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Development of Yarns from Plant-Waste Material China-Rose (*Hibiscus rosa-sinensis*)

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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 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 undertaken to address the issues of plant-waste utilization to the benefit of mankind. The ultimate aim of plant-waste management is to make its best utilization through useful product development. The study focused on the chemical extraction of china-rose (*Hibiscus rosa-sinensis*) fibres and studying the properties of its pure and blended yarns. China-rose bark was treated in 2.5% alkali solution (1:20 MLR) at a high temperature (100–120°C) for 2.5 hours. Softening of fibres was done with silicone emulsion (0.5% by weight of fibres) at room temperature. Higher denier values (69.12) and bundle strength (22.50 g/tex) were observed for china-rose fibres. Length of china-rose fibres (54.40 mm) was longer than cotton fibres with a moisture content 12.17%. The extracted china-rose fibres were hand spun in two types of yarns, i.e., 100% china-rose (100%) and blending with cotton at a ratio of 50H: 50C. Higher tenacity (2.49 gf/tex) and lower breaking force (512.2 g) of cotton blended yarn were found in comparison to 100% china-rose yarn. Besides, higher yarn count 2.89s was observed in case of 50H: 50C blended yarn. It can be concluded from the study that the blending of cotton with pure china-rose fibres increased the yarn's strength and elongation at break, making the yarn less stiff. Study of the physical and mechanical properties of yarn showed that it can be used for making heavy weight fabrics for home textiles and apparel.

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Keywords: Extraction; plant waste; china-rose fibres; cotton fibre; blended yarns.

1. INTRODUCTION

Hibiscus rosa-sinensis is commonly known as china rose, which is a large genus of shrubs widely distributed in the tropical and subtropical regions of the world. Out of 160 species, about 40 species occur in India. Many *Hibiscus* species are valued as ornamental plants and are cultivated in gardens throughout the tropical and subtropical regions. *H. cannabinus* and *H. sabdariffa* are important sources of commercial fibres. Plants which are compact/bushy in appreaence are maintained as hedges and require frequent pruning [1]. The bark of china-rose plant contains strong bast fibres, which can be harvested by removing the outer bark from pruned branches and scraping out the inner fibre layers. The fibres provide structural strength to the phloem, which carries the sugar produced during photosynthesis around the plant [2]. Other Hibiscus species, including *Hibiscus tiliaceus* which is commonly known as Hau plant, also provide strong fibres that were traditionally used to produce cordage [3].

Over the last few years, with the growing awareness of global warming, biodegradable fashion brands and bio-fabric fashion shows have sprouted up around the world. Sustainable clothing is not only a concern for western nations, but is gaining prominence in rising economies such as India and China. During Lakme Fashion Week (2018) in India, Indian designers presented their collections with special interest on the use of fabrics from non-conventional fibres such as nettle, organic cotton and yak, and merino wool [4]. Sustainable fashion in India is not just about being eco-friendly, organic fabrics cut in a certain way, but it's about bringing the smallest producers to the forefront, giving them empowerment opportunities, opening up the supply chain model and creating something that everyone can buy and consume. Natural fibres have wide range of application in the field of textiles, particularly in the light of recent global inclination towards sustainable textiles. User-friendly fabrics are gradually gaining importance and consumers are continuously looking for bio-degradable and recyclable textiles to preserve the natural environment, flora and fauna. However, reports of china-rose plant fibre extraction have not been found in the literature till date. The need to study the fibre properties was realized to produce variegated products for commercialization. The present study was planned with the below mentioned objectives.

- To extract textile fibres from the bark of pruned china-rose plant (*H. rosa-sinensis).*
- To study the physical parameters of extracted fibres and develop china-rose yarns.

2. MATERIALS AND METHODS

2.1 Procurement of Materials

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

2.2 Extraction of China-rose fibres

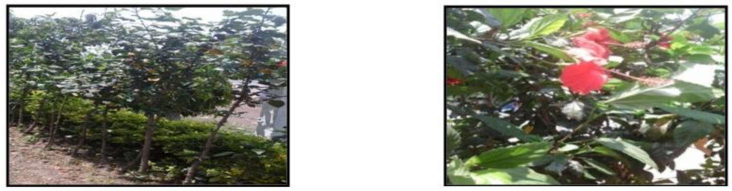
Chemical processing was done to extract the china-rose fibres from the bark. Fresh china-rose stems were washed with distilled water and the raw materials were treated in 3% NaOH solution keeping the material to liquor ratio 1:20 at 100–120°C for 2.5 hours. The residue was rinsed thoroughly and neutralized with 5% acetic acid. It was rinsed again to set the pH at 7. The fibres were treated with silicone emulsion (0.5% by weight of fibres) at room temperature to make them soft and pliable for spinning.

2.2.1 Process for development of blended yarns

Blending, carding and spinning processes were carried out in the laboratory of Uttarakhand Bamboo Fibre Development Board (UBFDB), Dehradun for the development of yarns [5]. To obtain the blend of china-rose fibres with cotton fibres in the ratio of 50H: 50C, the fibres were opened in the blow room and carded. The card silver was then handspun on *Charkha* (spinning wheel) to make 100% china-rose and 50H: 50C yarns (Fig. 3).

2.2.2 Testing of extracted fibres and blended yarns

The physical properties of the extracted fibres and blended yarns were examined at the laboratory of North Indian Textile and Research Association (NITRA), Ghaziabad using the standard testing methods as discussed below [6].



(a) China-rose plant (*Hibiscus rosa-sinensis*)

(b) Pruned china-rose stems **(c) Close view of china-rose stem**

Fig 1. (a-c) china-rose plant and pruned stems

(a) Bark of china-rose stems **(b) Chemically extracted china-rose fibres**

Fig. 2. (a-b) China-rose bark and extracted fibres

(a) Hand spun china-rose bleached yarn(100% china-rose yarn) **(b) Hand spun china-rose bleached yarn (50 china-rose: 50 cotton)**

Fig. 3. (a-b) China-rose hand spun yarns

2.2.2.1 Fibre properties

Such as 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 [7,8,9] were studied.

2.2.2.2 Yarn properties

Such as 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) [7,8,9] were tested.

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 the 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 150-200 nm thick layer, and observed in JEOL, JSM-35M-35CF electron microscope at 15 KV accelerating potential. The Scanning Electron Microscope (SEM) is 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 china-rose

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 examined physical properties are linear density (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 china-rose plant consists of two main parts, a central woody core, and a surrounding cortex which contains the bast fibres (Fig 1c).

3.1.1.1 Microscopic structure of the china-rose fibre

Morphology of textile fibres includes the study of the size, shape and structure of textile fibres, observed under a microscope. Fibre morphology influences fabric characteristics and performance and the process that will be used in producing a finished fabric. Under the microscope, china-rose fibre appeared cylindrical with many irregularities, thick and uneven cell walls (Fig. 4). The cell wall appeared as dark region. The fibres were rod like with broken lines with gummy substances inside the fibres.

3.1.1.2 Scanning Electron Microscopy (SEM) structure of china-rose fibres

It is clear from the micrographic structure of the fibre that what appears as a single fibre to the naked eye is in fact a bundle of fibres, consisting of a number of ultimate fibres or cells, five or six in this case. This arrangement of cells makes the cross-section of fibre bundle much polygonal than circular. For this particular fibre bundle, the average cross section was found to be 10 µm. As shown in Fig 5a-c, the cross-section of almost all the fibres is polygonal. A similar polygonal cross section has also been observed in flax fibres and hemp [10], which are also bast fibres like china-rose. Therefore, taking the average width of the fibres and using it as average diameter can give erroneous results for evaluation of tensile properties of fibres.

3.2 Visual and Tactile Properties of the Extracted China-rose fibres

China-rose, as bast fibre, was easily spinnable into pure yarns. These cream coloured fibres were found to be long, strong with comfortable soft and smooth textured. These fibres were considered suitable for blending with cotton.

China-rose fibres were obtained under the optimum conditions of treatment with 2.5% alkali solution (1:20 material to liquor ratio) at 100-120°C for 2.5 hours. It is evident from the data presented in Table 1 that the fibre fineness of china-rose (69.12 ±18.68 denier and CV%-27.03) was suitable for weaving heavier blended textile materials than what could have been possible from the blending fibres. The fineness of the fibre directly affects the properties of resultant yarn and fabric. According to Franck [11], the physical properties of the fibres are the key factors in deciding the end-use to which fibres could be put and utilised for exploiting their potential to the maximum. Franck highlighted that the nettle fibres ranging between 20-80 denier with tenacity 5.65g/denier was found to be suitable for home textiles and technical applications. The denier values for the bast fibres such as ramie (16-125), and sisal (100-400) were reported to be suitable for the home textiles [11].

Fig 4. Microscopic structure of china-rose fibres

(a) SEM of China-rose fibre (China-rose bundle fibres with X 90 and X 270 magnification)

(b) China-rose stem fibre with X 1000 and cross section view of fibre (X 750 magnification)

(c) Cross-sectional view of china-rose fibre with X 1500 and X 3000 magnification

Fig 5. (a-c) Scanning electronic microscopic (SEM) structure of china-rose

Table 1. Physical parameters of china-rose and cotton fibres used for blending

Test parameters	China-rose fibres	Cotton fibres
Fibre denier	69.12 ± 18.68	1.75
CV (%)	27.03	27.08
Bundle strength (g/tex)	22.50	21.10
Fibre length (mm)	54.40	28.00
CV (%)	49.35	13.00
Moisture content (%)	12.17	7.34

**CV=Coefficient of variation*

Fibre strength is the next important property after the fibre denier. The china-rose fibres had more length 54.40 mm with CV%, 49.35 as compared to the cotton fibres with bundle strength of 22.50 g/tex. Moisture content in the fibres is the most important and desirable property for comfort. It was observed that the moisture content of china-rose fibres was 12.17%. The china-rose fibres possessed the highest moisture content in contrast to other non-conventional fibres such as flex (10%), hemp (10%), nettle (9.8%), kenaf (10%) and sisal (10%). Moisture content of china-rose fibres was found to be close to jute (12.1%) [12,13].

The data in Table 2 presents the mechanical properties of the extracted fibres from china-rose stems. Breaking strength for china-rose fibres was found to be 135.02± 66.79 g and CV%, 49.46, whereas breaking strength of cotton fibres was 4.75 g and CV%, 37.88. The results depicted that china-rose fibres had much higher breaking strength as compared to cotton fibres. This might be partially due to its higher denier as compared to the cotton fibres.

China-rose and cotton fibres had the elongation of 2.90 ± 1.50% and 7.33%, respectively (Table 2). Thus, china-rose fibre had much lower elongation at break. The higher elongation of cotton fibres is due to the coiled molecular structure and the waves and bends in the fibre. The tenacity of the china-rose fibre was 2.00 ± 1.01 g/denier which were lower than that of the cotton fibre. The stress strain curve of both the fibres showed the point of breaking at the maximum strain. Young's modulus for the china-rose was 59.15 ± 61.44 at 2% and 7.43 ± 24.10 at 5%. It has been reported in studies that Young's modulus of *hibiscus cannabinus* was 21696.1 which is very high. So, it is suitable for applications in paper industry, geotech, mobiltech and aerobic fabric applications [14].

3.3 Analysis of Physical Properties of Developed China-rose (100%) and China-rose/cotton (50:50)

Yarn H_1 (china-rose 100%) exhibited lower twists per inch with the mean value of 5.46±0.20 and it increased up to 9.30± 0.33 when 50% cotton was blended with it (Table 3). Statistically, the difference in twists per inch between H_1 and blended H_2 yarns was significant at 5 per cent level indicating significant increase in twists on blending china-rose fibres with cotton. Higher yarn count (2.89s) was observed in single ply H_2 yarn with blending ratio of 50:50 (china-rose/cotton) whereas, the yarn count of single ply H_1 (100% china-rose) yarn was 0.73s.

Table 2. Mechanical parameters of china-rose and cotton fibres used for blending

Mechanical properties		China-rose fibres	Cotton fibres
Breaking strength (g)		135.02 ± 66.79	4.75
CV (%)		49.46	37.88
Elongation at break (%)		2.90 ± 1.50	7.33
CV (%)		51.88	34.62
Tenacity (gm/denier)		2.00 ± 1.01	2.84
CV (%)		50.55	-
Young's modulus	(2%)	59.15 ± 61.44	-
	CV (%)	103.86	
	(5%)	7.43 ± 24.10	-
	CV (%)	324.43	

**CV=Coefficient of variation*

Table 3. Physical properties of china-rose pure and blended yarns

Physical properties	Proportions		
	China-rose (100%) ,H_1	China-rose/cotton (50:50) H_2	T-value
Yarn TPI	5.46±0.20	9.30± 0.33	13.21**
CV (%)	11.21	10.87	
Twist direction	Z	Z	
Breaking force (g)	1236.0 ± 130.22	519.2 ± 63.32	4.45**
CV (%)	29.8	34.5	
Elongation at break (%)	2.40 ± 0.26	3.88 ± 0.36	3.464*
CV (%)	30.6	26.7	
Tenacity RKM (gf/tex)	1.53 ± 0.17	2.49 ± 0.31	2.500*
CV (%)	29.8	34.5	

**CV=Coefficient of variation **, *=Significant at 5 per cent and 1per cent level of significance, respectively*
H_1= China-rose (100%), H_2= China-rose/cotton (50:50)

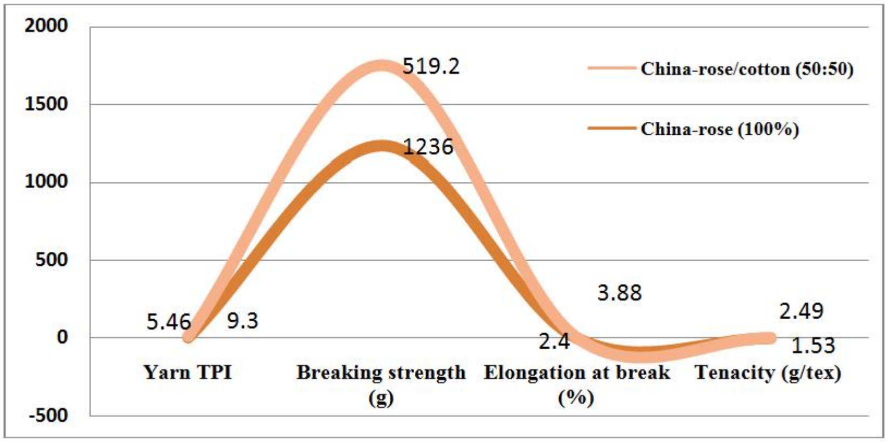


Fig. 1. Physical properties of pure china-rose and blended yarns

It is general practice to estimate the spinning performance of any yarn by breaking force values. It was observed that the breaking force value of H_1 yarn was higher (1236.0±130.22 g) than H_2 yarn (519.2±63.32 g) (Table 2). The mean difference in breaking force of the blended yarn and pure yarn was found to be significant (4.45 g). The blended H_2 (china-rose/cotton) yarn exhibited significantly (at 5% level) higher elongation (3.88%±0.36) as compared to H_1 yarn (2.40%±0.26). The tenacity of blended H_2 yarn and H_1 yarn was found 2.49±0.31 gf/tex and 1.53±0.17gf/tex, respectively. The difference in the tenacity of H_1 and H_2 blended yarns was found significant at 5% level. Zhang (2003) reported that blending cotton into pure kenaf yarn can increase yarn's strength and elongation at break, and make the yarn less stiff [15].

4. CONCLUSION

It can be concluded from the above study that the blending of cotton with pure china-rose fibres can increase yarn's strength and elongation at break, and make the yarn less stiff. The physical and mechanical properties of yarn showed that it can be used for making fabric and other products like jackets, shawls, stoles and mufflers coats and home-textiles, e.g. cushion covers, rugs, table runners, mats and accessories such as tote bags, purses.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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