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Studies on The Extraction of Naturally-Occurring Banana Fibers

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ABSTRACT
A study was carried out to investigate how naturally-occurring fibers can be extracted by chemical retting method. In this study, banana fibers were obtained through chemical retting using banana trunk. The retting was conducted in four different media of different concentrations; 0.0M $NaOH_{(aq)}$, 0.01M $NaOH_{(aq)}$, 0.05M $NaOH_{(aq)}$ and 0.1M $NaOH_{(aq)}$ solutions respectively. In the pH study of the process, the pH of all the retted solutions converged at the range 6.71 to 7.60 while the optimum pH was found to be 7.39. The moisture content and moisture absorption calculated from the study showed moisture content of 94.88% and moisture absorption of 14.92%. Fiber yields of 0.25% to 0.55% were obtained from the four solutions studied. This, in large scale production will find application in composite development for various applications and an appropriate scenario of conversion of waste to wealth.

KEYWORDS: *Chemical retting, fiber, Sodium hydroxide, Banana, Alkaline treatment*

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I. INTRODUCTION

The production of high quality natural fibers is as much of an art and science. The process of obtaining natural fiber from plant stem is known as Retting. It is the microbial decomposition of pectin, which binds the fibers to the woody inner core of the stem of the plant. The process employs water and microbial action to separate fiber from the woody core (i.e. the Xylem) and surrounding the epidermis as well. This process has major impact on the final product quality. Besides differences in variety, the influence of climatic conditions and soil, ripeness at harvest and harvesting method, the retting procedure is of crucial importance to the processability of the fibers. Alkali treatment of cellulosic fibers, also called mercerization, is the usual method to produce high quality fibers. Alkali treatment improves the fiber-matrix adhesion due to the removal of natural and artificial impurities. Moreover, alkali treatment leads to fibrillation which causes the breaking down of the composite fiber bundle into smaller fibers. In other words, alkali treatment reduces fiber diameter and thereby increases the aspect ratio. Therefore, the development of a rough surface topography and enhancement in aspect ratio offer better fiber-matrix interface adhesion and an increase in mechanical properties [1]. Alkali treatment increases surface roughness resulting in better mechanical interlocking and the amount of cellulose exposed on the fiber surface. This increases the number of possible reaction sites and allows better fiber wetting. The possible reaction of the fiber and NaOH which is represented as (1) is as shown below [2].

$$\text{Fiber-OH} + NaOH \text{ ------- } \text{Fiber-}O^{-}Na^{+} + H_2O \qquad \text{------------------------- Equation 1}$$

The chemical constituents of natural fibers can be classified into cellulose and lignin. Lignin plays the role of binding the fibers of cellulose. Alkaline treatment is used for the release of fibers just as it is one of the standard procedures in the pulp and paper industries for lignin removal, lignin can be dissolved in sodium hydroxide (NaOH) solution and the cellulosic fibers can be extracted with relative ease. NaOH causes dissolution of lignin by breaking it into smaller segments whose sodium salts are soluble in the medium [3]. Natural fiber like banana plant fibers which is of huge economic importance are used in the process of making basket in Ecuador [4]. Cordage and textiles are all made from fibers with pulp and paper which is a product of fibers being marketed by the natural paper company in the U.S.A [5]. Retting can be achieved mechanically by hammering or chemically by boiling & applying chemicals. The choice depends on the availability of water and the cost of retting process. In "water retting" plants such as flax, jute, hemp or kenaf etc are submerged in water, soaked for a period of time to loosen the fibers from the other components of the stem. Retting can also be done by placing the already cut or chopped stand of the plant in fields in wet fall called "dew retting". In either approach, bacterial action attacks pectin and lignin, freeing the cellulose fibers [6].

During retting, the stems are monitored to avoid excessive degradation of the fiber material [7] which will affect the fiber strength. The fiber degrades when bacterial acts on it. There is a direct correlation between retting time, cellulose polymerization degree and fiber strength [8]. There is also a need to allow for complete retting because in under-retted samples the pectin content is too high for good separation of bast fibers and shives, which will give substantial problems in further processing (decortation, cleaning, and combing, fiber separation).

The number of days required for retting depends on water temperature, locality, time of year, weather conditions, depth and source of water, thickness of stalks and quantity of straw in relation to volume of water [7]. Once retting is completed, the stems are removed and washed, and subjected to mechanical processing to remove the soft tissues and then dry to obtain the fibers. Extraction processes of natural fibers can be performed by different procedures that include mechanical, chemical and biological methods. Each method presents different advantages or drawbacks according to the amount of fiber produced or the quality and properties of fiber bundles obtained [9].

The yearly banana plant waste (the trunk) will always be on the increase as a result of banana growth plantation and the high demand for banana. There is therefore the need to convert this waste to wealth by extracting the fibers from banana trunk which finds application in the plastic, textile and paper industries as increase in population will be a huge disposal problem.

II. METHODOLOGY

Banana plants were obtained and the trunk cut into equal parts of four each weighing 2kg. Sodium hydroxide solutions of 0.1M, 0.05M, 0.01M and 0.00M were prepared and each poured into labeled containers. The banana trunks were completely immersed into the four labeled containers and covered. The trunks were left to ret for 6 weeks and the pH monitored daily. Some physical observations were also made for both the banana trunk and their various solutions.

The moisture content of the banana trunk determined after the final weights of the various trunk which were dried in the oven for 72hrs were measured and deducted from the initial weights and percentage moisture content calculated using (2) below:

$$MC = \frac{M1 - M2}{M1} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 2$$

Where MC is the moisture content, M1 is the initial weight of banana trunk before drying and M2 is the final weight of banana trunk after drying.

Weight absorption was measured by immersing the banana trunk in distilled water and left for 24hrs. The weight difference was measured and the total water uptake was calculated using (3):

$$WA = \frac{M3 - M4}{M4} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation } 3$$

Where WA is the weight absorption, M3 is the weight of banana trunk after absorption of H_2O and M4; the weight of banana trunk before submerging into H_2O.

The fiber yield was also calculated. A cross sectional area of the fiber obtained via retting was viewed using Nikon Eclipse ME 600 microscope.

III. RESULT/ DISCUSSION

Table 1: Observations after retting period of 6 weeks

S/N	SOLUTION (NaOH)	SOLUTION COLOUR	FIBRE YIELD (%)
1	0.1M	Dark brown	0.25
2.	0.05M	Beige	0.30
3.	0.01M	Amber	0.35
4.	0.0M	Off white	0.55

The solutions in which the trunks were immersed to ret showed colour changes as shown in TABLE 1 above. The retted solutions of 0.1M NaOH, 0.05M NaOH, 0.01M NaOH and 0.0M NaOH changed from clear solutions to dark brown, beige, amber and off white colour respectively. This period of retting the banana trunk with the change in colour of the solutions resulted in fouling of the retting solutions and hence discolours the fibers [7]. It was also observed that the retting started from the edge of the trunk since its internal components i.e. the xylem and epidermis are exposed directly to the various solutions unlike the bark covering of the banana trunk.

The pH study showed that only the 0.00M NaOH solution was acidic with a pH of 5.83 indicating that the banana is acidic. Whereas the alkalinity of the other three solutions could be as a result of the various concentration of the sodium hydroxide i.e. 0.1M, 0.05M and 0.01M added to the solutions showing pH of 12.51, 12.22 and 11.60 respectively.

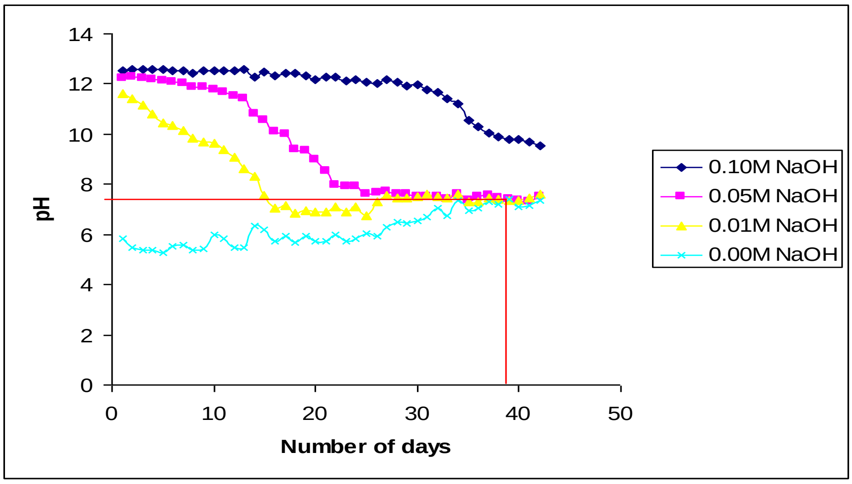

Figure 1: Plot of pH against number of days

Looking at the retting solutions as plotted in Fig 1, it is observed that the higher the concentration of the retting solutions, the longer it takes the retting solution to reach its maximum pH. By the 13th day of the retting, trunks from the retted solutions of 0.01M NaOH, 0.05M NaOH and 0.1M NaOH were softened whereas 0.0M NaOH became soft on the 28th day and if on testing of the retted stalks fiber is found loosening, it is considered ready for extraction. After soaking for a period of time, the fibers were loosened from the other components of the stem freeing the cellulose fibers [6] due to the alkalinity of the solution and bacterial action attacks on pectin which binds the fibers to the woody inner core of plant stem and lignin. The softening of fiber takes place due to action of the enzyme released by the bacteria acting on the stem [7]. From the graph we can deduce that on the 39th day of retting, the optimum pH was 7.39.

The 0.0M NaOH retting solution has better advantages over the other solutions because of the yield it produces at the end of the process. The retted solutions of 0.1M NaOH showed 0.25% yield while 0.30% fiber yield was obtained from 0.05M NaOH retted solution, and 0.35% yield was obtained for 0.01M NaOH retted solution. Also a yield of 0.55% was obtained for 0.0M NaOH retting solution.

Fig 1 is a representation of the Plot of pH against number of days. Here, there was gradual drop in pH for the fiber retted with 0.1M NaOH solution until the 34th day where there was a slight sharp drop of 6.15% into the 35th day. And the pH of the solution continued to drop. The pH of the fiber retted with 0.05M NaOH solution dropped gradually from the first day to the 13th day with a drop of 5.28% into the 14th day. Then the slight drop in pH continues from the 25th day to the 42nd day, a pH drop from 7.60 to 7.28 was observed. The pH of fiber retted with 0.01M NaOH solution also followed suit with the above trend. But from the 3rd to the 4th day 3.33% drop was observed and a rise in pH was observed from the 15th day ranging from 6.77 – 7.61.

For the acidic solution, a significant change in pH was between the 26th and the 27th day with 5.71% and a pH rise from pH 6.71 to pH 7.39 being observed on the 42nd day. These pH rise observed from fig 1 could be the possible point at which retting is been completed. This could be the optimum retting point.

Figure 2: cross-sectional area retted banana fiber (x400) using Nikon Eclipse ME 600 microscope

Figure 3: A photograph of banana fiber

A cross sectional area of strand of the fibers obtained (Fig 2) shows a white line which revealed the cellulose in the fiber while the dark spots and lines indicated points of microbial attack of the cellulose [10]. Figure 3 shows fibers that have been completely retted from banana trunk.

From (2), moisture absorption for the banana was found to be 14.92% whereas from (1), moisture content was found to be 94.88%. This showed that banana weight consist mainly of moisture.

IV. CONCLUSION

Banana fibers have been successfully extracted from banana harvest waste using various concentrations of sodium hydroxide as retting media. The study showed that irrespective of the route taken for fiber retting, optimum pH for retting is in the neutral pH region (around pH 7). It is also observed that the higher the concentration of the retting solutions, the longer it takes the retting solution to reach the region of the optimum pH (7.39).

A fiber yield of 0.25% to 0.55% was obtained. With large cultivation or plantation of banana, after harvest, large quantity of fibers from banana waste of commercial significance for application in new materials development like body parts of cars, partitioning panels, ceiling boards, plumbing yarn, etc. can be obtained. This will be an appropriate scenario of conversion of waste to wealth.

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