



Usefulness of raw bagasse for oil absorption: A comparison of raw and acylated bagasse and their components

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ABSTRACT

Raw bagasse or sugar cane cellulosic residues were modified using acylation grafting with fatty acid. The capability of the grafted bagasse to absorb oil from aqueous solution was studied and compared with the raw bagasse. It was found that the grafted material was significantly more hydrophobic than the raw bagasse. This grafted bagasse had little affinity for water and good affinity for oil. It was also found that bleaching of raw bagasse did not enhance its oil absorptivity. The grafted raw bagasse would be most suitable for applications where oil is to be removed from an aqueous environment. For oil absorbing applications in the absence of water, the raw bagasse was an excellent material.

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1. Introduction

The importance of systematic utilization of bagasse or sugar cane cellulosic residues has been noted in the past decade. Environmental concerns have fueled this focus not only because of the quantity of bagasse produced annually but also because of the nature of the material (Almazan et al., 1998; Ritter, 2007; Arnaud, 2008). The growth of the sugar cane plant is remarkably efficient photosynthetically. The sugar product from this plant represents only thirteen percent of the biomass. Bagasse from sugar production is twenty eight percent of the biomass (Almazan et al., 1998). These numbers vary depending on the source of the sugar cane, as well as on the interpretation of an author. Even so, huge amounts of bagasse are and will continue to be generated and the utilization of this material is of growing importance. The use of bagasse in the production of paper products is becoming increasingly more important (Taylor, 2000; World Centric, 2008). While ethanol as a biofuel is currently produced from corn in the United States and from a sugar solution in Brazil, the use of bagasse for ethanol production instead has received considerable investment by major international chemical companies during this past year (McCoy, 2007, 2008). Bagasse has also received attention in the construction industry (Youngquist et al., 1996; Golbabaie, 2006). The study of bagasse as an absorbent of environmental pollutants has also received attention recently (Khan et al., 2004; Lee and Rowell, 2004; Igwe and Abia, 2006; Abia and Asuquo, 2006;

Nada and Hassan, 2006; Deschamps et al., 2003; Hussein et al., 2008; Ludwick et al., 2002, 2005). Heavy metals are attracted to modified bagasse. These modifications are relatively simple processes that could be expanded to a pilot scale and then to full production.

Oil pollution remains a serious concern. Regulations (US EPA, 2008) have done much to prevent oil waste contamination during transport on the open seas. The Clean Water Act of the USA provides a model for an approach to achieve an environmentally safe water system (Davenport, 1992; Kenney, 2006). These national and international regulations have been evaluated periodically so as to maintain their viability (Davenport, 1992; Kenney, 2006; GEF/UNDP/IMO, 2008). When oil pollution does occur, the issue is not only the cleaning of the environment but also recovery of this precious commodity. Hence any oil absorbing material used must also be able to release the oil. Current studies examine not only oil absorbing properties of materials but also the ability to recycle of these materials (Deschamps et al., 2003; Hussein et al., 2008). In the present work, raw bagasse was modified using acylation grafting with fatty acid. The capability of the grafted bagasse to absorb oil from aqueous solution was studied and compared with the raw bagasse.

2. Experimental

2.1. Materials

Bagasse consists mainly of cellulose and lignin (Fig. 1a and b, respectively). In the current study the raw bagasse was obtained

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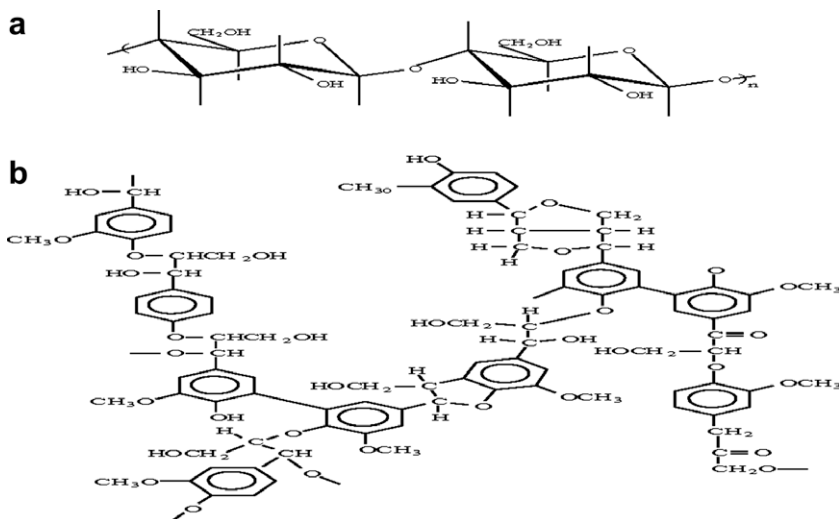


Fig. 1. Structure of bagasse: (a) cellulose and (b) lignin.

from Abou-Korkas Sugar Factory, El-Minia, Egypt. Treatment of this raw bagasse to remove lignin was carried out by Miser Edfu Pulp Writing and Printing Paper Company, Edfu, Egypt. Bleached cellulose (without pith and lignin) was developed by Quena Paper Industry Company, Quena, Egypt. The bleaching of cellulose resulting from pith and lignin removal was carried out by chlorine dioxide, ClO_2 , (1.5%) and oxygen 75–85 °C and a pH of 4.5–5.5.

2.2. Synthesis

Grafted/modified bagasse components – each bagasse component was modified as follows: the bagasse component (raw, pulp, and pulp plus pith), in excess, was mixed for 2 h with stearic acid, basic compounds, and water. The mixture was dried in a vacuum at 60 °C for 20 h. This procedure resembles a patented procedure (Ceaser, 1988).

The morphology of the washed raw bagasse obtained from the sugar cane mill is shown in Fig. 2a. It consists of a mixture of cellulosic short fibers and fine particles. After removing the lignin,

2.3. Method

Oil/water absorption procedure: The samples were weighed, placed in oil or water for 10 min, drained for 15 min, and then reweighed. Used Caltex Valor 100 motor oil, Caltex Egypt, was employed in the absorptivity study. The water used was distilled. Three replications were obtained for each data point. The average reproducibility of the data is $\pm 5.5\%$.

The percentage absorptivity was calculated according to the following equation.

$$\text{Absorptivity} = \frac{\text{Weight of sorbent containing absorbed fluid} \times 100}{\text{Initial weight of sorbent}} \quad (1)$$

A sample that did not absorb fluid (oil or water) gives an absorptivity of 100%. This equation can be expressed as a ratio between the weight of oil absorbed and the weight of sorbent. Thus,

$$\text{Sorption Capacity} = \frac{\text{Weight of sorbent containing absorbed fluid} - \text{Initial weight of sorbent}}{\text{Initial weight of sorbent}} \quad (2)$$

(Fig. 2b), the material is fairly hard coarse cellulosic particulates. The modified or grafted bagasse, shown in Fig. 2c, has a fluffy soft texture.

3. Results and discussion

Raw bagasse is a combination of cellulose, lignin, and other minor components. It is a material that absorbs hydrophilic and

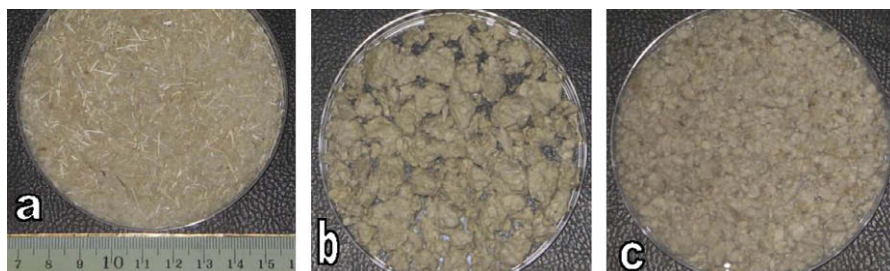


Fig. 2. Morphology of bagasse: (a) raw, (b) without lignin, and (c) grafted with fatty acid.

hydrophobic materials. The mechanism is partly because there are hydrophilic and hydrophobic sites of bagasse that can attract these materials, respectively. It is also partly because the architecture of the bagasse system has spaces that can trap these materials (Chiparus, 2004). Bagasse is typically treated by the paper industry to remove lignin and other non-cellulose components, resulting in a largely cellulosic material called pulp. Cellulose molecules are more attracted to hydrophilic than to hydrophobic materials. The hydrophobic parts of the cellulose molecule are mostly covered by the hydroxyl groups extending from the six-member rings of the cellulose polymer chain. Pith contains cellulose and lignin (Chiparus, 2004). Pith is part of the raw bagasse but can be separated from it. The oil absorbing capabilities of raw bagasse, cellulose and pith and pulp (bleached and unbleached) are shown in Fig. 3. Clearly the raw bagasse is the most effective at absorbing oil and the pulp the least.

The water absorbing properties of these materials were also examined (Fig. 4). The raw bagasse showed an initial weight loss indicated by absorptivity, followed by a significant weight gain. This could be explained by the initial washing of residual water-soluble materials, such as sugar, followed by the absorption of water. The hydrophilic and hydrophobic nature of the bagasse and its architecture can be used to rationalize these observations. The cellulosic pulp absorbed water, as expected. Neither the pulp nor the combination of pulp and pith showed the initial weight loss that the raw bagasse did, since procedures used to obtain these materials had cleared the water-soluble materials from these systems.

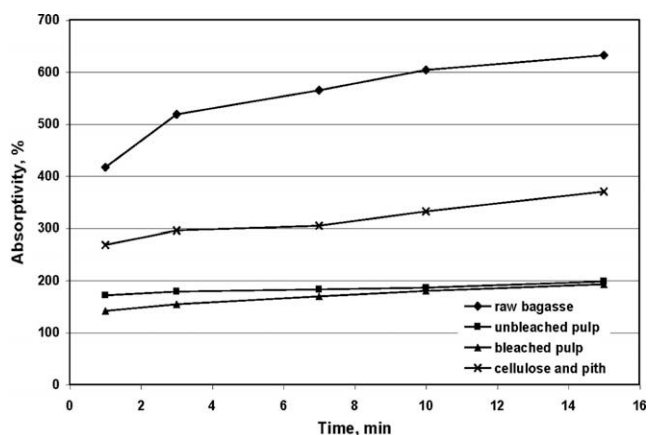


Fig. 3. Oil absorption by bagasse materials: (♦), raw bagasse; (■), unbleached pulp; (▲), bleached pulp; and (×), cellulose and pith.

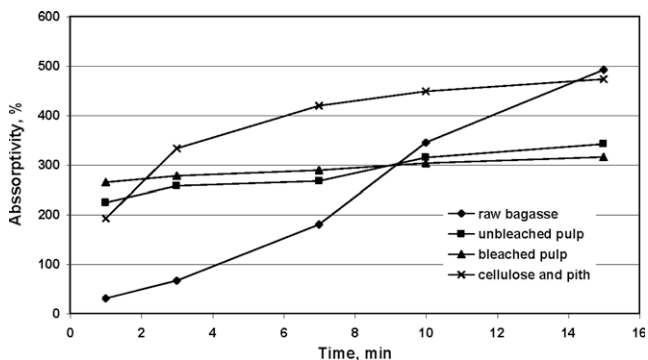


Fig. 4. Water absorption by bagasse materials: (♦), raw bagasse; (■), unbleached pulp; (▲), bleached pulp; and (×), cellulose and pith.

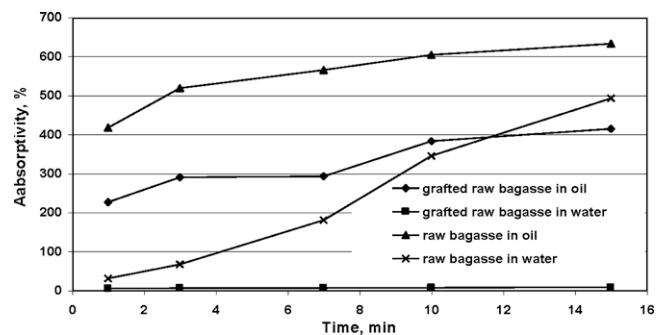


Fig. 5. Oil and water absorption by grafted raw bagasse in comparison with raw bagasse: (♦), grafted raw bagasse in oil; (■), grafted raw bagasse in water; (▲), raw bagasse in oil; and (×), raw bagasse in water.

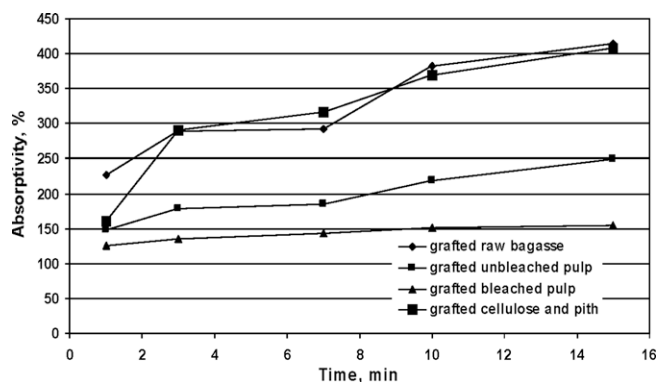


Fig. 6. Comparison of oil absorption by grafted bagasse materials: (♦), grafted raw bagasse; (■), grafted unbleached pulp; (▲), grafted bleached pulp; and (×), grafted cellulose and pith.

Oil and water absorption by grafted raw bagasse in comparison with raw bagasse are shown in Fig. 5. The grafting (modification) of a fatty acid to raw bagasse places a relatively long hydrophobic chain on the bagasse. This grafting can occur between the fatty acid carboxylic functional group and the alcohol groups of cellulose, the alcohol groups of lignin, and/or the phenolic group of the lignin. Regardless, the stearic acid chain provides a hydrophobic envelope for the bagasse architecture. The lack of water absorption by the grafted bagasse demonstrates this envelope. This hydrophobic envelope would, however, be attractive to oil and apparently contributes to the oil absorbing properties of the grafted raw bagasse. This implies that the grafted raw bagasse would operate effectively as an oil absorbing material for oil and water mixtures. The grafted raw bagasse would float on the surface of the water, as would the oil. The grafted raw bagasse would selectively absorb the oil and would remain on the surface to be removed when the application was complete. The material containing oil can be used as a fuel in the production of sugar cane or other industrial heating processes. Raw bagasse would absorb both water and oil from the mixture of these materials. However, raw bagasse would be an effective absorbent of oil alone from a non-aqueous environment. Additionally, raw bagasse was the most cost effective material in this study.

Further insight on the capacity of the various parts of bagasse for oil and water absorption, respectively is provided in Figs. 6 and 7. There was much similarity between grafted raw bagasse and grafted cellulose and pith. It appears that the bleaching of pulp modifies the structure enough so that a significant difference can be seen between the oil and the water absorption of these materials. Considering the chemistry of pulp formation, it is possible that before bleaching some of the lignin associated materials remains

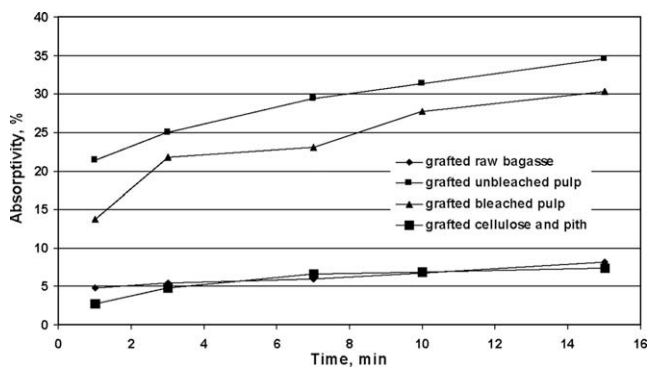


Fig. 7. Comparison of water absorption by grafted bagasse materials: (◆), grafted raw bagasse (■), grafted unbleached pulp; (▲), grafted bleached pulp; and (●), grafted cellulose and pith.

with the cellulose. These lignin-associated materials are more easily oxidized during the bleaching process (Lee, 2005). Regardless, the pulp (unbleached or bleached) is not a useful material for oil absorption.

It should be noted that when raw bagasse was grafted with fatty acid and used as a sorbent for pure oil, a sorption capacity of 3g/g was achieved after about 15 minutes. This was derived from Fig. 6 by converting the absorptivity (Eq. (1)) to sorption capacity defined in Eq. (2). It is also noticed from Fig. 6 that the grafted cellulose with pith has similar absorptivity or sorption capacity as the grafted raw bagasse. Both materials have the least affinity for water absorption. In comparison with a recent study using walnut shell as an oil absorbent material (Srinivasan and Viraraghavan, 2008), the grafted raw bagasse, developed in the current work, is by far superior. It provides about four times the sorption capacity of the walnut shell which only provided less than 0.8 g/g at approximately the same time exposure of 15 min.

4. Conclusions

The modification of bagasse by acylation grafting with a fatty acid produced a material significantly more hydrophobic than the bagasse starting material. This grafted bagasse had little affinity for water and good affinity for oil. Raw bagasse had been shown to absorb oil better than the other materials in this study. However, raw bagasse also absorbed water. Hence the grafted raw bagasse would be most suitable for applications where oil is to be removed from an aqueous environment. For oil absorbing applications in the absence of water, the raw bagasse was found to be an excellent material. It can be prepared for this application by simply cleaning to remove residual sugar and drying.

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