641 cm^{-1}, 2304.94 cm^{-1}, 3448.72 cm^{-1} and 3736.2 cm^{-1}) (Fig.3). These results were similar to the previous studies of FT-IR characterization of sugarcane bagasse (Jayapal et al. 2013; Chandel et al. 2014). In general, the vibration around 898 cm^{-1} is indication of glycosidic bond β-(1→4) cellulose (Pandey and Pitman 2003) and band between 1,200 and 1,100 cm^{-1} is due to the vibration of hemicellulose and cellulose. The band around 1,035 cm-1 was due to C-O stretching and 1,164 cm^{-1} for the irregular stretching of C-O-C (Pandey1999; Colom et al. 2003; Pandeyet al. 2005; Chandelet al. 2014) and the peak around

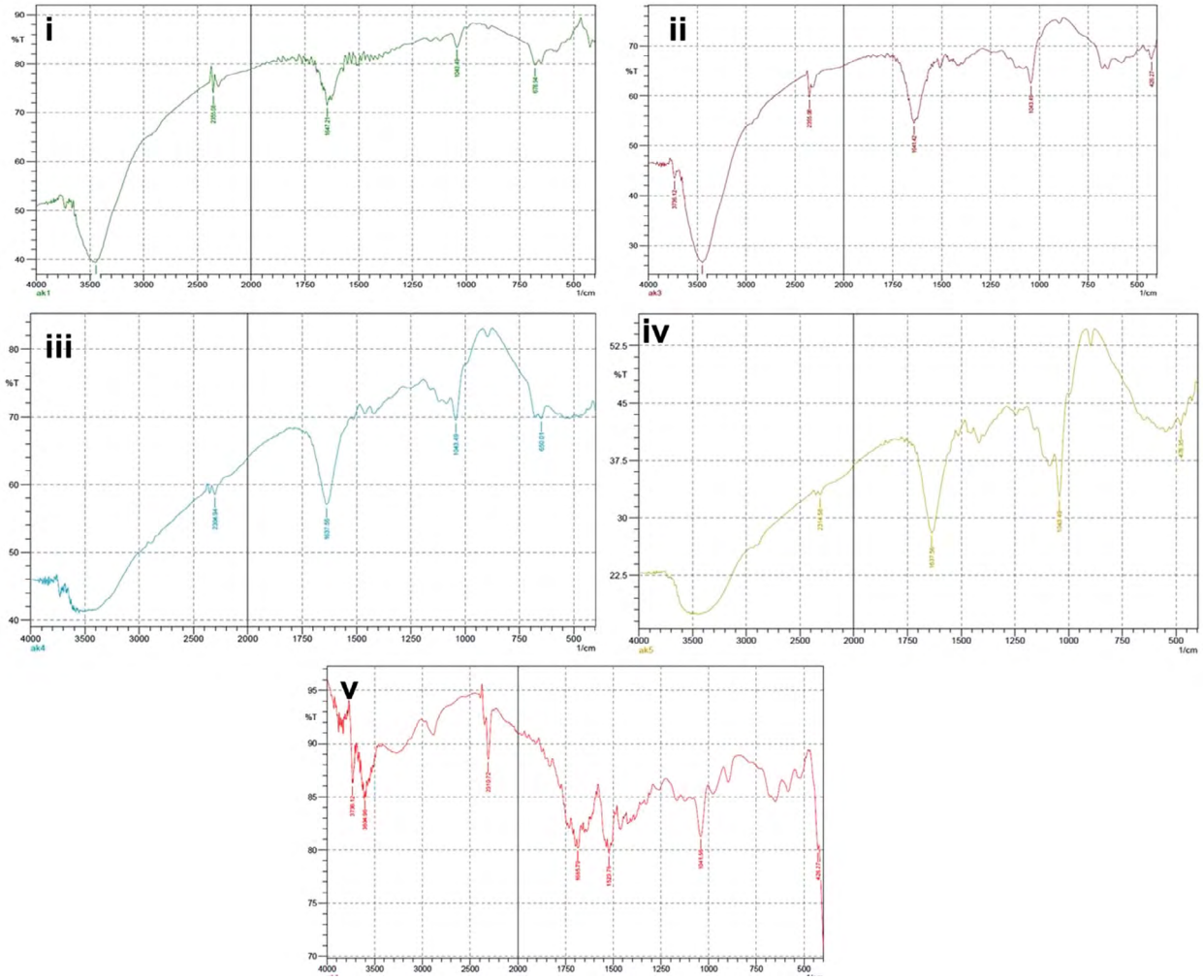

Figure 3: FT-IR spectral profile of alkali extracted xylan from sugarcane bagasse. Sugarcane genotypes: i) Co 86032; ii) Co 2001- 15 iii) SES 159 iv) SES 181 and v) Commercial Beechwood xylan.

1,247 cm^{-1} was due to the stretching of C-O, which is the indication of hemicellulose and lignin presence in the sample (Pandey and Pitman 2003). Vibration around 1,458 cm^{-1} was due to a change of lignin CH2 and CH3 groups, and groups showing vibration around 1,515 cm-1 and 1,604 cm^{-1} are characterized as C = C and C =O stretching in lignin aromatic ring (Pandey 1999; Colom et al. 2003; Chandel et al. 2014). A peak around 1,733 cm-1 was known to have C = O stretching of unconjugated hemicellulose (Chandel et al. 2014). The band around 2,850 cm^{-1} was characterized as CH and CH2 asymmetric stretching, whereas vibration around 2,918 cm^{-1} was from the CH2 and CH groups which were reported as important feature of cellulose presence (Ivanovaet al 1999; Chandelet al. 2014). Also the spectral band region between 3,800 and 3,000 cm-1 was reported as crystalline structure of cellulose. This is mainly due to the addition of all the vibration from the intra-molecular and intermolecular hydrogen bonds of the OH group between these regions (Hinterstoisser and Salmen 1999).

To summarize the findings, present study has clearly demonstrated that alkali treated sugarcane bagasse samples have yielded highest crude xylan recovery up to 97%. FT-IR characterization of alkali extracted xylan has given clear indication of presence of hemicellulose structures in the IR spectra and revealed the apparent purity characteristic of xylan. These results proposed the simple alkaline pretreatment can produce substantial xylan yield and provide economically feasible technology for using sugarcane bagasse as important raw material for development of value added products and its applications in biofuel, cosmetic, paper, pharmaceutical and food industries.

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