Experimental Investigation of Kraft Paper Making from Banana (Musa Sapientum) Stem Fibres and Study of Advancements in Fibre Extraction Process

Prashant A Giri[1], Ramprasad Nigudkar[2], Shubham D Kalan[3],
[1]Assistant Professor, [2,3]Undergraduate Student,
[1]Department of Chemical Engineering,
[1]Finolex Academy of Management and Technology, Ratnagiri, India

Abstract— In this modern age, the consumption of paper has increased tremendously. Conventionally, paper is manufactured from cellulosic materials like bamboo, hardwood, cotton, etc. Agricultural residues of non-woody nature like cotton stalks, wheat straw, rice straw, sorghum stalks, hemp, jute, etc., are possible raw materials which could be used for paper making. One of the materials found to be promising is Banana stem waste, which is a very good source of cellulose. After harvest of fruit, huge quantities of waste biomass is generated and discarded as waste due to nonindustrial utilization. Studies have shown that with some modification in chemical and physical treatment different parts of Banana can be utilized to Kraft paper. For the study presented here, we have chosen Banana plant as a raw material to produce paper by Kraft process. The Banana stem has low lignin content along with long cellulose fibres of higher strength which is resulted in reduced demand for chemicals and energy for processing. The abundance of Banana plantation in Konkan region is having scope to establish a paper industry utilizing Banana stems as a feedstock. In this project we will study the various stages of paper and pulp making using Banana stem.

Keywords: Kraft Paper, Banana Stem, Fibres, Cellulose, Lignin

I. INTRODUCTION

The Indian handmade paper industries have been placed the category of village industry and had seen significant growth in last one decade. As per estimates, there are nearly more than 500 handmade paper units scattered all over India producing nearly 50,000 tonnes of handmade paper and board. The Indian handmade paper industry in the recent past wherein the production of handmade paper industry has reached to a turnover of Rs 250,000 million which provides employment to about 15,000 people and most of them are situated in the rural areas [1, 10]. The Indian Paper Industry has emerged as a diversified and specialized industry that produces numerous types of papers that comes in various use such as watermark, filter paper, drawing sheets, etc. Other products including Paper Bags, paper diaries, paper photo Frames, Greeting Cards, Handmade paper Boxes, paper Albums, etc, are manufactured and exported across the world. Today, the Indian exporters export nearly Rs.400cr. worth of paper products per annum to the developed nations [2, 11].

Banana is one of the earliest and important fruit crops cultivated by man in tropical parts of the world. Banana is distributed in more than 120 countries, over an area of 48 lakh hectares, with an annual production of 99.99 million tons in the year 2011 (Indian Horticulture Database, 2011). Banana farming generated huge quantities of biomass all of which goes as waste due to non-availability of suitable technology for its commercial utilization. Normally this biomass is used for animal feed and fuel. Among its multi faced uses like therapeutic, alcohol, starch extraction and other innumerable uses, they are the best source of fibre. India has about 8.3 lakh ha under banana cultivation (Indian Horticulture Database, 2011) producing approximately 51.18 million tons of pseudo-stem waste per year. Wild species like Musa balbisiana var. cola, Musa balbisiana var. andamanica existing in Andaman and Nicobar Islands are used for extracting fibres. In the Philippines, it is woven into a thin, transparent fabric called “agna” which is the principle material in some regions for men’s shirts. It is also used for making hand kerchiefs. In Sri Lanka, it is fashioned into soles for expensive shoes and used for floor coverings. Improved processes have made it possible to utilize banana fibres for manufacture of paper, currency, ropes, cordages, gunny bags, handicrafts etc. [3].

Banana tree consists of three parts. Namely leaves, stem and roots. The leaves and roots are cut out as they do not have any commercial as well as agricultural use. Cellulose is the main component in manufacturing of paper which is highly found in Banana stem. Today Banana stem has been used as a source of raw material for preparation of paper pulp. This pulp is used to make different types of papers like tissue, bloating, tracing, writing and printing paper. Making a tissue paper by a Banana stem will be good because Banana stem is the rich source of cellulose. Tissue manufacturing uses other sources like Jute, Cotton, Bamboo, etc. In making of pulp for paper we mainly use three processes namely Sulphate process, Sulphite process and Soda process. When initially pulp is obtained by Sulphate process, the pulp is in dark brown colour. This pulp required treatment of bleaching or peroxide to remove the colour impurities. [4]. The Banana stem which is separated from freshly chopped from tree is 30 cm in diameter and 70 cm in diameter. The layered outer black can be separated from pseudo stem. [5].

II. THEORY

Fresh Banana stems weight around 25 Kg with moisture content of around 95%. India has over 500,000 acres of land under Banana cultivation. It is a perennial herb with underground rhizome, attaining height of 3 - 9.5 meters. The trunk (Pseudo stem) is formed from tightly rolled spiral leaf bases [1]. Normally there are 25 sheaths in one stem. The outer 4-5 sheaths give coarse fibres and inner - most 5 sheaths give soft fibres. The yield of fibres is about 2 - 4 % of the O.D. weight of stem. India can generate about 2 lakhs tons of Banana fibres annually which can produce nearly 1.65 lakh tonnes of handmade paper [1, 6].

Table 1: Chemical composition of Banana Stem

Particulars	Banana Fibre	Rice Straw*	Wheat Straw*	Sugarcane*	Jute*
Ash, %	2~3	15~20	4.5~9	1.5~5 0	0.5~2
Lignin, %	11~14	12~16	16~21	19~24	21~26
Cellulose,%	82~85	28~48	29~51	32~48	45~63

The Kraft process (also known as Kraft pulping or Sulphate process) is a process for conversion of wood into wood pulp consisting of almost pure cellulose fibres. It entails treatment of wood chips with a mixture of sodium hydroxide and sodium Sulphide, known as white liquor, which breaks the bonds that link lignin to the cellulose. The Kraft process is the dominant chemical pulping method [7, 8].

III. Material and Method

A. Material

Banana stem obtained from local farmer of species Musa Sapientum. Sodium hydroxide (NaOH) (Molychem), Hydrogen Peroxide (H_2O_2) solution (30 %V/V) (Molychem), Sodium Carbonate (Na_2CO_3) (Molychem) were purchased from local suppliers.

B. Fibre Extraction and Paper Making Procedure[7]

Step 1: Fibre Extraction: Banana stem is required to chop in size of about 1.5-2 inches. Chemical pulp extraction is achieved by heating dried stem chips in alkaline medium of sodium hydroxide.

Step 2: Peroxide Treatment: Peroxide treatment is done for decolourisation by oxidizing organic matter. Peroxide treatment is done by using Hydrogen peroxide. Washing with water is done afterwards to remove the oxidized lignin and un-reacted peroxide. After peroxide treatment, small quantity of HCl (2-4 ml) is added to neutralize NaOH (If remained).

Step 3: Dilution (Slurry Making): The treated pulp followed by water wash is then diluted to form slurry to aid the pour it on screen. The concentration of slurry is adjusted so to utilize minimum quantity of water.

Step 4: Mixing of Additives: At this point, various additives are added to meet the market demand and to improve the quality of finished product. At this stage, starch is added as a binding agent. Added starch helps to attach fibres to each other.

Step 5: Screening: This step requires a wire woven screen of 70-80 mesh. Screen is constructed of the same size of the desired size. Along with screen, deckle is required to hold the slurry till the liquid passes the screen

In screening, screen is placed horizontal position and deckle is placed on it. The diluted slurry is poured in it and water allowed passing through screen.

Step 6: Drying: After the removal of residual water by mechanical pressing, the wet sheet of paper is allowed to partially dry on the screen to be enough stiff to be removed from screen. The removed paper sheet is then kept for drying. The equilibrium moisture content is 9%.

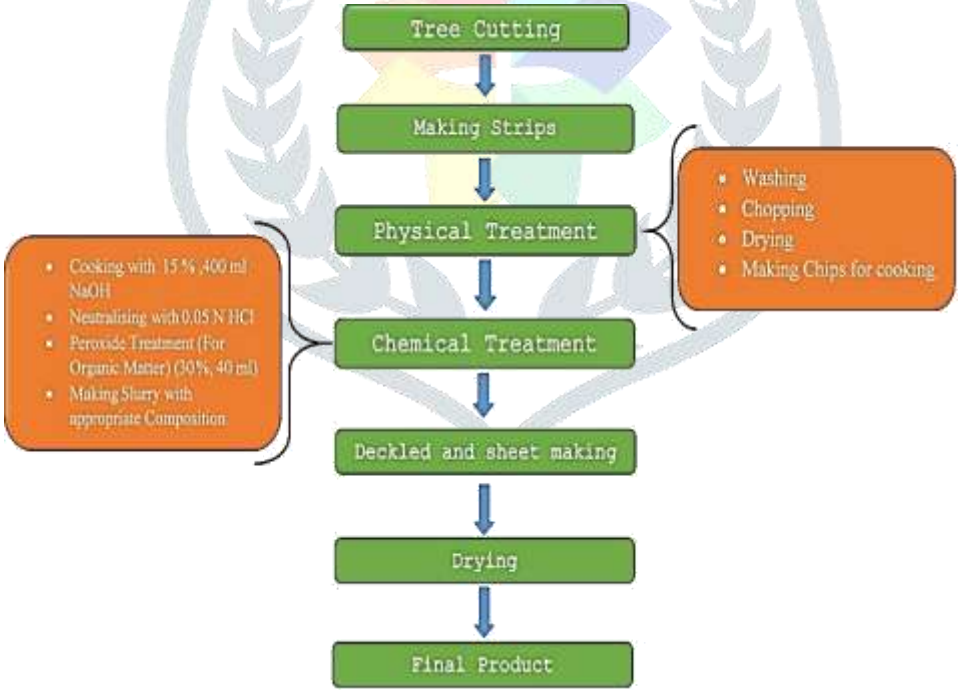

Figure 1: Experimental Procedure for Kraft Paper Making

C. Method and Experimental Procedure

Banana stem is obtained after harvesting the fruit is chopped in intermediate size ranging from 1.5" to 2 inches. These pieces are then sun dried to reduce the moisture contain of 11 to 15% prior to further procedure of chemical retting. The dried stem chippings are then cooked in 15% NaOH solution (the concentration of alkaline can be varying for different qualities of pulp and fibres). After Cooking the cooked fibres were kept for 20 to 30 min. to lowering its temperature. After cooling the sludge, 40 ml of peroxide is added to remove colour impurities and odour of sludge. The mixture is allowed to react for 20 min. During the peroxide treatment the slurry is constantly agitated to increase effectiveness of peroxide. After 20 min washing is done with 4-5 ml of 0.1N HCl for neutralization. After washing the slurry is oven dried for 150 min (Two and Half hour) to remove moisture content. The dried fibres are weighted. The weighted fibres are the basis for Kraft paper. The

different quantities of fibres are added with different quantity of starch (as an additive). The slurry is made in 450 ml of water. The starch is added.

a) Cooking of fibres **b) Cooked fibres**

c) Peroxide Treatment **d) Extracted Banana Fibres**

Figure 2: Experimental laboratory Batch Setup at room temperature

IV. RESULTS AND DISCUSSION

The pulp is successfully extracted from Banana stem by chemical retting. Pulp resulting is found excellent to produce paper. The 18% concentrated Na_2CO_3 solution requires 120 min of cooking which gives 34.5 gm of fibres from 50 gm of dried stem. The 18% concentrated NaOH solution requires 90 min of cooking which gives 32.5 gm of fibres from 50 gm of dried stem and the 15% concentrated NaOH solution requires 90 min of cooking which gives 29.6 gm of fibres from 50 gm of dried stem.

Table 2: Result of pulping process

Weigh of Dried Stem	Cooking Time (min)	Concentration of Solution for cooking	Chemicals for Cooking	Final weight of Fibres
50 gm	120	18 % , 450 ml	Na_2CO_3	34.1 gm
50 gm	90	18 % , 450 ml	NaOH	32.5 gm
50 gm	70	15 %, 450 ml	NaOH	29.6 gm

NaOH solution can be effectively used for retting process. High NaOH concentration decreases the cooking time and increase in concentration of alkali cause to increase the quality of fibres. Increase residence time with peroxide causing whitening of fibres. A concentration of Alkali (NaOH) increases from 15% to 18% results to decrease the cooking time from 90 min to 70 min. The concentration and cooking time also affects the final yield of fibres. The yield for 18% alkali solution is 65% and for 15% solution, it reduces to 59.2%. The weak alkali like Na_2CO_3 take 120 min to give high yield compare to NaOH for same 18% solution. We have produced sheet of paper from extracted pulp which can find applications in packaging of agricultural products.

V. CONCLUSION

Chemical retting process to extract fibres from Banana stems is economical and simple process. The yield of chemical retting method is higher than mechanical retting as well as microbial retting process. The investigation of Banana stem with cellulose content (82~85%) and lignin (11~14%) showed that this raw material is very suitable for producing Kraft paper. The low lignin content indicates that this fibres will require very mild pulping conditions. At 18% of NaOH cooked pulp have good strength properties which make a suitable fibre for paper making. The paper obtain from kraft process has high strength which is suitable material for packing. Kraft process (Sulphate Process) to make Kraft paper from Banana fibres is commercial viable process. The high biomass output of the fibre plants could provide large amounts of pulp, which could substitute the conventional raw materials used in India. As evident from the results depicted in table 8 that the strength properties

increased remarkably in many parameters. Here, it may also be recommended that this banana fibres, can replace imported long fibres wood pulp sheets which are being imported by big paper mills.

REFERENCES

[1] Kumar A, Singh P.B, Jain. R. K, Sharma A. K., "Banana Fibre (Musa Sapientum): "A Suitable Raw Material for Handmade Paper Industry via Enzymatic Refining". International Journal of Engineering Research & Technology (IJERT). Vol. 2 Issue 10, October – 2013.

[2] Reddy. J. B, Madireddy. S, Naidu. A, "Production of Pulp from Banana Pseudo stem for Grease Proof Paper". International Journal of Engineering Research and General Science Volume 2, Issue 1, January 2014.

[3] Preethi P, Murthy. B. G, "Physical and Chemical Properties of Banana Fibre Extracted from Commercial Banana Cultivars Grown in Tamil Nadu State", Agrotechnology AGT, an open access journal. Special Issue 11, 2013, ISSN: 2168-9881.

[4] Singh. L, Bandyopadhyay T. K, "Handmade paper from Banana stem", International Journal of Scientific & Engineering Research, Volume 4, Issue 7, July-2013.

[5] Rosal A, Rodríguez A, González Z, Jiménez L., "Use of Banana tree residues as pulp for paper and combustible"., International Journal of Physical Sciences Vol. 7(15), 2406 - 2413, 9 April, 2012, ISSN 1992 – 1950.

[6] Khan.M.Z.H., Srakar.M.A.R, Imam.F.I., Malinen.R.O, "paper Making From Banana Pseudo-Stem:Charaterision and Comparison", Journal of Natural Fibres, 11:199–211

[7] Kumar A, Singh P.B, Jain. R. K, Sharma A. K., "The Use of Alternate Ligno-cellulosic Raw Materials Banana (Musa sapientum) Ankara (Calotropis procera) and Pineapple (Ananas comosus) in Handmade Paper & their Blending with Waste Paper", American Journal of Engineering Research (AJER), Volume-02, Issue-09, 171-189.

[8] Debabandya Mohapatra, Sabasachi Mishra and Namrata Sutar, "Banana and its byproducts utilizations", Journal of Scientific and Industrial research, 69, 2010, 323-329.

[9] C. Vigneswaran, V. Pavitra, V. Gayathri, K. Mythili, "Banana Fibre: Scope and Value Added Product Development", Journal of Textile and Apparel, technology and management, Vol 9, Issue 2, 1-7.

[10] Giri Prashant A., Badgujar Sunil M., Marag Raju K., "Study of Effect of Concentration on Adsorption of Methyl Red Dye using different Adsorbents", International Journal for Research in Applied Science and Engineering Technology, Volume 5, Issue XI, Nov 2017, 1741-1745.

[11] Giri Prashant A., Badgujar Sunil M., Dere Shubham B., Gurav Sangram M., Panjari Mayuresh M., "Experimental study of Methylene Blue dye adsorption using Cashewnut Charcoal as an alternate adsorbent", Journal of Emerging Technologies and Innovative Research, Volume 4, Issue 11, Nov 2017, 380-383.