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Extraction of Fibres for Development of Yarns from Plant-Waste Material: Ashoka (*Polyalthia longifolia*)

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Authors' contributions

This work was carried out in collaboration between both authors. Author LR designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author KB managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

The present study was focused on the development of blended yarns using ashoka bast fibres extracted from pruned ashoka plant-waste material, the usefulness of which was hardly explored for the purpose. Unethical and un-thoughtful disposal of huge amount of a plant waste is causing multiple hazards through deterioration of the environment and consequently, the public health. Development of textile textures from plant-waste may help in addressing to this problem, in addition to providing self-employment through entrepreneurship development in related products. The study was focused on chemical extraction of ashoka (*P. longifolia*) fibres and properties of blended yarns. Ashoka barks were treated in 3% alkali solution (1:20 MLR) at a high temperature (100–120ºC) for 2.5 hours. Softening of fibres was done with silicone emulsion (0.5% by weight of fibres) at room temperature. High denier value for ashoka fibres (76.45) and bundle strength (24.75 g/tex) were observed. Length of ashoka fibres (59.64 mm) was more than the wool fibres with moisture content 9.70%. The extracted ashoka fibres were hand spun in two types of yarns-ashoka (100%) and the blend of ashoka/wool (50:50). Higher tenacity (1.09 gf/tex) and breaking force (892.0 gf/denier) of 100% ashoka yarn were found

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in comparison to 50A:50W blended yarn. Furthermore, higher yarn count 1.77s was observed in case of 50A:50W. Both the yarns were considered suitable for developing fabrics for home textiles and apparel.

Keywords: Extraction; plant waste; ashoka fibres; blends and wool.

1. INTRODUCTION

India is an agrarian nation where major part of the arable ground is used for agriculture and diverse crops are cultivated in different regions of the country. The plant waste materials include orchard and vineyard prunings, vegetable by-products from farming, residual fruits, vegetable residues, and other crop remains after the usable crop is harvested, other plant wastes from canneries, wineries, or other industrial sources [1,2]. Plant residues left in the field after harvesting of produce, trimmings and plant parts discarded during pruning operations, weeds, surplus plants from thinning operations lead to tremendous plant waste materials. The potential of using the enormous raw material for extraction of textile fibres is unexplored. Use of sustainable resources helps in minimizing the dependence on natural resources. Many studies have been conducted not only on development of commercial textiles using plant fibres, but also on the growth and propagation of the plant material in most sustainable manners [3]. Through waste management, the plant residues are allocated at the suitable place and time to render as profitable products. It is therefore evident that new applications need to be found for plant residues. Ashoka (*P. longifolia*), a perennial plant, exhibits symmetrical pyramidal growth with willowy pendulous branches [4]. The ashoka stem is rounded to oval, and some cracks are present on the surface. It does require pruning in order to maintain its tall and straight main trunk with short, drooping branches. Generally, it is pruned all over the year and huge amounts of plant-waste are allowed to decay in the open. Ashoka bark being biodegradable, sustainable and recyclable is suitable for extraction of green fibres. Greater acceptance of such materials is expected during the recent times due to persistent issues of the climate changes and regulatory measures for the clean environment and utilization of renewable resources.

Even during Lakme Fashion Week in 2018, Indian designers presented their collections with special interest on the use of fabrics from non-conventional fibres. In the European countries, high-fashion houses are rediscovering the ecological and high-quality textiles produced from the plant fibres such as jute, nettle, hemp, agave, etc [5]. In addition, the small-scale entrepreneurs can also provide indirect income to the farmers who grow plants and crops in their fields [6]. Plant and agro-waste therefore, can be a boon if appropriately utilized. It is capable to provide multidimensional products, with a variety of end uses ensuring employment in various segments [7]. In Punjab and Haryana, the waste materials from plants and crops available are wheat, corn and paddy straws, leaves, corn dollies, grasses, plant straws, and pruned branches, etc. which were used to make products mainly for domestic consumption. However, these can be utilized more profitably through product diversification and design development.

Such a method may helps to increase income in the- agribusiness because the plant wastes of ashoka (stem) are rich in fibres. Ashoka plants are resistant to any diseases and vermin and therefore do not require any contaminating pesticides. Usually, this plant residue is not used and has no appropriate destination. So, the present study is undertaken with the below mentioned objectives for utilization of ashoka plant waste to the benefit of mankind.

- To extract textile fibres from bark of pruned ashoka plant *(P. longifolia)*
- To study the physical parameters of extracted fibres and developed ashoka yarns.

2. MATERIALS AND METHODS

2.1 Procurement of Materials

Pruned ashoka stems were procured from Punjab Agricultural University Campus, Ludhiana to extract the fibres. Wool fibres were procured from the Dev Woollen Mills, Ludhiana. The chemicals procured from Thames Chemicals, Ludhiana (Punjab) for extraction of ashoka fibres were sodium hydroxide (NaOH), acetic acid, silicone emulsion, sodium hypochlorite (NaClO).

2.2 Extraction of Ashoka Fibres

Chemical process was followed to extract the ashoka fibres. Fresh ashoka stems were washed with distilled water. To extract fibres from bark (Fig. 1a), the raw material was treated in 3% NaOH solution keeping material to liquor ratio 1:20 at 100–120ºC for 2.5 hours and was rinsed thoroughly. The residue was neutralized with 5% acetic acid and rinsed again to set pH 7. The fibres were bleached by the cold process at room temperature using sodium hypochlorite (NaClO) with 1:10 material to liquor ratio for 7-8 hours. The bleached fibres (Fig. 1b) were washed thoroughly with distilled water and then dried in air. The fibres were treated with silicone emulsion (0.5% by weight of fibres) at room temperature to make these soft and pliable for spinning.

2.2.1 Process for development of blended yarns

Blending, carding and spinning processes were carried out in Uttarakhand Bamboo and Fibre Development Board (UBFDB), Dehradun for the development of yarns [8]. To obtain the blend of ashoka fibres with wool fibres in the ratio of 50a:50w, the fibres were opened in the blow room and carded. The card silvers were then handspun on *Charkha* (spinning wheel) to make yarns (Fig. 2).

2.2.2 Testing of extracted fibres and blended yarns

The testing of physical properties of the extracted fibres and blended yarns was done at North Indian Textile and Research Association (NITRA), Ghaziabad using standard testing methods which are given below.

2.2.2.1 Fibre properties

Fibre denier (ASTM-1577:2007), Bundle strength (ASTM 3776), Fibre length (IS: 10014(pt.2) (Reaffirmed-1999), Moisture content (IS: 1670-91(Reaffirmed-2007), breaking strength, elongation at break, tenacity and Young's modules [9-11].

2.2.2.2 Yarn properties

Yarn count (IS: 1315-1977 (Reaffirmed-1999), Yarn TPI (IS: 832-1985 (Reaffirmed-2006), Breaking force (IS: 1670-91(Reaffirmed-2007), Elongation at break (IS: 1670-91 (Reaffirmed-2007) [9-11].

(a) Ashoka stem **(b) Bark of pruned ashoka stems** **(b) Bleached ashoka fibres**

Fig. 1 (a-c). Ashoka stem, ashoka bark and bleached ashoka fibres

(a) Hand spun ashoka bleached yarn (100% ashoka) **(b) Ashoka bleached yarn (50Ashoka:50Wool)**

Fig. 2 (a-b). Ashoka hand spun yarns

2.2.2.3 Fibre morphology

The degummed fibres were observed under the microscope fitted with micrometer scale for measurement of fibre length, width and wall thickness and lumen width.

2.2.2.4 Scanning Electronic Microscopic (SEM)

Fibres were separated and mounted on specimen holders with the help of electro-conductive tapes. The samples were coated with gold in an ion sputter coater (Hitachi S-3400N) in low vacuum with layer 150-200 nm thick, and observed in JEOL, JSM-35M-35CF electron microscope at 15 KV an accelerating potential. The Scanning Electron Microscope (SEM) is a type of electron microscope capable of producing high resolution image of a sample surface. SEM images have a characteristic three-dimensional appearance and are useful for judging the surface structure of the sample.

3. RESULTS AND DISCUSSION

3.1 Evaluation of Fibre Properties of Ashoka

This section includes microscopic and micrographic study of the structural properties with respect to longitudinal images of the fibres through scanning electron microscopy (SEM). The physical properties examined are linear densities (denier), bundle strength, breaking strength, elongation at the break, tenacity, length and moisture content.

3.1.1 Analysis of structural properties of ashoka fibres through microscopic images and Scanning Electron Microscopy (SEM)

The stem of the ashoka plant consists of two main parts, a central woody core, and a surrounding cortex which contains the bast fibres (Fig. 1a).

3.1.1.1 Microscopic structure of ashoka fibre

Ashoka fibre under an optical microscope looks like cylindrical filaments with uneven edges. The filament shows nodes at intervals. In fact, it looks like bamboo sticks joined transversely at places resulting into a little unevenness (Fig. 3).

3.1.1.2 Scanning Electron Microscopic (SEM) structure of ashoka fibres

The fibre structure was analyzed in scanning electron microscopic (SEM). The plate shows light grey areas, the matrix (dark grey areas) and the air filled voids described as porosity areas (black areas). It has been observed from the Fig. 4 a-c that the ashoka fibre is irregular with two or more longitudinal striations. The white areas showed the lignin or gummy substance present on the surface of the fibres. There were some occasional pores visible in the surface of the fibres. The cross section of the ashoka fibre cell is polygonal with slightly rounded corner. Robson reported that fibre of the bundle length varied between 60-100 nm implying that within the length of bundle there will be several ultimate fibres joined end to end and side by side with natural binding materials such as lignin, wax and pectineus material [12]. Fig. 4 a-c showed cross-sectional and longitudinal views of ashoka fibres, and also it shows the spiral annular vessels.

3.2 Visual and Tactile Properties of the Extracted Ashoka Fibres

Ashoka fibres were examined for their visual and tactile properties, which are very necessary to understand the end uses for their application. Ashoka fibres have somewhat wool like texture and gave a feeling of warmth when touched. The natural colour of the ashoka fibres is brown. It has a comparatively rough surface.

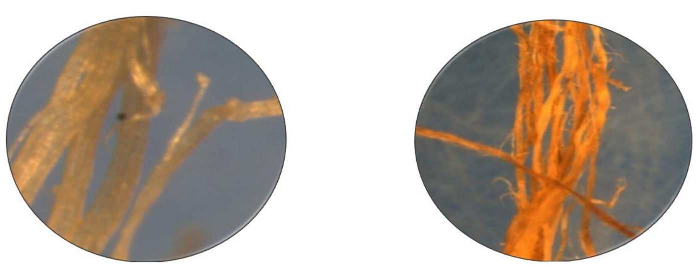
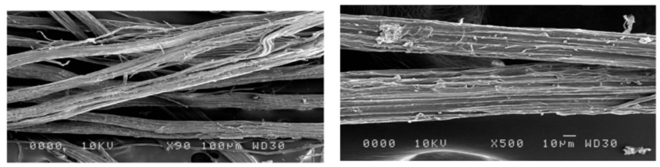
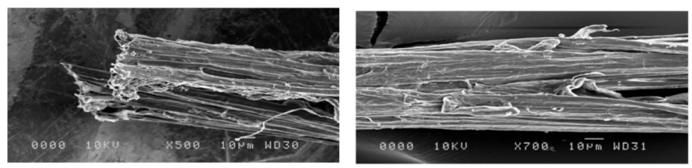


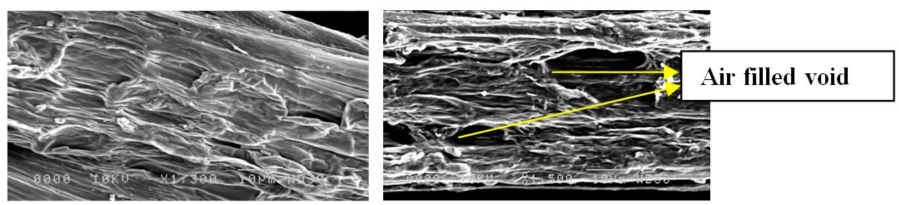
Fig. 3. Microscopic structure of ashoka fibres



(a) SEM of ashoka fibre (Ashoka fibre with X 90 and X 500 magnification)



(b) SEM of ashoka fibre with X 700 magnification and cross section of ashoka fibre (X 500)



(c) Ashoka fibre with X 1300 and X 1500 magnification

Fig. 4 (a-c). Scanning electronic microscopic (SEM) structure of ashoka fibres

Table 1. Physical parameters of ashoka fibres

Test Parameters	Ashoka fibre	Wool
Fibre denier CV (%)	76.45 ± 20.17 26.38	27.43 23.55
Bundle strength (g/tex)	59.64	51.00
CV (%)	49.32	11.50
Fibre length (mm)	24.75	-
Moisture content (%)	9.70	13.8

**CV=Coefficient of variation,*

Fineness is of the one most important fibre properties because it determines how many fibres may be present in the cross-section of a yarn of given thickness. The fineness of the fibre directly affects the properties of resultant yarn and fabric. It is evident from the data presented in Table 1 that the denier value of ashoka fibres was 76.45**±** 20.17 and CV%- 26.38. Thus, it is coarser than wool. The ashoka fibres had more length (24.75 mm) as compared to wool fibres. Fibre strength is the next important property after the fibre denier. Among the extracted fibres, the bundle strength of the ashoka fibres was higher (59.64 g/tex) than that of wool fibres (51.00 g/tex). Thus, blending of wool with ashoka is likely to improve the strength of resultant yarn.

The main drawback of natural fibres is their hydrophilic nature as a result of their high cellulose content which contains free Hydroxyl (OH-) polar group in their structure. This radical readily combines with free Oxygen (O2) to form water, which is why they have high water absorption capacity which affects their compatibility with the hydrophobic polymer matrices [13-16]. Ku et al [13] have shown that moisture greatly affects the tensile properties of plant fibre. The moisture content of the fibres is the most important and desirable property for comfort. It was observed that moisture content of ashoka fibres and wool fibres had 9.70 % and13.8%, respectively. Bamboo and sisal fibres have almost same moisture content (9.16% and 9.76%) which is just closer to moisture content of ashoka (9.70) [17].

3.3 Mechanical Properties of Extracted Ashoka Fibres

The mechanical properties of the extracted fibres have been presented in Table 2.

Table 2. Mechanical parameters of ashoka fibres

Mechanical properties		Ashoka fibre	Wool fibres
Breaking strength (g)		159.48 ± 63.03	35.79
CV (%)		39.52	31.83
Elongation at break (%)		5.78 ± 1.67	1.31
CV (%)		28.98	-
Tenacity (gm/denier)		2.05 ± 0.55	46.21
CV (%)		26.99	17.50
Young's modulus	(2%)	48.70 ± 11.48	-
	CV (%)	23.57	
	(5%)	24.64 ± 19.11	-
	CV (%)	77.58	

**CV=Coefficient of variation*

The data in Table 2 presents the mechanical properties of the extracted fibres from ashoka bark. Breaking strength for ashoka fibre was 159.48 g and CV%-63.03% whereas that of wool fibres was found to be 35.79 g and CV%- 31.83. The results shown that the ashoka fibres have higher breaking strength compared to wool fibres. This might be partially due to its higher denier as compared to wool fibres.

Tenacity and elongation are two most important physical properties which are of great importance in evaluating the quality of raw fibre and suitability of the fibre for yarn making or other textile applications. The knowledge of these properties are very essential to researchers who wish to develop natural or man-made fibres with specific or improved characteristics. Ashoka fibres and wool fibres had the elongation of 5.78± 1.67% and 1.31%, respectively (Table 2). Thus, ashoka fibre had much higher elongation at break as well. The tenacity of the ashoka fibre was 2.05± 0.55 g/denier, which was much lower than that of the wool fibres (46.21±17.50 gm/denier). Some researchers showed that the viscose rayon fibres have almost the same tenacity (2.0-2.6 gm/denier) as ashoka fibres. The stress strain curve of both fibres showed the point of breaking under the maximum strain. Young's modulus for ashoka fibres was 48.70 ± 11.48 at 2 per cent and 24.64 ± 19.11 at 5 per cent. Ashoka fibre also revealed higher extensibility at 2 per cent.

3.4 Physical Properties of Developed Ashoka Blended Yarns (Ashoka 100% and Ashoka/Wool (50:50)

3.4.1 Analysis of physical properties of ashoka pure and blended yarns

The higher TPI (5.99±0.17) was found in case of A_1 (ashoka 100%) yarn with CV%- 8.45 followed by TPI 8.01± 0.62 in case of A_2 (ashoka/wool 50:50) yarn with CV%- 23.05. The difference in TPI of A_1 and A_2 was statistically significant (p≤. 05). Higher count (1.77s) was observed in single ply A_2 yarns with blending ratio ashoka/wool (50:50) whereas, the count of single ply A_1 (100% ashoka) yarn was 0.72s.

Table 3. Physical properties of ashoka pure and blended union yarns

Physical Properties	Proportions		
	Ashoka yarns (100%) A_1	Ashoka/wool (50:50) A_2	t-value
Yarn TPI	5.99±0.17	8.01± 0.62	3.73**
CV (%)	8.45	23.05	
Twist direction	Z	Z	
Breaking force (gf/denier)	892.0 ± 92.75	442.6 ± 73.50	2.75*
CV (%)	42.2	47.0	
Elongation at break (%)	2.40 ± 0.33	3.04 ± 0.72	0.76
CV (%)	42.2	66.8	
Tenacity RKM (gf/tex)	1.09 ± 0.12	1.30 ± 0.22	0.75
CV (%)	32.9	47.0	

**CV=Coefficient of variation **, *=Significant at 5 per cent and 1per cent level of significance, respectively*
A_1= Ashoka (100%), A_2W= Ashoka/wool (50:50)

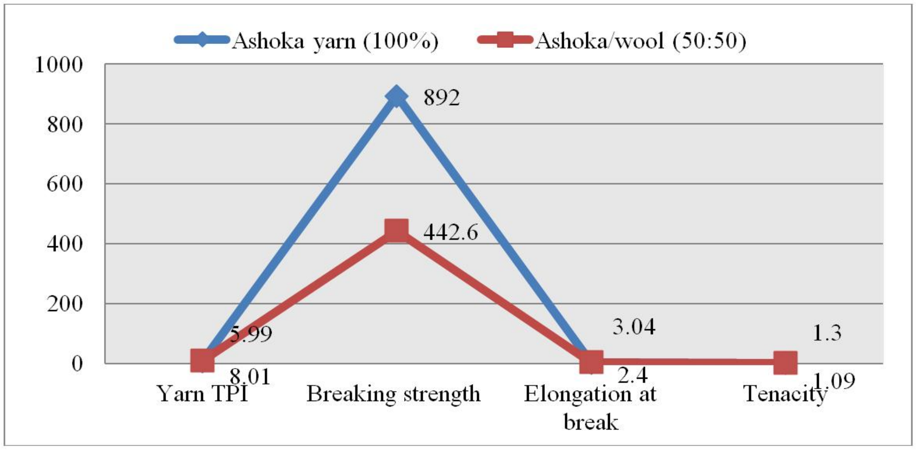


Fig. 5. Physical properties of ashoka pure and blended yarns

The experimental results showed that A_1 yarn exhibited higher breaking strength than A_2 blended yarn. The higher mean value of breaking force of A_1yarn was observed 892.0 ± 92.75gf/denier as compared to the A_2 (50:50) blended yarn 442.6 ± 73.50gf/denier. The higher elongation percentage (3.04 ± 0.72%) was found in blended A_2 (ashoka/wool) yarn as compared to the 100 per cent ashoka A_1 yarn, which had 2.40±0.33 per cent elongation at break (Table 3). The lower elongation of the A_1 yarn might be due to its polymeric configuration or stiffness.

Also, higher tenacity 1.30±0.22 gf/tex was observed in the blended A_2 yarn (ashoka/wool) as compared to the A_1 yarn (ashoka 100%) was (1.09±0.12 gf/tex). Yarn strength directly depended on the fibre strength [18]. It is clear that higher tenacity was obtained in blended yarns due to the presence of wool fibres in the blend than pure ashoka yarns.

4. CONCLUSION

The physical and mechanical properties of ashoka plant fibres have been studied and found suitable for yarn making. It is concluded that the extracted fibres were suitable for blending with wool owing to harsh and warm tactile properties resembling wool. Higher bundle and breaking strength, elongation and good moisture content in combination with sufficient fibre length render. These fibres are suitable for textile use. Low tenacity of the ashoka fibres was closer to that of viscose rayon fibres, i.e. 2.0-2.6 gm/denier. The chemically extracted ashoka fibres were found to be adequate for developing heavyweight fabrics for home-textiles and clothing applications like blazer, jackets and stoles.

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COMPETING INTERESTS

Author have declared that no competing interests exist.

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