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RESEARCH PAPER

Subjective evaluation of bagasse composite handmade papers for variegated applications

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Abstract: The handmade paper industry in India offers considerable potential to meet the increasing demand for paper products in an environmentally sound way. Though most paper made today comes from automated and continuous production systems, the handmade paper has enjoyed resurgence both as a traditional craft and as an art-form. In addition, traditional papermaking methods can provide insights to help in modern applications involving cellulosic fibers.Locally available eco-friendly renewable resources *viz.,* sugarcane bagasse, sisal fibre and maize husk, waste paper and cotton rags have been used for development of handmade papers with different blend proportions (60:40 and 40:30:30) and GSM. It was found that, among the fibre blends bagasse: sisal: cotton pulp (40:30:30) was found to be more suitable for production of handmade paper with optimum physical properties and further subjected to large scale production for validation and cost feasibility. Based on the sensory evaluation results, it was found that the blended handmade paper possessed acceptable rating for colour, texture, durability and thickness. Majority of the respondents stated that, the developed handmade paper was more suitable for production of carry bags, paper plates, file covers and food wrappers. The production cost of bagasse: sisal: cotton pulp (40:30:30) blended handmade paper was comparatively cheaper (Rs.136/kg pulp) than commercial cotton handmade papers (Rs.160/kg pulp). Hence, optimum utilization of underutilised natural fibres for handmade paper making is an environment friendly process with an affordable cost and provides sustainable enterprise for rural artisans.

Key words: Bagasse, Composites, Cotton pulp, Lignocelluloses, Sisal

Introduction

The handmade paper industry in India offers considerable potential to meet the increasing demand for paper products in an environmentally sound way. People are moving to maximize the use of handmade and recycled paper to generate a reverse chain reaction. For over 2000 years the manual craft of papermaking has been practiced all over the world utilizing a variety of techniques. Almost every aspect of modern papermaking technology has been foreshadowed by traditional practices. Such practices were passed down for many generations within families of papermakers. Though most paper made today comes from automated, continuous production systems, handmade paper has enjoyed resurgence, both as a traditional craft and as an art-form. In addition, traditional papermaking methods can provide insights to help in modern applications involving cellulosic fibers. In present era materials extracted from renewable sources, eco-friendly, biodegradable *etc*. are preferred by everyone throughout the world to save earth from future problems. The growing demand concerns for the degradable environmental conditions have led to the development of eco-friendly and bio degradable fibres in the ever expanding horizon of textile fibres. These eco-friendly products being environmental friendly, do not pose the toxicity and waste disposal problems.

Sugarcane bagasse is a residue widely generated with high proportions in the agro-industry. It is a fibrous residue of cane stalks left over after the crushing and extraction of juice from the sugarcane. Bagasse is generally gray-yellow to pale green in colour. It is bulky and quite non uniform in particle size. The sugarcane residue bagasse is an underutilized, renewable agricultural material that consists of two distinct cellular constituents' *viz*., rind and pith. The main chemical constituents of bagasse are: Cellulose and hemicelluloses; they are present in the form of hollow cellulose in bagasse which contributes to about 70 % of the total chemical constituents present in bagasse. Lignin; It acts as a binder for the cellulose fibres and also behaves as an energy storage system. Bagasse consists of water, fibre and small quantities of solids in solution in following proportions. Water 46-57 %, Fibre 43%-53%, Solids in solution (sugar) 2%-6 % (Mishra, 2007). About 54 million tons of dry bagasse is produced annually throughout the world. For a long time bagasse has been used as fuel for factory. Now a day it is used as a biofuel and as a renewable resource in the manufacture of pulp and paper products, building materials, renewable power generation and for production of bio-based materials (Asagekar and Joshi, 2014). Hence, the study was designed with an objectives to produce handmade papers from bagasse and other natural fibres and to assess the quality parameters and suitability for different end uses.

Material and methods

Procurement of raw materials

The study is focused on effective management of locally available agro based fibres released from University of Agricultural Sciences, Dharwad *viz.,* sugarcane bagasse (Var. SNK 09293), sisal fibre (Var. BAS -1) and maize husk (Var. GPMH 1101). The office waste papers were procured in bulk from UAS campus and pulp of knitted cotton rags from paper industries operating at Tarihal Industrial area, Hubli.

Sugarcane Bagasse

Sugarcane bagasse (SNK 09293) was procured from Agricultural Research Station, Sankeshwar. Sugarcane bagasse is a residue generated after juice extraction and mainly used for co-generation in sugar industry. The bagasse is valuable raw material for textile application which consists of water-insoluble basis, *i.e.,* "pith" from the center of the stalks (30%), "fiber bundles" (65- 50% from the rind and 15% from the internal material) and the epidermis (5%).

Sisal Fibre

Traditionally, sisal has been the leading raw material for agricultural twine because of its strength, durability, ability to stretch, affinity for certain dyestuffs and resistance to deterioration in saltwater. A sisal plant can produce about 200-250 leaves before flowering, each of which contains 1000-1200 fibre bundles. The leaf is composed of 4% fibre, 0.75% cuticle, 8% dry matter and 87.25% water. It is currently found on embankments, bunds, roadsides serving the purpose of soil conservation and protection as hedge plantations. For the present study the Sisal (*Agave americana*) fibre variety BAS -1 was procured from the Regional Agricultural Research Station, Vijayapura, Karnataka. The sisal fiber was extracted by using Raspador machine and the extracted fibre was subjected to washing and sun drying. The dried sisal fibre was cut into 2 inches in length, softened by required amount of softening agent (3% non ionic detergent) and further used for paper making.

Waste Paper

The waste paper recycling is a need of an hour, it involves a number of steps, including collection, sorting, processing into usable raw materials and finally using that raw material to produce new paper production. All the recovered or collected paper waste was chopped into small pieces. The chopped paper was soaked in hot water for removal of dirt and ink. The deinked papers were used for paper making.

Pulps of cotton knits rags

The processed cotton knits pulp was procured from local paper mills for paper making. Garment and hosiery industries generate abundant waste of the cotton rags, trims and cuttings mainly during the manufacturing of garments. Cotton has highest percentages (87 to 96 %) of cellulose; it can be used for manufacturing of value added products (Chauhan, *et. al.,* 2009).

Pre-treatment

Softening of bagasse fibre

Bagasse sheath/ slackened strips were subjected to alkali treatment using NaOH at room temperature with 1:15 MLR for 6 hours followed by beating using electrical beater/ mixer to get good quality bagasse fibre.

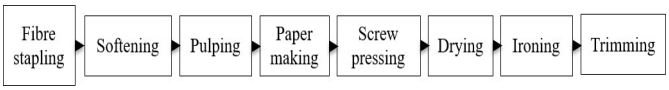
Blend Ratios

All the above explained fibres were blended in different ratios for the production of handmade paper.

Blending	Ratio
T_1 – Pure Cotton (Control)	100 %
T_2 – Bagasse + Cotton	60 : 40
T_3 – Bagasse + Maize husk + Cotton	40 : 30 : 30
T_4 – Bagasse + Sisal fibre + Cotton	40 : 30 : 30
T_5 – Bagasse + Waste paper + Cotton	40 : 30 : 30

Development of blended handmade paper

Softened and delignified bagasse fibres were subjected to beating in a Hollander beater in which fibres were cut into very short staple length. Softening treatment makes the pulping process easier and reduces the time of pulping. According to required GSM, the pulp was blended and poured manually on the nylon mesh with wooden frame. The frame is immersed in the water and transferred the paper onto padding stand. The developed paper needs to be pressed by screw pressing machine in order to remove the excess water and air bubbles completely. The pressed paper is flat dried and hanged over the ropes around 6-7 hours. After drying, ironing process was carried out to achieve even surface of paper. The dried sheet was subjected to cutting or trimming process (Plate1). Further, developed composite handmade papers which were subjected to physical properties using TAPPI standards.



Subjective evaluation of handmade papers

Subjective evaluation *viz.,* texture, colour, durability and thickness of developed handmade papers were assessed through mean and Anova. The sensory evaluation was done by 30 members comprised of students, teachers of College of Community Scince, UAS, Dharwad and handicraft makers using 5 point scale. (Likert scale quality scoring).

Plate 1. Manufacturing process of handmade paper

Production cost of bagasse composite handmade papers was calculated considering variable cost for manufacturing one kg of paper.

Results and discussion

Quality assessment of Bagasse composite hand papers

Effect of fibre blending on physical properties of handmade composite paper is presented in Table 1. Among all the papers the highest thickness was found in T_3-bagasse + maize husk + cotton paper *i.e.,* 692 (mm) followed by T_5-bagasse + waste paper + cotton (668 mm), T_2-Bagasse + Cotton (630 mm), T_4-Bagasse + Sisal fibre + Cotton (610 mm) and T_1-Pure Cotton composite paper (320 mm) due to the thicker cell wall of bagasse fibre *i.e.,* 20ìm compared than eucalypt, making it stiffer (Thomas, 2016). Similarly the effect of cobb values of T_3 - bagasse + maize husk + cotton paper (79 g/m^2) exhibited high water absorption because of absorption capacity of bagasse, maize husk and cotton. Wherein, cellulose content of these fibre absorbs at least two times its weight of water and has comparable hydration capacity (Bakre, 2013). However, similar results were noticed in T_4 (Bagasse + sisal +cotton) and T_5 (Bagasse + waste paper + cotton) *i.e.* (43 g/m^2) and (47g/ m^2) respectively. The control sample *i.e,* pure cotton rags handmade paper exhibited greater folding endurance (57) than the blended fibres handmade papers. This may be due to fibre inherent microstructure and effective fibre bonding during pulping leads to even soft and pliable structure contributed better folding endurance property. The folding endurance value of the blended sheets was appreciable in T_4- Bagasse + Sisal + Cotton (28) followed by T_5 - Bagasse + Waste Paper + Cotton (22) and T3 - Bagasse + Maize husk + Cotton (20), respectively. This may be due to individual fibre properties and their bonding potential.

In the same way among the blended papers greater tear strength was found in T_5-bagasse + waste paper + cotton (181.2 dm^2), but, tear factor was slightly on far in T_4 - Bagasse + Sisal + Cotton (179.6) handmade paper. This may be explained by the predominance of stiff and hard sisal fibres would have better reinforcing property in paper making (Fagbemi, 2014). Whereas, T_3-bagasse + maize husk + cotton (97.6) possessed low levels of bonding which leads to lesser tear strength due to presence of maize husk. Among the combination fibre sheets T_4- Bagasse + Sisal fibre + Cotton sample possessed greater bursting strength compared to T_5- bagasse + waste paper + cotton (9.98 kg/cm^2), T_3- bagasse + maize husk + cotton (6.00 kg/cm^2), respectively. This may be due to presence of adequate number of strong and flexible sisal micro fibrils possessing greater ability to form effective bonding than the fibres from maize husk wherein, it has soft and pliable structure leads to least bursting strength. Tensile strength among all the blended papers greater strength was found in T_4- Bagasse + Sisal fibre + Cotton (2.28 kN/m) followed by T_5- bagasse + waste paper + cotton (1.88), T_1- pure cotton (1.66), T_2- Bagasse + Cotton (1.45) and T_3- bagasse + maize husk + cotton (1.06) papers. T_4 handmade paper showed greater strength due to the high fibre strength of sisal fibre (563.68 gf/tex) and bagasse fibre strength (329 gf/tex). Blending of sisal with bagasse and cotton pulp has been found to influence the sheet properties like burst factor, tear factor and tensile strength. Among the fibre blends bagasse: sisal: cotton pulp (40:30:30) was found to be more suitable for production of handmade paper with optimum physical properties and further subjected to large scale production for validation and cost feasibility.

Subjective evaluation of bagasse composite handmade papers

There is an immediate need for an efficient route with lower chemical load and energy with lesser levels of pollution with improvement of product quality is being felt and remedies to such type of problems are now answering by application of biotechnology using appropriate enzymes for specific applications during refining as per the process requirement. Among the fibre blends bagasse: sisal: cotton pulp (40:30:30) was found to be more suitable for production of handmade paper with optimum physical properties and further subjected to large scale production for validation and cost feasibility. Based on the sensory evaluation results, it was found that the blended handmade paper T_1, T_2 and T_4 possessed highly acceptable rating for colour, texture, durability and thickness. However, it was found that, the handmade paper T_3 possessed only acceptable rating, this may be due slight variation in colour and texture (Table 3). Based on the sensory evaluation results it can be stated that, the blended handmade paper were found to be on par with commercial handmade papers free from chemicals (Plate 2). Blending with recycled paper pulp also further increased the strength of the sheets with better textural properties reduced. However, conventional method of paper making uses high amount of chemicals and energy thereby

Table 1. Effect of fibre blending on physical properties of handmade composite paper

Treatments (mm)	Thickness (g/m^2)	Cobb endurance	Folding factor (dm^2)	Tear factor (kg/cm^2)	Burst strength (kN/m)	Tensile
T_1– Pure Cotton (Control)	320	16	57	207.6	15.3	1.66
T_2– Bagasse+Cotton	630	25	14	101.8	7.17	1.45
T_3– Bagasse +Maize husk+Cotton	692	79	20	97.6	6.00	1.06
T_4– Bagasse + Sisal fibre + Cotton	610	43	28	179.6	13.9	2.28
T_5– Bagasse + Waste paper + Cotton	668	47	22	181.2	9.98	1.88
S.Em.±	0.707	0.707	0.707	0.070	0.449	0.007
C.D. (5%)	2.085	2.085	2.085	0.208	1.325	0.020

releases toxic substances that cause environmental pollution (Pandita, *et. al*., 2015) which can be reduced by usage of other underutilized cellulosic fibres to overcome the pollution.

Preferences and suitability of bagasse composite handmade papers

Majority of the respondents stated that T_1 handmade paper was highly suitable for drawing paper for art work, card sheets and unique carry bags 30 (100%) followed by paper plates 25(83.33%). This may be due to textural appearance of the paper, which was prepared by pure cotton pulp can certainly imparts better surface properties than the other blended papers. Further, T_2 handmade paper was more suitable for utilities *viz.,* drawing sheets, unique carry bags, filter papers and file cover 30(100%) than the other paper products this may be due to bonding between fibre molecules and finishing effect of the paper. In the same way more number of respondents expressed that T_3 handmade was highly suitable for unique carry bags, paper plates, file covers and food wrappers due to surface quality of the paper and type of fibres used. Majority of the respondents accepted that T_4 handmade paper was highly suitable for unique carry bags, paper plates 3(100%), file covers 28(93.33%), drawing sheets 25(83.33%) and document paper 25 (83.33%) may be because of blending proportion bagasse, sisal and cotton pulp, fibre morphology and bonding between fibre molecules. Majority of the respondents stated that, the developed handmade paper was more suitable for production of carry bags, paper plates, file covers and food wrappers. Based on the results recommended paper was further used for production of paper bags and paper plates for commercial application (Table 3 and plate 2).

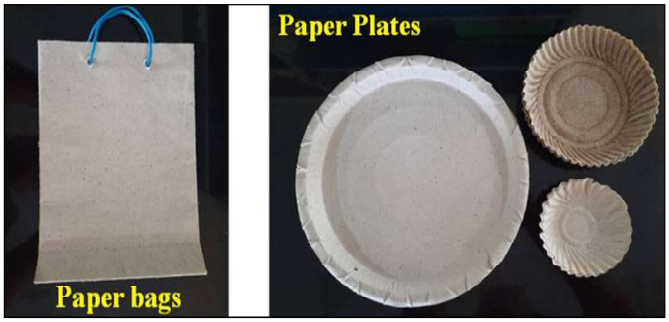


Plate 2. Development of handmade paper bags and plates

Production cost of pure and bagasse composite handmade papers

Production cost of bagasse: sisal: cotton pulp (40:30:30) blended handmade paper was found comparatively cheaper (Rs. 136/kg pulp) than commercial cotton handmade papers (Rs. 160/kg pulp) (Table 4). This may be due to variable cost was found to high in pure cotton pulp papers than the blended handmade fibres. Moreover, the rising cost of traditionally used cellulosic raw materials like cotton rags and hosiery waste, being used in handmade paper making is been forcing the industry to search for additional cellulosic raw materials for production of handmade paper which are available as waste biomass in different parts of the country. This should help in providing more opportunities for cost effective, locally available lingo-cellulosic raw materials / agro residues like bagasse there by addressing the problem of environment and the issue of global warming in a right prospective as stated by Kumar *et al*., (2013).

Table 2. Sensory evaluation of paper from pure cotton pulp and Bagasse + sisal + cotton pulp

Treatments	Physical properties (N= 30)			
	Texture	Colour	Durability	Thickness
T_1: Pure cotton 130 GSM	4.67	4.77	4.30	4.60
T_2: Pure cotton 200 GSM	4.80	4.80	4.43	4.63
T_3: Bagasse + Sisal + cotton pulp 130 GSM	3.45	3.38	3.50	3.80
T_4: Bagasse + Sisal + Cotton pulp 200 GSM	4.20	4.54	4.40	4.50
Mean	4.28 (HA)	4.37 (HA)	4.15(A)	4.38 (HA)
Std	0.562	0.605	0.415	0.384
F value	3.098**	3.238**	3.238**	3.490**

1.00 – 1.80 (U - Unacceptable), 1.81 – 2.60 (S U - Slightly Unacceptable), 2.61 – 3.40 (F A - Acceptable), 3.41 – 4.20 (A - Acceptable), 4.21 – 5.00 (H A - Highly Acceptable)

Table 3. Preferences and suitability of pure and blended handmade papers for various end utility

Various end products	Type of handmade papers			
	T1 (%)	T2 (%)	T3 (%)	T4 (%)
Drawing paper for art work	30 (100)	30(100)	20(66.66)	25(83.33)
Permanent Document paper	20(66.66)	25(83.33)	10(33.33)	25(83.33)
Card sheets	30 (100)	28(93.33)	16(53.33)	20(66.66)
Unique carry bags	30 (100)	30 (100)	30 (100)	30 (100)
Paper plates	25(83.33)	28(93.33)	30 (100)	30 (100)
Filter paper and pads	10(33.33)	30(100)	5(16.66)	8(26.66)
Insulation paper	15(50.00)	15(50.00)	5(16.66)	2 (6.66)
File covers 30 (100)	30 (100)	30 (100)	28(93.33)	
Food wrappers	30 (100)	15(50.00)	27(90.00)	18 (60.00)

T_1: Pure cotton (130 GSM), T_2: Pure cotton (200 GSM), T_3: Bagasse + Sisal + cotton pulp (130 GSM)
T_4: Bagasse + Sisal + Cotton pulp (200 GSM)

Table 4. Economic analysis of pure and blended handmade papers

Particulars	Quantity	Rate (Rs)	Amount(Rs)
Bagasse + Sisal + Cotton pulp (40:30:30) 22/32inch)			
Variable cost			
Bagasse	400 g	30/kg	12.00
Sisal	300 g	25/kg	7.50
Cotton pulp	300 g	80/kg	24.00
Processing charges	1 kg pulp	80/kg	80.00
Overhead expenses	1 kg pulp	@ 10 %	12.35
Total production cost			135.85 (136.00)
T_1 and T_2 : Pure cotton (130 and 180 GSM)			
Variable cost			
Cotton pulp	300 g	80.00/kg	80.00
Processing charges	1 kg pulp	80/kg	80.00
		Total production cost	160.00

Conclusion

Locally available eco-friendly renewable resources *viz.,* sugarcane bagasse, sisal fibre and maize husk, waste paper and cotton rags have been used for development of handmade papers with different blend proportions (60:40 and 40:30:30) and GSM. Bursting, tear and tensile strength was found to be greater in bagasse/ sisal/ cotton blended handmade paper (40:30:30) followed by bagasse/ maize husk/ cotton blended handmade paper than the baggase/ cotton and pure cotton paper. It was found that, among the fibre blends bagasse: sisal: cotton pulp (40:30:30) was found to be more suitable for production of handmade paper with optimum physical properties and further subjected to large scale production for validation and cost feasibility. Based on the sensory evaluation results, it was found that the blended handmade paper possessed acceptable rating for colour, texture, durability and thickness. Majority of the respondents were of the opined that, the developed handmade paper was more suitable for production of carry bags, paper plates, file covers and food wrappers.

The production cost of bagasse: sisal: cotton pulp (40:30:30) blended handmade paper was found comparatively cheaper than commercial cotton handmade papers. Hence, effective utilization of underutilised natural fibres for handmade paper making is an additional advantage of being amendable to conversion by environment friendly processes with an affordable cost and above all it provides sustainable enterprise for rural artisans.

References

Asagekar S D and Joshi V K, 2014, Characteristics of sugarcane fibres, *Indian Journal of Fibre and Textile Research*, 39:180-184.

Bakre L G, Quadri W G and Bamiro O A, 2013, Evaluation of cellulose obtained from maize husk as compressed tablet excipient, *Der Pharmacia Lettre,* 5(5):12-17.

Booth J E, 1996, Principles of Textile Testing. CBS Publishers & Distributors.

Chauhan Y, Sapkal R S, Sapkal V S, Zamre G S, 2009, Microcrystalline cellulose from cotton rags, *International Journal of Chemical Sciences,* 7(2):681-688.

Fagbemi O D, Otitoju O, Mgbachiuzor E and Igwe C C, (2014), 'Pulp and paper making potential of corn husk', *International Journal of Agricultural Science,* Vol. 04 No. 04 pp. 209- 213.

Kumar A, Singh B P, Jain R K, and Sharma A K, 2013, Banana Fibre (*Musa sapientum*): A suitable raw material for handmade paper industry via enzymatic refining. *International Journal of Engineering Research & Technology,* 2(10):1338-1350.

Mishra P, 2007, Effect of environment on mechanical properties of bagasse fibre reinforcement polymer composite, *Master thesis of Technology in Mechanical Engineering, Dept. of Mechanical Engineering, National Institute of Technology, Rourkela*.

Pandita S, Kaula B, Passey S, 2015, Use of weeds and agro-based raw materials and their blends for handmade paper making. *Journal of Undergraduate Research and Innovation*, 1(3):169-179.

Thomas J, Rainey T J, and Covey G, 2016, Pulp and paper production from sugarcane bagasse. *Sugarcane-based Biofuels and Bioproducts*, Wiley, ISBN: 9781118719824.