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Declaration

I, Mostarin Ara, declare that this thesis is the result of my own effort and extensive work and this work has not previously been accepted in substance for any degree, and that it must not be approached to any other University or Institution to achieve any other degree whether it is accepted by the Board of Examiner or not.

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Signature of supervisor

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Dedicated To

My beloved parents

Acknowledgement

All praises goes to the Allah the creator and ruler of the universe, whose mercy keeps us alive. I want to express my sincere gratitude to my beloved parents who brought me in this earth and helped me in every work of my life. Thus they enables me pursue my education in Forestry and Wood Technology Discipline and to complete my thesis work for the degree of Master of Science in Forestry.

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Abstracts

Golpata (*Nypa fruiticans*) represents a type of abundant renewable resources and its petiole is a waste material. In this study, the physical and mechanical properties of hand sheet from Golpata petiole were evaluated to determine its suitability for papermaking and the effect of mechanical treatment (blending) was investigated. Petiole of Golpata was treated with NaOH and Na_2S liquor to obtain good fibre fibrillation. After that, blending was carried out at different revolution. Hand sheets were formed at four level of revolution and then sheets were tested. The result indicated that Petiole of Golpata can be recommended as a papermaking material and at 37000 revolutions, the properties of hand sheet paper reached the optimum values. From the result, it can be concluded that the properties of hand sheet papers increased with the increase of blending revolution up to a certain limit after which the properties started to decrease due to mechanical damage

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Chapter One

Introduction

1.1 Introduction:

World paper consumption was about 300 million tons in 1996/1997 and its rising day by day (Hurter, 1998). The growth rate is 2.8% per year (Shabharwal, 1996). For the development and determination of standard of a country, the consumption of paper and paper products of its citizen is rising (McNutt, 1997). For pulp and paper industries massive areas of trees are felling which turn leads to deforestation and this also increases the cost of wood products (Atchison, 1996). This felling of trees increases the scarcity of raw material for pulp and paper but demand of paper products is increasing (Alcaide, 1991). To reduce the pressure on woody substances, during the last 25 years there has been a great increase in non-wood pulping capacities. In 1970 it was only 6.7% of the world wide pulp production and with timing it is in an upward trend (FAO, 2002). Now a day's many countries are using non wood fibre for paper making. Over the last several years, a number of plants have been tested for their papermaking qualities (Sattanayayan, 1982). A number of centers and organizations like Paper Industrial Research Institute of China (PIRIC), United Nations Industrial Development Organization (UNIDO), Central Pulp and Paper Research Institute (CPPRI) in India, and International Agro-Fiber Research center in Wisconsin Madison have been involved in this research. Bangladesh is facing an acute shortage of fibrous raw material for pulp and paper industry, on the other hand demand of paper and paper product is increasing day by day. To mitigate the balance between production and demand import of paper has increased and domestic production has decreased drastically in Bangladesh. There are available non wood fibres in Bangladesh and their potentiality is suitable for papermaking like straw, jute, dhoincha, golpata frond, bagasse, corn stalk, cotton stalks etc. Petiole of Golpata also can be a potential non woody candidate for paper making because of its chemical and other properties. There are no major uses of Golpata except fuel wood and after harvesting a considerable amount of petiole remains unused. Moreover, paper production requires quality fibre bonding which can be found by blending treatment. In this study, to increase the properties of hand sheet paper, blending was carried out at different revolutions. As petiole of Golpata becomes a papermaking material, the study will suggest a new direction in the application of petiole of Golpata.

1.2Objectives of the Study:

- ✓ To evaluate the Physical and Mechanical Properties of hand sheet paper made from the petiole of Golpata
- ✓ To evaluate the effects of blending on the physical & mechanical properties of hand sheet paper made from petiole of Golpata

Chapter Two

Literature Review

2.1 Introduction:

The family Arecaceae (Palmae) is one of the largest monocotyledonous families and it comprises over 200 genera and about 2,600 species in total (Dransfield et al., 2008). The genus *Nypa* is monotypic and *Nypa fruticans* is its only species, which is placed under its own subfamily, the Nypoideae (Dransfield et al., 2008). It is one of the most ancient angiosperms and probably the oldest species of palms (Päiväke, 1996). Fossil records of its pollen, fruit, leaf, flowering parts, leaf epidermis and root have been discovered (Dransfield et al., 2008), back to the Upper Cretaceous period, 65–70 million years ago (Gee, 2001). The generic name *Nypa* is derived from the Latin word "nipah", which is the native name used in the Moluccas and the Philippines (Duke, 2006).

Figure 2.1: General feature of Golpata

2.2 General description:

The morphology of Nypa has been described by many authors: Arnold (1952), Baja-Lapis et al. (2004), Collinson (1993), Corner (1966), Moore (1973), Päiväke (1996), Tomlinson (1986), Whitmore (1973). Baja-Lapis et al. (2004) explained the morphological traits of Nypa as follows. Nypa grows in clusters, often forming large colonies. The underground stem called rhizome lies horizontally underneath the ground and reaches to about half a meter long. At the end of the growing rhizome, a new plant rises which adds to the cluster in the colony. The leaves called fronds which alike large feather-like in appearance, sometimes reaching more than 7 meters long with the mature fronds usually leaning away from the centre of the growing plant. The leaflets progressively become shorter towards the stalk and the top of the frond. The arrangement of the flowers in the floral axis (inflorescence) has erect and stout stalk with a large orange colour sheath (called spathe), which is olive green at the top. The stalk ends with a cluster of female flowers which are enclosed by gold colours leaf-like structure which called bracts, and the sides with club-shaped unstalked spikes of male flowers. Both male and female flowers are yellow, the males in thick spikes and the females with large head. The cluster of fruits is more or less the size of a human head with about 20-30 cm in diameter which is supported by a thick stalk, dark brown colour when fresh. The individual one-seeded woody fruit breaks when ripe. The seeds which usually germinate naturally while floating on the water in the swamps establish themselves in the mud flats and along muddy banks.

2.3Distribution:

2.3.1Geographical Distribution at Present time:

Nypa is widely distributed ranges from Srilanka, the Ganges Delta, Myanmar, and to the Malay Peninsula, through Indonesia, Papua New Guinea and the Solomon Islands, and up north in the Philippines and down south in northern Queensland (Tomlinson 1986; Baja-Lapis et al. 2004; Corner 1966; Gee 2001; Päiväke 1996; Saenger et al. 1983; Whitmore 1973). According to different authors Nypa grows plenty in number in Australia (Bunt et al. 1982; Covacevich 1981), Indonesia (Johannes 1979; Samingan 1980), Papua New Guinea (Pajimans & Rollet 1977; Percival & Womersley 1975), Philippines (Agaloos & Nepomuceno 1977; Gonzales, 1979), Thailand (Aksornkoae 1976; Changprai 1984), Malaysia (Burkill 1935; Fong 1984; Whitmore 1973), India (Anonymous 1966; Thothathri 1980), Bangladesh (Khan & Karim 1982), Vietnam (Fong 1984; Moore 1973), Sri Lanka (Fong 1984; Moore 1973), Myanmar (Fong 1984; Moore 1973), Carolines (Fong 1984; Moore 1973), Ryukus (Fong 1984; Moore 1973) and Solomons (Fong 1984; Moore 1973). Nypa was introduced into West Africa in 1906 (Päiväke 1996; Saenger et al. 1983) and till then it has been well established, co-existing with native mangroves in Southeastern Nigeria (Moses 2000; Ukpong 1997).

2.3.2Geographical Distribution in Ancient Period:

Back to 74 million years ago Nypa was made its own appearance in the new world (Gee, 2001). The maximum expansion of the biogeographical distribution of nypa in earth's history corresponds with the climatic optimum of the Cenozoic period during the early Eocene era (Gee 2001). Nypa was ranged as far north as present-day southern England which was at a paleolatitude of roughly 45°N during the Eocene (Ziegler 1990) and as far south as the southernmost coastlines of what is today Tasmania(Pole & Macphhail 1996).

2.4 Uses:

Different parts of Nypa are used for different purposes which are described in short below.

Mature Leaves: From reviewed literature, it is found that mature leaves is used in many purposes such as roof thatching, wall partitioning of dwellings, umbrella, sun-hat, rain-coat, basket, mat, bags(Baja-Lapis et al. 2004; Burkill 1935; Fong 1984, 1992; Hamilton & Murphy 1988; Ilias et al. 2002; Päiväke 1996), Robillos 1978)

Young Leaves: Young leaves are used to make cigarette wrappers and also to wrap cooked rice (Baja-Lapis et al. 2004; Burkill 1935; Fong 1984, 1992; Päiväke 1996; Robinson 1911)

Main Axes: Main axes are used for fishing poles (Fong 1984, 1992).

Leaflet Midribs: Leaflet midribs are used as brooms (Fong 1992), and it can be used as rope by soaking and twisting in water (Fong 1984).

Outer layer of the leaf stalk: An outer layer of the leaf-stalk yield pulps is suitable for making good-quality boards of intermediate density (Razzaque 1969).

Young Seed: Young seeds are eatable and used as food in the form of sweetmeat and snack.

Mature Seed: Mature seeds are so hard so that they are used a material for button (Burkill 1935; Fong 1984; Päiväke 1996; Whitmore 1973).

Sap: Sap is used for producing vinegar (Baja-Lapis et al. 2004) and biofuel is produced from alcohol and used as fermented drink (Hamilton & Murphy 1988; Päiväke 1996).

2.5 Golpata in Bangladesh:

Nypa fruticans is a mangrove species locally named as *Golpata* in Bengali, popularly known as the poor man's tin-sheet, is one of the important non-timber forest products in the coastal belt of Bangladesh (Das et al. 2000). It is a stemless palm with tall erect fronds and underground rhizomatous stem (Shahidullah 2001). It possesses an extensive root system, well suited to resist swift running water (Percival & Womersley 1975). The management practice of *Nypa* in locally based on indigenous knowledge. *Golpata* is mainly used for housing, food, fuel, fence-making, medicine, cigarette wrapping, molasses, wine, fishing etc. The kernels of immature fruits are used as food. The sap is used for making molasses and alcohol. Newly developed shoots used as a vermicide. Ash from *Golpata* is used as an analgesic against tooth pain and headache. Dry leaves, petiole, stem wood, fruit residues etc. are used as fuel. In Bangladesh, the natural distribution of *Golpata* is restricted to the Sundarbans, the largest single continuous tract of mangrove forest in the world (Chaudhury & Naithani 1985, Akhtaruzzaman 2000). Shiva (1994) reported that *Golpata* has a great potential for commercial use in housing and medicine in Bangladesh. The role of *Golpata* is invaluable for both the rural and urban livelihood economies of Bangladesh. About 50,000 people living around the Sundarbans depend on *Golpata* and about 80% of houses in the area are made of *Golpata* (Faizuddin et al. 2000a).

2.6 Harvesting of Golpata:

Golpata harvesting is started from 6-7 years old. Among the plantation whose age exceeds this range, harvesting is started immediately. A slanting cut, with a 45° angle is used. Traditional process is used for harvesting. According to the farmers, if the density is high cutting is undertaken at 7 or 8 cm above the ground and in case of low density, at 5 or 6 cm. The harvesting season is generally January to February and new shoot begins to develop in March. The reason behind the harvesting season practiced is to allow access to the new leaves for the next month.

2.7 Petiole of Golpata: The slender stalk by which a leaf of Golpata is attached to the stem.

Figure 2.2: Petiole of Golpata

2.8 Uses of Petiole: Petioles are used for floats for fishnets (Frog 1984, 1992), arrows (Burkil 1935). Dried petioles are used as fuel wood (Brown 1951, Bukril 1935). So it is seen that there is no major uses of petioles.

2.9 Chemical Composition of Petiole: The cellulose content of *Nypa fruticans* petiole is 37.56% , lignin is 21.15 %, Ash is 3.01% and left is hemicellulose.

Table 2.1 Chemical Composition of Petiole of Golpata

Petiole	Chemical %
Cellulose	37.56
Hemicellulose	38.28
Lignin	21.15
Ash	3.01

(Anieken, 2012)

2.10 Why Petiole as Raw material?

Basically there are no major uses of petiole in Bangladesh and harvesting of Golpata is done in traditional way. It is harvested 6-7 cm above the ground which totally remains a waste material. For proper utilization of this wastage is one of the reasons for choosing it as raw material.

Besides this, chemical composition is more or less near about many conventional raw materials for paper manufacturing, this is another reason.

The fibre length of the petiole is1.06 mm; this is shorter than the hardwood and softwood (Grace 1993) but longer than of cotton stalks (0.6-0.8 mm), kenaf core fibre (0.6 mm) Papyrus (1.0 mm), and maize (0.75mm).

It is stated that if slenderness ratio of a fibrous material is lower than 70, it is invaluable for quality pulp and paper production (young 1981, Bektas 1999). But slenderness ratio of petiole of Golpata is 90.56 which indicate more than 70. This indicates high rate of tear resistance.
Runkel ratio is an important parameter for paper making. If rankel ratio of a material becomes less than 1 or near 1 it shows high properties of wood (Cassey 1980) whereas petiole of golpata shows 1.36.

Considering its status, chemical composition and other properties, petiole of golpata can be considered as a potential candidate for paper manufacturing.

2.11 Effects Mechanical Treatment on the properties of Paper:

Beating is the most important physical treatment carried out on pulp before paper making; it highly affects the physical properties of the prepared paper sheets. It serves the purpose of increasing the area of contact between the fibers by increasing their surface through fibrilation and by making them more flexible (Raymond, 1986). The refining process caused an increase in all handsheet property values compared to unbeaten pulp and the increase in the degree of refining caused an increase in the property values of the handsheets(Abdel, 2013). Mechanical beating process created a partial skin fibrillation, while grinding turned fiber from micro to nanoscale through nanofibrillation mechanism. The partially fibrillated and nano fibrillated fibers had significant effects on paper density, tear strength, tensile strength and water drainage time. The effect of nanofibrillation on paper properties was quantitatively higher than that of mechanical beating. Paper sheets from nanofibrillated cellulose have a higher density, higher tensile strength and lower tear strength compared to those subjected to mechanical beating. Mechanical beating and nanofibrillation were both found to be promising fibre structural modifications (Alfra, 2013). The main factors affecting the tensile index of paper are the strength of fiber combination and the average fiber length. Beating produced many tiny fibers in the pulp, which could fill in the space gaps among the long fibers, thus increasing the number of hydrogen bonds and improving fiber combination.

The tiny fibers played a bridge role in the paper and contributed to its network structure. However, when the beating degree of the pulp continued to increase, the ratio of tiny fibers and small components also increased (Gao, 2011).

From the study on Tobacco stalk it is found that with increasing the revolution of beating properties of wood like Tensile Strength, Burst and Tear index increased. This happened up to a certain limit. But when the beating degree of the pulp continued to increase, the ratio of tiny fibers and small components also increased. Average fiber length was reduced, while the tensile index of the paper decreased. Similar fact happens in case of Tear index and Burst index (Gao, 2011).

Table2.2: Physical Properties of Paper

Revolution number (rpm)	Tensile index (N.m/g)	Tear index (mn.m$_2$/g)	Burst index (kpa.m$_2$/g)
1500	28.81	.88	.92
2500	28.51	.98	1.39
3500	33.14	1.34	1.63
4500	33.03	1.25	1.45
5500	32.82	1.16	1.32
6500	30.94	1.13	1.24

(Gao, 2011)

On the study of Baggase Pulp, Wood Pulp and Rice straw Pulp, it is seen that with increasing beating, properties of paper also increases (Ibrahim, 1989).

At different revolutions, it is studied that the physical and mechanical properties of handsheets from bleached Eucalyptus pulp increases with increasing revolution.

Table2.3: Properties of Hand sheet from Eucalyptus pulp

Revolution	Tensile Index (Nm/g)	Burst Index(KPam^2/g)	Tear index(100*gf*m^2/g)
0	25.7	1.25	38.6
1000	41.3	2.65	63.9
1250	47.6	3.2	68.4
2500	64.5	4.25	65.3
3750	85.5	4.65	50.1

(Gonzalez, 2012)

Chapter Three

Materials and Methods

3.1 Materials and Pre-treatment:

Petiole of Golpata was collected from Golpata plant in green condition and was cut approximately with size 2-3cm which was done manually with Knife. The aim was to cut smaller size is to facilitate cooking treatment. As pre treatment washing was also done to remove adhere impurities with the materials. Next Moisture content was determined by oven dry method. Model No: DHG-9101, oven was used for determining moisture content. Moisture content of samples were determined by the following equation

$MC\% = (W_w - W_\circ) \times 100/W$

Where, W_w= Green Weight of samples.

$W_\circ$= Oven dry weight of samples.

MC%= Moisture content.

3.2 Kraft Pulping:

Sodium Sulphide and Caustic Soda was used as chemicals for kraft pulping. Mini digester of Pulp and Paper Laboratory, Khulna University was used for cooking. With 27% sulphidity and 17% causticity of liquors, 100 gm air dried sample was charged into the digester. Cooking temperature and chemical charge were examined as independent variable with using mini digester. The ratio of liquor to solid material was 5:1.The cooking temperature was 160 -170C. Cooking temperature was kept constant for 2 hours. The next two hours was fixed for cooking time.

Sulfidity: Sulphidity of white liquor is the ratio of Na_2S to active alkali expressed as percentage. It protects against carbohydrate degradation directly.

$$\text{Sulfidity} (\%) = Na_2S/ Na_2S + NaOH \times 100 \text{ .... } (1)$$

Causticity: Causticity is the ratio of NaOH to active alkali expressed as a percentage.

$$\text{Causticity}(\%) = NaOH/Na_2S+NaOH \times 100 \text{................. } (2)$$

3.3 Treatment after Cooking:

In the subsequent stage of karft pulping, pressure inside digester was released and black liquor drained off. Then cooked material was washed with running water flow for 2-3 hrs to wash out chemical adhere with material.

3.4 Mechanical Treatment:

The cooking material then blended in three different types of blender for preparing pulp. Normal Blender, Beater and High speed blender was used which revolute at 15000, 25000 and 37000 rpm. Fifteen minute time duration was fixed for each type of blender for blending. Pulp with different blending degree was obtained.

3.5 Yield Determination:

Yield is a term indicating the amount of material recovered after a certain process compared to the starting 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. Oven dry method was used for evaluating yield of pulp.

$$Yield(\%) = \frac{\text{Dry product mass out} * \text{Cellulose } \%}{\text{Dry product nass in}} \times 100 \;\ldots\ldots\ldots\ldots (3)$$

3.6 Hand Sheet Paper making:

The pulps were diluted with mixing water and dispersed by shaking the mixture with sterilizer. A hand sheet mold was placed in a chamber and added water into the chamber until the level of the water was one inch above the screen. Bottom part of the mold was covered by a towel. Slurry was poured into the mold from the top and agitated the pulp with fingertips for 3 seconds, without scraping the surface. Dewatering was done by the water pump. Dewatering time was different for pulp from different blending revolution. It took approximately 2hrs for normal blender, 3 hrs for beater, 4.1 hrs for high speed blender and 3.3 hrs for the sheet made from mixture of beater and high speed blended pulp. After dewatering sheet was detached from the mold and it was air dried for 3-4hrs.

3.7 Calendaring:

Calendaring was done to make the surface smooth.

3.8 Strength Properties measurement:

Strength properties of wood such as Tensile Strength, Tear Strength, Burst Strength were tested from Pulp and Paper Laboratory, BCSIR, Dhaka, Bangladesh.

Chapter Four

Results and Discussions

4.1 Viscosity:

When pulp was blended at high speed blender, it showed highest viscosity and lowest when blended in normal blender (Figure 8). Blending speed was highest for the mixture pulp but viscosity may fall due to damage of fibre for over mechanical treatment

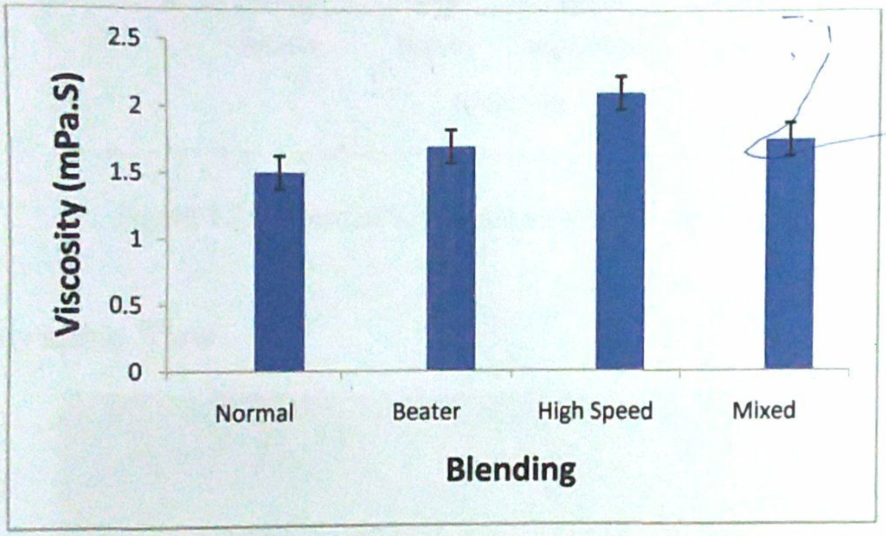

Figure 4.1 Viscosity of pulp at different blending revolution

4.2 Impact of Treatment on Dewatering Time:

For different blending revolution, hand sheet showed different dewatering time (Figure 5). Like other properties, it also trends a linear relationship except the mixture pulp. With the increase of blending speed, dewatering time also increased. It started from 2 hrs for 15000 rpm and reached 4.1 hrs for 37000 rpm. For fibrillation surface area increased which strengthen the bonding of fibre and increases the water holding capacity. High dewatering time with high revolution may happen due to this reason. But for mixture pulp, it took lower time for dewatering than high speed blender though blending speed was higher. It can be explained by this way that, for high speed revolution, fibre may damage which may affect fibre bonding. This may reduce water holding capacity of hand sheet paper. As a result dewatering time also reduced. Long dewatering time was an important drawback for this experiment.

Figure 4.2: Impact of Treatment on Dewatering Time

4.3 Photographic View:

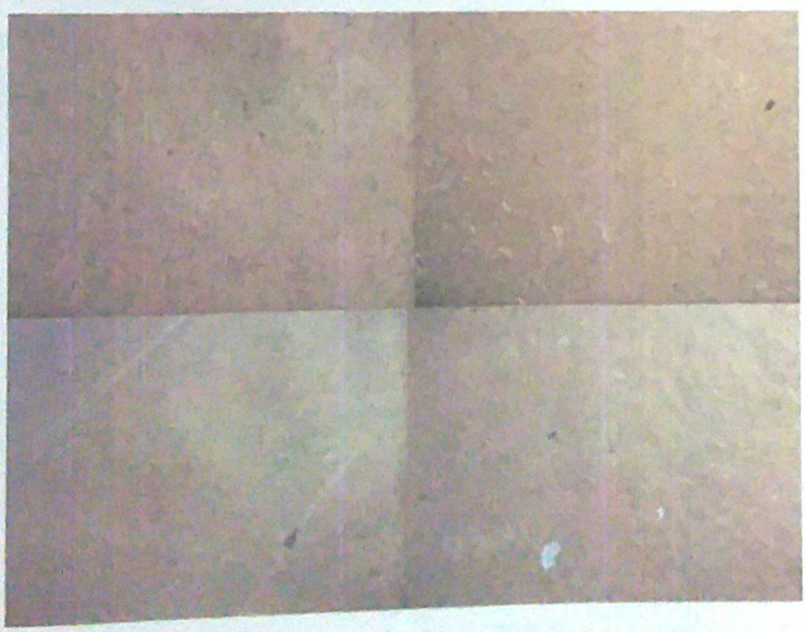

Figure 4.3: Photographic View of Hand sheet Paper at different blending revolution

4.4 Morphology:

After pre treatment the yield of material was 51.54%. Blending involves on many physical change of pulp. From the microscopic view, it is shown that with increasing blending revolution, fibrillation also increased and fibre bundles started to breakdown. But some fibres bundle remains intact which needs further treatment. This may be the reason for some lower mechanical performance of hand sheet paper.

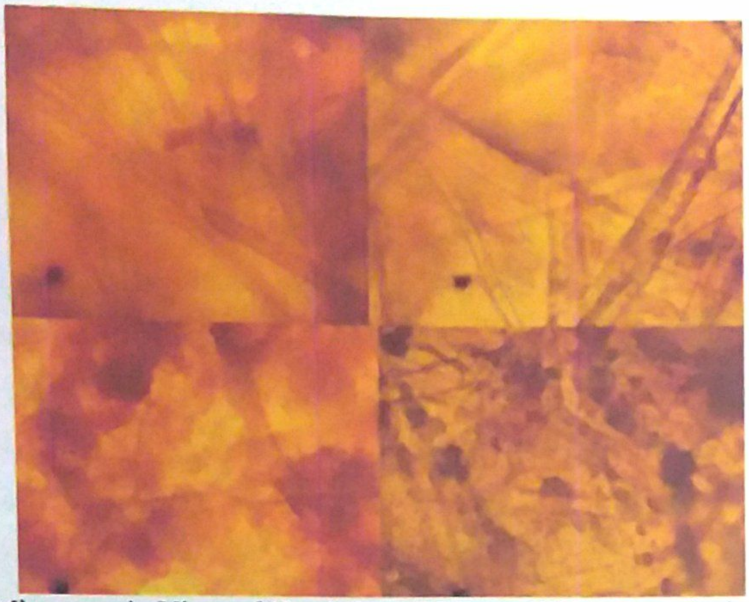

Figure 4.4: Microscopic View of Hand sheet Paper at different revolution of blending

4.5 Impact of Treatment on Density:

Blending induced an increase of paper density until the maximum value at 37000 rpm (Figure 9). For blending influences, fibre -fibre bonding increased and density also increased (Smook, 1997). Proceed blending decreased the density of hand sheet. Similar trend was found from coir hand sheet properties (Maria, 2014).

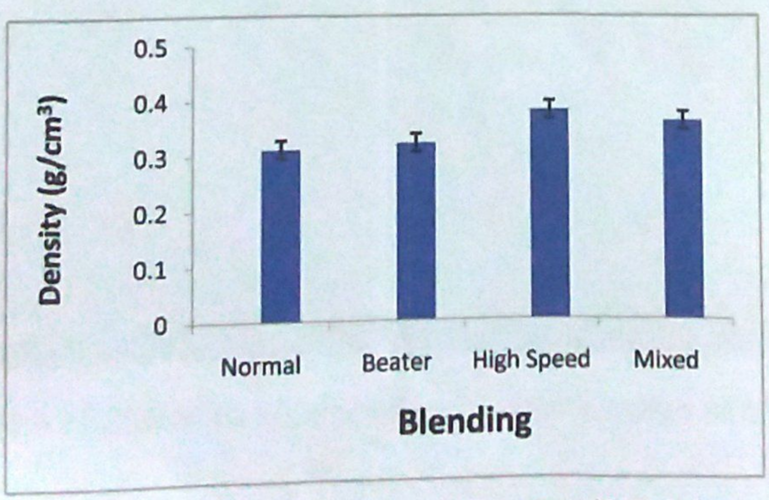

Figure 4.5: Impact of treatment on Density of Hand sheet.

4.6 FESEM image analysis:

Fibres blended at 15000 rpm showed numerous empty spaces between fibres without any appreciable damage (figure 7a). Figure (7b) represented fibril formation on the fibre surface. This fibrils increased surface area which allowed interaction between fibres. Because of fibrillation hydrogen bonding increased and fills the empty spaces of the paper sheet. This feature becomes more evident in figure (7c) where blending revolution is gradually increased. But figure (7d) represented that, fibres become more damaged and empty cell are more prominent than figure (7c), though blending speed is higher. Over blending may damage the fibre fibrillation which creates so tiny fibres and increased empty spaces.

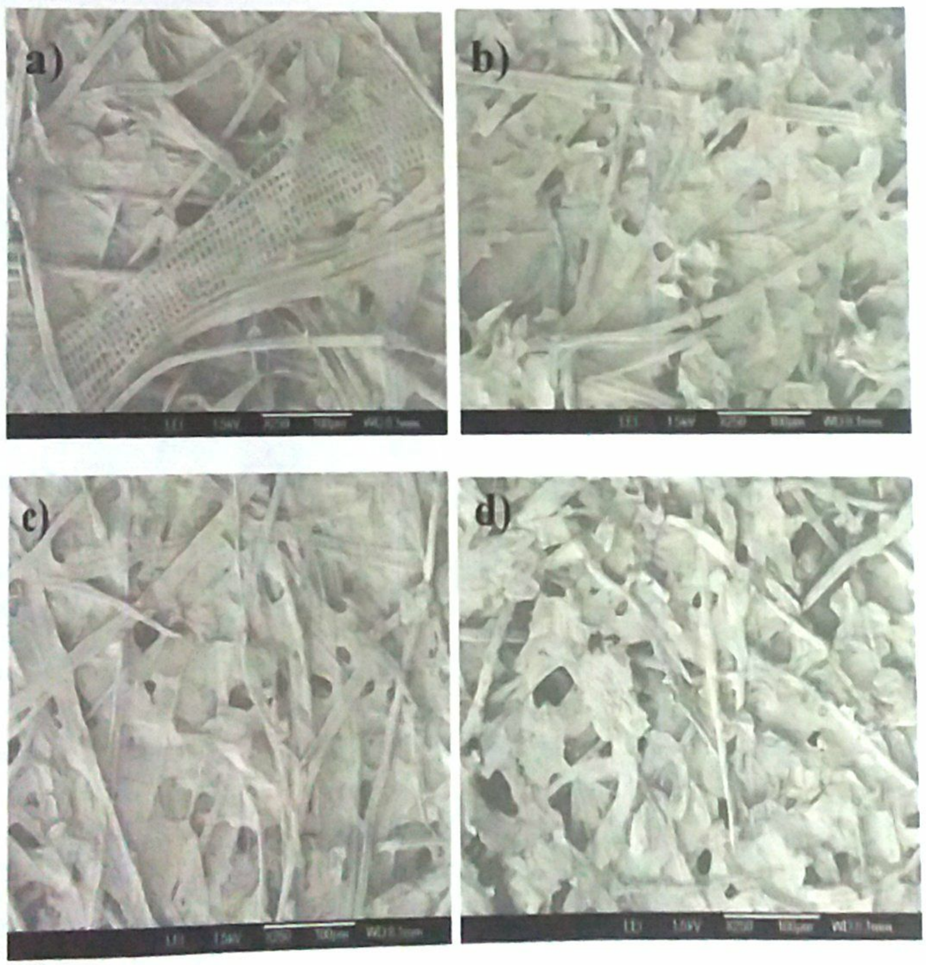

Figure4.6 : FESEM image at different speed blended hand sheet.

4.7 Impact of Treatment on Tensile Strength:

When blending rpm was 15000, then tensile strength was 21.79 and reached to 32.11 Nm/g by increasing blending revolution 37000rpm (Figure 10). But with increasing blending revolution, tensile strength decreased for mixture pulp. This can be explained by Gao (2011) who was carried out research on Tobacco stalk. According to him mechanical treatment produced many tiny fibres in pulp which could fill the space gabs among the long fibres. This tiny fibres play as a role of bridge in the paper which increases the tensile strength of paper and when blending revolution continue to increase number of tiny fibres increased and average fibre length decreased which may reduce tensile strength

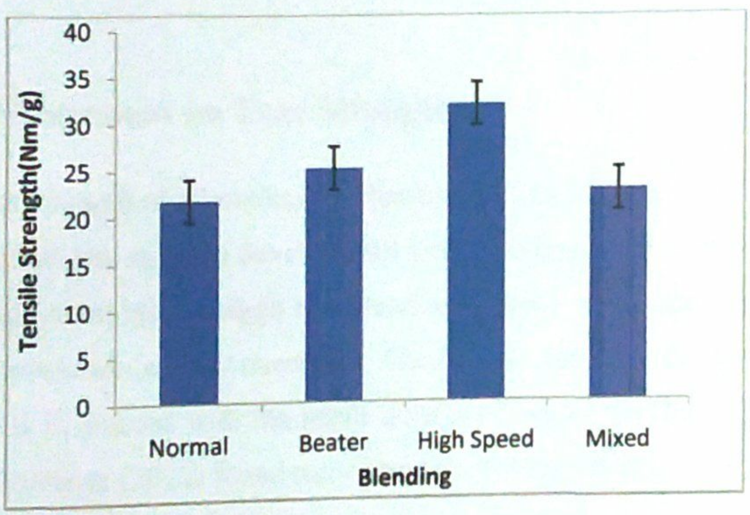

Figure 4.7: Impact of Treatment on Tensile Strength

4.8 Impact of Treatment on Burst Strength:

The burst strength (Figure 11) of hand sheet initially showed an increasing trend with increasing blending revolution, which was followed by its decrease. It continued to increase until blending revolution of 37000 rpm. At this level, highest burst strength was 2.59 $KPa.m^2/g$. With increasing revolution, fibre showed fine fibrosis and wove best which enhanced burst strength but for over blending, decrease of average fibre length causes the reduction of burst strength (Gao, 2011).

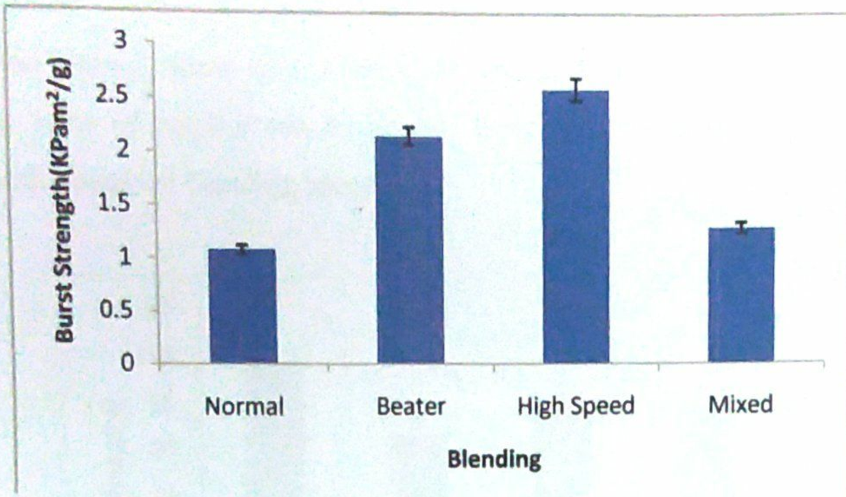

Figure 4.8: Impact of Treatment on Burst Strength

4.9 Impact of Treatment on Tear Strength:

. The range of tear strength of all unbleached hand sheet was 8.26 - 11.01mN.m^2/g. Figure 12 indicates the trend of tear strength development with blending revolution. The developments of unbleached hand sheet tear strength continued to increase when blending revolution were raised until over revolution when it decreased. The highest tear strength was 11.01mN.m^2/g at 37000 rpm. This is in aligned with the result obtained from unbleached sweet bamboo pulp (Suphat, 2005). Gonzalez (2012) found same trend on Eucalyptus pulp.

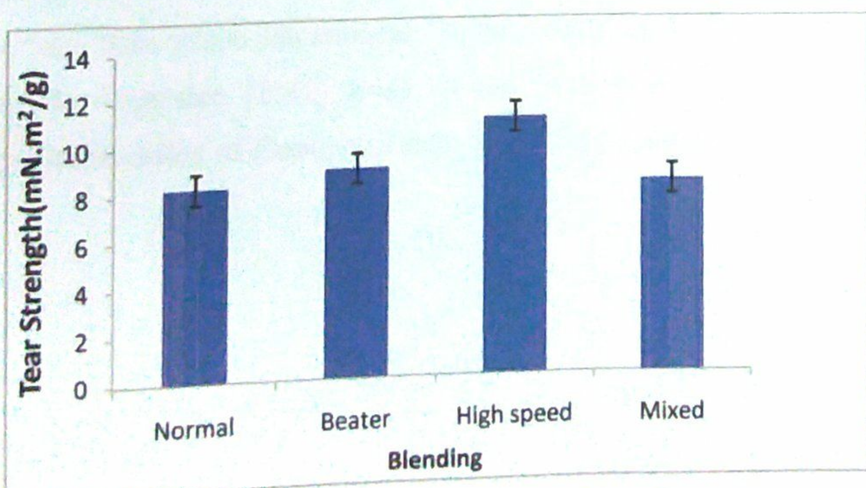

Figure 4.9: Impact of Treatment on Tear Strength

4.10 Brightness:

Brightness was highest, when rpm of blender was 15000 and lowest at 25000 rpm(Figure 13). From the value of result it can be roughly concluded that Brightness does not follow linear trend with increased blending speed.

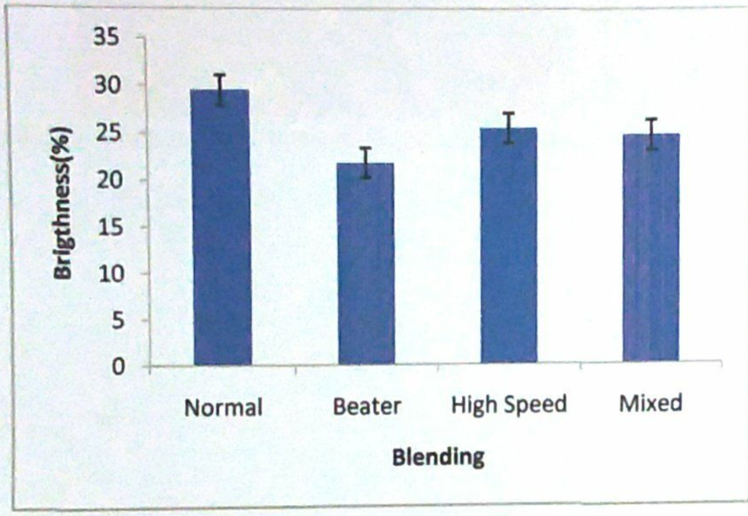

Figure 4.10: Impact of Treatment on Brightness

4.11 Incorporation of Nano fibres:

In order to evaluate the influence of Nanofibre in Golpata pulp, NF was introduced into Golpata pulp. For this reason 9% Nanofibre was incorporated with pulp for hand sheet preparation. From the microscopic view (Figure 14) it seems that with incorporating nano fibre at level 9% with the petiole cellulosic hand sheet paper, the gap of the paper has been filled by the Nano fibre which can enhance the mechanical performances of the hand sheet. According to the Gonzalez (2012) study, it has been seen that with 9% Nano fibre incorporation Tensile index of Eucalyptus pulp hand sheet raised two times than the normal hand sheet.

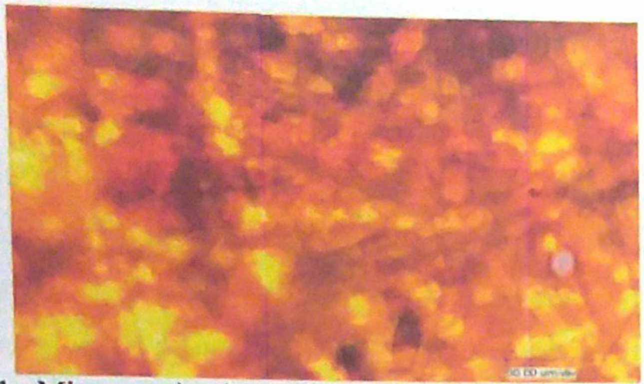

Figure 4.11: Microscopic view of Hand sheet incorporated by nonofibre

Chapter Five

Conclusion

5.1 Conclusion

After pre treatment and mechanical treatment, petiole of golpata formed pulp and hand sheet were prepared. To obtain good fibre fibrillation mechanical treatment was carried out by different revolute blender. SEM image analysis showed that blending speed improved the fibrosis of fibre. The tensile, tear and burst indices the paper increased after mechanical treatment but exception happened for mixture blended sheet due to fibre damage for over mechanical treatment. At a speed of 37000rpm blender, all properties recorded optimum values except brightness. From the microscopic view of hand sheet with nano fibre incorporation showed that, performances of hand sheet can increase by nanofibre incorporation with normal cellulosic paper. In conclusion, petiole of golpata may become a potential material for paper making such as packaging paper, newspaper and so on which means a new comprehensive utilization of wastes, while also improving the value of petiole of golpata.

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