Handmade paper from banana stem

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Abstract

Banana stem is easily collected from banana trees after collection of banana fruits. The stem is used as a waste product and used in domestic cooking purpose. Mainly chemical process is used to collect the cellulose from the lignin. Lignin is separated from the lignocelluloses. It is removed after cutting of banana stem in small pieces and then stem is blowing inside the digester at a high pressure and successive use of sodium hydroxide, sodium sulphide and sodium hypochlorite. The fiber is molten and making pulp. Kappa number is used to know the lignin percentage in the pulp. This pulp is used to prepare the tissue, bloating and tracing paper. This process of pulp and paper making is economically viable and it is energy saving as sun ray is used for drying purpose.

Key words: Banana, pulp, paper, energy

1. Introduction

Today banana stem is used as a source of raw material for preparation of a paper pulp. This pulp is used to prepare different types of paper such as tissue, bloating, tracing and writing printing paper. Banana stems are easily available and cultivates in large scale at the North Eastern (NE) region of India. After harvesting, the farmer cuts the banana trees and throws away enormous amount of these stems into the fields because after harvesting the fruit, there is no significant use of banana trees. Constructing a tissue paper through the banana stem will be good for farmers because after harvesting the fruit there is no use of this but using the banana stem for the production of tissue paper will help the farmers get some money and will increase their interest in culminating banana crops. Several industries manufacture the tissue paper using bamboo, hardwood, softwood and jute etc. as the raw material, because it contains very good percentage of cellulose. On this basis, banana stem acts as a very suitable alternative raw material, containing very good percentage of cellulose [1, 2]. Banana trees separate into mainly three parts viz. leaves, stem and roots but the leaves and roots are cut out as it has no use. Cellulose is the main Raw Material for tissue paper and the stem part of banana trees contain the highest percentage of cellulose[3, 4].

In the North Eastern region of India, several varieties of banana trees are found, one of which is genus musa. North Eastern region of India has very suitable weather for banana crops. Genus musa is cultivated in large scale as well as it contains very good percentage of cellulose[5, 6].

In Manufacturing of the tissue paper, lignin creates the problem because it cannot be easily separated due to the intermolecular linkage of cellulose. Lignin is a combination of phenolic groups and it interconnects with the cellulose and the resultant bond is very strong. But delignification is very important to obtain a high-quality pulp because about 85-90 percent lignin separations ought to be done for making a white tissue paper [2, 6, 7]. Removal of 85-90 percent lignin implies that white pulp is produced because the brightness of the pulp depends upon the removal of the lignin percentage. The extent of lignin removal is characterized by the use of kappa number. Kappa number is directly proportional to the percentage of lignin removal, hence with the decrease in lignin removal percentage there is a decrease in the kappa number. In making a pulp, we generally know the three processes i.e. sulphate process (also known as kraft process), sulfite, and soda process are suitable. In addition, various semi-chemical, mechanical and semi mechanical can be used[8, 9].

In production of a tissue paper through the banana stem, kraft pulp process is preferred. It is the oldest and very famous process to prepare a pulp. The kraft process was discovered in Germany in 1879 and was first applied in Swedish mill in 1885. When initially paper was manufactured through the kraft process, the paper obtained was much stronger than any paper previously manufactured [10, 11]. A dark brown pulp is obtained through this process. After that through the bleaching process, a white pulp is obtained and this pulp gives a very good strength tissue paper [5, 7, 12].

Among the latest developments in paper industry for production of tissue paper, banana stem acts as a superior material and it provides easily manufacturable & good strength tissue paper [1, 13]. The different uses of banana stem consist of manufacturing grease proof paper, fiber, board, writing paper and tissue paper. As a point of economy, the banana stem raw material is cheaper than wood [14-16].

In the present scenario of the north eastern region of India, still the economic situation is not yet enhanced, therefore, on this basis, a small plant for production of

tissue paper should be stabilized which will be very useful for the society and its environment.

2. Process of making pulp and paper

Chopping of the banana stem waste, After harvesting of the fruits procured as raw material and is then that banana stem cuts into small pieces (approximately 4-5 cm) that is called chopping of the banana stem. After that small pieces of banana stem drying in the sun up to 90% drying of the banana stem (See in Fig.2). The chemical composition of a representative sample is shown in Table No. 1. Sulfide process is used for making of pulp as a feed of paper machine. This process removes the lignin and hemicelluloses after cutting of banana stem as a small pieces which digesting the banana stem chips with high pressure steam and successive use of sodium hydroxide, sodium sulphide and sodium hypochlorite. This process of chemical pulping is used to separate the lignin percentages of lignocelluloses from the cellulose and improve the brightness of the pulp. The lignin percentage in the pulp is determined with the help of kappa number. The effective viscosity, rheology and concentration of the pulp also determines with the help of rotational viscometer, Rheometer and Consistency tester. The pulp behaves like time independent non-Newtonian pseudo-plastic flow behavior. The pulp is used to prepare the several types of paper. But here we used for preparation of tissue, bloating and tracing paper. Calcium carbonate is used as a sizing material We have to observe several properties of the paper pulp and paper such as strength (tear factor, burst factor, tensile strength), °SR(freeness), smoothness, formation, brightness and air permeability of the paper.

Table No. 1 Composition of Banana Fiber

Sr. No.	Constituents	Percentage
1	Cellulose	32.5 ±0.5
2	Hemi cellulose	14.72 ± 2.15
3	Lignin	15.12 ± 0.76
4	Moisture	9.5 ± 1.5
5	Ash	8.25 ± 0.14

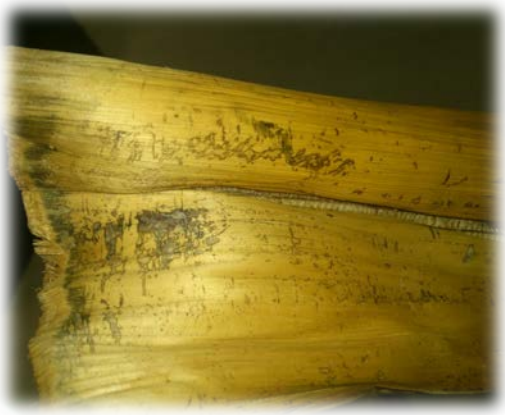
Table No. 2 Paper Properties

Properties	Tissue	Blotting	Tracing
GSM	24-30	80-100	60-70
Burst Strength (KPa)	80-100	120-150	205-265
PH	7.5	7.5	6-7
Tensile Strength (Nm)	22-60	150-180	220-440
Roughness (ml/min)	350-400	300-350	100-300
Brightness (%)	80-90	75-80	70-75

Table No. 3 Name of the equipment uses in pulp and paper testing quality

Sr. No.	Properties	Name of the equipment
1	GSM	GSM Tester
2	Tear factor	Tear Factor Tester (Presto)
3	Burst Factor	Mullen tester
4	PH	PH meter
5	Tensile Strength	Alwetron TH-1
6	Roughness	Air-leak Tester
7	Effective viscosity	Rotational viscometer
8	Pseudoplastic flow behavior	Rheometer
9	Pulp Consistency	ConsistencyPRO

(a) Banana Trees



(b) Banana Stem Fiber

Fig.1. (a) Banana Trees, (b) Banana Stem Fiber

(a) Unbleached Tissue Paper

(b) Bleached Tissue Paper

(c) Blotting Paper

(d) Tracing Paper

Fig.2. (a) Unbleached Tissue Paper, (b) Bleached Tissue Paper, (c) Blotting Paper and (d) Tracing Paper.

3. Pulping Process

3.1. Pulping by kraft process

Generally chemical pulping is done by cooking the Banana Stem in a digester (like 5 liters pressure cooker) at high temperature and pressure which dissolve the lignin and leave behind the cellulose. Each pulping trial was carried out on 50 gram of banana stem. In a conventional kraft cook, an aqueous solution of sodium hydroxide/sodium sulfide/water, also known as white liquor, is reacted with the raw materials in a pressure vessel called a digester. The white liquor and the banana stem chips are heated to a cooking at approximately 105°C, this cooking temperature and time are usually for softwood fibers. During this treatment, the hydroxide and hydrosulfide anions react with the lignin, causing the polymer to portion into smaller water/alkali-soluble fragments. There are several variations in cooking process both for the batch and continuous digester. Under high temperature and pressure lignin and Cellulose degrade to give fragments that are soluble in the strongly basic liquid.

Reactions of sulfide process in the digester

$$NaOH + Na_2S + \text{Banana stem} \rightarrow Na - \text{organic} + S - \text{organic} + NaHS$$

$$NaOH \rightarrow Na^+ + OH^-$$

$$Na_2S \rightarrow 2Na^+ + S^{2-}$$

$$S^{2-} + H_2O \rightarrow SH^- + OH^-$$

$$NaOH + Na_2S + H_2O \rightarrow 3Na^+ + 2OH^- + SH^-$$

The resulting pulp was washed through the hot water and grind through the grinder mixer. Finally made the slurry type of thick paste and once again washed with hot water. The pulp was processed in a defibrator to separate the fiber, the screened on 70 and 95 mesh sieves (see in fig.2). The rejects were retained on 70 mesh sieves. After screened of the pulp again boil with water if once boiling is start then added up to 50 to 60% of the sodium hypochlorite and heated up to 45 minutes and again washed through the hot water and this process repeat two three times because the thick paste initially in the black color after boiling the

sodium hypochlorite and repeated this process two three time and get colorless solution (through this process remove the black color of the pulp) and this process is also known as bleaching process. After the bleaching process in the pulp or colorless solution again boiled with water and added the calcium carbonates (up to 5-6%) because calcium carbonate gives the soft and white tissue paper.

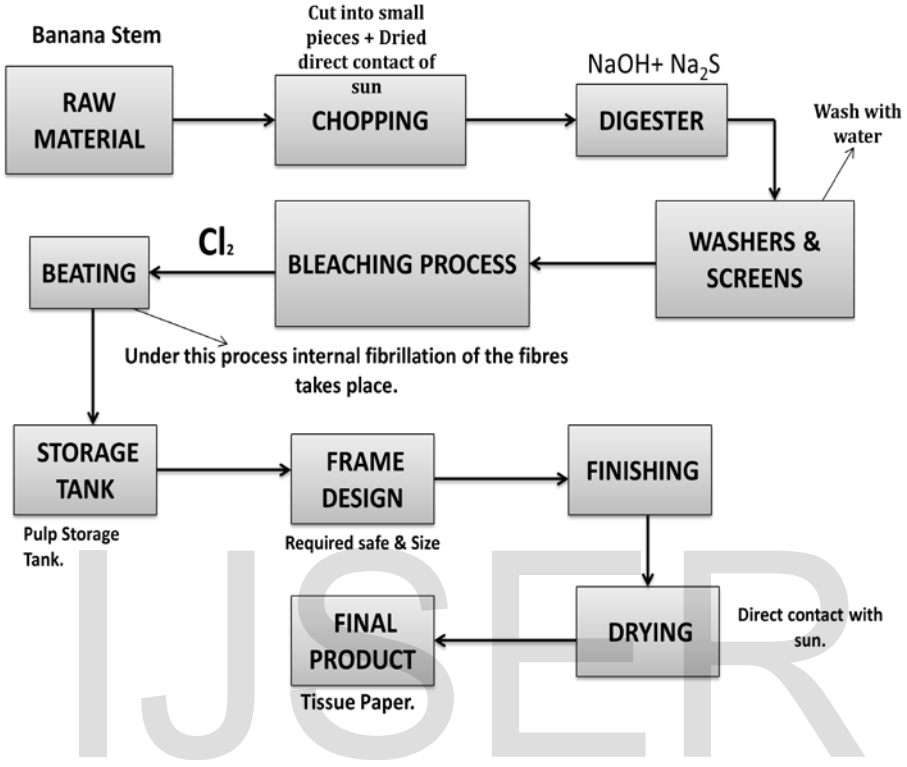


Fig. 3. Flow sheet diagrams.

4. Result and discussions

4.1 Effect of Grinding degree or ^{o}SR with tensile strength

Figure 4 shows that plot of tensile strength vs. grinding degree, ^{0}SR. From this plot we observed that tensile strength increases with increasing grinding degree, ^{0}SR up to degree of grinding 55 ^{o}SR and after that tensile strength of the pulp gradually diminishing. This is due to decreasing of fiber size with increasing grinding degree, ^{0}SR. The reason of increasing strength the rearrangement of fiber (formation) with decreasing the fiber size and making the strong fiber to fiber bond. But strength of fiber decreases after crossing the optimum limit of 55 ^{o}SR. This is due to increasing of freeness causing lowering of strength.

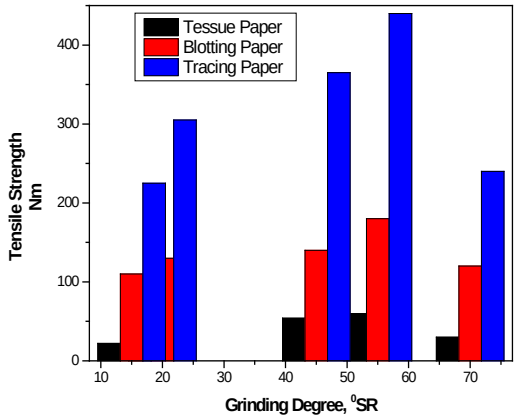
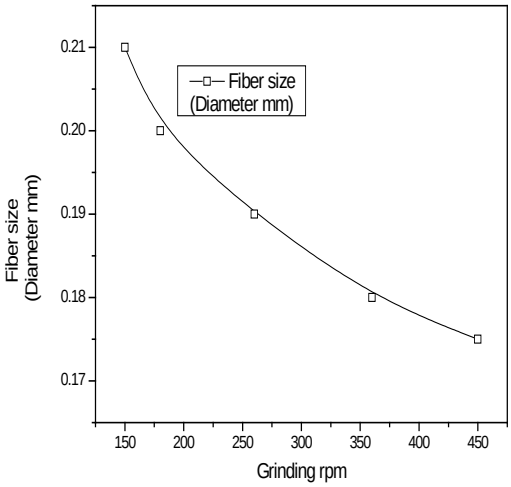


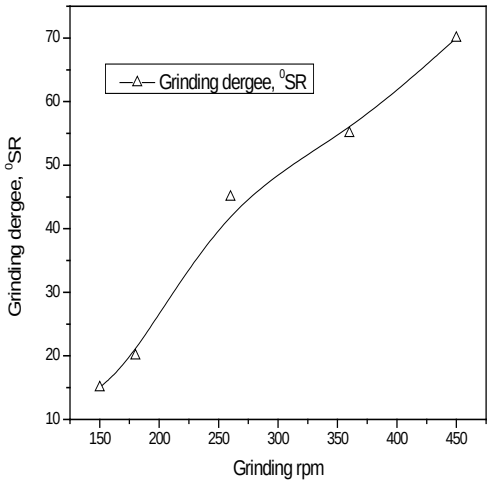
Fig. 4. Effect of grinding degree or ^{o}SR vs tensile strength

4.2 Effect of Grinding rate (rpm) with fiber size and °SR (freeness)

Figure 5 shows that plot of fiber size °SR (freeness) with rate of grinding. This plot indicates that °SR (freeness) increases and fiber size decreases with grinding rate.



(a) Effect of Grinding rate (rpm) vs fiber size



(b) Effect of Grinding rate (rpm) vs °SR (freeness)

Fig. 5. (a) Effect of Grinding rate (rpm) vs fiber size, (b) Effect of Grinding rate (rpm) vs °SR (freeness)

4.3 Effect of bleaching with strength and brightness

Figure 6 shows that brightness of the paper increases but strength of the paper decreases due to the increasing of bleaching. This is due to increasing the bleaching reduction ability of the pulp increasing but lower down the pulp strength as the breaking of fiber-fiber bond observed with excessive bleaching of the pulp.

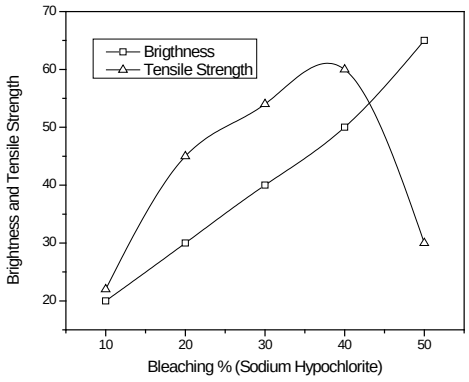


Fig. 6. Effect of bleaching with strength and brightness

4.4 Effect of calcium carbonate with softness and strength of the paper

Figure 7 shows that softness of the paper increases with increasing the calcium carbonate but strength of the paper decreases. Here calcium carbonate is used as a sizing chemical which can decrease the bond strength of the fiber but increase the softness.

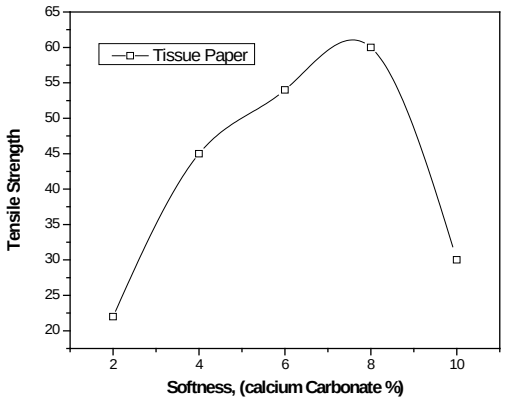


Fig.7. Effect of calcium carbonate vs softness and strength of the paper

4.5 Effect of grinding rate with burst factor, °SR (freeness), roughness

Figure 8 illustrates that the plot of strength (burst factor), °SR (freeness), roughness, of the paper with the grinding rate. This plot indicates that strength of the paper increases with rate of grinding up to (rpm) and after that strength is diminishing. But °SR (freeness) increases and roughness decreases. This is due to improve of paper formation and decrease of air permeability. The strength is increasing with grinding rate for increasing the entanglement of the fiber but again decreasing due to increasing the water holding capacity i.e. freeness causing the lowering of the strength of the paper. Smoothness and formation of the paper increases with increasing the grinding rate but air permeability decreases. This is due to the rearrangement of the fiber lower down the porosity causing lowering air permeability.

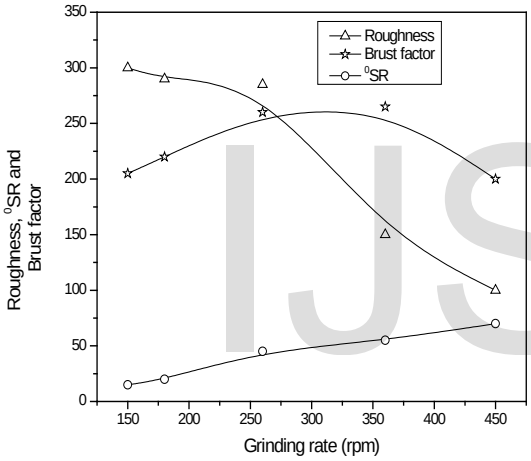


Fig. 8. Effect of grinding rate vs burst factor, °SR (freeness) and Roughness

5. Conclusions

(a) Banana stem is a cheapest and easily available raw material as a source of making paper pulp for the production of various types of paper. The process of making pulp is economically violable. The lignin separated from cellulose with the help of chemical treatment.

(b) The making of paper is handmade. Sun ray is used for drying operation of paper mat. So energy is consumed from nature and according to economic standpoint it is profitable.

(c) Strength and quality (brightness, formation, softness, smoothness) of the Paper produced in this process is marketable. Process cost is very low**.**

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