ISOLATION AND CHARACTERIZATION OF PULP FROM SUGARCANE BAGASSE AND RICE STRAW.

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Abstract

The amount of sugarcane bagasse and rice straw in the state of Perlis (Malaysia) is abundant while its utilization is still limited. One of the alternatives for the bagasse and straw utilization is as pulp raw material. This paper reviews on pulp from sugarcane bagasse and rice straw and its suitability for paper production. In this study, the pulp was extracted by the Soxhlet extraction method. The objective of this study was to investigate the cellulose, lignin and silica content of the pulp from sugarcane bagasse and rice straw. For rice straw, the presence of large amount of pentosanes in the pulp and black liquors, which also contain silica were decreased the using of straw in the paper industry. Therefore, formic acid pulping and NaOH treatment are studied to reduce or prevent silica. The isolated pulp samples were further characterized by Scanning Electron Microscope (SEM) to investigate their fiber dimensions.

Keywords: Sugarcane bagasse, rice straw, formic acid pulping and fiber dimension.

Introduction

World paper consumption was about 300 million tons in 1996/97 and is expected to rise above 400 million tons by the year 2010. In view of the shortage of conventional raw materials for pulping and the increasing demand for paper products worldwide, non-wood plants and agricultural residues attracted renewed interest [1]. Various agricultural residues such as straw, stalk, bagasse and cereal have taken a significant place in supplementing the dwindling supply of conventional forest raw material for catering the ever-increasing demand on the pulp and paper industry [2]. In some countries, their researchers found that the agricultural residues like sugarcane bagasse, leaves and rice straws are suitable raw material for the production of pulp [3].

Sugarcane (*Saccarhum officinarum*) bagasse is a residue produced in large quantities by sugar industries. In general, 1 ton of sugarcane bagasse generates 280 kg of bagasse, the fibrous by-product remaining after sugar extraction from sugarcane [4]. However, the utilization of sugarcane bagasse is still limited and is mainly used as a fuel to power the sugar mill [5,6]. These polymers are important for the production of pulp.

Annual world rice (*Oryzae sativa*) production was about 577 million tons for 1997 – 98. More than 50 countries contributed to this sum with the production of at least 100, 000 tons of rice annually [proposal no8]. One of the countries is Malaysia. Among these large quantities of agricultural residues (rice straws), only a minor portion of the residues is reserved as animal feed. However a huge quantity of the remaining straws is not used and burnt in the fields. The air pollution, therefore is a serious problem by burning these residues in this area. Therefore, the use of these straws in pulping or papermaking has many advantages including reducing the need for disposal and environmental deterioration through pollution and fires [7]. The main reasons for the decreased use of rice straw in the paper industry is due to the presence of large amount of pentosanes in the pulp and black liquors, which also contain silica. The need to add alkali to reduce or prevent silicate deposites to remove silica from the black liquors currently limiting the use of rice straws in paper mills [8]. In this article, we present processing techniques and pulp properties obtained through cooking rice straw with formic acid. This procedure makes it possible both to selectively separate the main chemical compounds of the plant material and to preserve most of the silicon derivatives in the cellulose fibers.

Cellulose, the major constituent of all plant materials, forms about half to one third of plant tissues and is constantly replenished by photosynthesis. In particular, cellulose is the main constituent of higher plants, including sugarcane bagasse and rice straw. Chemically, cellulose is a linear natural polymer anhydroglucose units. Paper is composed of cellulose fibers. Plant matter that has been processed to create a solution consisting of cellulose filaments suspended in water can be made into paper. A screen is passed through the solution so that the filaments can collect on it and thus form a layer. This layer of cellulose fibers is then pressed and dried to produce a usable sheet of paper. The source of the cellulose fibers, and the degree to which that source is refined, determine the nature and quality of the paper produced. The two most important factors that affect the quality of paper are the presence of impurities and an acidic pH. Finished papers may contain natural impurities, such as lignins that have not been removed during processing, unnatural impurities, such as residual chemicals, like sulfites, not washed out during final processing, or such chemicals as alum that have been added during final processing. Lignins, which are the combined glues that hold plant cells together, are undesirable in a finished paper product. They age poorly, turn brown, become acidic over time, are waterproof, and resist the natural bonding of cellulose fibers to each other. If lignins are not removed and are left in contact with the surrounding cellulose fibers in paper, their acidity will break down the cellulose and the paper will become brittle [9].

The objective of this study is to investigate the cellulose, lignin and silica content of the pulp from sugarcane bagasse and rice straw. The isolated pulp samples are characterized by Scanning Electron Microscope (SEM) to investigate their fiber dimensions.

Materials and Methods

Sugarcane bagasse and rice straw were obtained from a local sugar factory and local farmers in Perlis. The samples were first dried in sunlight and then cut into small pieces (1-3 cm). The cut bagasse and straw were ground to pass a 1.0 mm size screen. The dried powder were first extracted with toluene-ethanol (2:1, v/v) in a Soxhlet apparatus for 6 h and the dewaxed meal was allowed to dry in an oven at 60 ^{0}C for 16 h. All weights and calculations were made on an oven-dried (60 ^{0}C, 16 h) basis.

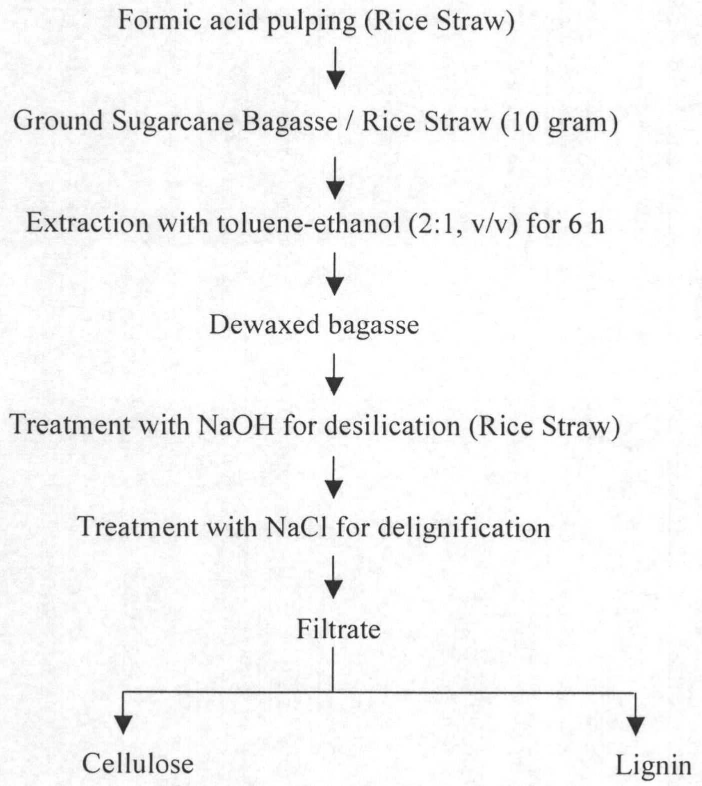

Figure 1 : Scheme for isolation of cellulose from delignified sugarcane bagasse and rice straw.

For formic acid pulping, the rice straw is soaked in the cooking liquor (95 % w/w) at 80 ^{0}C for 2 h. The resulting pulp was extracted, washed with NaOH (1 M, 30 ^{0}C, 18 h) for desilication. The pulp was then washed with acidified NaCl (1.3 % w/w, pH 3.5 – 4.0, adjusted with acetic acid) for delignification. To reduce errors and confirm the results, each experiment was repeated in triplicate under the same conditions and the yield of cellulose was given as the average of these three replicates. The fiber dimensions analysis were performed using Scanning Electron Microscope (SEM), MODEL JEOL (JSM/6460LA).

Results and Discussion

It is well known that celluloses are the major components of the secondary layers on the cell wall in lignocellulosic fibers. These celluloses are present in the surface layer, i.e., the outer layer of the fibres, where these polymers can act as adhesives to strengthen the bonds between individual fibres in the three-dimensional network of a sheet of paper. The result of Soxhlet extraction of cellulose and lignin content in sugarcane bagasse and rice straw can be seen in Figure 2. From the figure it can be seen that the percentage of cellulose in the sugarcane bagasse is 21.11 %.

Traditionally, acidified sodium chlorite is used to delignify wood as an initial step in the isolation of pure cellulose, and chlorine is widely used as a bleaching agent ia the pulp or cellulose industry. In aqueous media their reactions with lignocellulosic materials result in aromatic substitution, in some cases accompanied by displacement of side chains, and in oxidation reactions leading to quinonoid structures. Its reaction with lignin is fast compared with its reaction with cellulose. However, its rate of reaction with the cellulose is still happened and the reaction damages the fibres during the usual conditions of chlorine bleaching. In the present study, delignification of the sugarcane bagasse with acidified sodium chlorite yielded 3.32 % lignin (Figure 2).

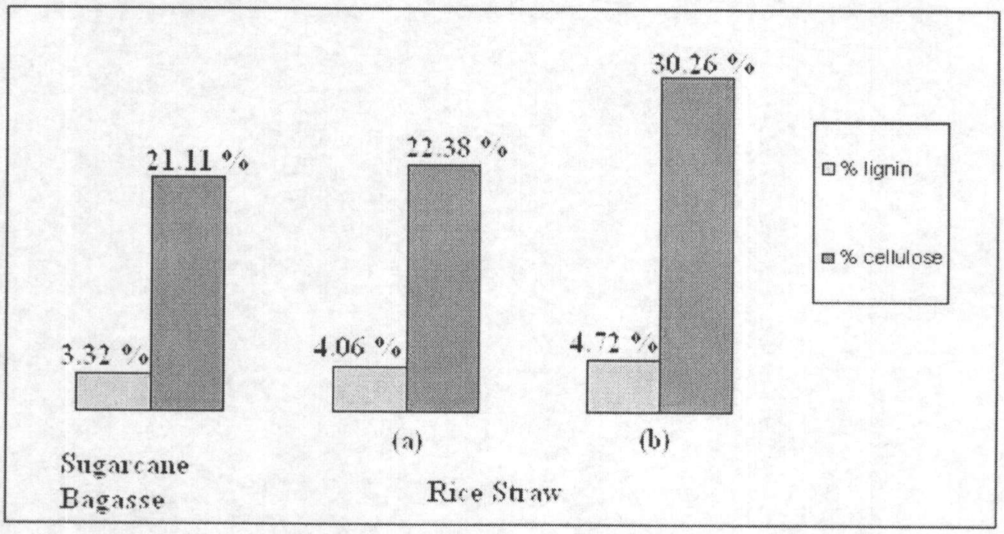

Figure 2 : The yield of lignin and cellulose was extracted from sugarcane bagasse and rice straw.

The severe effect temperature has on delignification and cellulose yield during rice straw cooking in formic acid can be explained by the positive role of increased temperature on :

- Environment acidity
- Availability of formic acid to active plant matter sites
- Reaction speeds leading to matter breakdown (primarily hemicellulose attack)
- Lignin solubility in formic acid

Temperature also has a stronger effect on cellulose yield, when cooking conditions are less efficient, particularly when cooking is performed at relatively low formic acid concentrations. Too low a temperature means increased contact time and too high a temperature means reducing contact time to avoid carbohydrate degradation. A 95 %w/w formic acid concentration was shown to be the most efficient.

From the Figure 2, sample (a) of rice straw is the sample that was treated with formic acid cooking and NaOH, while sample (b) is the sample that was not treated with formic acid cooking and NaOH. For sample (a), the cellulose and lignin content is 22.38 % and 4.06 %. While for sample (b), the content is 30.26 % and 4.72 %. The result shown that treated with formic acid and NaOH can reduce the lignin content, but it also reducing the cellulose yield. Therefore, the treatment helps eliminate most of the lignin in the pulp.

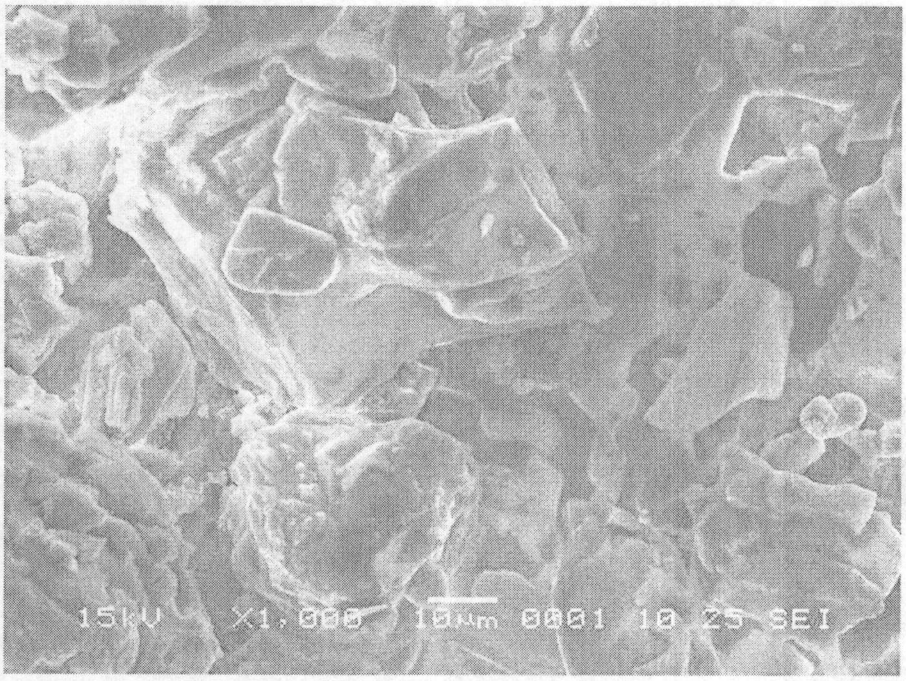

Figure 3 : SEM micrograph of cellulose that was extracted from sugarcane bagasse.

SEM micrographs of the surface of the cellulose that was extracted from sugarcane bagasse and rice straw are shown in Figure 3 and 4. For sugarcane bagasse, the fibrous structures display stronger binding fibres compared to the cellulose that was extracted from rice straw. It showed an interlocking of the fibres and construction of fibrous bridging. Therefore, the pulps from sugarcane bagasse are suitable for production of soft papers compared to rice straw.

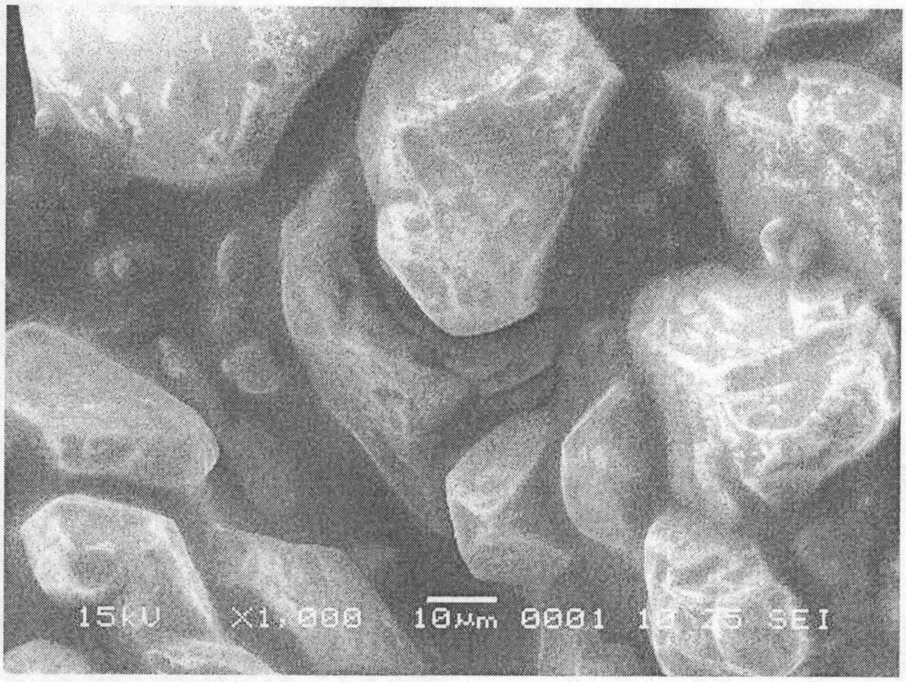

Figure 4 : SEM micrographs of cellulose that was extracted from rice straw (treated with formic acid and NaOH).

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