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A STUDY ON SPINNABILITY OF CHEMICALLY CHANGED BANANA FIBRE

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Abstract: Banana is one such natural ligno-cellulosic natural fibre. In this work, the effect of alkali treatment on the properties of banana fibres was studied. This type of treatment has been shown to cause several changes in the fine structure, such as the creation of voids and fibrillation of fibres. It was demonstrated that this kind of treatment leads to several changes in fine structure, such as voids creation and fibre fibrillation. The main aim of this study was to discover the effect of various experimental parameters such as alkali concentration, time, and temperature on Gum Removal from banana fibres. The effect of these experimental parameters and optimal experimental conditions were ascertained by Response Surface Methodology (RSM) using Box-Behnken design. From RSM generated model, the optimum conditions for Degumming were identified to be at alkali concentration of 11g/L. Time of 3 hours and temperature of 90^0C. At the optimum conditions, predicted gum removal was 40 percent.

Key Words: *Banana fibre, alkali treatment, RSM.*

1. INTRODUCTION:

1.1. Importance of Natural Fibre:

Mankind has been strongly dependent on plant fibers for all kind of purposes. Banana farm waste is eco-friendly and is found in abundance and can be used as raw materials for the manufacture of home textiles, clothing, non-woven and industrial fabrics. Banana fiber is a natural fiber with high strength, which can be blended easily with cotton fiber or other synthetic fibers to produce blended fabric and textiles. Open-cell urethane foams and fiberglass are the two main materials for acoustic absorbers. Industrial textiles are subgroups of a broader category of technical textiles, involving mainly those textile products used in manufacturing operations or incorporated in industrial products such as electrical components and industrial appliances.In recent years there has been significant interest in the use of natural fibres as potential reinforcement for both organic and inorganic matrices. Before the advent of man-made fibres, in particular glass fibre, natural fibres of both vegetable and mineral origin were the only reinforcement available for fibre-reinforced composite materials. The use of fibres like flax, hemp, jute or sisal in this industry so far is small since availability of a durable semi-finished product with constant quality is often a problem. Recent research and development have shown that these aspects can be improved considerably. Knowing that natural fibers are cheaper and have a better weight strength than glass, resulting in lighter parts, the increased interest in natural fibers is obvious.The environmental impact is smaller since the natural fibre can be thermally recycled and fibres come from a renewable resource. The natural fibers are used in reinforcing both thermosetting and thermoplastic matrices to provide mechanical strength. Thermosetting resins, such as epoxy, polyester, polyurethane, phenolic, are widely used in combination with natural fiber composites, where composites require higher quality. They provide sufficient mechanical properties, such as stiffness and strength, at acceptably low price levels. With considerations to the ecological aspects of material selection, replacing synthetic fibers by natural ones is only a first step.

1.2. Banana Fibre:

Banana fiber is obtained from the pseudostem of banana plant is a lingo-cellulosic fiber which comes under the category of bastfiber which has a relatively good mechanical properties. It has good specific strength comparable to those of conventional material, like glass fiber and has a lower density then glass fibers. These fibers can be explored to develop various technical textiles which are the need of the hour. This study aims in developing technical textiles that can serve multipurpose uses like soundproof, fireproof and antimicrobial at the same time. Noise pollution today has caused several detrimental effects to the population affecting both health and behavior of individuals. Owing to the effects of noise pollution several places such as schools, hospitals and certain commercial buildings require suitable acoustical engineering facility to overcome the problem. The advancement of sound absorption control of noise offers a great opportunity to study different porous materials ' acoustic attenuation technique.The commercially available sound absorptive materials used are generally classified as granular, cellular, and fibrous materials. The fibrous materials used can be either natural or synthetic, the advantage of using acoustic panels made from natural

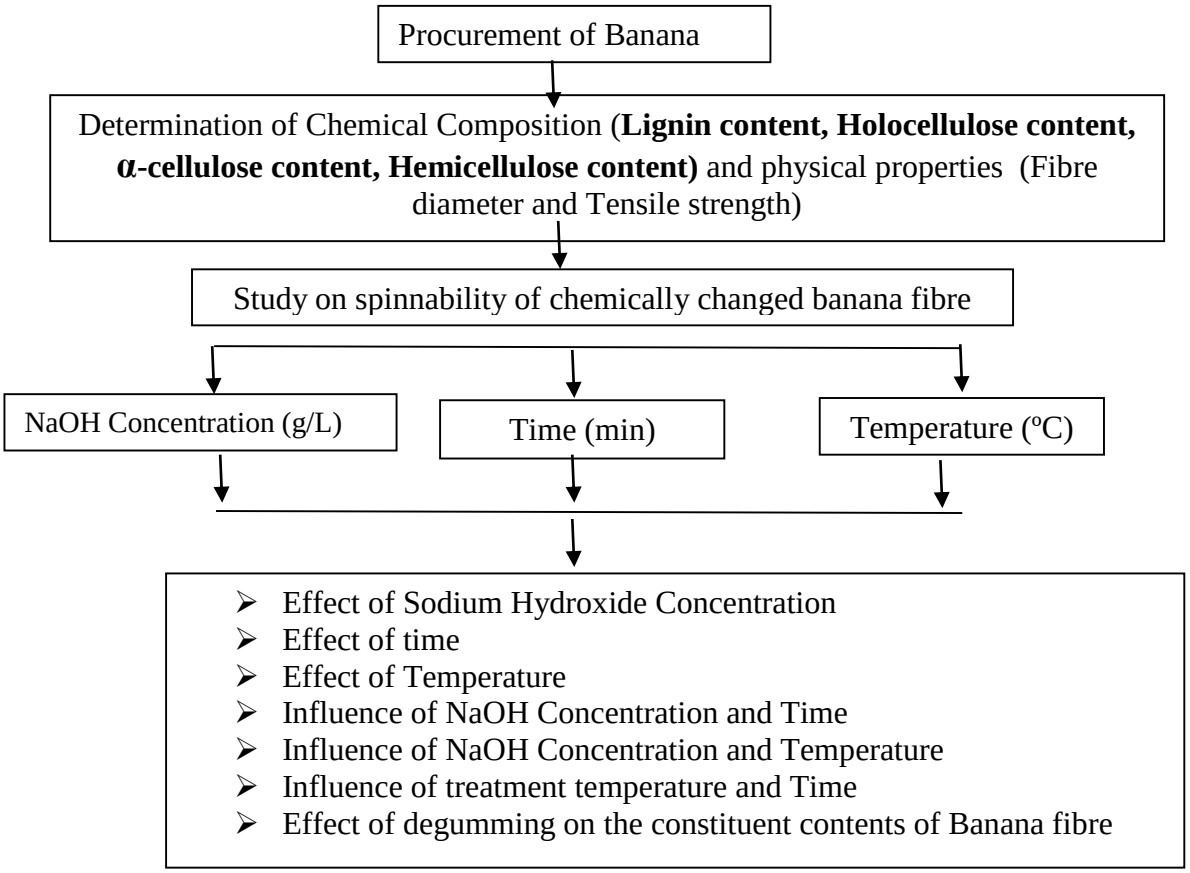
fibers are less hazardous to human health and more eco-friendly than those made of synthetic fibers. Therefore, growing concern for human health and safety issues has encouraged manufacturers and engineers to seek alternative materials from natural fibers as a replacement for synthetic fibers.

2. MATERIALS AND METHODS:

2.1. Procurement of Raw Materials:

Banana fibre was purchased from Ecostar unit, TNAU, Coimbatore, India. Polyester (200 GSM), Polyurethane (100 GSM) and Polypropylene (300 GSM) were purchased from PSG COE, Neelambur, Coimbatore, India.

2.2. Experimental Plan:



2.3. Pretreatment Of Fibers (Banana Fibers):

2.3.1. Treatment of Banana Fibers:

In order to obtain the optimum NaOH concentration for degumming, banana fibres were treated with different Sodium Hydroxide concentration viz 6g/L, 8g/L, 10g/L, 12g/L, 14g/L and the solution was made with Sodium Carbonate 1g/L, fibre to liquor ratio 1: 20, and treated at 90^0C for 120 min, followed by washing and finally dried in an oven. The procedure was repeated if the fibers were not processed properly.

2.4. Fibre Analysis:

2.4.1. Lignin Content:

Two grams of extracted sample were placed in a flask and 15 ml of 72% sulphuric acid was added. The mixture was stirred frequently for two and half hours at 25°C and 200 ml of distilled water were added to the mixture. Then the mixture was boiled for next two hours and cooled. After 24 hours, the lignin was transferred to the crucible and washed with hot water repeatedly until becoming acid free. The collected lignin was dried at 105°C and cooled down in desiccator and weighed (Barreto, Costa, Sombra, Rosa, Nascimento, Mazzetto andFechine, 2010). The drying and weighing were repeated until constant weight, and the gum decomposition was calculated using Eq.1:

$$\text{Gum Decomposition} = \{(M_0 - M_1) / M_0\} \text{ X } 100 \quad (1)$$

Where M_0 is the gum content of the raw banana fibre, M_1 is the residual gum content of the degummed banana fibre.

2.4.2. Holocellulose Content

Three grams of air dried banana fibre were weighed and placed in an Erlenmeyer flask and then, 160 ml of distilled water, 0.5 ml of glacial acetic acid and 1.5 g of sodium chloride were added successively. The flask was

placed in water bath and heated up to 75°C for an hour and then additional 0.5 ml of glacial acetic acid and 1.5 g of sodium chloride were added. Acetic acid and sodium chloride additions have been repeated twice an hour.The flask was placed in an ice bath and cooled down below 10°C. The holocellulose was filtered and washed with acetone, ethanol and water respectively and at the end, sample was dried in oven at 105°C before weighed.

2.4.3.α-Cellulose Content:

In a beaker, two grams of holocellulose were placed and 10 ml of sodium hydroxide solution was added (17.5 percent).The fibres were stirred up by glass rod so that they could be soaked with sodium hydroxide solution vigorously. Then sodium hydroxide solution was added to the mixture periodically (once every five minutes) for half an hour and the mixture temperature was kept at 20°C. About 33 ml of distilled water was added in the beaker and kept it for an hour. Filtered and transferred to the crucible, the holocellulose residue washed with 100 ml of sodium hydroxide (8.3%), 200 ml of distilled water, 15 ml of acetic acid (10%)and again water successively. The crucible with α-celluloses was dried and weighed.

2.4.4. Hemicellulose Content:

1 g of extracted dried banana fibre was transferred into a 250 mL Erlenmeyer flask. 150 mL of 500 mol/m3 NaOH was added. The mixture was boiled for 3.5 h with distilled water. It was filtered by vacuum filtration after cooling and washed until neutral pH. In a convection oven, the residue was dried to a constant weight of 105^0C.The difference between the sample weight before and after this treatment is the hemicellulose content (%w/w) of dry banana fibre

The content of hemicelluloses of banana fibre was calculated from Equation (2)

Hemicelluloses = Holocellulose – α-cellulose (2)

2.4.5 .Fibre Diameter:

Figure 1. Polarised microscope (Lieca make)

The surface morphology and diameter were measured using apolarised microscope (Lieca make) with a magnification of 4x and 10x and interfaced with a PC. Banana Fibres were measured for diameter in at least 10 different locations for 30 different fibres and the average of these measurements was calculated.

2.4.6. Tensile Property:

Figure 2.Zwick tensile tester

Tensile properties of the banana fibres were measured according to the ASTM D 3822 – 01 standard test method for tensile properties of single textile fibres. The test was performed with 1kN loadcell at a crosshead speed of 5 mm/min, and approximately 20 fibres were tested for each sample, at 10mm gauge length inZwick tensile tester.

3. STATISTICAL ANALYSIS:

The experimental plan was designed using the Box-Behnken method to optimize the process parameters. Three levels and their three variables have been selected in this experimental plan. This method also offers the advantage of being rotatable, which means that the fitted model estimates the response at all points in the factor space with equal precision. are equidistant from the centre. The significant variables screened by PBD were optimized by Box-Behnken Design (BBD). The number of experiments for k factors in BBD based on 3 level is given by 2k(k-1)+c where c is number of centre points. According to BBD table, 15 experiments were performed for 3 factors with 3 central points. A coefficient of the quadratic model was calculated using the following equation,

$$Y = b_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ij} X_i^2 + \sum_{i_{i<j}}^{k} \sum_{j}^{k} b_{ij} X_i X_j$$

Where, Y is the predicted response and i,j are linear, quadratic coefficients respectively, b and k are regression coefficients and the number of factors studied in the experiment respectively. The significance of each coefficient was determined and the results were analysed by trial version of design expert. Three dimensional surface plots were obtained to study the interaction effect between variables. The optimum values were obtained based on the humps in 3-D plots.

4. INTERPRETATION:

4.1. Statistical Analysis:

The experimental plan was designed using the Box-Behnken method to optimize the process parameters .In this experimental plan, three levels and their three variables was selected (Table 1). This approach also provides the benefit of being rotatable, which ensures that the fitted model estimates the answer at all points in the variable space with equal precision.are equidistant from the centre. A quadratic polynomial has been used to evaluate the relationship between each answer and the three independent variables as shown below:

$$Y = R_o + \sum_{i=1}^{k} R_i X_i + \sum_{i=1}^{k} R_{ii} X_i^2 + \sum_{i=1, i<j}^{k-1} \sum_{j=2}^{k} R_{ij} X_i X_j + \varepsilon$$

Where R_0, R_i, R_{ii} and $R_{ij}$are the coefficients of the regression equations; i and j, the integers; and Y, the response of the dependent variables.

LEVELS	PROCESS PARAMETERS		
	NaOH Concentration (g/L)	Time (min)	Temperature (^{0} C)
1	8	60	70
2	10	120	80
3	12	180	90

Table 1 Details of process parameters and different levels for Gum Removal

The raw fibre was cut into equal length (1 inch) of small fibres and based on the Box-Behnken method, fifteen trials were conducted (Table 2). The constituent contents were tested according to the following methods.

4.1.1. Lignin Content:

Two grams of extracted sample were placed in a flask and 15 ml of 72% sulphuric acid was added. The mixture was stirred frequently for two and half hours at 25°C and 200 ml of distilled water were added to the mixture. Then the mixture was boiled for next two hours and cooled. After 24 hours, the lignin was transferred to the crucible and washed with hot water repeatedly until becoming acid free. The collected lignin was dried at 105°C and cooled down in desiccators and weighed. The drying and weighing were repeated until constant weight, and the gum decomposition was calculated using Eq.1

Gum Decomposition = $\{(M_0 – M_1) / M_0\}$ X 100 (1)

Where M_0 is the gum content of the raw banana fibre, M_1 is the residual gum content of the degummed banana fibre.

Run No.	NaOH concentration g/L	Time (hours)	Temperature (^{0}C)	Gum Decomposition %
1	8	1	80	11.80
2	8	3	80	17.60
3	12	1	80	23.20
4	12	3	80	36.40
5	8	2	70	10.00
6	8	2	90	28.20
7	12	2	70	19.40
8	12	2	90	35.30
9	10	1	70	10.50
10	10	1	90	21.20
11	10	3	70	24.10
12	10	3	90	39.50
13	10	2	80	35.13
14	10	2	80	35.3
15	10	2	80	35.28

Table 2Gum Decomposition of banana fibre samples using different process parameters

4.1.2. Holocellulose Content:

Three grams of air dried banana fibre were weighed and placed in an Erlenmeyer flask and then, 160 ml of distilled water, 0.5 ml of glacial acetic acid and 1.5 g of sodium chloride were added successively. The flask was placed in water bath and heated up to 75°C for an hour and then additional 0.5 ml of glacial acetic acid and 1.5 g of sodium chloride were added.Acetic acid and sodium chloride additions have been replicated twice an hour. The flask was placed in an ice bath and cooled down below 10°C. The holocellulose was distilled and washed respectively with acetone, ethanol and water, and the specimen was dried at 105 ° C in the oven before weighing.

4.1.3.α-Cellulose Content:

Two grams of holocellulose were put in a beaker and 10 ml (17.5 percent) of sodium hydroxide solution was added.The fibres were stirred up by glass rod so that they could be soaked with sodium hydroxide solution vigorously. Then sodium hydroxide solution was added to the mixture periodically (once every five minutes) for half an hour and the mixture temperature was kept at 20°C. About 33 ml of distilled water was added in the beaker and kept it for an hour.Filtered and transferred to the crucible, the holocellulose residue washed with 100 ml of sodium hydroxide (8.3%), 200 ml of distilled water, 15 ml of acetic acid (10%) and again water successively. The crucible with α-celluloses was dried and weighed.

4.1.4. Hemicellulose Content:

1 g of extracted dried banana fibre was transferred into a 250 mL Erlenmeyer flask. 150 mL of 500 mol/m3 NaOH was added. The mixture was boiled for 3.5 h with distilled water. It was filtered by vacuum filtration after cooling and washed until neutral pH. In a convection oven, the residue was dried to a constant weight of 105^{0}C.The difference between the sample weight before and after this treatment is the hemicellulose content (%w/w) of dry banana fibre.
The content of hemicelluloses of banana fibre was calculated from Equation (2)
Hemicelluloses = Holocellulose – α-cellulose (2)

4.1.5. Fibre Diameter:

The surface morphology and diameter were measured using a polarised microscope (Lieca make) with a magnification of 4x and 10x and interfaced with a PC. Banana Fibres were measured for diameter in at least 10 different locations for 30 different fibres and the average of these measurements was calculated.

4.1.6. Tensile Property:

Tensile properties of the banana fibres were measured according to the ASTM D 3822 – 01 standard test method for tensile properties of single textile fibres. The test was performed with 1kN loadcell at a crosshead speed of 5 mm/min, and approximately 20 fibres were tested for each sample, at 10mm gauge length in Zwick tensile tester.

5. RESULTS AND DISCUSSION:

5.1. Effect Of Sodium Hydroxide Concentration:

In order to obtain the optimum NaOH concentration for degumming, banana fibres were treated with different Sodium Hydroxide concentration viz 6g/L, 8g/L, 10g/L, 12g/L, 14g/L and the solution was made with Sodium Carbonate 1g/L, fibre to liquor ratio 1: 20, and treated at 90^{0}C for 120 min, followed by washing and finally dried in

an oven (Mohapatra, Mishra and Sutar, 2010). After that, the gum decomposition was tested to estimate the effect of sodium hydroxide concentration on banana fibre. Table 3 and Figure 1 show the results.

S.No.	Sodium Concentration g/L	Gum decomposition %
1	6	8.45
2	8	28.65
3	10	37.10
4	12	38.22
5	14	38.42
6	16	38.43

Table 3 Effect of sodium concentration on gum decomposition

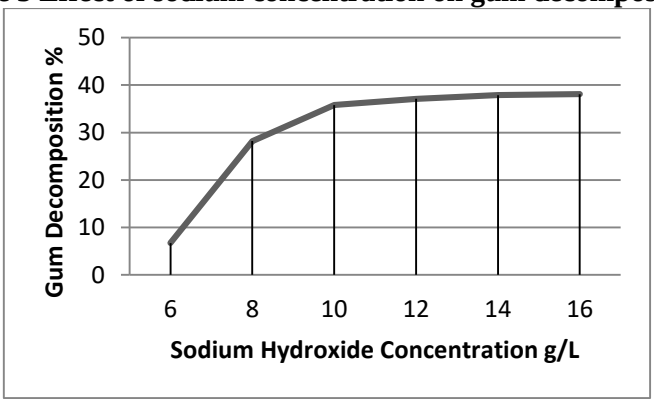


Figure 3. Effect of sodium concentration on gum decomposition

Table 3 and Figure 3 shows that the gum decomposition value increased up to 36% with the NaOH concentration increased up to 10g/l, and again increased slightly with further increase of NaOH concentration. The variations in GD% were observed at three different concentrations (8g/l, 10g/l, 12g/l). so these concentrations were taken as a three different levels in Box-Behnken design.

5.2. Effect of Time:

In order to get optimum process time for degumming, the banana fibre was treated for different time viz 60 min, 120 min 180 min, and the solution was made with NaOH 10g/L, Sodium Carbonate 1g/L, fibre to liquor ratio 1: 20, and treated at 90^0C followed by washing and finally dried in an oven. After that, the gum decomposition was tested to estimate the effect of treatment time on banana fibre. The results are shown in Table 4 and Figure 4..

S.No.	Time (min)	Gum Decomposition %
1	60	21
2	120	31
3	180	39.7
4	240	41.1

Table 4 Effect of time on gum decomposition

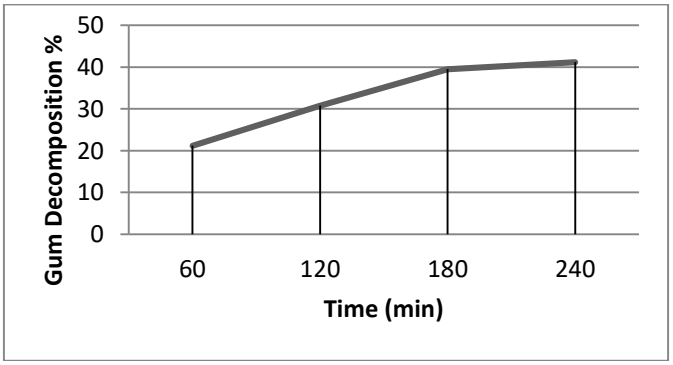


Figure 4. Effect of time on gum decomposition

Figure 4 shows that the gum decomposition value was almost linearly increasing with the increase of treatment time, but no obvious changes were observed after 180 min. It may be explained that the extent of banana fibre swelling increased with time and was fairly complete within 180 min. the gum loosened and opened up, allowing the auxiliary agents to easily penetrate into the fibre. As a result, the auxiliary agents react sufficiently with non-cellulosic materials, and make them decompose and dissolve in the treatment solution. At the same time, it may be also explained that the decomposable materials have been completely removed in 180 min. so there is no need to continue treatment after 180 min.

5.3. Effect Of Temperature:

In order to obtain optimum temperature for degumming, banana fibre was treated with different temperature viz. 70^0C, 80^0C, 90^0C, and the solution was made with NaOH 10g/L, Sodium Carbonate 1g/L, fibre to liquor ratio 1: 20, and treated for 120 min followed by washing and finally dried in an oven. After that, the gum decomposition was tested to estimate the effect of treatment temperature on banana fibre. Table 5 and Figure 5 show the results.

S.No.	Temperature (C^O)	Gum Decomposition %
1	70	21
2	80	31
3	90	39.7

Table 5 Effect of temperature on gum decomposition

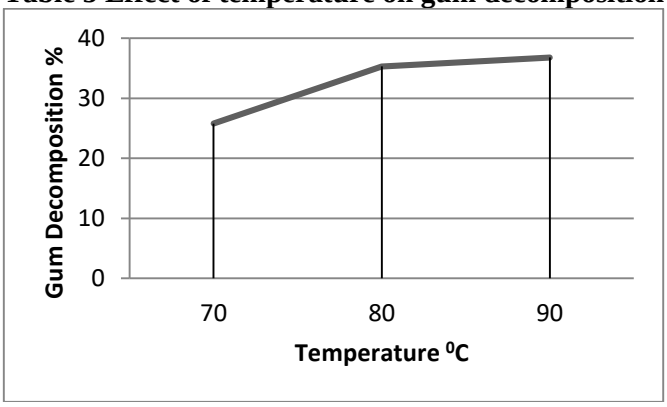


Figure 5. Effect of temperature on gum decomposition

Figure 5 shows that gum decomposition value was almost linearly increasing with the increase in temperature. There is a significant change in the GD% with respect to the treatment temperature.

6. CONCLUSION:

The degumming process is necessary for improving the textile properties of banana fibre. The mechanically extracted fibre was degummed by varying three important parameters for degumming like NaOH concentration, treatment time and treatment temperature and the degumming process was an effective method to remove hemicellulose, lignin, pectin and some other non-cellulosic materials. According to the results of Box-Behnken method, the gum decomposition ratio of 40% and diameter of 131µm were obtained with the optimum treating conditions such as NaOH concentration of 11g/L, treatment time of 3hrs and temperature of 90^0C. Further, by flat carding action, banana fibre was made even finer and shorter so that it approximates cotton. The total gum removed after all carding action was nearly 83.5%.

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