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Study on Enhancement of Hydrophobic Property of Handmade Paper from Raw Jute by Using MCC as External Additives

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Abstract: The study was aimed at enhancing the hydrophobic properties of handmade paper (HMP) produced from raw jute as an alternate packaging material. The hydrophobicity and strength of the HMP are both crucial properties for packaging materials, hence internal (rosin) and external additives (microcrystalline cellulose) along with fiber reinforcement were used to improve these properties. The addition of the additives improved the hydrophobic character of the HMP. The optimum water resistance was achieved by using rosin and alum as internal additives, and MCC as external additive. The hydrophobic character was increased by 92.46%. The introduction of hydrophilic jute fiber as reinforcement resulted in lower water resistance index.

Keywords*: Handmade, Jute, Paper, Hydrophobic, Property*

1. Introduction

With the rise of consumerism and globalization the demand of packaging materials is increasing day by day. Due to its user friendliness and cheap price, the market of packaging materials is currently dominated by polythene. But the uncontrolled use of polyethylene and polypropylene has taken a huge toll on our environment. Due to its non-biodegradability, it disrupts the natural ecosystem. In Bangladesh the excessive use of polythene has caused major ecological issues, according to reports. The land fertility is reduced greatly as large lands are filled with non-biodegradable poly bags. This also causes hindrance to rain water movement, paving the way for flooding. The use of plastic, Polypropylene (PP) and Polyethylene (PE) as packaging materials has posed a threat to the environment and economy of Bangladesh [1]. The current global awareness of the harmful effects of plastics and consequent restrictions on its use has created a golden opportunity to explore natural raw materials for packaging. Biodegradable paper from natural raw material with high strength and hydrophobicity can be a good substitute for polythene. Traditionally jute was used for packaging in Bangladesh but due to the easy availability and cheap price of polythene, the demand for jute packaging has decreased considerably [2].

Deforestation and global warming has greatly reduced the availability of wood plant fibers. The demand of non-wood fibers as raw materials for pulp is increasing rapidly [3, 4]. The use of jute can be diversified; it may be used as raw material for pulp and paper industry.

Studies have shown that addition of MCC in the form of regenerated cellulose gel to bleached kraft pulp for producing hand sheet improves the mechanical properties (Young Modulus, Tensile & Tear indices, Folding Endurance) [5]. The tensile strength and folding endurance of hand sheet increase with addition of swollen starch pulp with wood pulp. The starch pulp improves inter fiber bonding between wood pulps, resulting in the reinforcing effect on the hand sheets. Poly-amidiamine epicholohydrin resin (PAE) is a wet strength resin. When PAE is added together with swollen starch pulp it has a synergistic effect on the increase of folding endurance [6]. The study on the effect of MCC, CMC and mixture of MCC and CMC on the hydrophobicity of paper produced from jute showed that MCC suspension treatment increased the water repellency of handmade paper. In case of treatment with 50:50mixture of MCC suspension and CMC solution the hydrophobic character increases with MCC concentration but the hydrophobic character decreases with the CMC solution concentration in the mixture [7, 8].

The effect of fiber reinforcement combined with the presence or absence of sizing materials have not been studied properly yet. The effect of internal sizing materials (rosin,alum,wax emulsion etc.) and external sizing materials (MCC suspension) can have huge impact on pulp properties. In this study we explored the potential of handmade paper from jute as packaging material by introducing internal sizing materials (rosin alum,wax emulsion) and external sizing material MCC solution prepared from jute [9] and raw jute fibres as reinforcement to the pulp.

2. Materials and Methods

Raw jute of Bangladesh white B grade was collected from Bangladesh Jute Research Institute. All chemicals used were of reagent grade provided by Menonite Central Committee, Dhaka.
Four sets of experiments (Table 1) were performed using Rosin and alum as internal additives, MCC as external additive and raw jute as fiber reinforcement to find the optimum additives for enhanced hydrophobicity and strength (Table3).

2.1 Fiber Sample Preparation:
The collected jute fibers were cleaned carefully and cut into small pieces of 1.27 cm -2.54 cm (0.5 -1 inch) size.

Table 1: Experimental variables for finding optimum additive combination for hydrophobicity and strength.

Experiment	Internal sizing	Fiber reinforcement	External sizing
Experiment 1 (control)	none	none	none
Experiment 2	none	Raw jute fiber	Microcrystalline cellulose
Experiment 3	Rosin and alum	none	Microcrystalline cellulose
Experiment 4	Rosin and alum	Raw jute fiber	Microcrystalline cellulose

2.2 Pulp Preparation:
2.2.1Boiling and beating:
The raw fibers were boiled in alkaline solution to remove impurities soluble in mild alkalis at moderately high temperature as well as to soften and condition the fiber. 300 gms of the fiber samples were boiled in NaOH (18g) solution in water (10 liter). The water level was constantly maintained at 10 liters and the boiling process was continued for 4 hours. The boiled fibers were washed with water until the fiber stock was clean enough with minimum fiber loss. The washed jute fibers were beaten in an open vessel of beater in 70 kg of fresh water for 2.25 to 2.5 hours. The resulting pulp was kept standing for 17.25 hoursand washed to neutral pH.

Table 2: Parameters used for pulp preparation in different experiments

Experiment No.	Atmosphere of Pulp Preparation		p^H After Washing	p^H with Additives	Remarks
	Temperature ^0C	Relative Humidity (%)			
1	27.0	47	7.5	-	No additive used
2	27.7-32.7	37-46	7	-	No additive used
3	28.4-28.7	39-50	6.5	5.5	
4	28.4-28.7	39-50	7.5	5.5	

2.2.2 Internal Sizing:
500gm of rosin powder was dissolved in hot caustic solution (50gm NaOH in 1l water) and the solution was boiled for 30 mins. 4.5gm Rosin solution (1.5% of weight of washed pulp sample) was further diluted with hot water before application to pulp.
For another set of experiment the rosin solution was applied with 5 minute stirring, then the pulp was rested for 30 mins. 0.75% emulsion was introduced to the pulp and stirred for 5 mins followed by application of 3% alum solution with 5 mins stirring. The rosin solution was applied to the pulp and stirred for 5 mins then rested for 30 mins followed by application of 3% alum solution with 5 mins stirring.

The pulp was rested for 20 mins after internal sizing application.
For easy liquid drainage the pulp was kept on a net and washed thoroughly to achieve neutral pH. The p^H of the pulp showing the degree of acidity or alkalinity was measured by standard p^H paper.

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2.2.3 Lifting:
1 litre of 0.05% polyimide solution mixed with 20 litre of water in a lifting vat. The Pulp was suspended uniformly in the water of the lifting vat and lifted in sheet form from the lifting vat and kept on a bed table using cloth separators.

2.3 Fiber Reinforcement:
Jute fiber filaments from carded sliver of BTB jute were used as reinforcement between two layers of pulp manually keeping a distance of 2.54 cm between fibers (both vertically and horizontally).

2.4 Sheet formation and drying:
Hydraulic press of 10 ton capacity was used to press the pulps in lap form for 15 minutes to produce paper sheet. These sheets were sundried followed by calendaring.

2.5 External sizing:
Paper sheets were soaked in 0.5% MCC suspension for 1 minute, then dried in sunlight. Another batch of paper sheets were soaked in 0.5% wax emulsion for 1 minute and dried in sunlight.

2.6 Characterization:
The physical properties of paper were measured for each experimental group as per TAPPI standard test methods. For each property representative samples were taken from all the samples.
The following physical properties were tested.

2.6.1 Thickness: The thickness of the paper sheets was measured by venire calipers according to TAPPI T441om-97 method. 10 samples (10cm× 10cm) for each experiment were taken and five readings from each sample were recorded in mm.

2.6.2 GSM: The weight of the samples were taken by electronic balance and converted to Grams per Square Meter (GSM).

2.6.3 Cobb Water Absorptivity: Three representative samples (12.5cm× 12.5cm) from each experiment were used to test the water absorptivity according to TAPPI T 441om-98 method. The samples were weighed to the nearest 0.01g. A dry rubber mot was placed on the metal plates then the sample was placed on it and the metal ring was placed on the sample and fastened firmly in place with crossbar to prevent leakage. 100 ml water of room temperature was poured into the ring as rapidly as possible creating a head of 1.0± 0.1cm. The water was quickly removed from the ring after 110seconds. The crossbar and the metal ring were removed carefully and quickly and the sample was placed with its wetted area for the pre-determined test period (2 minutes), a sheet of blotting paper was rolled back and forward forth once over the pad without exerting any additional force on the roller. The sample was folder with the wetted area in side and was re-weighted immediately and the absorbed water was calculated by the following formula,
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Weight of water absorbed (Gm/m^2)= {Final wt. (g)- Conditioned wt (g)}× 100

Water Absorption Index= W_1/GSM

Where, W= Weight of water absorbed in GM/ M^2, GSM= Weight paper in Gm/M^2.

3. Results

The characterization results of the handmade paper are given in the following table

Table3. Characterization properties of the handmade paper from Jute fibers

	Thickness(mm)				**GSM(Gm/m^2)**				**Cobb water Absorptive Test**	
Expt. NO.	Mean	CVw (%)	Mean	CV_b (%)	Mean	CV_b (%)	Mean	CV_b (%)	Water absorbed Gm/m^2	WRI (%)
1	0.28	11.16			175.8	09.84			557.33	-
2	0.34	12.16	0.33	12.62	190.6	10.66	188.85	5.55	660.00	-18.42
3	0.32	07.37			187.7	04.81			242.00	92.46
4	0.38	22.38			201.3	15.00			047.33	91.51

CV_w= Co- efficient of Variation within experiment, CV_b = Co-efficient of Variation between experiments, WRI =Water Resistance Inversed

4. Discussion

The characterization results show that the mean thickness and GSM of paper were 0.33mm and 188.85 respectively. The mean thickness of the paper sheet varied considerably as the CV% of paper thickness (within experiments) was 7.37%-22.38% and the CV% (among experiment) was 12.62%. The mean GSM of paper also varied as the CV% were 4.81%-15 % (within experiment) and that among experiment was 5.55 %. These variations can be explained by the lack of uniformity in the lifting process. A more uniform distribution of pulp while lifting can ensure paper sheets with constant thickness and GSM

The hydrophobic character of the paper sheets increased with the addition of the internal and external additives but for one case where the paper was treated by MCC. The increase in the hydrophilic properly in experiment 3 was due to the introduction of hydrophilic raw jute fibre as reinforcement. The application of rosin along with MCC improved the water resistance of the paper sheet as seen in the results where water resistance index were 92.46 % and 91.51% respectively in experiment 3 & experiment 4.The water index for experiment 4 was a little lower compared to experiment 3 because of the presence of hydrophilic raw jute fibre as reinforcement.

The optimum result in respect to water resistance was achieved when the pulp was treated by MCC suspension along with rosin and alum. This achievement can be applied to produce handmade suitable for making eco- friendly paper bags for grocery and shopping which could largely replace the non-biodegradable plastic(LDPE) carry bags.[10]

5. Conclusion

The hydrophobic properties of handmade paper can be greatly improved by external additives. Among our experiments the maximum hydrophobicity was achieved by using a combination of MCC, rosin and alum as additives. Our results also show that addition of hydrophilic jute fibers as reinforcement causes the hydrophobicity of the handmade paper to decrease.

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