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EXTRACTION OF PAPER FROM MULBERRY (*MORUS INDICA* L.) TWIGS AND ITS ANALYSIS

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ABSTRACT

Mulberry belongs to the genus *Morus* sp. and the leaves of mulberry are generally used for feeding the silkworms. Due to the periodical pruning practice mulberry shoots considered as major farm waste from mulberry garden. Farmers often burn the shoots, twigs resulting in depletion of biomass and adding to pollution. The present study aims to produce paper from mulberry shoots. Paper sheets were prepared from mulberry shoots of G4 and V1 variety and analyzed the properties of paper, *Viz.*, tensile strength, tearing strength, bursting strength (Physical), optical properties. Paper sheets prepared from the shoots of G4 mulberry showed that lower paper density, air resistant, lower tensile strength, smoothness, higher fiber diameter, beautiful, unique and strong compared to others properties.
***Keywords*:** Mulberry shoots, value addition, paper making, commercial utilization

Introduction

Paper is a simple material, it is essentially a mat held together by the fiber's roughness, and can be made from almost any fibrous material like wood or recycled paper or silk and cotton rags. Formed from wood pulp (a fibrous material prepared by chemically or mechanically separating cellulose fibres from wood paper is chiefly used for written communication. Several paper types are produced from fibers from tree and shrubs, for various specialized application. The earliest paper was papyrus, produced from reeds by the ancient Egyptians. Paper was made by the Chinese in the second century from such things as tree bark and old fish netting. Recognized almost immediately as a valuable secret, it was 500 years before the Japanese acquired knowledge of the method. Papermaking was known in the Islamic world from the end of the eighth century A.D.

Current challenges in the pulp and paper making industry include attaining affordable quality pulp while preserving the environment by reducing the energy, water and chemical requirements during the pulping process (Laftah and Abdul Rahaman, 2015). The bulk of fibres for pulp production world-wide are derived from wood which has increased deforestation and poses an environmental degradation (Kamoga *et al*., 2013). Wood products including paper account for 10% of total deforestation, whilst deforestation is responsible for 12% of greenhouse gas emissions world-wide (Corcelli *et al*., 2018). To mitigate deforestation, it is imperative to investigate alternative sources of making pulp with similar characteristics to wood. Most lignocellulose-based agricultural residues have unique cellular arrangements, composition and characteristics which make them suitable for many applications such as production of composites, fuel, textiles and paper (Fuqua *et al*., 2012).

Many plants can be used to make pulp, from which paper is made. Hardwood and softwood trees, hemp, cotton, bamboo, bagasse (processed sugar cane waste), kenaf and on and on. Whether or not any of these raw materials are actually used is dependent on the desired paper type and quality, and the cost of harvesting, pulping and preparing the fiber for use. Paper can be produced by any plant which has more starch and produced better slurry.

Mulberry, *Morus alba* L., belongs to the family of Moraceae, and has been cultivated in China, India, Korea, Japan and Thailand where the leaves are used as food for silkworms (Wang *et al*., 2008). Unfortunately, the agricultural and industrial activities derived from such crops generate waste that constitutes a serious environmental problem. For example, pruning mulbery shoot is a typical agricultural residue generated in the mulberry industrial process (Fukui, 2008).

As noted above, mulberry is not just used in sericulture for rearing the silkworm, but is a potentially useful biomass resources. Nowadays, the average annual dry matter biomass of pruned mulberry shoot is 1.7 kg/plant, or approximately 17.0 - 22.5 t/ha. In India, 12 tonnes of mulberry shoots can be generated as waste from one hectare of mulberry garden (Datta, 2002). However, most of the pruning mulberry shoots are used only as fertilizer and a small proportion is used as a constituent of fish feed or even regarded as industrial waste (Kandylis *et al*., 2009). Therefore, lots of pruning mulberry shoots had not been fully utilized. Indeed, disposal of pruning mulberry shoot is a serious problem, because parasitic insect and pathogenic microorganism in the waste are fatal damage to mulberry field due to their simple accumulation. The current study focused with the aim of investigating the characteristics of paper sheets prepared from mulberry shoots from G4 and V1 mulberry varieties.

Materials and Methods

The study was carried out to extract paper from mulberry shoots of G4 and V1 variety and its analysis the properties for their uses. The entire work was carried out in the Research and Development laboratory at the Forest College and Research Institute (FCRI), TNAU, Mettupalayam. The details of the experiments and the methodologies followed are furnished below.

Selection of mulberry shoots

The following characters are considered for selection of superior plants for paper production, *Viz.*, basal girth, girth at breast height (GBH), height, texture of bark, bole straightness and insect-pest incidence.

Estimation of pulp properties

Kraft Pulping

400 gm of OD chips were cooked by Kraft process in an electrically heated glycol bath series digester consisting of six bombs each 2.5 lit capacity under the following constant pulping conditions.

S. No	Properties	Conditions
1.	Chemical added as Na_2O (%)	17
2.	Bath Ratio	1:2.8
3.	TAA in White liquor (gpl)	85
4.	Cooking Temperature (°C)	170
5.	Cooking time (min.)	90
6.	H – Factor	1600

At the end of the cooking, the bombs were removed from the digester and cooled by immersing in water. Bombs were opened and spent pulping liquor was filtered off on double fold nylon cloth. The pulps were washed until the filtrate became colorless. The washed pulps were screened on a flat screen (slot 0.3mm). The Dryness of the pulp was determined and pulp yield was calculated on the basis of dryness of pulp (Plate 3).

Paper sheets preparation

Thirty gram (dry weight) of bleached pulp was taken and diluted to 1.5 per cent (w/v) with water. This pulp slurry was thoroughly mixed. The pulp slurry was further diluted to 1.0 per cent and kept for 30 min. The measured volume of this was transferred in the sheet form in order to make 60 gsm sheets. These hand sheets were prepared according to TAPPI standard T 205 om-88. By couching, the sheet was removed from the wire with the help of absorbent blotters. These sheets were pressed between the blotters at 0.27 Mpa to increase the dryness and to consolidate the sheet and then these sheets were dried at 27±1ºC and 65 per cent ±2 RH for 24 hrs.

Measurement of paper strength

The tensile strength, bursting strength, tensile energy absorption and elongation of paper sheets were measured according to TAPPI standard T 494 om-88. On the basis of yield and strength properties of kraft pulps, Guha (1969).

Measurement of optical properties

a) Pulp brightness

Three gram of oven dry pulp was weighed and washed with demineralized water in ASTM 325 mesh and diluted into slurry. The sample was filtered through a clean filter paper, placing one clean filter paper on the top of the pad while filtering. The top side

of the pad was placed in such a way that it faces a clean metal plate and two dry blotters were also placed. The pad was pressed for one minute in a sheet present at 0.275 Mpa pressure. The pad was dried at about 65oC for one hour in an IR lamp. The brightness was measured using Elrepho 2000 brightness tester at 457 nm. Also the opacity, scattering coefficient and Yellowness of the pulp were measured by using Elrepho tester.

Raw material selection and preparation

The appropriate size of mulberry is 3 to 5 cm in diameter. Only inner bark is used, typically steam or heat is applied to ease the peeling. The fiber obtained from this method is quite clean. However, dry bark is more preferable for machined paper making as it is easy for transportation and handing. Generally, dry mulberry inner bark is classified into 4 grades, SA, A, B and C. SA is the best grade which represents young mulberry aged 6-12 months, no defect or contamination and has white color. In case of dry bark, soaking step is required. The average time of soaking is 24 to 48 hours.

Digestion

Sodium hydroxide 10-15 % is used. For SA grade mulberry NaOH use can be reduced to as low as 8%. The average digestion time is 3-5 hours. The chemical dose and the operating conditions of digestion step are shown below:

Chemical dose and operating conditions of digestion

Item Quantity

- Sodium hydroxide (NaOH)- 10-15 % by wt.
- Liquid/dry bark -10:1
- Temperature of digestion -100°C
- Time required- 3-5 hr.
- Yield of unbleached pulp- 54 % wt.

Washing

The cooked bark is removed from the digester to a series of concrete tanks for washing. Each tank has fresh water coming in at the top and water discharge at the bottom. Cooked bark is manually turned during washing. This washing operation is repeated 2 or 3 times.

Bleaching

The purpose of this process is to whiten the pulp. Unbleached pulp will be loaded to the bleaching tanks. The common bleaching chemicals normally are sodium hypochlorite or calcium hypochlorite. The details of bleaching chemicals and conditions are shown below.

Bleaching chemical and conditions

Item Quantity

- Sodium hypochlorite (NaOCl)- 4 %wt of unbleached pulp
- Pulp consistency- 6%
- Operating temperature- 40˚C
- Time required- 6-12 hrs.
- Pulp yield- 52 % wt. of bark

Washing

The bleached bark is transferred to the concrete tanks for washing. Similar to the previous washing step, this washing is performed 2-3 times or until the smell of chlorine disappears. Generally, contaminated and defective pulp are also manually removed in this step.

Pulping and beating

The prepared bark was cooled for 8 hours in a 0.8 % wt sodium hydroxide aqueous solution. The amount of water was equal to 10 times the weight of dry bark. The cooked bark was thoroughly rinsed in water, and unevenly cooked parts and discoloured parts were removed by hand. The treated bark was dried at 110 ºC for 24 hours and was cut in lengths of 10 mm to facilitate beating. The pulp obtained was beat in beater. The freeness (Canadian Standard Freeness) of the pulp was determined. The mulberry pulp is quite long, therefore, an effective beater is required. Time required for beating depends on the characteristics of bleached pulp. Normally, for3 kg of pulp one hour of beating is required. Now, the pulp fiber is ready to make the mulberry paper, so it is fed into the paper making step.

Paper making

The pulp fiber is suspended in the concrete tanks. For sheet forming the pulp fiber must have a consistency of approximately 2 %. This paper making unit consists of many unit operations such as: sheet forming, transferring, pressing, and drying. The pulp was disintegrated by a pulp disintegrator and paper sheets were prepared with a square type (250mm by 200 mm) sheet machine. The wet sheets were pressed under 0.4MPa for 15 min and dried at 100 ºC using a rotary dryer. Finally, we obtain the mulberry paper.

1. Collection of mulberry twigs

2. Pulping and beating **3. Paper sheet making**

4. Drying of paper sheets **5. Dried mulberry paper**

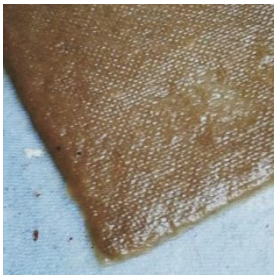

Plate 1. Schematic representation of paper making process

Statistical analysis

Complete Randomized Design was used for this study and three replications were maintained for each analysis. The obtained data analyzed through Analysis of Variance (ANOVA) p value < 0.05.

Results and Discussion

Properties of mulberry paper

Fibre diameter

The fibre diameter and Canadian standard freeness (CSF) obtained from mulberry shoots was presented in the Table 1. When comparing the fibre diameter and Canadian standard freeness the mulberry variety G4 (16.2 µm, 355) showed superior values than the V1 variety (14.5 µm, 348) respectively. Jitjaicham and Kusuktham (2016) produced fibres from paper mulberry and studied the morphological and quality parameters the results showed that fibres from paper mulberry showed good uniformity.

Helman-Ważny (2016) reported that composed of woody plant phloem fibers, such as *Broussonetia* sp. (Paper mulberry) or *Morus* sp. (Mulberry), derived from living plants. These are considered to be the best materials for creating high quality paper.

Table 1 : Fibre diameter in paper sheet

S. No	Raw material (Mulberry variety)	CSF	Fibre diameter in paper sheet (µm)
1.	G4	355	16.2 ± 0.50
2.	V1	348	14.5 ± 0.45

The values are expressed in Mean ± SD (Three replications).

Estimation of physical properties

The thickness, wet strength, tearing strength, folding endurance, smoothness, air resistance, and stiffness of the paper sheets were determined according to ISO 534-compatible. The tensile properties of the paper sheets were measured at room temperature using a tensile tester. The initial sample length and width were 20 mm and 5mm respectively and the extension rate was 100 per cent per minute. Ten measurements were performed for each sample. By comparing the physical properties, the variety G4 seems to yield superior quality paper.

Table 2 : Physical properties of mulberry paper

S. No	Parameters	Mulberry variety (Raw material)	
		G4	V1
1.	Tensile strength (MPa)	8.10^{b}	9.00^{a}
2.	Young modulus (MPa)	92.30^{b}	95.00^{a}
3.	Breaking elongation (%)	9.20^{a}	8.50^{b}
4.	Bursting strength (MPa)	1.90^{a}	1.10^{b}
5.	Wet strength (kN/m)	0.05^{a}	0.06^{a}
6.	Tearing strength (N)	2.35^{a}	1.80^{b}
7.	Folding endurance	2.50^{b}	2.30^{a}
8.	Smoothness(S)	0.58^{b}	1.06^{a}
9.	Air resistance (S)	4.70^{b}	5.10^{a}
10.	Stiffness	33.10^{b}	35.10^{a}
p value @5%		0.032*	

The paper produced from mulberry shoots were subjected for analyzing the physical properties. There was significant difference was observed between the G4 and V1 variety in irrespective of all the parameters studied. They are tensile strength (8.10 MPa, 9.00 MPa), young modules (92.30 MPa, 95.0 MPa), breaking elongation (9.20 %, 8.50 %), bursting strength (1.90 MPa, 1.10 MPa), wet strength (0.05 kN/m, 0.06 kN/m), tearing strength (2.35 N, 1.80 N), folding endurance (2.50, 2.30), smoothness (0.58 S, 1.06 S), air resistance (4.70 S, 5.10 S) and stiffness (33.10, 35.10) were observed in respect to G4 and V1 mulberry variety.

The present results of physical properties of the mulberry sheets corroborates with findings of Takasaki *et al.* (2012) paper sheets prepared from the bark of mulberry showed lower paper density, air resistance (0.85) and smoothness (0.53) and higher fibre diameter (17.5) in comparison with the paper sheets obtained from the bark of kozo (*Broussonetia* sp.). Paper sheets of the mulberry bark were lower anisotropic, tensile strength (7.8) and young's modulus (91.1) than that of the kozo bark.

Dutt *et al.* (2005) reported that mulberry paper is a highly specialized paper exclusively used for making wedding and greeting cards. Also, some the writing and printing properties, a few mechanical properties such as folding endurance, burst factor and tear factor are important for mulberry paper. The same properties are studied in the present study also which showed the paper obtained from G4 and V1 mulberry variety can be used for commercial utility for making the specialty cards. Ramgopal *et al.* (2016) produced pulp from groundnut shells and analyzed their properties the result showed that groundnut shells are considered as agriculture residue it may serve as alternative biomass resource material for producing pulp for paper making.

Conclusion

The mulberry *Morus indica* is widely used for the silkworm rearing as an efficient feed. The improved and widely prevailing shoot rearing method paves way for the more wastage of twigs. Farmers often burn the twigs resulting in depletion of biomass and adding to pollution. On considering this view, we have projected to extract paper from the mulberry bark to increase the resource use efficiency, to increase the income and have successfully extracted the paper by using the above extraction procedure and analyzed its physical and chemical properties. And all the results showed that the paper is suitable to use and recycle. This paper from chopped twigs of mulberry makes for paper that is beautiful, unique and strong. These, paper are acid free, sustainable paper and are print friendly for screen printing purposes and are also used for sketching, artwork, wedding cards, gift tags, special notes, packaging, wedding cards and stationery.

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