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Manufacture of ring spun blended yarn from waste biomass of sugarcane stalk (sugarcane bagasse)

PREETI KAUR SACHDEVA*[1], BHAWANA CHANANA[1] AND M.S. PARMAR[2]
Research Scholar and Associate Professor & Director (Academic)
[1]Department of Fabric and Apparel Science, Lady Irwin College,
University of Delhi, New Delhi (India)
[2]Northern India Textile Research Association, Raj Nagar, Ghaziabad (U.P.) India

ABSTRACT

The present monograph deals with the Solid Waste Management (SWM) of organic crop residue called bagasse left after crushing of sugarcane stalk for juice extraction. Crushed and milled bagasse was alkali delignified to extract purified cellulosic fibers. The study revealed that higher sodium hydroxide concentration (highly alkaline pH) and elevated temperature adversely affect the tenacity and length of fibers. Though, fineness may increase but the fibers loose strength to be spun into yarn. Fibers extracted with 1.5% (w/v) sodium hydroxide concentration for 60 minutes at boil with fiber fineness 13 tex and tenacity of 10.6 g/tex were ring spun into yarn. The blending was done in blow room in the fixed proportion of 30:70 sugarcane fibers: cotton/viscose fibers. Yarns with 13s count were developed on ring spinning frame. The ring spun yarns were evaluated for yarn count, tenacity and elongation. It was found that ring spun sugarcane: viscose yarn (30:70) has more tenacity and elongation in comparison to sugarcane: cotton (30:70) yarn.

Key Words : Cellulose, Delignification, Hemicellulose, Lignin, Lignocellulosics, Sugarcane fibers

INTRODUCTION

Organic solid waste generated after sugarcane processing is well known as bagasse. Bagasse is an unexplored abundant source of cellulosic textile fibers (Bhanu Rekha *et al.*, 2013). This kind of fiber is an unconventional source in nature as food and textile fiber are being considered for generation from the same cash crop. Fibers extracted from unconventional sources like agricultural residues (cornhusk, pineapple, banana, sugarcane, okra, barley, palm leaf, etc.) have the advantage of renewability, biodegradability, abundance, low cost, and reduced health hazard. In the last one decade itself these kinds of fibers have received considerable impetus with the possibility of replacing petroleum based synthetic fibers for textile applications (Oneyeagoro, 2012). The major constituent of plant origin fibers are cellulose, hemicellulose and lignin, thus often referred to as lignocellulosics (Reddy and Yang, 2005). Removal of lignin and conversion of hemicellulose into cellulose by alkaline and enzymatic delignification ultimately increases the cellulose content available in the fiber. Thus, fiber becomes absorbent, pliable and tensile to be used for high performance textile applications (Das *et al.*, 2010). Research on extraction of textile fibers from the above mentioned unconventional sources is an effort towards a bigger, least addressed menace of organic solid waste management

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of agricultural crop residues. Such experimental effort will bear duplicate advantage of supporting rural economy by value addition to waste product of agriculture as well as reducing ill effect on the health of environment by utilization of the solid waste generated during agricultural activity.

One of the largest agro-industrial by product is sugarcane bagasse. It is the fibrous residue of cane stalks (Paturau, 1989). It is composed of two morphologically different sections, *viz.*, rind and pith. The outer rind contains longer and finer fibres, and an inner pith of short fibres. In addition to cellulosic fibres in the sugarcane stalk, 18% lignin and 30% hemicelluloses are also present. Lignin is the cementing material which holds hemicelluloses and cellulose bind together. Initial studies by Collier and Collier (1998) shows that controlled removal of lignin and hemicelluloses (non- cellulosic fractions) on subjecting material to mechanical and chemical treatments separates the thin fibre bundles. Romanoschi (1998) has done extensive work on extraction of cellulosic fibres from sugarcane rind and studied the chemical and physical properties of extracted fibres. But no work is reported on extraction of sugarcane fibres in India and their use in textiles and allied products. Thus this research deals with development of the extracted sugarcane fibres in to yarn by ring spinning.

METHODOLOGY

Raw material and chemicals :

Crushed and milled sugarcane bagasse was collected from local juice vendors of East Delhi in the month of March. Laboratory grade sodium hydroxide and glacial acetic acid was procured from Merck. Silicon based softener was sourced from M/s Resil Chemicals Pvt. Ltd.

Extraction of sugarcane fibres :

The collected sugarcane bagasse consisted of two physically distinct components, *viz.*, an outer rind, which contains longer and finer fibres, and an inner pith of shorter fibres. Since, the outer rind is desired for fibre extraction, thus it is vital to remove pith from the collected sugarcane bagasse. The bagasse was retted for five days to make pith swell up. The swollen pith was manually removed and remaining rind was dried till constant moisture content of 10% achieved. The dried rind was cut from nodes. The rind was treated at different concentrations of sodium hydroxide (0.5, 1.0, 1.5 and 2.0%) for different temperatures (60, 75, 90° C and boiling) for time duration (30, 45, 60 and 90 minutes). The material to liquor ratio was maintained at 1:40 in all experiments. Alkali extracted fibres were thoroughly washed and neutralized with 10% acetic acid solution. After rinsing, fibres were thoroughly dried in ambient conditions. Parameters for fibre extraction were optimized on the basis of fibre fineness and strength. To make fibres soft and pliable, they were treated with modified polysiloxane based softener. The fibres were then blended with cotton and viscose to make ring spun yarn.

Assessment of physico- chemical properties :

The extracted sugarcane fibres were assessed for fibre fineness and bundle strength.

Fibre fineness:

Fibre fineness was measured according to IS: 3674. Fibre fineness was measured by calculating linear density of the representative fibre sample. Direct relation between weight and length was calculated to determine fineness in denier. First length of 20 fibres was noted and the same fibre bundle was weighed. The following relation was used to determine fineness.

$$\text{Denier} = \frac{\text{Weight (gm)}}{\text{Length (meter)}} \times 9000$$

***Bundle strength and elongation at break*:**

In natural fibres, due to lack of uniformity across the fibre length, fibre strength varies. Therefore, rather than analyzing single fibre strength, fibre bundle strength was taken as indicative. It was measured in grams per denier. It was determined as the force necessary to break fibres. It is an important parameter to judge the quality and strength of the resultant yarn. Stelometer was used to measure the force necessary to break the bundle of fibres. The instrument breaks a flat bundle of fibres and indicates the force required to break the fibres on a graduated scale. The elongation is determined on another graduated scale at the breaking point of the fibre sample. After determination of strength and elongation at break, the weight of the broken fibre bundle was taken and bundle strength was calculated as per the following relation:

$$\text{Tenacity} = \frac{\text{kg (Force)}}{\text{mg (Weight)}} \times 15$$

Moisture regain :

Moisture content was determined according to I.S -199 standards in triplicate.

Spinning of sugarcane blended yarn :

Extracted fibres were ring spun to form yarn. After various trials it was found that the 100% sugarcane fibres cannot be spun, thus blending with cotton and viscose was done manually. The composition of the blended fibres is given in Table 1. The manually blended fibres were fed into blow room for uniform and homogeneous mixing. The lap formed in the blow room was passed through carding and draw frame to form sliver. The sliver was formed into roving on simplex, and formed into ring spun yarn.

Table 1 : Fibre blend composition

Blend percentage	Code
30:70 sugarcane: cotton	SC
30:70 sugarcane: viscose	SV

RESULTS AND DISCUSSION

Extraction of sugarcane fibres :

The cellulosic fibres in sugarcane rind are interconnected with each other by lignin and hemicelluloses (Patra *et al.*, 2013) to form fibre bundles. Thus, removal of lignin and hemicelluloses is imperative for separation of fibre bundles. Extraction of sugarcane fibres was carried out using alkali extraction method. The optimum treatment conditions such as concentration of alkali (sodium hydroxide), temperature and treatment time were optimized on the basis of following results:

Effect of alkali concentration :

The optimum sodium hydroxide concentration was decided depending upon fibre fineness and bundle strength. In this experiment, temperature at boil and time 90 minutes were kept constant, while sodium hydroxide concentration was varied from 0.5 to 2.0% owf. At 0.5% owf sodium hydroxide concentration, fibres did not open well. They were in bundle form, which indicates presence of lignin and hemicelluloses. The effect of alkali concentration on fibre fineness and bundle strength are depicted in Fig. 1 and 2, respectively.

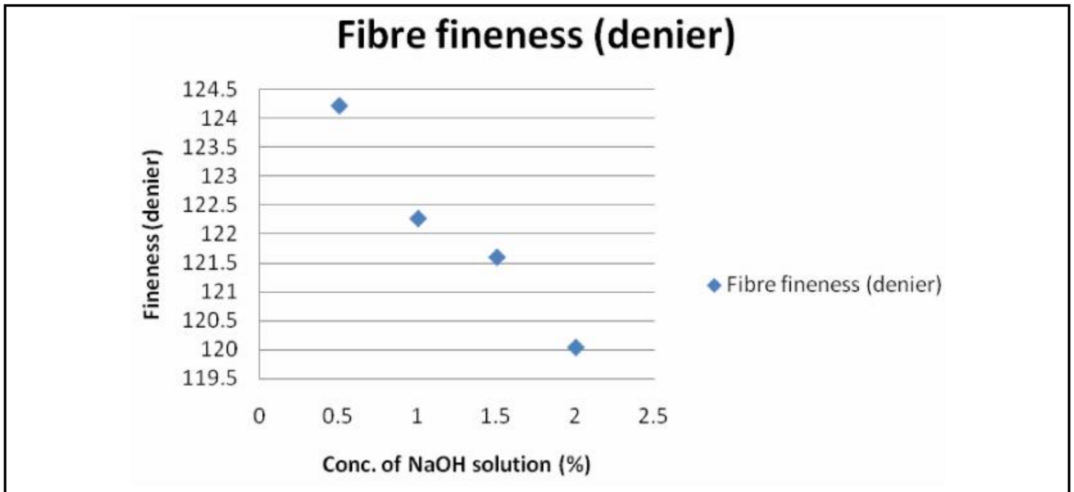

Fig. 1 : Effect of Sodium hydroxide concentration on fibre fineness

Earlier studies on sugarcane fibre extraction indicate increase in sodium hydroxide increases fineness but simultaneously the concentrated alkali affects cellulose polymer and thus length of fibres decrease with decrease in strength of the ultimate fibre (Collier and Collier, 1998). Same trend is evident from Fig. 1 and 2. With gradual increase in alkali concentration a sharp fall was witnessed in fineness and bundle strength. At 2% alkali concentration, the bundle strength dropped from 2 g/den (1.5% conc.) to 1 g/den. Thus, out of 1% and 1.5% concentration, latter concentration was optimized as it was found to give better fineness and bundle strength, both being important parameters for fibres to be spun into yarn.

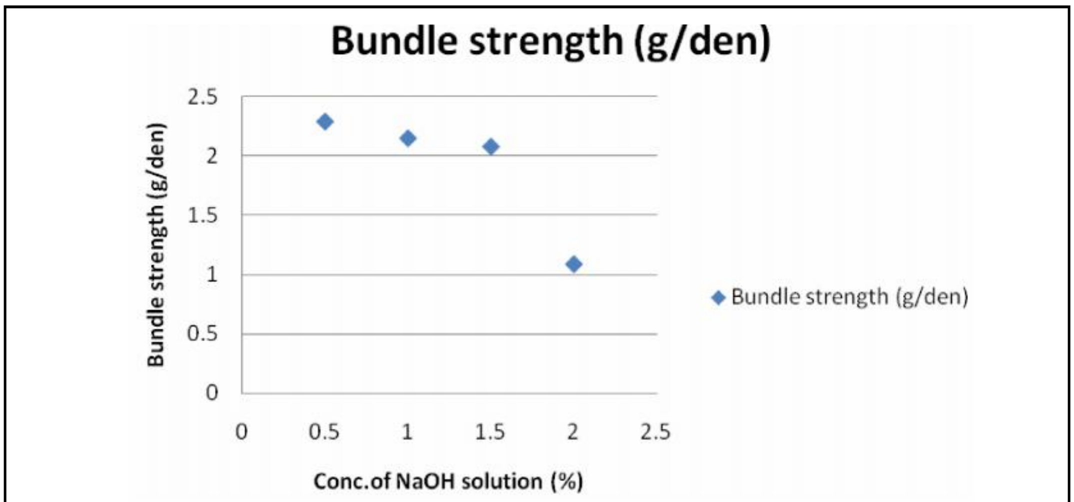

Fig. 2 : Effect of Sodium hydroxide concentration on bundle strength

Effect of temperature :

To optimize the extraction temperature, dried sugarcane rind (pith removed) was treated with 1.5% sodium hydroxide solution for 90 minutes at 60, 75, 90° C and boiling. It was found that at 60° C, bagasse rind did not disintegrate at all, at 75° C opening of rind started but the fibres were in bunches. At 90° C, the bunch of fibres opened up but very coarse fibres of 157.9 denier fineness were obtained. At boil, the fibres became clean, ultimate long finer fibres of 121 denier fineness were obtained. Thus, extraction temperature at boil was optimized for further studies.

Effect of treatment time :

For optimizing treatment time, concentration of sodium hydroxide (1.5% owf) and temperature boil) were kept constant and treatment time duration was varied (30, 60 and 90 minutes). With 30 minutes treatment time no disintegration of rind was visible. At 60 minutes treatment time, the fibres were obtained in thick bundle state. At 90 minutes treatment time, proper opening of fibre strands took place. The fibres obtained at 90 minutes treatment time, were opened completely and single fibre strand were obtained. Therefore, 90 minutes treatment time was selected for further study.

The optimized parameters for bulk extraction of sugarcane fibres from sugarcane rind were; 1.5 % owf alkali concentration, 90 minutes treatment time at boil.

Physical and chemical properties of extracted fibres :

The physico- chemical properties of the extracted sugarcane fibres were analyzed and compared with other cellulosic fibres (Table 2). For natural fibres, fineness is a major factor which influences cohesiveness. Finer fibres are soft and pliable than coarse fibres. From Table 1, it is clear that sugarcane fibres are coarser (121 denier) than all other cellulosic fibres, nearest to sugarcane is corn husk fibre with fineness of 86 denier. Tenacity of sugarcane fibres is in range of 2-3 g/den as other cellulosic fibres. This means sugarcane fibres are strong enough to be blended with other cellulosic fibres to be spun into yarn. The amount of stretch or extension on application of force that a fibre possesses is referred to as elongation. Sugarcane fibres have low elongation, *i.e.* 2.2% than cotton (6.7%) and viscose (30%) but higher than that of jute (1.2%). The fibres with low elongation tend to have low elastic recovery, thus made need frequent ironing if woven into fabric. The ability of bone dry fibre to absorb moisture is called moisture regain. Sugarcane fibres have 10.11% moisture regain, which makes these fibres comfortable to be used for clothing purpose as other cellulosic fibres. Higher moisture regain means good absorbency of dyes, special finishes, easy laundering and greater comfort in hot conditions (Sekhri, 2014). The higher surface area and capillary action contributes to higher regain value.

Table 2: Comparative fibre properties

Property	Test method	Sugarcane	Cotton	Viscose	Jute	Corn husk
Fibre fineness (denier)	IS:3674, ASTM D-1448	121.60	1.8	1.5	18	86
Tenacity (g/den)	ASTM D-1445, IS:3675	2.08	2.1	2.3	3.3	1.3
Moisture Regain %	IS 199	10.11	7.5	13.1	13.8	11.4
Elongation at break %	ASTM D-1445, IS:3675	2.2	6.7	30	1.2	18.5
Fibre length (cm)	IS:3674, ASTM D-1448	10-12	2.5- 3	4-5	22- 24	3- 4

Treatment of extracted sugarcane fibre with softener :

The fibres obtained were harsh in texture due to long treatment time with concentrated alkali solution. The modified polysiloxane micro emulsion was used to impart a smooth handle and reduce brittleness. Finish was applied by nip dip method as per material safety data provided by the company (Resil Pvt. Ltd.).

Ring spinning and yarn quality evaluation :

The extracted fibres have primary properties comparable to other cellulosic fibres (Table 2). Thus, the fibres were blended and ring spun without any modification (apart from softening). All the yarns had Z-twist. From Table 3 it is clear that the yarns spun with sugarcane were coarse, with sugarcane viscose yarn being finer than the sugarcane cotton yarn.

Table 3: Properties of blended ring spun yarn

Code	Count (Ne)	Twist per inch	Tenacity (g/tex)	Elongation (%)
SC	13.84	13	10.70	3.95
SV	11.19	14	12.28	16.38

Both the yarns manufactured are coarse due to presence of sugarcane fibres which are coarse fibres. SC yarn has lower tenacity 10.70 g/tex than SV yarn, 12.28 g/tex. The possible reason could be higher tenacity and elongation of viscose fibres than cotton. But, the tenacity of both yarns is comparable; it indicates good tenacity of sugarcane fibres. Similarly, SV yarn shows higher elongation value, *i.e.* 16.38% than SB yarn having elongation of 3.95% (Table 3).

Conclusion :

The experimental trails show that better extraction of cellulosic fibres from sugarcane rind takes place when treated with 1.5% sodium hydroxide at boil for 90 minutes. The fibres obtained are long, fine and strong to be spun into yarn. The fibres were seen to have high moisture regain property which makes them an alternative to cotton and other conventional cellulosic fibres used in textile Industry. The yarns produced from sugarcane had high tenacity, comparable to that of 100% polyester yarn, *i.e.* 13g/tex (Sowmya *et al.*, 2017).

Such yarns can be used to weave and knit fabrics of high GSM and used for clothing and home textile purpose.

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