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Development of Fabric from *Girardina Diversifolia* **Stem Fibres and its Blends**

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ABSTRACT: The use of unconventional lignocellulosic fibres for development of fabric and nonwovens has come into existence due to the great demand associated with conventional fibres like cotton and silk. Eco friendliness and sustainability are the concepts underlying textile manufacture and marketing of textile products. Designers, manufacturers and retailers are looking out for new raw materials and processes that will entice the consumers to walk into their selling outlets. Bioprocessing, which involves the use of enzymes in processing, is being widely adopted as a clean technology in manufacturing. This paper deals with the use of enzymes for the extraction of fibres from *Girardina Diversifolia*, the Himalayan Nettleplant bark obtained from Uttarkhand, India. The fibres have been bioscoured and biosoftened and blended with organic cotton/ bamboo (nettle: organic cotton and nettle: bamboo in the ratio 50:50) to make it suitable for open end spinning. The experimental fabrics were developed with 100% organic cotton yarns in the warp direction and the blended yarns in the weft direction ; 100% bamboo yarns in warp direction with the nettle blended yarns in the warp the weft direction. The physical and mechanical properties of the experimental fabrics were compared with that of the control fabrics. The experimental fabrics could be used for many applications where an aesthetic value is desired.

KEYWORDS: Lignocellulosic fibres, Bioretting, Open end spinning

I. INTRODUCTION

Nettle is a fibre yielding plant which is being grown by the Himalayan communities in Uttarkhand. These plants are also found in Jammu and Kashmir, Himachal Pradesh, Sikkim and Arunachala Pradesh in India. The Uttarkhand Bamboo and Fibre Development Board estimate that a total of seven hundred and seventy square kilometer area has naturally growing nettle which provides around 24,704.26 tons of raw dried fibre annually [1]. The global textile industry is looking out for other natural fibres sources to reduce its heavy reliance on cotton and silk. Jute, hemp and flax are some of the fibres that are being used extensively and India has realized the importance and potential of this naturally occurring nettle plant in the Himalayas and Tibet.

The Himalayan Nettle (Girardinadiversifolia) has been lately added to the list of possible commercial fibre producing plants having the advantage of being 100% sustainable. Many research institutes have conducted studies in cultivating and propagating nettle in a sustainable manner apart from developing commercial textiles. Nettle is a perennial plant which grows on nitrogenous soil and is resistant to diseases and pests thereby reducing the need for pesticides and pollutants to protect them. The PFAF research association, which provides information on ecologically sustainable horticulture, has provided information on the Himalayan Nettle as seen in Table 1 [2]. This plant is known as the Himalayan Nettle and grows in a moist and shady habitat in waste lands and forest areas in India, China and Malaysia. The fibre is obtained from the stem and is useful for making ropes, twine and coarse cloth. Figure 1 shows the picture of the Himalayan Nettle plant.



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 Table 1- Characteristics of Girardinadiversifolia[2]

Fig. 1. Nettle plant [2]

Particulars	Description				
Common Name	Himalayan Nettle				
Family	Urticaceae				
Synonyms	G.heterophylla, G.palmata.Gaud.Urticaheterophylla				
Habitats	Waste ground and shrubberies; moist, shady, forest areas				
	at elevations of 1200-3000 meters in Nepal				
Range	E.Asia- India to China and Malaysia				
Physical features	Annual perennial plant growing to 3m and flowers				
	(dioecious) during September to October				
Hazards	Virulant stinging hairs that cause skin problems				
Propagation	Seeds sown in beds grown to a certain height and				
riopogation	transplanted in the forest areas				
Lines	Cooked leaves – edible; roots for medicinal purposes; fibre				
Uses	from stem for coarse cloth, ropes and twine				



The fibre is obtained from the outer sheath of the stem of the nettle plant. The cut stem is dried and then retted in a pond and cleaned for further use. Hand spinning is undertaken and a kilo of yarn is produced in ten days [3]. Thefibre used for this study is Himalayan Nettle (*Girardinadiversifolia*) from Uttarkhand. The fibre collection is carried out by the Fibre user group from Van Panchayat Area at Uttarkhand is given in the Figures 2 and 3. The stems of the



Fig. 2: Mature Nettle Plants

Fig. 3: Collected Nettle Sticks



Fig. 4 -Nettle fibre with bark [2]

mature plant are cut and taken out separately for drying. The collected nettle sticks are dried thoroughly and the bark with fibres are separated from the nettle sticks manually and bundled together for further treatment as shown in Figure 4.

II. MATERIALS AND METHODS

2.1 Materials:

The raw material used was Himalayan Nettle fibres from the Van Panchayat area of the Uttarkhand region. The raw material was obtained from the outer sheath of the nettle plant and dried for further use. The nettle fibres were extracted from the dried raw material by enzymatic process. Blending of fibres was carried out to improve the properties of the fabrics to be developed from nettle fibres [4,5].

Two fibres organic cotton and bamboo were chosen for blending with the nettle fibres for yarn development. The properties of the nettle, bamboo and organic cotton fibres are given in Table 2.



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Table 2. Properties of nettle fibre, Bamboo fibre and Organic Cotton fibre

Properties	Nettle fibre	Bamboo fibre	Organic Cotton fibre
Length (mm)	10-90	40	29.6
Diameter (µm)	2.5	1.22	3.9
Strength (gf/tex)	33.5	24.2	25
Elongation (mm)	2.7	5.02	1.86

The enzymes chosen for the study were from M/s. Novozymes, Denmark. Viscozyme L, a brown liquid, is a multi-enzyme complex containing a wide range of carbohydrases including arabanase, cellulase, beta-glucanase, hemicellulase and xylanase. This enzyme is produced from a selected strain of Aspergillus aculeatus. The enzymes present in Viscozyme L has the ability to liberate bound materials and to degrade non-starch polysaccharides thereby seperating plant materials [6]. Enzyme arabanase has the ability to partially degrade the linkages present in the primary cell wall polysaccharides [7]. The cellulase enzyme is involved in the hydrolysis of cellulose by the transfer of cellodextrins, glucose and cellobiose from the surface of the cellulose particles to the aqueous phase and the hydrolysis of cellodextrins and cellobiose into glucose in the aqueous phase. The crystalline regions of cellulose are difficult to degrade and hence cellulase enzyme is used to enhance the process [8, 9]. Xylanases are responsible for the cleavage of the xylan backbone into smaller xyloglucan oligosaccharides which can be further degraded to xylose [10]. It has been reported that endoglucanases change the cell wall architecture ranging from wall expansion to dissolution [11]. Reports state that anaerobic microorganisms have evolved a system to break down plant cell walls by the formation of large extracelllular enzyme complex called cellulosomes that have many potential biotechnological applications. Cellulases and hemicellulases along with other enzymes are capable of systemic degradation of cell wall and cellulose [12,13,14]. Endo glucanases are used for the partial degradation of cell walls β -glucans in animal feed production and in industrial processes such as malting and brewing [15]. Viscozyme L was used for the extraction of fibre from the sheath covering the stem of the plant.

Bioscouring and biosoftening of the fibres was carried out using Scourzyme L and Cellusoft L. Scourzyme L, a brown liquid, is a pectate Lyase (EC 4.2.2.2), CAS No. 9015-75-2, produced by the submerged fermentation of a genetically modified Bacillus micro organsim. This enzyme helps in removing the impurities by breaking down the pectin in the primary cell wall of cotton without any degradation of the cellulose and has no negative effects on the strength of the fibre [16]. Cellusoft L, a brown liquid, is a cellulase (EC 3.2.1.4), CAS No. 9012-54-8, produced by submerged fermentation of a Trichoderma micro organism. This enzyme helps in biopolishing of cotton fabrics where controlled hydrolysis of the cellulosic fibres is carried out to modify the fabric surface [17].

2.2 Methods:

2.2.1. Nettle Fibre Extraction and Pretreatment : The nettle fibres were extracted from the dried sheath surrounding the stem of the nettle plant. The box and benkhen statistical design, Minitab 17 software, was used to determine the enzyme dosage for extraction of the fibre from the stem sheath on the basis of parameters like strength and flexural rigidity of the extracted fibre. The results of the box and benkhen design showed that the enzyme gave best results with 0.3% (owm) on the weight of the material used. Wetting oil (3 gpl) and a chelating agent (4 gpl), the required enzyme and the moistened nettle raw material was taken in the Gyro washing machine with a material liquor ratio of 1: 10. The pH was maintained at 4.5 -5.0, temperature at 55°C and the time for working the fibre was 45 minutes. After 45 minutes the water was drained followed by a hot water rinse for 15 minutes at 70°C to deactivate the enzyme and a cold water rinse at 35° C for 15 min. Figures 5,6,7 show the different stages of extraction of fibre from the outer sheath of the plant stem. The untreated sheath collected from the dried stems of the nettle plant is shown in figure 5. The action of the enzyme is clearly seen by the seperation of the fibres from the sheath after bio retting as in figure 6.



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Fig. 5 Dried untreated sheath



Fig. 6 Fibre seperation from sheath after bioretting

The bioretted fibers were allowed to dry and were seperated manually for pretreatment as in figure 7. The pretreatment of the fibre included bioscouring to remove the impurities present in the fibre and bio softening to reduce the flexural rigidity of the fibre. Bioscouring with Scourzyme L was carried out with 0.4 gpl enzyme, wetting agent 0.5 gpl with a pH maintained at 8.5, temperature 55° C for 30 minutes. The bath was drained and refilled followed by the enzymatic treatment with Cellusoft L. The bath for bio softening had enzyme 2% owf (on weight of material) and sequesterant 0.5% owf with temperature 50° C, pH 4.5 – 5 and time 40 minutes. This was followed by a hot rinse at 70° C for 15 minutes to deactivate the enzyme followed by a cold rinse at 35° C for 15 minutes. The fibres were dried and kept ready for yarn development. Figure 8 shows the bioretted fibres after the pretreatment process of bio scouring and bio softening.



Fig.7 Manual Seperation of the fibres



Fig. 8 Bioscoured and biosoftened Fibres

2.2.1 Yarn development

Open end spinning was used for yarn development. The open end spinning system is used for unconventional fibres that have structural problems and may result in coarse to medium counts [18]. After the enzymic pretreatment the flexural rigidity of the nettle fibre reduced by around 11 %. Many trials were undertaken to find the best blend ratio foryarn development and the optimum results were found in the ratio 50:50 nettle fibre :organic cotton and 50:50 nettle

Carding - Likerin speed	Open end spinning
Feed : 0.5000	Yarn count : 8 – 10
Cylinder speed : 860	Feed Hank : 10
Doffer speed (for lap) : 0.32	Twist Direction : Z
Doffer speed (for sliver): 0.37	Open roller speed : 30,000
	rpm

Fable 3	Machine	settings f	for ope	n end spi	nning of	sample yarns
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Yarn length : 5000 m



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fibre :bamboo. The yarn development was carried out using the Trytex Rotor Spinning machine with the machine settings as given in Table 3 . Yarns of similar count were developed from 100% organic cotton and 100% bamboo to be used as control for comparison of properties with the nettle/bamboo and nettle/organic cotton blended yarns. Figure 11 shows the lab model open end spinning machine in the KCT- TIFAC CORE research center.



Fig 11 Open end spinning machine

2.2.3. Fabric Development

Four different samples were developed using the handloom with the nomenclature and combinations given in Table 4. The nomenclature OC and B were assigned for the control fabrics and NOC and NB for the experimental fabrics.

Particulars		Yarn	is used		Fabric Samples		
	100% 100%		50:50=	50:50	Warp	Weft	nomenclature
	OC	В	N: OC	N: B	_		
Yarn Nomenclature	OC	В	NOC	NB			
Sample 1	✓				OC	OC	Control OC
Sample 2		√			В	В	Control B
Sample 3	✓		✓		OC	NOC	Expt. NOC
Sample 4		√		✓	В		Expt. NB

Table 4. Nomenclature of the control and experimental fabrics

From the table it can be understood that the control fabrics were developed from 100% organic cotton yarns in the warp and weft direction and 100% bamboo yarns in the warp and weft directions. The experimental fabrics had 100% organic cotton yarns in the warp direction and 50:50 nettle/organic cotton yarns in the weft direction; 100% bamboo yarns in the warp direction and 50:50 nettle/organic nettle/organic cotton.

2.2.4. Testing

The testing was done in the yarn and fabric stages. Yarns were tested for count (Test method -IS:1315 (1977), twist (Test method-IS:832-2 (2011), strength and elongation (Test method- ASTM D2256 (2007). The developed fabrics were tested for physical and mechanical properties namely fabric count, fabric thickness (Test method -ASTM D1777-96 (2002), drape (Test method –IS 8357 (1977), fabric stiffness (Test method ASTM- D 1388 (2007), Crease recovery (Test method BS 3086 (1979), Abrasion resistance (Test method ASTM D 4158 – 08 (2012), Strength and elongation (Test method ASTM D5035-11 (2007).

2.2.5. Statistical Analysis

The t test was carried out for all the test results to determine if the two sets of data (control and experiment samples) were significantly different [19].



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III.RESULTS AND DISCUSSION

3.1. Yarn test results

The results of the yarn tests carried out are given in table 5. The table shows an increase in strength in the yarns NOC and NB when compared to the respective control yarns by 4.5% and 4.9% respectively. This increase may be due to the higher strength observed in the nettle fibreswhen compared to the other two fibres bamboo and organic cotton. A drop

Table 5 :	Properties of 100%	% organic cotton	, 100% bamboo ai	nd the nettle	fibre blended yarns
			/		•/

Sl. No.	Yarn tests	100% Organic Cotton(OC)	50:50= Nettle: Organic Cotton (NOC)	100% Bamboo (B)	50:50 Nettle : Bamboo (NB)
1.	Count	10s	9.8s	10s	9.9s
2.	TPI	31.8	29.82	32.16	30.71
3.	Single yarn strength (gf/tex)	63.21	66.25	64.96	67.62
4.	Elongation (mm)	21.27	17.23	32.16	30.71

in elongation is observed in the blended yarns which may be due to the flexural rigidity of the fibre which is higher in the case of nettle fibre. In order to improve the flexibility of the fibre, to facilitate spinning, biosoftening was undertaken.

3.2. Fabric Test Results

The fabric test results namely fabric count, thickness, drape, flexural rigidity and crease recovery are given in Table 6. The number of yarns in the blended fabrics are slightly lower than the control fabrics as there is a difference in the yarn count. Meagre differences are noticed in the thickness and drape of the control and experimental fabrics. In

		-					
SI.	Fabric tests	Control	Expt.	% gain/loss	Control	Expt.	% gain/loss
No.		OC	NOC	over control	В	NB	over control
1.	Ends per cm	16	14	-12.5*	16	14	-12.5*
2.	Picks per cm	11	9	-18.18*	12	10	-16.6*
3.	Thickness (mm)	0.581	0.576	-6.02*	0.374	0.354	-5.34*
4.	Drape	0.99	0.86	-0.13*	0.95	0.84	-0.11*
5.	Flexural rigidity(mg.cm) Warp	468.7	350.98	-25.11*	391.96	316.25	-19.31*
	Flexural rigidity(mg.cm) Weft	189.99	134.35	-29.28*	414.599	349.22	-15.76*
6.	Crease Recovery - Warp	133.9	132	-1.41*	121.25	118.4	-2.40*
	Crease Recovery - Weft	116.5	116.1	-0.34*	113.25	109.9	-3.04*

 Table 6 Properties of the 100% organic cotton and bamboo Control fabrics and Experimental Fabrics from nettle blended varns

general, the flexural rigidity is lower in both the warp and the weft direction; the reduction in the weft direction is greater showing that the bio pretreatment of the fibres have a positive effect on the experimental fabrics. However higher drape co-efficients are seen in both the control when compared to the experimental fabrics which may be accounted to the lower yarn counts used in the experimental fabrics [20]. When the control and experimental fabrics are compared there is a slight reduction in draper co-efficients in both NOC and NB fabrics by 0.13% and 0.11% respectively. The crease recovery angle is lower in the experimental fabrics when compared with the respective control fabrics indicating that they will crease easily [21]. In almost all the test results evaluated , the 't' results were significant at 1% level.

The abrasion resistance, strength and elongation of the developed fabric samples are given in Table 6 and Figure 12.An increase in values was noticed in abrasion resistance, strength and elongation in the experimental



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fabrics when compared with the control fabrics in both the organic cotton and bamboo fabrics. A higher strength can benoticed in the experimental fabrics in both the blends when compared to the control fabrics which may be due to

 Table 6 - Abrasion Resistance, Strength and Elongation properties of the Control and Experimental Fabrics

Sl.	Fabric tests	Control	Expt.	% gain/loss	Control	Expt.	% gain/loss
No.		OC	NÔC	over control	В	NB	over control
1.	Abrasion Resistance	81.89	84.43	3.10%*	86.60	90.27	4.23%*
2.	Tensile Strength(kgf) Warp	24.90	27.63	14.21%*	33.43	36.85	10.23%*
	Tensile Strength(Kgf) Weft	14.80	16.45	11.1%*	25.41	27.98	10.1%*
3.	Elongation (mm) Warp	22.13	23.96	8.26%*	15.13	16.27	7.53%*
4.	Elongation (mm)Weft	12.41	14.74	18.7%*	28.39	30.45	7.25%*



*Significant at 1% level



the higher strength in the *Girardina Diversifolia* fibres. Many reports state that this fibre has been used for the manufacture of cords, belts and sail cloth in earlier times. Another point that is highlighted here is that the elongation of fabric in both the experimental fabrics show higher values in the weft direction when compared to the control fabrics which may be attributed to the bio softening process given to nettle fibres used in the blended yarns in the weft direction. The t test results also show that the significance level is at 1% in most of the tests conducted.

IV. CONCLUSION

The results show that the enzyme processed nettle fibres from the *Girardina Diversifolia* plants, could be blended in the ratio 50:50 with other fibres to produce 10s count yarn. After enzyme treatment the flexural rigidity of the fibre has reduced to make it suitable for open end spinning. The control fabrics are useful in comparing the results



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of the fabrics with blended yarns. However the count is low and the applications of the fabric developed would be suitable for the outer covering of functional articles like files, bags and other articles which require an artistic look. It can be used for home textiles and for partitions with frames that support the fabric. It can be used for technical applications similar to jute as the fibre is basically strong and for textile fibre composites. A great deal of research can be done in the area of natural lignocellulosic fibres by addressing the lignin content of the fibres with enzymes to make it suitable for spinning. Availability of enzymes for textile processing is a major drawback as the required enzymes are not available freely like other textile chemicals and auxillaries. Further the impact of the purity of enzymes and the combination of enzymes for textile use is an important area of research. Enzymes, the protein building blocks, can perform ideal tasks in the field of fibre extraction and modification leading to usage of unconventional fibres in technical textiles and apparels.

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