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Title: Fabrication of craft paper from Banana (*Musa acuminate*) pseudo stem

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Programme: Bachelor of Science in Forestry

Fabrication of Craft Paper from Banana (*Musa acuminate*) Pseudo Stem

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Course Title: Project thesis

Course No: 4114

This project thesis has been prepared and submitted for the partial fulfilment of the requirement for the Degree of Bachelor of Science (Hon's) in forestry from forestry and wood technology discipline, Khulna University, Khulna

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DECLARATION

I. Amena khatun, hereby, declare that this thesis paper is the result of my own effort and extensive work and this work has not previously accepted in substance for any degree and it must not be approached to any other university or institution to achieve any other degree whether it is accepted of the examiner or not.

I, hereby, give consent for my thesis, if accepted, to be available for photocopying and for enter library loans

Signature

Amena Khatun

Dedicated

To

My beloved parents.

ACKNOWLEDGEMENT

At the very outset, I would like to coherent my gratitude Allah for his benevolent glance upon me for the successful completion of this thesis paper.

I would like to disclose my earnest gratitude and intense appreciation to my supervisor Dr. Md. Nazrul Islam, Professor, Forestry and wood technology discipline, Khulna University, Khulna, for his constant supervision, guidance, thoughtful suggestion, constructive criticism and inspiration and providing useful books and papers in preparing this study. It was a great privilege for me to work under him whose keen interest made it possible to accomplish the work.

I would like to divulge my heartfelt thankfulness to Md. Nasim Rana, Ph.D. Student, Forestry and wood technology discipline, Khulna University, Khulna for his cordial support and help me to arrange the thesis paper and constructive advice to make paper.

My deepest appreciation to my classmate Mamum Molla, Omor Faruk, Rifah Tasnia for their assistance during my laboratory experiments and other stages of this long work without whom this work would not have been possible.

Finally I would like to divulge my gratefulness to my family members who always inspired me and sacrificed their happiness for my education at Khulna University

ABSTRACT

Banana (Musa acuminate) pseudo stem contains about 90% moisture. By removing this moisture, it can be used as alternative source of raw material for craft paper making. After removal of moisture, raw materials were cooked by soda process having different concentrations (10, 12, 14, 16%) at 130°C. The solid to liquor ratio was 1:9. Highest yield (56%) and viscosity (790ml/g) was found at 12% alkali charge. The best pulp was then bleached by hydrogen peroxide in same condition (temperature was130C and time 2h). After analyzing the result, it was found that after bleaching hand sheet strength properties increased. Research result is that yield, tensile index, viscosity tear index, and brightness of banana pseudo stem are 46%, 16.64 Nm/g, 1.83 mN.m2/g,7590ml/g and 8.65% respectively. After bleaching, hand sheet strength properties of banana pseudo stem increased and yield, tensile index, tear index, viscosity and brightness of banana pseudo stem are 41%,24.32Nm/g, 6.73 mN.m2/g, 5790ml/g and 20.55 respectively. The produced pulp can be used in craft paper manufacturing.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Back ground of the study

Paper is a network of plant fibers laid down as a thin sheet which are normally produced by separating wood cells using mechanical or chemical processes (Sridach, 2010). Paper the name comes from papyrus, used in ancient Egypt as writing materials (Aithal, 2016). Paper was invented by Chinese (Bloom, 2017). Paper manufacturing brings the revolution of knowledge (Marella et. al., 2014).As paper is the major source of communication, storage and dissemination of information in various forms like newspaper, letter writing, book binding, decorating, painting, wrapping (Marella et. al., 2014; Quader, 2011). Paper is used as learning tool. Various types of paper are used to fulfil our need like newsprint, white print, and ledger paper, cover paper, craft paper (Holik,2006). Among these types of paper craft paper is mostly used in arts and crafts.

Paper is made from suspension of fiber known as pulp. Pulp is obtained in different pulping methods. Fiber morphology differs because of the various pulping methods. There is a strong relationship between fiber morphology and paper strength (Gurnagul et al., 1990; Seth and Page, 1988; Ververis et al., 2004).

There are two types of pulping method, chemical and mechanical method (Wayman, 1973). Both the chemical and mechanical pulping process has its advantages and disadvantages (Smook, 1992; Biermann, 1996). Mechanical pulping yields high up to 90 %, Chemical pulping yields approximately 50 % but offers higher strength properties (Bajpai, 2004).Soda pulping is a chemical pulping process that is environmental friendly and makes strengthened fibers for papermaking. Soda pulping permits the production of many different types and qualities of pulps for a broad range of applications. Only sodium hydroxide is used in soda pulping. Sodium hydroxide, a widely-available and inexpensive source of alkali, used to produce high pulp brightness and quality (Hurter and Byrd, 2001). The most common pulping process for non - wood fibers is the soda process (Sridach, 2010).

The main source raw material for the pulp and paper industry is wood and it is up to 90% (Holik, 2006). So, the paper industry is mainly depending upon forest resources as a result deforestation take place (Hussain and Tarar, 2014). An insufficient of wood supply for growing demand has forced to search for alternative fiber sources, such as non-wood fiber plants (Sridach, 2010). As lingo-cellulosic materials are environmentally friendly (kumer et al., 2013). It is the time to place a high emphasis on forest preservation and rational use of forestry and agricultural residues (Li et al., 2010). Many non-wood fibers, such as bamboo, jute, straw, rice, abaca, and bagasse, are currently used in pulping operations as an alternative to wood for paper making (Darkwa, 1988). Annual plants could also be a new source of lingo-cellulosic materials. (Hornsby et al., 1997; Cordeiro et al., 2004; Karolia and Malha, 2005).Studies have shown that the production process of paper from non-wood fiber is significantly less expensive than from wood fiber (Weston, 1996). Agricultural residue such as banana pseudo stem has the potentiality of paper making (Poonam and Gupta, 1991). Banana fiber can be an alternative raw material of paper industries like writing paper, anti-grease paper, cheque paper as well as hard board industries (Muraleedharan and Perumal, 2010; Mohapatra et al., 2010 and Cordeiro et al., 2004). These non -wood lingo-cellulosic materials can be used to meet the scarcity of raw materials. As banana fiber is a natural fiber with high mechanical properties.

Banana pseudo stem can be a good raw material for the production of craft paper. Banana is one of the most important fruit crops grown everywhere in Bangladesh (Mohiuddin et al., 2013). Banana pseudo-stem has been known as a potential cellulose source.It has low lignin content. Banana is the most widely grown tropical fruits, cultivated over 130 countries (Mohapatra et al., 2010). It produces only one bunch of banana in each year, after harvesting banana the bare stem are cut and left in the soil (Hussain and Tarer, 2014). So, a large amount of organic waste is produced that causes emission of CO2 gas rising pollution. This cellulosic fiber can use in paper production. As banana pseudo stem is available and relatively cheaper. The banana fiber have important advantages such as low density high disposability and renewability. Banana pseudo-stem shows satisfactory physical properties, such as relatively high tensile strength and stiffness (Li et al, 2010). Moreover, they are recyclable and biodegradable (Kumer et al., 2013). However, there are only few studies related to the production of craft paper from this important and huge amount of neglected raw material Thus, this study was carried out to produce pulp from banana pseudo stem by the soda pulping process. The produced pulp was bleached by peroxide bleaching process which were then used to produce the craft paper.

1.2 Objectives of the study

Wood is the main raw material for paper making industry. Dependency on forest is increased that leads to over extraction resulting in deforestation. Deforestation causes global warming and environmental pollution. If it is possible to find out other alternatives of wood containing cellulosic materials like agricultural residue would minimize the dependency on forest as well as would be eco-friendly. The study was carried out to find out alternative lingo-cellulosic raw materials for the production of pulp from it. Banana pseudo stem might be an alternative lingo-cellulosic material which can be used to produce pulp. The produce pulp can be used to make paper/craft paper. Thus, the specific study of the objectives are

A. To assess the potentiality of banana pseudo stem for pulping by soda process.

B. To use the produce pulp for the production of craft paper.

CHAPTER TWO: LITERATURE REVIEW

2.1 General description of banana plant

Banana is the most important and oldest food crops in humankind with evidence of cultivation dating to 4000 BCE in New Guinea (Denham et al. 2003, 2004).Banana (Musa sp.), is a member of the family Musaceae. It is a large perennial herb with leaf sheaths that form trunk-like pseudo stems (FAO). The leaves roll slightly and overlap each other, forming 'trunks.' These leaves are very large and slightly waxy (Smith, 2015). It has about 8-12 Waxy leaves. The plant can spread via rhizomes, which is important in the propagation of these plants, to make a new banana plant a piece of the rhizome is broken off and replanted (Vezina, 2015).Root development is so prolonged in loosen soil up to 30 ft. laterally. Flower development initiated after planting of its 9 to 12 month. Flowers develop in clusters and spiral around the main axis (Smith, 2015). Fruits mature in about 60 - 90 days after flowers first appear. The fruit quality is determined by size. The ripe Bananas grow well over a wide range of Hawaiian soil. The ideal soil should be well drained but have good water retention capacity. Soil pH should be between 5.5 and 6.5.The pseudo stem should be cut back after the bunch is removed. Banana is grown all the year round. The pseudo-stem of banana tree, currently considered an agricultural waste (Chavez, 2011).

Figure 1. Young banana plantation showing pseudo stem and leaves(Anon,2010).

2.1.1 Banana pseudo stem

Banana pseudo stem is the stem of banana plant. The pseudo-stem is the part of the banana tree that rises from the ground to the fruit, and after the crop is harvested, the pseudo-stem becomes an agricultural by-product(Becker et al, 2013).The pseudo-stem is a clustered, cylindrical aggregation of leaf stalk bases (Kumer et al., 2013).Pseudo stem is formed from tightly rolled spiral leaf bases. The pseudo stem is the main part of the banana plant tree which serves some physiological functions such as to hold the glass, transport water and minerals, and store food reserves (Chavez, 2011.a).Fresh banana stem weight around 25 Kg with a moisture content of around 95% (kumer et al.,2013).The yield of fiber is around 2.5-3.0% of the dried weight of the pseudo stem of banana. Before dying it produces a single bunch of banana and new pseudo stem appeared. The banana plant produces one bunch of banana each year and generates huge amount of agricultural waste. Banana is the second largest fruit production in terms of quantity that is about 16% of production of fruit. A large amount of banana pseudo stem is cut and left on the ground as unused and it causes contamination of water source, emission of carbon dioxide that leads to environmental pollution and life of living beings (Aziz et al., 2011, Hossain et al., 2011).

FIG: Banana pseudo stem.

2.1.2 Structure of banana pseudo stem

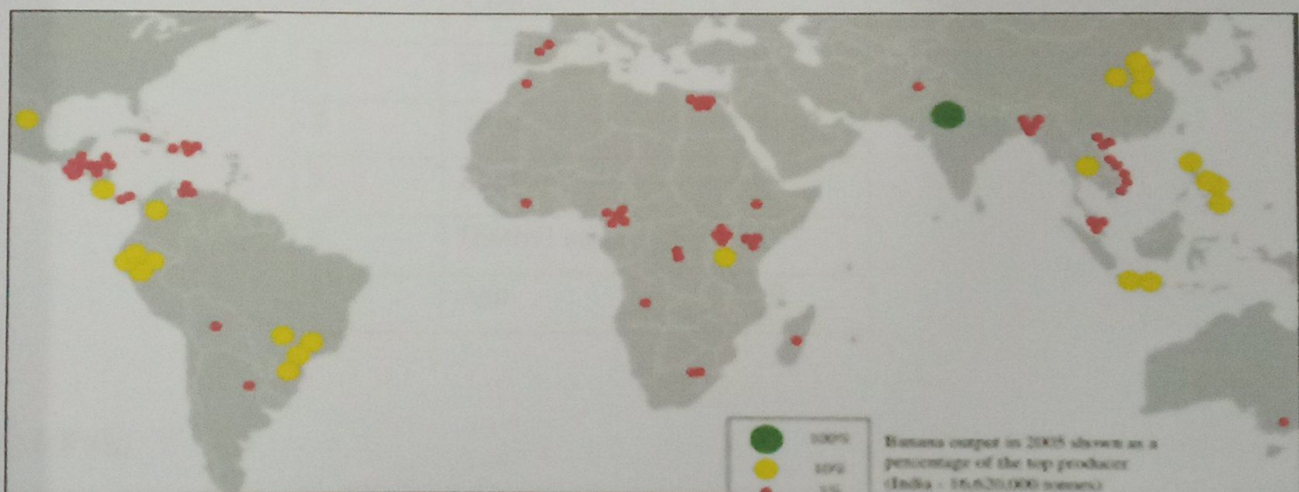
The plant is normally tall and fairly sturdy. The trunk of the banana plant is actually a false stem or pseudo stem (Stover and Simmond, 1972).Even though the pseudo stem is very fleshy and consists mostly of water .The pseudo stem is normally 5 to 7.6 meters tall. Pseudo stem consists of a tender core and several outer sheaths. Normally there are 25 sheaths in one stem the outer 4-5 sheaths give coarse fibers and inner - most 5 sheaths give soft fibers.Exterior11 leaf sheaths in the pseudo stem can be used for extracting fibers and the sheaths in the interior fibers have poor strength (Manilala and Sony, 2011).The inner part of the banana sheath is non-fibrous and consist of large air canals separated by narrow parenchyma, and is thus easily detached from the outer fibrous region(Githinji et al., 2015).The pseudo stem continues to grow in height as the leaves emerge one after the other and reaches its maximum height when the inflorescence emerges at the top of the plant.

2.2 Utilization of banana pseudo stem

Being a rich source of natural fibers, the pseudo stem can be profitably utilized for numerous applications and preparation of various products (Bhowmik,et al., 2012). Banana fiber is environmentally friendly and biodegradable. Nowadays, banana pseudo stems are widely used in animal feeding, clothing and paper industry. It also used as glue. In some countries banana pseudo stem is eaten as vegetable. It is used for making apparels, garments and home furnishing. The pseudo-stem of banana trees is most often utilized in the building industry (Becker et al., 2013). It is extensively used in the manufacture of certain papers, particularly where high strength is required and also for decorative design items for the interiors of buildings (kumer et al., 2013). Most of the banana fiber produced today is used for making ropes and cordage (Vingneswerna, 2015). Banana fiber is resistance to sea water and its natural buoyancy has created a ready market for it to manufacture of marine cable. Banana pseudo stem is also used in making composite materials. Banana fiber is used to make fine cushion covers, Neckties, bags, table cloths, curtains (Vingneswerna, 2015).The fiber extracted by manual process is of superior quality and extensively used for making high quality special pare and decorative papers. Banana fiber is also used in making socks in European countries and it is used in Japan to making traditional dresses. The banana foliage and pseudo stems are used as cattle feed during dry periods in some banana producing areas. Various handicraft items are prepared using banana fiber (Mohapatra et al., 2010 and Manandhar, 2010). It includes various types of decorative wall hangings, bags, coaster, table mat, pillow, jajim, tosok, sofa sets, dolls, key chains, etc. (Mohiuddin et al., 2014).

2.3 Origin and distribution

The banana is a tropical herbaceous plant (Ho et al., 2012). Banana is possibly the world's oldest cultivated crop (Bhowmik et al., 2012). Banana pseudo stem (Musa sp.) is widely distributed geographically in the tropics. In general, banana pseudo-stem is an abundant natural resource in subtropical and tropical regions and has potential for providing profitable products such as manure (Ultra et al., 2005). The distribution is disjunct though contiguous, in that the species occur in the hundreds of islands of south and southeast Asia and west tropical Pacific Ocean, Sri Lanka, through India, Bangladesh, south and southeast China, Myanmar, Laos, Vietnam, Cambodia, Thailand, Malaysia, Indonesia, Philippines (Nayar, 2010). All the wild bananas are warm-region plants.



Fig; Geographical distribution of banana pseudo stem.

2.4 Description of banana fiber

The fiber of banana have complex in structure. They are generally lignocellulosic, consisting of helically wound cellulose micro fibrils in amorphous matrix of lignin and hemicellulose (Kumer et al., 2013). A high cellulose content and low micro fibril angle impart desirable mechanical properties for fiber. Fiber length of banana fiber is 1.33mm (Sridach, 2010). The banana fiber have important advantages such as low density, appropriate stiffness and mechanical properties and high disposability and renewability. Moreover, they are recyclable and biodegradable.

2.5 Chemical composition of banana stem

The moisture content of the fresh banana pseudo-stem was about 96% (Li et al., 2010). It was found that the content of holocellulose in banana pseudo-stem was much lower than wood fibers (Gong, 2007; Cai and Tao, 2007). But still higher than straw, which is a typical kind of non - wood fiber (Liu et al., 2003). The major constituents of banana plant fibers are lignin, cellulose, hemicellulose, and extractives. Each of these components contributes to fiber properties, which ultimately impact product properties.

Table no1: Chemical composition of banana pseudo stem (Cordeiro et al., 2011).

Serial no	composition	%
1	Cellulose	34.5
2	Lignin	12
3	Holocellulose	60.1
4	water	8.9
5	Ethanol	4.6
6	Diethyl ether	0.6
7	Ash	13.9

2.6 Pulp

Pulp consists of wood or other lignocellulosic materials that have been broken down physically or mechanically that discrete fibers are liberated or can be dispersed in water and reformed into web. Pulp is a fibrous material which is the suspension of fiber. Pulp is one of the most abundant raw materials worldwide which is used predominantly as a major component in the manufacture of paper and paperboard.

2.6.1 Methods of pulping

Pulping is the process of separation individual from each other mechanically or chemically with a minimum mechanical damage and purifies the fiber chemically. Pulping is the process of isolation of cellulosic fibers from raw materials. There are 4 broad categories of pulping process used to separate the wood fibers. They are

1. Mechanical pulping.
2. Chemical pulping.
3. Semi-chemical pulping.
4. Chemi –mechanical.

2.6.2 Mechanical pulping

Mechanical pulping separates fibers from each other by mechanical energy applied to the wood matrix causing the bonds between the fibers to break gradually and fiber bundles, single fibers, and fiber fragments to be released. Mechanical pulp is favorable for printing properties (Bajpai, 2004). In the mechanical pulping, the objective is to maintain the main part of the lignin in order to achieve high yield with acceptable strength properties and brightness.

There are different types of mechanical pulping. Those are:

Stoneground wood pulp (SWP).

The ground wood pulping process grinds wood into pulp. Usually this involves taking a log and pressing it against a rotating surface to grind off small pieces. The ground wood pulp is then often cooked to soften it. This pulp is used in newsprint and other low cost book grades where it contributes bulk, opacity, and compressibility (Bajpai, 2005). Ground wood pulp is economical since all the wood is used.

Pressure ground wood (PGW).

By pressurizing the grinder with steam at temperature1050-1250C. The wood is heated and softened prior to the grinding. It gives better separation of fiber with less cutting action and fine generation. Pressure ground wood produces stronger pulp with high freeness and tear strength and is brighter than stone ground wood (Biermann, 1996).

Refiner mechanical pulp (RMP).

Refiner mechanical pulp is produced disintegrating chips between revolving metal discs or plates with raised bar at atmospheric pressure (Biermann, 1996). Some of the generated in the process softens the incoming chips that maintain more of their original integrity compared to stone ground wood.

Thermo-mechanical pulping

Thermo-mechanical pulping is very similar to refiner mechanical pulp except that pulp is made in special refiners that are pressurized with steam in first stage. Thermo- mechanical Pulping is carried out in two refiners. First refiner - pressurized with steam .Second refiner is atmospheric. It produces longer fiber and fewer shrives.

Chemi- mechanical pulp

At first, a mild chemical treatment is given to the pulp then mechanical pulping is done. A vacuum is first applied to remove much of the air from logs that allow better penetration of chemicals. Yields of Chemi- mechanical pulp is about 89-95%.

2.6.3 Chemical process

Chemical pulping is used on most papers produced commercially in the world today (Smook, 1992b; Biermann, 1996b). Traditionally, this has involved a full chemical treatment in which the objective is to remove non cellulose wood components leaving intact the cellulose fibers (Bajpai, 2004). Chemical pulping is the process in which lignin the binding material is removed by digesting the raw materials, cut to suitable size in presence of chemicals. This is achieved by putting wood chips into a digester where it is mixed and cooked with chemicals and water under high pressure. Because of their method of separation the fibers retain most of their intrinsic strength characteristics (waymen, 1973). It requires a good chemical recovery. Yield of pulp from chemical pulp is lower than mechanical pulp usually between 40-45% of original substance. There are two principle chemical method1. Sulphate or Kraft pulping.

2. Sulphite pulping

Sulphate process or soda pulping

In soda process only sodium hydroxide is used. The sulfite process produces wood pulp which is almost pure cellulose fibers by using various salts of sulfurous to extract the lignin from wood chips in large pressure vessels called digesters. The salts used in the pulping process are either sulfites (SO_3^{2-}), or bisulfites (HSO_3^{-}), depending on the ph. The counter ion can be Sodium, Calcium, Magnesium or Ammonium.

Sulphite or Kraft process.

The Kraft (sulfate) process is the most dominating chemical pulping process worldwide. The term "sulfate" is derived from the makeup chemical sodium sulfate, which is added in the recovery cycle to compensate for chemical losses. In the Kraft pulp process the active cooking chemicals (white liquor) are sodium hydroxide and sodium sulfide. Kraft process is applicable to all. Sulphite pulp enough white to be used in newspaper and other printing papers without bleaching (Waymen, 1973). Kraft pulp possesses superior pulp strength properties in comparison to sulfite pulping for packaging and high-strength papers and board.

2.6.4 Semi-chemical process

Semi chemical pulping is a process for obtaining high yields of pulps with characteristics suitable for certain end uses. Semi chemical pulping can achieve from 60% to 80% yields. Semi chemical is the process where pulp is done with light chemical treatment followed by a mechanical process. Here chemical treatment make the pulp soft and some portion of lignin is also removed. Various types of semi chemical pulps are produced by the acid sulfite, neutral sulfite, Kraft, soda, and cold soda pulping processes (Someshwar, 1992).

2.7 Paper

Paper has traditionally been defined as a sheet formed on a fire screen from a water suspension of fiber. Paper is made by spreading a layer of pulp fibers in suspension on the surface of a moving wire screen so as to form a wet paper web which after pressing to remove water and consolidation the fiber mate is dried to form paper.

2.7.1 Raw material for paper making

Pulp and paper are manufactured from raw materials containing cellulose fibers, generally wood, recycled paper, and agricultural residues (Bajpai, 2012). In developing countries, about 60% of cellulose fibers originate from non -wood raw materials such as bagasse, cereal straw, bamboo, reeds, esparto grass, jute, flax, and sisal (Gullichsen, 2000; Marques et al.,2010).

Some Non wood fibers are given below,

1. Agricultural Residues such as wheat straw, rice straw, barley straw, bagasse etc.

2. Agricultural crops such as Cotton, Hemp, Kenaf, Jute, Sarkanda etc.

3. Grasses such as Bamboo, Esparto, and Elephant Grass etc.

2.7.2 Classification of paper

Paper is classified into two broad categories. Paper and paper board on the basis of weight per unit area of the sheet. The dividing line is usually 250 grams per square meter. Categories of paper is given below.

1. Coated papers
2. Newsprint paper
4. Airmail paper
5. Art paper.
6.Bible paper
7.book paper.
8.bond paper
9. Ledger cover
10.Blotting paper
11. Cigarette paper.
12.Grass-proof paper
13.Imitation art paper

2.7.3 Process of paper making

1. Pulping

Pulping is the process of making pulp. Pulp is a crude fiber materials produced mechanically or chemically from fibrous cellulosic raw materials. After suitable treatment of pulp paper, paper board is produced.

2. Pulp cleaning

After pulp production, pulp processing removes impurities, such as uncooked chips, and recycles any residual cooking liquor via the pulp washing process (Smook, 1992). The digested pulp contain a huge amount of waste materials like knots, sieves, dirt that creates problem in further processing of pulp. So to remove this pulp must wash. Washing of pulp is carried out mostly mechanically. Some pulp processing steps that remove pulp impurities are screening, defibering, and deknotting. First step of pulp cleaning is screening.in the actual screening operation pulp of low consistency flows over a perforated metal plate which allows the accepted to pass and retains reject. Screening is done in two or three stages.

Pulp screening

Screening of the pulp is done to remove oversized and unwanted particles from good papermaking fibers so that the screened pulp is more suitable for the paper or board product in which it will be used (Biermann, 1996b; Ljokkoi, 2000). The main purpose of fine screening is to remove shives.

3. Pulp bleaching

Pulp bleaching is a process by which remaining impurities are removed systematically step by step to a desirable stable brightness. Bleaching by removing the lignin gives higher brightness to the paper than is possible by leaving the lignin in the pulp and brightening by decolonization, and also leads to a more durable and stable paper. The purpose of bleaching is to dissolve and remove the lignin from wood to bring the pulp to a desired brightness level (Farr et al., 1992; Fredette, 1996; McDonough, 1992; Reeve, 1989).Bleaching is usually performed in several stages, using different chemicals in each stage (Brannvall, 2009). Bleaching is accomplished by oxidizing or reducing agent. Oxidation by chlorine dioxide, hypochlorite, or peroxide is essential to remove the final discoloration and obtain full high brightness (Someshwer, 1992). Nowadays pulp is bleached with hydrogen peroxide, ozone, chlorine dioxide, oxygen etc. Bleaching is a1. Pulping to remove the final discoloration and obtain full high brightness (Someshwer, 1992). Nowadays pulp is bleached with hydrogen peroxide, ozone, chlorine dioxide, oxygen etc. Bleaching is a Dyes and colors are added to manufacture colored paper. There are three types of dyes normally used acid dyes, basic dyes and direct dyes. Some of the commonly used dyes in coloring paper are insoluble pigments and water soluble dyes are used.it is normally done in beaters.

Other additives

To give special characterization in paper additives are used. These include resins to improve the wet strength of the paper, dyes and pigments to affect the color of the sheet. Fillers such as talc and clay to improve optical qualities (Bajpai, 2004). Additives, such as alum or synthetic resins, are used to increase the water repellency of the fibers (Kirwan, 2011).

2.7.4 Stock preparation

Before pulp can be made into paper, it must undergo several steps called stock preparation (Smook, 1992; Biermann, 1996). This steps that are adapted to one another as fiber disintegration, cleaning, fiber modification cation, and storage and mixing.Stock preparation is composed of following stages

1. Beating 2.sizing 3.loaing 4.colouring 5.use of other additives.

Beating

Beating is one of the most important operations when preparing papermaking fibers (Baker, 2000; Bajpai,2005; Biermann 1996; Stevens 1992). Beating is a mechanical treatment given to fibers in paper making in the form of bruising, cutting, or crushing action.it increases fiber flexibility. During beating, fibers randomly and repeatedly undergo tensile, compressive, shear and bending forces (Baker, 2000; Bajpai,2005b; Biermann,1996d; Stevens,1992).

Sizing

To make the paper less impervious to the penetration of inks some materials is added to size the paper. Rosin soap along with alum is used as sizing materials. Sizing agents to control penetration of liquids and to improve printing properties (Bajpai, 2004; Hodgson, 1997). Sizing reduces porosity and hence reduces absorption ability (Mohiuddin, 2014).

Loading

Loading means the incorporating of inorganic materials into fibrous web to improve the quality. The principal fillers used are clay, talcum powder, calcium carbonate, titanium dioxide, zinc sulphide, calcium sulphate. It is important in case of printing paper to improve the printing surface.

Colorings

Dyes and colors are added to manufacture colored paper. There are three types of dyes normally used acid dyes, basic dyes and direct dyes. Some of the commonly used dyes in coloring paper are insoluble pigments and water soluble dyes are used.it is normally done in beaters.

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2.7.5 Paper manufacturing

After stock preparation, the next step is to form the slurry into the desired type of paper at the wet end of the paper machine. To make paper then the pulp is pumped into the head box of the paper machine at this point (Smook, 1992; Biermann, 1996). The slurry consists of approximately 99.5 % water and0.5 % pulp fiber. The fibrous mixture pours onto a traveling wire mesh in the Fourdrinier process, or onto a rotating cylinder in the cylinder machine (Biermann, 1996). The Fourdrinier machine is essentially a table over which the wire moves. Greater quantities of slurry released from the head box result in thicker paper. As the wire moves along the machine path, water drains through the mesh. Fibers align in the direction of the wire travel and interlace to improve sheet formation. After the web forms on the wire, the remaining task of the paper machine is to remove additional water. Vacuum boxes located under the wire aid in this drainage

2.7.6 Pressing and drying

The next stop of paper manufacturing is pressing and drying where additional dewatering occurs (Smook, 1992; Biermann, 1996). The newly created web enters the press section and then the dryers. The moisture is reduced to less than 10%, depending on grade, by passing the sheet over steam heated cylinders. When the paper leaves the press section, the sheet usually has about 65 % moisture content. The extent of water removal from the forming and press sections depends greatly on the design of the machine and the running speed (Kirwan, 2011). The paper web continues to thread its way through the steam heated dryers loosing moisture each step of the way. At the end of the paper machine, paper continues onto a reel for winding to the desired roll diameter.

CHAPTER THREE: MATERIALS AND METHOD

3.1 Collection of raw materials

Mature banana stem was collected after harvesting of the banana from a banana plantation around the Khulna city. The collected pseudo stem was cleaned and washed properly to remove the dirt. The whole stem was collected and used as raw materials for this study. Laboratory grade NaOH and H2O2 were collected from the commercial market and were used for cooking and bleaching, respectively.

3.2 Preparation of banana pseudo stem for cooking

The stem is consists of layers were separated manually and were pressed by hand roller to remove the excess moisture. It was then chopped manually into small pieces about 3-5 cm in size. The chopped samples were then air dried for several days to become the moisture content of around 40%.These samples were used in cooking by soda process.

3.3 Cooking

The samples were cooked by soda process in digester (PL 1-2, 15L intelligent rotary digester, China) at 110° C for 3 hours. Four different NaOH concentrations (10, 12, 14 and 16%) were used for cooking where the solid to liquor ratio was 1:9 always. The rotation of the digester was 3 per minute.

3.4 Washing of cooked materials

At the end of cooking, pressure inside digester was released and black liquor was drained off. The cooked materials was washed with running water flow to remove the black liquor. Proper washing is very important as it would increase the brightness of pulp/paper. The moisture of the pulp was removed by hand pressing and then stored in refrigerator until hand sheet making.

3.5 Pulp disintegration

After washing the pulp was blended in a blender which help to disintegrate the fibers. After - blending, the pulp was screened to remove the oversized bundle of fibers or dirt. These pulp was to bleach and hand sheet making.

3.6 Assessment of pulp properties

- Yield calculation: Yield is the term indicating the amount of recovered after a certain process compared to the staring amount before the process. In pulping operation the yield is the oven dry pulp mass expressed as a percentage of the oven dry wood mass. The pulp yield was calculated using the equation 1

$$\text{Yield (\%)} = \frac{\text{dry product mass out}}{\text{dry product mass in}} \times 100 \text{.......................................Eq.1}$$

- Viscosity: The pulp viscosity was measured using viscometer. Viscosity is the measure of a substances resistance to motion under an applied force. Viscosity is typically expressed in centipoise (cP) or milipascal second (mPa s). The viscometer measures the torque required to turn an object in a fluid as a function of that fluid's viscosity. Prepared pulp of banana pseudo stem was contained in a beaker and stirred well for proper disperse before the adhesive was used for viscosity measurements

Depending on the yield and viscosity of the pulp, the best pulp was chosen for the next stage like bleaching and hand sheet making.

3.7 Bleaching of pulp

Half of the disintegrated chosen pulp was by single stage hydrogen peroxide. Pulp taken into double plastic zip lock bags in a water bath. Bleaching chemicals and water were added together into pulp and the mixture and mixed vigorously by hand. It was then put into the water bath for prescribed time. The bleaching condition was in table 2. After bleaching, the pulp was then washed with running water to remove the chemicals. These pulp was used to produce bleached hand sheet. PH of the mixture was measured. Bleaching condition for the pulp by TCF bleaching is given in table 2.

Table 2: Bleaching condition for the pulp by TCF bleaching

Temperature	time	consistency	ph
80 °C	2h	20%	10

3.8 Preparation of hand sheet

Hand sheet was made from both bleached and unbleached pulp. The expected GSM of the paper was 110. The weighted pulp was mixed with water and shacked it for 4-5 minutes. It was then put into the hand sheet maker for preparing a hand sheet having the diameter of 22cm .Water was drained off by water pump. A layer of pulp was produced and it pressed to remove water as possible.

3.9 Drying

After making the sheet, it was dried in the paper drier machine having the temperature of 900C. Flowers, leaves or other designing things were added on the paper surface before drying. After drying calendaring was done manually to smooth the surface.

3.10 Assessment the properties of hand sheet

Moisture content

Moisture content of pulp and paper was done by using oven dry method.it was calculated by using the equation 2

$$MC = \frac{Wg - Wo}{Wo} \times 100 \qquad \text{Eq.2}$$

Where, Wg = Green weight of sample.

W o = Oven dry weight of samples.

MC% = Moisture content

Brightness test

The hand sheet brightness was measured by using brightness tested machine (DRK 103A Brightness Meter, China) following by TAPPI test and T-218 standard. Brightness is the percentage of light reflected from a thick pad of papers.

Tensile strength.

Tensile strength was measured using UTM (SHIMADJU, 50 KN, Japan) machine following by TAPPI test and T-494 standard and calculated the value using the equation 3.

Tensile strength $= \frac{\text{Tensile reading} \times 20000}{3 \times \text{GSM} \times 102}$ Nm\g...Eq.3

Tear test

The tear test was measured using Elmendorf tear tester following TAPPI T-494 standard and the strength was calculated by using the equation 4

Tear strength $= \frac{\text{tear reading} \times 1600}{\text{GSM}} \times 0.0980665$...Eq.4

CHAPTER 4 RESULT AND DISCUSSION

4.1 Yield

When banana pseudo stem was pulped with different alkali charge (10, 12, 14 and 16%) a wide range of yield was found with same cooking conditions. It was found that yield decreased with the increase of chemical charge. As carbohydrate degraded and lignin removed during cooking process with higher alkali concentration, yield decreased. The highest yield (46%) was found when the alkali charges was 12%. In previous study it was found that, 2.3,23,37,34 % yield was found at5, 10, 18, 25% alkali charge (cordeiro, 2004).

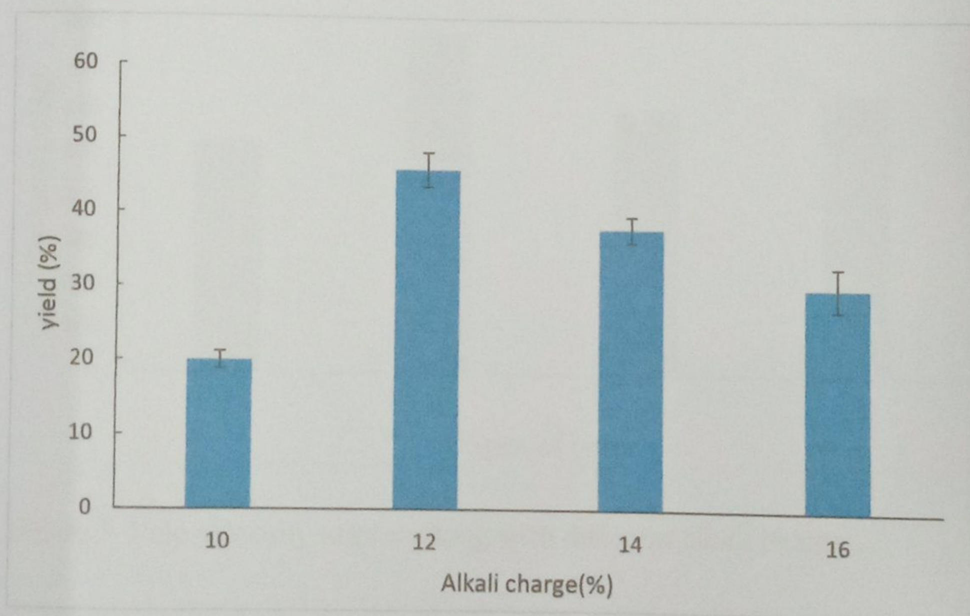

Fig. 3. Pulp yield after cooking with different alkali charges

4.2 Viscosity of unbleached pulp

Viscosity was measured of the 4 types of pulp with different alkali charge (10, 12, 14 and16%) by viscometer. Viscosity is the measure of a substances resistance to motion under an applied force. The viscosity was found 534, 790, 614 and 650ml/g for 10, 12, 14 and 16% alkali charge. So, the highest viscosity was found at 12% alkali charge. Cordiero, 2004 reported that viscosity of unbleached pulp was (451, 564, 550, 500 ml/g) at (5, 10, 18, 25%) alkali charge.

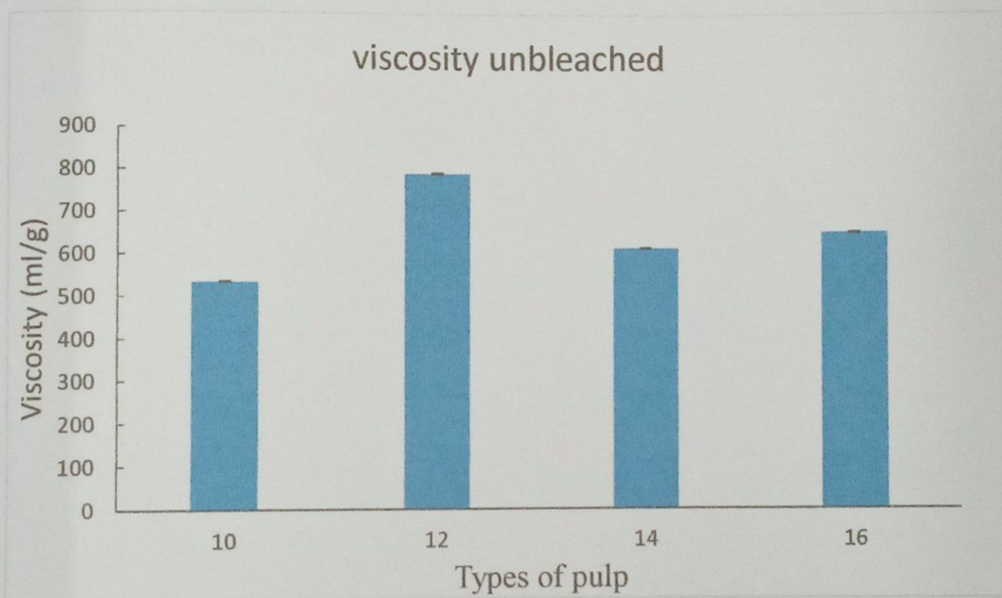

Figure 5. Pulp viscosity after cooking with different alkali charge

After analyzing the result of yield and viscosity, it is found that, highest yield and viscosity was found at 12% alkali charge than(10,14 and16%) alkali charge. So, best result was found at lower alkali charge. In next stage, the best pulp obtained from 12% alkali charge is bleached with hydrogen peroxide with the same condition and after bleaching hand sheet is also made. Then the strength of bleached and unbleached hand sheet is compared in terms of viscosity, brightness, tensile index, and tear index

4.3 Brightness test

Brightness is the percentage of light reflected from a thick pad of paper. Bleached and unbleached paper made from banana pseudo stem showed 20.55 ISO and 8.65 ISO brightness respectively. So performance of bleached paper is higher than unbleached paper. Decreasing of brightness could be due to the removal of lignin in the bleached pulp during bleaching process (Histed et al., 1996). A light absorbing substance in the pulp which is derived from the lignin of the absorbing constituents allow the paper to more reflect. These light absorbing substance are oxidized and reduced to make them soluble in aqueous solution to remove them from the lignin during bleaching process. From the previous study it was found that, after cooking, brightness was 6.56% ISO, after oxygen delignification brightness was 8.42% ISO (Khan et al., 2014).

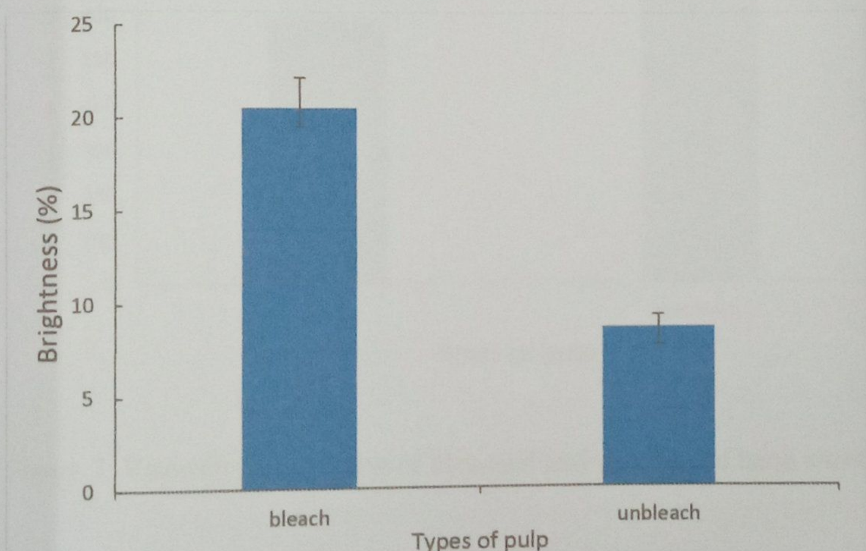

Figure 6. Brightness comparison of bleached and unbleached hand sheet

4.4 Viscosity of bleached pulp

The average of polymerization degree of pulp was measured by the viscosity and it indicated the degree of carbohydrate degradation during pulping and bleaching. After bleaching there was a significant decrease of viscosity. The viscosity of unbleached pulp was, 790ml/g and it drop to 590ml/g after bleaching. The results showed that degradation of carbohydrate during bleaching could contribute to viscosity drop in the bleached pulp solution. Previous study shown that viscosity of bleached and unbleached pulp was 614 and 534ml/g (khan et al., 2014) respectively.

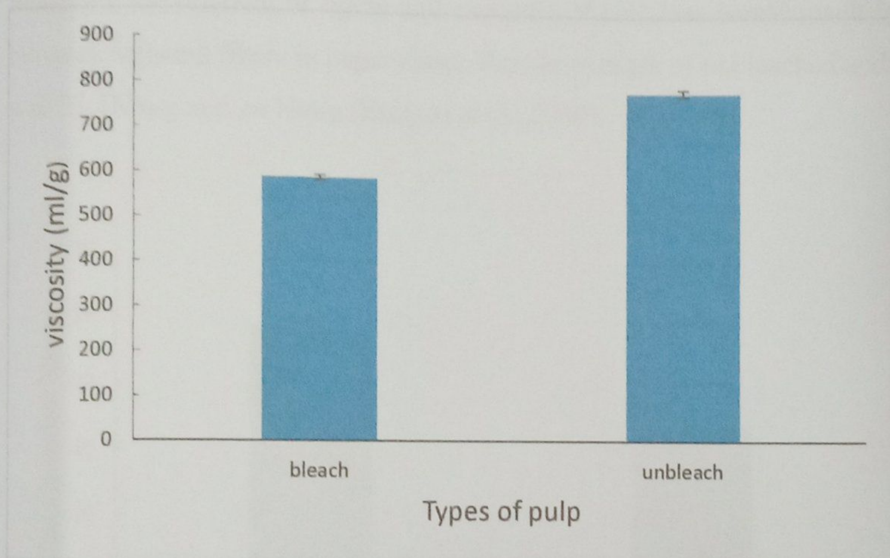

Figure 7. Viscosity comparison of bleached and unbleached hand sheet.

4.5 Tensile strength

Unbleached and bleached paper made from banana pseudo stem showed tensile strength 16.34 N/mm2 and 24.32 n/mm2 respectively. Bleached paper showed higher tensile strength than unbleached paper. As the tensile index depends on fiber strength and length characteristics and internal fiber bonding, as well. Energy or strength required to breaking bonds per unit area of paper sheet. Due to the hydrophobic nature the presence lignin in the bonded area may constitute a barrier to the formation of hydrogen bonds between the cellulose molecules. During the bleaching the removal of lignin and exposure of cellulose would result in more hydrogen bond between adjacent fibers in paper sheet. Tensile strength of unbleached and bleached canola stalks was 23.1Nm/g and 24 Nm/g (Enayati et al., 2009).

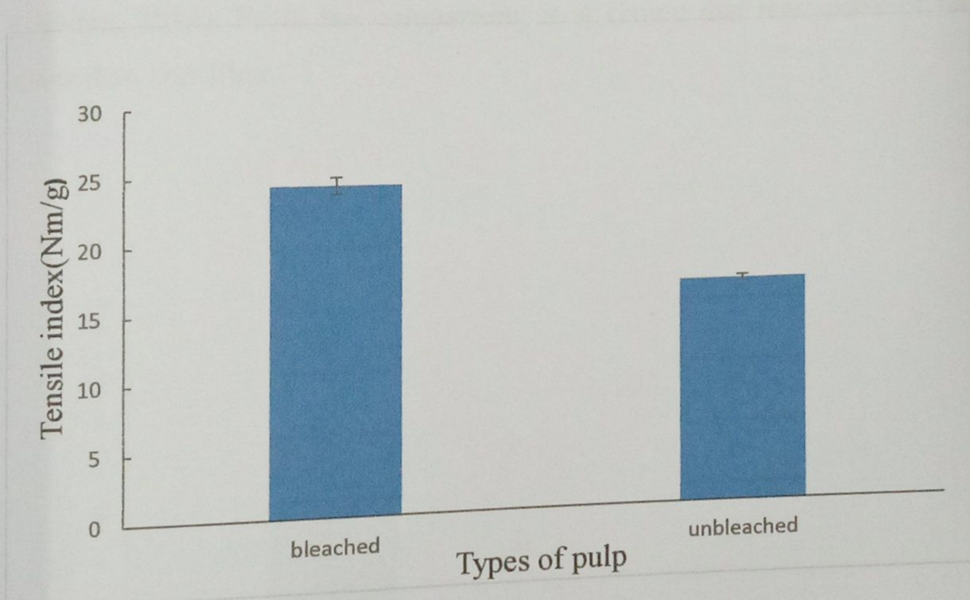

Figure 8. Tensile strength comparison of bleached and unbleached hand sheet

4.6 Tear index

Bleached and unbleached paper made from banana pseudo stem showed 6.73 mN.m2/g and 1.83 mN.m2/g Tear index. Bleached paper showed higher tear strength than unbleached paper. As the tear index depends on fiber strength and length characteristics and internal fiber bonding, as well. Fiber bonding means energy or strength required to breaking bonds per unit area of paper sheet. Due to the hydrophobic nature the presence lignin in the bonded area may constitute a barrier to the formation of hydrogen bonds between the cellulose molecules. During the bleaching the removal of lignin and exposure of cellulose would result in more hydrogen bond between adjacent fibers in paper sheet. That's why tear index increased after bleaching. Bleached and unbleached paper made from coir fiber showed 11.78 mN.m2/g and 7.05 mN.m2/g (Jani and Rushdan, 2014). From the comparison, it is shown that tear index of banana pseudo stem is lower than coir fiber.

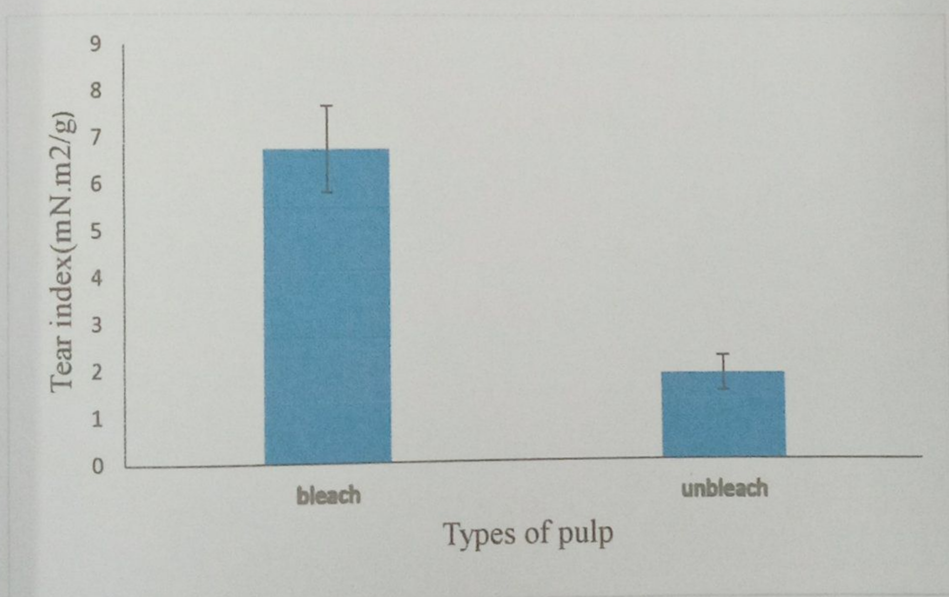

Figure 9. Tear strength comparison of bleached and unbleached hand sheet

CONCLUSION

Banana pseudo stem is a source of fiber materials. In this research an attempt was taken to understand the strength properties of paper made from banana pseudo stem. According to the findings all the strength properties of paper made by banana pseudo stem was superior to other non-wood raw materials. At present we are suffering from the scarcity of raw materials for paper manufacturing, so from the comparison with other conventional raw materials to becoming the potential source of raw materials for paper manufacturing. So further study may carried out to improve the properties of paper made by banana pseudo stem.

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Appendix

ANOVA for yield among different alkali charge.

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	742	3	247.3333333	70.66666667	0.000639021	6.591382116
Within Groups	14	4	3.5			
Total	756	7				

ANOVA for viscosity among different alkali charge

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	69085.5	3	23028.5	1212.026	2.26E-06	6.591382
Within Groups	76	4	19			
Total	69161.5	7				

t test for tear index of bleached and unbleached pulp

tear	*bleach*	*Unbleach*
Mean	6.733333	1.836667
Variance	2.640633	0.430433
Observations	3	3
Pooled Variance	1.535533	
Hypothesized Mean Difference	0	
df	4	
t Stat	4.839679	
P(T<=t) one-tail	0.004201	
t Critical one-tail	2.131847	
P(T<=t) two-tail	0.008402	
t Critical two-tail	2.776445	

t test for brightness of bleached and unbleached pulp

brightness	*19.93*	*10.43*
Mean	20.86	7.76
Variance	0.2738	0.8192
Observations	2	2
Pooled Variance	0.5465	
Hypothesized Mean Difference	0	
df	2	
t Stat	17.72051	
P(T<=t) one-tail	0.001585	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.003169	
t Critical two-tail	4.302653	

t test for tensile test of bleached and unbleached pulp

tensile	*24.41*	*16.5*
Mean	24.275	16.76
Variance	2.18405	0.2592
Observations	2	2
Pooled Variance	1.221625	
Hypothesized Mean Difference	0	
df	2	
t Stat	6.799235	
P(T<=t) one-tail	0.010477	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.020954	
t Critical two-tail	4.302653	

t test for viscosity of bleached and unbleached pulp

t-Test: Two-Sample Assuming Equal Variances			
viscosity	*593*	*792*	
Mean	589	789.5	
Variance	98	84.5	
Observations	2	2	
Pooled Variance	91.25		
	0		
df	2		
t Stat	-20.9893		
P(T<=t) one-tail	0.001131		
t Critical one-tail	2.919986		
P(T<=t) two-tail	0.002262		
t Critical two-tail	4.302653		