# Extraction and characterization of cellulose from sugarcane bagasse by using environmental friendly method

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## Abstract

Cellulose is the most abundant biomass material in nature, and possesses some promising properties, such as good mechanical properties, low density, thermal stability, biocompatibility and biodegradability. Thus, cellulose has been widely applied in various industrials applications. Sugarcane bagasse (SCB) is one of the main agricultural residues in Thailand which is recently going tremendous interest. The extraction of cellulose from SCB was investigated using steam explosion and xylanase based environmentally friendly pre-treatment. The chemical compositions and characteristics were studied before and after extraction using a TAPPI standard, Fourier-transform infrared spectroscopy (FTIR) and scanning electron microscope (SEM). Pretreatment with steam explosion and xylanase resulted in 23% reduction of bleaching chemical. FT-IR and SEM studies supported about the removal of hemicellulose and lignin of each fiber in different processing stages. The suggested results showed that the environmentally friendly method, steam explosion and xylanase pretreatment presented a great potential environmental friendly method for cellulose extraction, which can be applied in industrial scale.

**Keywords**: cellulose, sugarcane bagasse, xylanase, environmental friendly method

## Introduction

Currently, the increasing interest in environment-friendly materials has motivated industrial in development and use of biopolymer for various applications. In this context, intensive study has been devoted to cellulose. Cellulose is a linear homopolysaccharide composed of anhydroglucose units linked by β-1,4 glycosidic bonds (Mandal & Chakrabarty, 2011). Cellulose has a wide range of industrial applications in composite, textile, paper and pulp, food and additives in pharmaceutical industries(Uma Maheswari et al., 2012). Cellulose found in the major constituent of plant cell wall, including lignocellulosic material such as sugarcane bagasse (SCB), which is use as raw material in this current study. SCB is a low value agriculture residue and about 40-50% of bagasse is the glucose polymer cellulose (Sun et al., 2004).There are several approaches to pretreat lignocellulosic materials for extracted cellulose such as steam explosion, solvent extraction, alkaline treatment and organosolv pretreatment (Cardona et al., 2010).

The steam explosion process includes saturating the dry material with steam at elevated pressure and temperature followed by sudden release of pressure, resulting in substantial breakdown of lignocellulosic structure, hydrolysis of the hemicelluloses fraction, depolymerization of the lignin components and defibrillization (Abdul Khalil et al., 2012).In terms of bleaching treatments, chlorine-based chemicals were typically used for bleaching process resulting in chemical hazard released into environmental. The xylanases are glycosyl hydrolase that catalyze a random hydrolysis of the β-1,4-glycosidic bonds in xylan via a double displacement mechanical (Jeffries, 1996; Maalej-Achouri et al., 2012). Xylanase treatment improve accessibility of bleaching chemical to the pulp, decreasing diffusion resistance of degraded lignin fragments, facilitates the release of lignin, which is then readily available for further bleaching and thereby increases the efficiency of the bleaching process (Dedhia et al., 2014; Techapun et al., 2003). Thus, the use of enzymes to treat pulp before applying chemical bleaching help to reduce chemical required in bleaching stage.

The objective of this study was to extract cellulose from sugarcane bagasse by using steam explosion and xylanase as environmental friendly method in order to estimate the potential of xylanase treatment for reducing chemical bleaching and to determine the characteristics of cellulose from sugarcane bagasse.

## Methodology

### Extraction of cellulose

Cellulose was extracted from SCB by using steam explosion and xylanase pretreatment and bleaching process. The dried SCB treated with steam explosion (Nitto Koatsu Co., Ltd. Japan) at a pressure 13 bar (195 °C) for 15 min (Rocha et al., 2012) to obtain steam exploded SCB fibers. Then, the steam exploded SCB was treated with 20 U/g of xylanase using fiber to liquor ratio of 1:10 for 1 h at 50°C under constant agitation. The dried steam exploded SCB treated with xylanase (fiber to liqure ratio of 1:10) was then to bleached with 0.7% sodium chlorite ($NaClO_2$) adjusted to a pH 4 by the addition of acetic acid at 70 °C for 1 h. Sodium chlorite and acetic acid at the same loading were added to the reaction every 1 h until the cellulose became white. The cellulose fibers thus obtained was then filtrated, washed with distilled water until the pH of water neutral and dried at 55 °C for 24 h.

## Characterizations

### Chemical composition

Chemical constituents of fibers were determined according to standard method by Technical Association of Pulp and Paper Industry (TAPPI). α-cellulose (TAPPI T202 om-88), lignin (TAPPI T222 om-98), The hemicelluloses content was calculated from the difference between holocellulose (α-cellulose+Hemicellulose) values. The cellulose, hemicelluloses and lignin of the untreated SCB, steam exploded, steam exploded with xylanase treated and bleached fibers were determined.

### Fourier transform infrared spectroscopy (FTIR)

Fourier transform infrared spectroscopy (Bruker Tensor 27 spectrometer, USA) studies on untreated SCB, steam exploded SCB, steam exploded with xylanase treated and bleached fibers were carried out by dispersing the powdered fiber samples in KBr pellets. All spectra were recorded in the 4000-500 $cm^{-1}$ region with a resolution of 4 $cm^{-1}$.

**Scanning electron microscopy (SEM)**

The morphology of untreated SCB, steam exploded SCB, steam exploded with xylanase treated and bleached fiber were characterized by SEM (JEOL JSM5600LV, Japan). The samples were gold coated prior to recording the micrographs. The acceleration voltage was set at 10kV.

**Results and discussion**

**Chemical composition**

The chemical compositions of all samples in difference processing stages were determined followed by TAPPI standard, as summarized in Table 1. The results showed that the untreated SCB fibers present the high cellulose contents about 44.5% and also presents the hemicellulose and lignin content at 21.8% and 22.5%, respectively. The presence of high cellulose contents in untreated SCB indicates that the SCB suitable for use as cellulose sources. After steam explosion treatment, the α-cellulose increased from 44.5% to 65.7%, while the hemicelluloses and lignin decreased from 21.8% to 9.9% and 22.5% to 18.3%, respectively. The hemicellulose content after steam explosion were large decreased because of partial hydrolysis and decomposition under steam explosion, while the lignin content slightly decreased due to the strong interaction between cellulose fibers and polyphenolic compounds. From obtained results, the use of steam explosion was unable to completely eliminate non-cellulosic compound from the SCB fibers. Thus, the xylanase treatment was used as pretreatment method before bleaching treatment to depolymerize of lignocellulosic structure.

Xylanase treatment of steam exploded SCB showed the decreasing of hemicelluloses content due to hemicelluloses were hydrolyzed by xylanase, however, the lignin and cellulose content are slightly changed. After bleaching step, the obtained α-cellulose content was practically double comparing to untreated SCB fibers, a further decreased in the percentage of hemicelluloses and lignin component because the oxidation reaction between non-cellulosic compound residues and bleaching solvent (chlorite solution), resulting the non-cellulosic compound were dissolved in the water and also obtained the highly purified cellulose. The cellulose fibers extracted from SCB contained 89.3%, 4.3% and 1.5% of α-cellulose, hemicelluloses and lignin, respectively.

It interested to note that the xylanase treatment significantly slightly increased the cellulose content and decreased the hemicellulose content. In additional, the bleaching of steam exploded with xylanase un-treated fibers was used 18.2 g of $NaClO_2$, while bleaching of xylanase treated was used only 14 g. Thus, the treatment with xylanase resulted in 23% reduction of chemical bleaching when compared to the extraction processes without xylanase treated (Steam explosion and bleaching treatment). The reduction of bleaching chemical due to xylanase degraded xylan chain, the xylan-derived and associated molecule could be more easily removed and oxidized by chlorine dioxide, thereby facilitating the bleaching of the fibers and reducing the amount of bleaching chemical required.

**Table 1:** Chemical composition of sugarcane bagasse (SCB) samples at each stage of treatment

| Fibers | α-Cellulose (%) | Hemicellulose (%) | Lignin (%) |
|---|---|---|---|
| Untreated SCB | 44.5 | 21.8 | 22.5 |
| Steam exploded SCB | 65.7 | 9.9 | 18.3 |
| Steam exploded with xylanase treated | 66.3 | 8.8 | 18.6 |
| Bleached fiber | 89.3 | 4.3 | 1.5 |

**Fourier transform infrared spectroscopy (FTIR)**

FT-IR spectra of untreated SCB, steam exploded SCB, steam exploded SCB with xylanase treated and bleached fibers were carried out in Fig. 1(a-d). The FTIR spectra of untreated SCB (Fig. 1a) showed dominant peak around 3400 $cm^{-1}$, 2920 $cm^{-1}$,1515 $cm^{-1}$, 1463 $cm^{-1}$ and 1253 $cm^{-1}$, which corresponded to the stretching of –OH groups of cellulose, and the C-H stretching of cellulose, C=C stretching of aromatic ring in lignin, C-H deformation of lignin or hemicelluloses and –COO vibration of acetyl groups in hemicelluloses, respectively (Oksman et al., 2011; Uma Maheswari et al., 2012). After steam explosion, the intensity of the peak at 1463 $cm^{-1}$ and 1253 $cm^{-1}$ was decreased in the spectra of steam exploded fibers (Fig 1b). The peak at 1463 $cm^{-1}$ was decreased in the spectra of steam exploded with xylanase treated fibers (Fig. 1c). This indicated that the hemicelluloses were removed by xylanase treatment. The lignin and hemicelluloses peaks at 1515 $cm^{-1}$, 1463$cm^{-1}$ and 1253 $cm^{-1}$ fully disappeared in the bleached fibers (Fig 1d). Moreover, the peak at 898 $cm^{-1}$ was associated with β-glycosidic linkages of glucose ring in cellulose which significantly presented in purified cellulose extracted from SCB (Wong Sak Hoi & Martincigh, 2013).

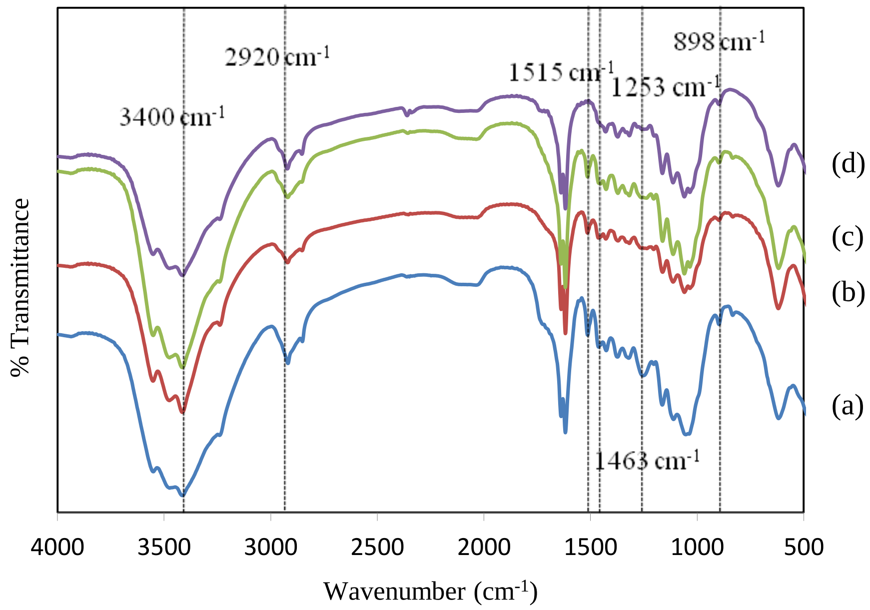


**Figure 1:** FT-IR spectra of (a) untreated SCB, (b) steam exploded SCB, (c) steam exploded SCB with xylanase treated and (d) bleached fiber

**Morphological analysis**

The morphology of SCB fibers was investigated using SEM to determine the change of fiber surface and morphology during extraction processing, as showed in Fig. 2(a-d). Fig. 2(a) showed the diameter of untreated SCB fibers was about 200 μm. The surface of untreated SCB fibers presented the smooth surface because of the presence of waxes and oil. After steam explosion, the clear demonstration of the defibrillation and depolymerisation by steam explosion was seen Fig. 2(b) and the fiber diameter of steam exploded SCB fibers were decreased to 80 μm. The fibers surface of steam exploded fibers showed the rougher surface than untreated fibers due to the effect of steam explosion. During steam explosion, the high temperature, high pressure and rapid reducing pressure had the effect on the surface of fibers, causing the fibers disruption. From this phenomena, the presence of rough surface was benefit to the high surface area resulted in the steam-exploded fibers easy to react with extraction solution. Comparison of xylanase treated and xylanase untreated of steam exploded SCB. Xylanase treatment fibers (Fig. 2(c)) showed the removal of the surface impurities such as hemicelluloses and lignin along with defibrillation, the fiber surface became to the rough surface (compared with xylanase untreated fibers or steam exploded SCB fibers). Fig. 2(d) showed the final cellulose fibers extracted from steam exploded SCB with xylanase treatment. The figure showed the fibers were separated in to individual fibers and the diameter of fiber was less than 20 μm during the bleaching process.

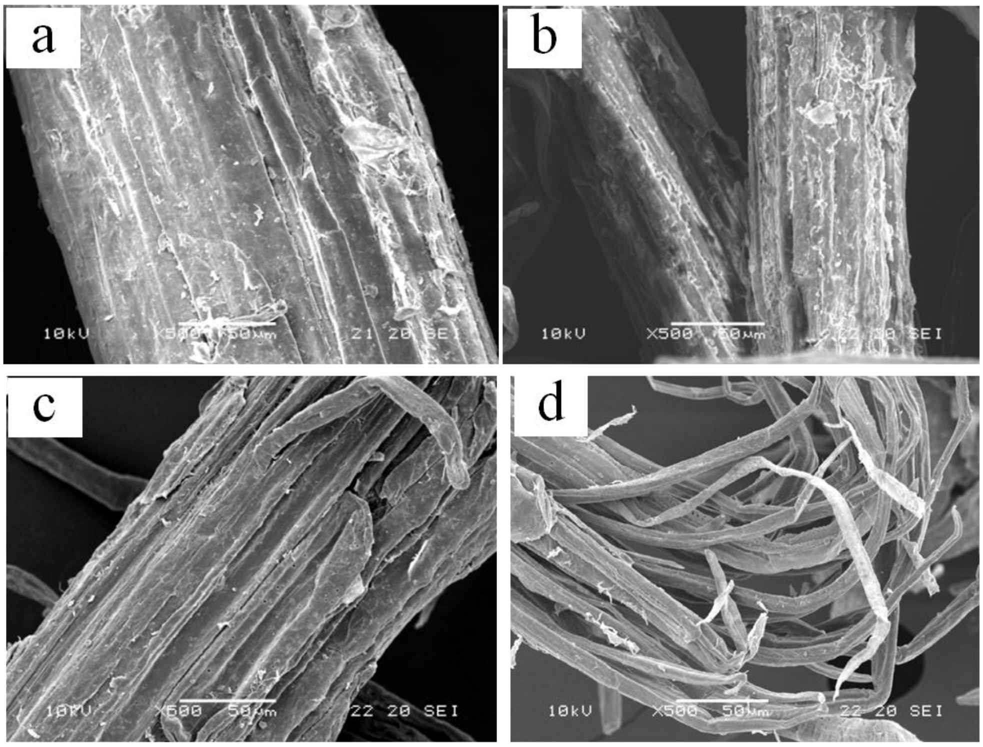


**Figure 2:** SEM pictures: (a) untreated SCB, (b) steam exploded SCB, (c) steam exploded SCB with xylanase treated and (d) bleached fibers

## Conclusion

The present work showed that cellulose can be successfully extracted from sugarcane bagasse. The chemical analysis results showed that extracted cellulose had higher cellulose content and lower hemicelluloses and lignin content than the raw material. The results derived from FTIR and SEM confirmed that both lignin and hemicelluloses were removed during the extraction process. Moreover, the xylanase treatment was an effective in 23% reduction of chemical bleaching. Therefore, the steam explosion and xylanase pre-treatment have great potential to use for cellulose extraction from sugarcane bagasse.

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