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TECHNOLOGY FOR FIBER EXTRACTION FROM AQUATIC WASTE – NOVEL MATERIAL FOR SUSTAINABLE TEXTILES

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Abstract

Lotus (*Nelumbo Nucifera Gaertn.*) is an aquatic perennial plant. Cultivation of Lotus generates lot of petiole waste. Petiole contains xylem cells in which soft lustrous fiber is assembled in helical form. Fibers were found promising for textile applications. Extraction of Lotus fiber by hand is practised by the small communities of Manipur, Myanmar, Vietnam and Cambodia which hinders to take this fiber for mass production. The aim of the study was to design and fabricate semi-automatic apparatus for extracting fiber. Two different apparatus was designed and fabricated by the researchers. Four different fine count of 100 % Lotus yarn were developed from apparatus 1. Two different types of coarser count of blended Lotus yarn were developed from the fibers extracted from apparatus 2. Four union and two blended lotus fabrics were prepared on Powerloom. Developed yarns and fabrics were tested for its quality as per ASTM standards.

Results revealed that both the apparatus was found successful. It has accelerated the production and meanwhile it has a capacity to obtain good quality raw materials. Fabrics was found promising in terms of strength, comfort and serviceability. Union fabrics were light in weight and superior in strength. Blended fabrics has good elongation property. Kawabata test suggested that fabrics can be used commercially for "women's suiting". Moving towards sustainability, not a single drop of chemical was used in the entire manufacturing process. Development of apparatus has solved the major drawback of Lotus fiber manufacturing. Small scale industry can be developed near the Lotus ponds. Skill of extracting and developing yarn can be imparted to rural peoples which will be way towards economy, empowerment and environment: 3E's. Textile and fashion industry always urge for new raw materials. Hence with this scientific and systematic line of technology, Lotus fiber can be taken in global fashion World.

Keywords: Lotus, Fiber, Sustainability, Fabric, yarn, Technology.

1. Introduction

The natural fibre segment is expected to grow the most with a CAGR of 5.6 per cent in terms of volume during the period 2022-2027. Diverse range of natural fibers is produced in India which provides an important source of livelihood for farmers and local communities. One of the major challenges in working towards new sources of natural fibers is the systematic processing lines. Natural fibers suffer from extensive manual operations and use of semi-automatic primitive machinery [1]. The aims of National fiber policy 2010-2011 is to increase the fiber availability in the country and resolve all the problems associated with the different fibers. The policy includes strengthening of modernization and technological upgradation in the processing of different fibers (Natural & Man-made) [2]. Nature has gifted us wide and diverse range of plants that are grown in various agro-climatic zones that has potential for extraction of fibers from stems [3]. Entire nation is consistently working towards sustainable development goals which needs to be fulfilled by 2030. Lotus

is the national flower of India. These precious fibers extracted from the petioles of national flower needs to be studied in the scientific manner. From the cited literature it was analyzed that, the very base line problem with the Lotus fiber is the time-consuming extraction process. This draws attention to design and develop machines (with different mechanisms) for fiber extraction and yarn development. Power loom is the key invention of the industrial revolution. It is one of the important segments of the textile industry in terms of production of fabric and generating employment. Any novel fiber should not only restrict to handlooms. The entire textile and fashion sector is very fast. Fashion changes in minutes. Designers and garment manufacturers always try to get the raw material that is fabric on time. The yarns should consist of certain characteristic for smooth production in power loom weaving. Till now, the Lotus fibers are only used for handmade fabrics in few countries. By implementing Lotus fiber in power loom weaving will open the wide opportunities to produce fabrics for various end uses. The main aim of the study was to develop good quality Lotus yarn which was produced from the fabricated machine. Majorly for the power loom weaving minor fibers does not go in its pure form, the particular raw material needs to be processed and blending with the other fibers is required to withstand stress of power loom weaving. The inherent quality of the Lotus fiber along with the technological implementation leads to successful fabric development on power loom.

2. Objectives of the study

a) To design and fabricate apparatus for extraction of fibres.
b) To develop pure and blended Lotus yarns and test its properties.
c) To construct union and blended Lotus fabric.

3. Literature review

The review of literature collected was discussed under the following sub sections: -

Win, S. (2020) conducted the study on Lotus fiber production in Sunn Ye Inn, Sintgaing Township, Mandalay region of Myanmar using the descriptive study design. Results revealed that Lotus plant Nelumbo Nucifera Gaertn. (Padonma Kya) in three different colors: white, red, pink were found abundantly at Sunn Ye Inn village. Petioles were long and rough with distinct prickles. Villagers harvest most of the suitable stems by boat four times a day. The fiber extraction was carried out mostly by women. In the extraction process, the stems were wrapped in the water soaked cloth for the whole day to prevent it from drying. Fourty five pieces of stems were put together on a small table and cut with the small knife to extract fiber which reveals 20-30 fine filaments. Later the fibers were hung to dry. One Lotus extractor produces 250 m of thread daily earning 10000 kyaats. One pack weight 8-10 grams per day which was continuously transported to Taunggyi and Innlay in Shan state. It was concluded that Lotus plant provides the job opportunities and better income for the villagers of Sunn Ye Inn area of Myanmar [4].

Dhama, A., & Singh, S. (2022) conducted the exploratory research on Lotus silk fabric – A luxurious fabric for high Fashion (Indian Silk 30-33). The attempt has been made to study the Lotus fiber with following objectives – Foundation, history and manufacturing process of Lotus fabric, reason of being a luxurious fabric, sustainability of Lotus Silk fabric and its life cycle assessment. To fulfill the objectives researchers did the secondary research. History depicts that Lotus fiber was originally originated from Myanmar and now this fabric making process is practiced by the small cottage industry of Japan, China, Vietnam and India. It is generally practiced by the women due to the expertise and patience. Due to the scare availability and labor-intensive process the fabric has remain exclusive. Manufacturing of Lotus fiber practiced till now is the exhaustive and labor-intensive

process. Life cycle assessment revealed that Lotus fibers has many superior properties and advantages as compare to other conventional textile materials but the only disadvantage is high price due to exhaustive and labour-intensive extraction process. It was further suggested in the research paper that there should be a comparative study done on Lotus Silk fiber with other natural fibers [5].

Hlaing, C.S. (2016) did the anthropological study on Lotus Robe in Kyaing Inlay lake, Shan state (South). Results revealed that according to buddhist doctrine when the world came into existence five buds appeared in Lotus plant an each contained a complete set of Thingan Pareikaya (Prescribed items used for buddhist monks). History revealed that 50-year-old women first observed this Lotus fiber. It was considered sacred. There are two varieties of Lotus a plant found: large Kyar Padommar and small Kyar Padommar. Before drawing the fibers, women must firstly clean herself and women cannot pull fiber during the menstrual cycle. Drawing fibers from Lotus needs great patience and probably it was not suitable for young women. It takes a long time for drawing Lotus fibers. It was believed that by offering the Lotus fiber robe, it would bring prosperity and good health. The robe is only used for the religious item. It was found that Innthar nationals at kyaing khan village adapt their environment for living and trying to hand over the traditional customs to next generation [6].

4. Methodology

The research is experimental in nature. Following methods were followed for the research:

a) **Collection of raw material:** petioles were collected from the lotus cultivators of Vadodara district of Gujarat.

b) **Construction of apparatus:** Two different apparatus were designed and constructed by the researchers in which one of the apparatuses consists of dual mechanism in which extraction of fibers and yarns were done simultaneously and another apparatus was developed for fiber extraction only. For the construction of both the apparatus assistance was taken from electrical and robotic engineer.

c) **Fiber and yarn development and its testing:** In the varying speed, four different counts of 100 % Lotus yarn were prepared from Apparatus 1. Raw fibers were extracted from apparatus 2. Raw fibers were further subjected for open end spinning for developing blended yarns with Cotton fiber in two different proportions that is 50:50 (Lotus:Cotton) and 70:30 (Lotus: Cotton)

Developed yarns were tested for strength, fineness and twist as per ASTM D – 885. Testing was done in the textile testing lab of Department of Textile Technology, Faculty of Technology, The Maharaja Sayajirao University of Baroda. Details of the yarn developed are mentioned in Table 1:

Table 1: Details of the yarn

Sr. No.	Type of yarn	Composition
1	MYHS1	100 % Lotus
2	MYHS2	
3	MYMS	
4	MYLS	
5	LRY (50:50)	50 % Lotus and 50 % Cotton
6	LRY (70:30)	70 % Lotus and 30 % Cotton

MYHS1 - Machine yarn high speed 1
MYHS2 - Machine yarn high speed 2
MYMS - Machine yarn moderate speed
MYLS - Machine yarn low speed
LRY (50:50) – Lotus rotor yarn: 50 % Lotus 50% Cotton
LRY (70:30) – Lotus rotor yarn: 70 % Lotus 30 % Cotton

d) **Fabric construction and testing:** Total six fabric were prepared on powerloom in which four union and two blended fabrics were prepared. The fabrics were tested for its properties: fabric count, thickness, cover factor, GSM, drape, shrinkage, pilling, abrasion, tensile and tearing strength. These testing was done in Textile testing lab of Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda.

Kawabata test was also done at CIRCOT, Mumbai for assessing the commercial application for this novel Lotus fabric. Details of the constructed fabrics are mentioned in Table 2:

Table 2: Details of the constructed fabrics

Sr. No.	Fabric	Warp	Weft
1	PL -1	100 % Cotton 80's	3/70's Lotus
2	PL -2	100 % Cotton 70's	3/60's Lotus
3	PL -3	100 % Cotton 40's	3/30's Lotus
4	PL -4	100 % Cotton 20's	3/28's Lotus
5	BL -5	50:50 Lotus: Cotton blended rotor spun yarn	
6	BL -6	70:30 Lotus: Cotton blended rotor spun yarn	

PL - 1 : Powerloom Lotus fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's
PL – 2 : Powerloom Lotus fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)
PL – 3 : Powerloom Lotus fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)
PL - 4 : Powerloom Lotus fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)
BL – 5 : Blended Lotus fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)
BL – 6 : Blended Lotus fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

5. Analysis and findings

Global population today relies on eco-sustainability. The natural fiber obtained from Lotus petiole represents sustainability in true sense. The research was aimed to utilize the aquatic waste that is Lotus petioles for textile applications. The major drawback of Lotus fiber is tedious and time-consuming extraction process. Hence two machines (with different mechanism) were designed and fabricated. The machine -1 was specifically designed for extracting and spinning the yarns simultaneously one at a time. Different counts of yarns were obtained from the machine-1. Yarns obtained from the machine were used directly for developing fabrics on Handloom and powerloom. The machine -2 was specifically designed for extracting raw fiber which can further used for developing blended yarn on rotor spinning system. The results have been given, analysed and discussed under following section.

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Extraction of fiber and development of yarn from apparatus – 1

Apparatus -1 was semi-automatic in nature shown in Figure.1. It is divided into two sections: a). Input (feeding device) b). Output (Winding device). The input device consists of wooden base. Over the three stands the long PVC pipe is attached. Between the two iron stands there is a U-junction to hold the PVC pipe. In the front area of input device, there is a cutting mechanism which consist of screw in which blade is attached. One side of the PVC pipe also contains the opener (cap) to hold the petioles together during the extraction and spinning. For extraction and spinning, bunch of three petioles are loaded in the PVC pipe. The opening area of the PVC pipe consists of blade that slits the petiole in the consecutive interval and gripper takes the slitted petiole with extracted fiber towards the winding device. With the stretching operating fibers are extracted and meanwhile it is twisted into yarn due to the rotation of PVC pipe. The output device consists of the bobbin in which yarns are uniformly winded. Four different types of 100 % Lotus yarns with different fineness were obtained by optimizing the speed of feeding and winding rollers of the fabricated machine.

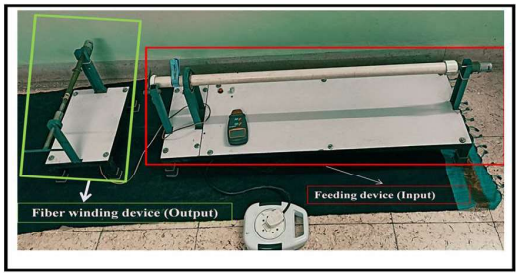

Figure 1: Apparatus -1 for Extraction of Lotus fiber and yarn development

Extraction of fiber from apparatus – 2

The apparatus is semi – automatic works on programming shown in Figure 2. It is divided into three sections that is: feeding, gripping and fiber collection sections. Before starting the extraction process, all the components of the machine are set in their home position. Six to seven petioles were arranged in the feeding device horizontally. After aligning the petioles, the blades slits petioles from upper and lower sides. After slitting the petioles, the gripper mechanism comes forward, grips the slited petioles. The gripper winds the slitted petiole over the fiber collection device.

The extracted raw fibers from the further subjected for developing blended yarn in two different proportion (50:50 Lotus: Cotton) and 70:30 (Lotus: Cotton) using rotor spinning technique shown in Figure 3. Raw fibers were initially weighted and subjected for carding and laps were prepared. Laps were further subjected for sliver preparation. From the sliver, yarns were developed.

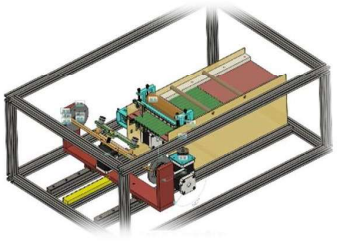

Figure 2: For Extracting Raw Lotus fiber

Figure 3: Development of blended yarn by Rotor spinning Technique

Properties of the yarn

All the yarns developed has its specific use**.** Fibers extracted from apparatus 2 was smooth and clean as compare to the fibers extracted by hand. The apparatus 2 has the capacity to extract 130 gms if fiber in 1 hour. The blended yarns developed from these fibers were soft, coarser and low in count. The extension of LRY (70:30) yarn was higher that is 32 mm as compare to LRY (50:50) yarn that is 30.5 mm this may be due to inherent elongation property of Lotus fibers. These yarns can be used to develop thick fabric for the applications in overcoats, denim pants, shawl and jackets.

In the category of pure Lotus yarn, finer 70's count yarn also called as "apparel count yarn" can be achieved in the higher speed. The tensile strength of machine extracted and spinned Lotus yarns were tested and values are mentioned in Table 3. Due to the delicate nature of Lotus fiber, maintaining and achieving strength of the yarns from the fabricated machine was challenging. Tensile strength is very important in handling yarns in manufacturing and developing a durable fabric. This MYHS1 yarn has obtained higher tenacity of 42.06 gf/tex. All the yarns has obtained S-direction twist. Both the yarn MYHS1 and MYHS2 has obtained higher twist of 10 TPI which is very good to handle strength during weaving on handloom. The pure Lotus yarns has obtained higher tenacity, production and uniform quality as compare to the yarns obtained by the manual method. From fabricated apparatus 1, one manpower can produce 100 gm of developed Lotus yarn of 71's and 60's count. As compare to the manual method, more amount of yarn can be achieved can from fabricated machine.

Properties of the fabrics

All the union fabrics containing fine and medium count Lotus yarns obtained from apparatus 1 was compact with higher fabric count whereas the blended fabric has obtained lower fabric count due to the coarser yarn count and spinning technique mentioned in Table 4. GSM is one of the most essential considerations when it comes to selecting the fabric for specific purpose. It is the important factor for the consumers also. Union fabrics was light and medium in weight that can be used for blouses, shirting, light summer dress, bottom, slacks whereas blended fabrics was heavier in weight. Union fabric PL-1 has obtained lower thickness 0.27 mm due to the very fine 70's count of yarn obtained from Apparatus- 1. BL -6 (Blended Lotus fabric made of 70:30 rotor yarns) has obtained higher thickness of 0.52 mm. Tensile and tearing strength is a most important aspect for the fabric durability and performance. PL -1 has obtained higher tensile and tearing strength (Table 5 & Table 6). Higher strength is due the higher tenacity of the yarns and also it depends on the invention of the apparatus-1. Blended fabrics has obtained higher elongation properties (Table 5). It is due to the inherent elasticity property of the Lotus yarns. It also depends on the spinning system that is blending in the fiber stage which contribute to the resultant fabric with the inherent property of both the fibers present in the blended structure. The term drape is used to describe the way a fabric hangs under its own weight. It is important factor from the aesthetic point of view. Table 7 shows the drape property of the constructed fabrics. When the value of drape co-efficient is low then the fabric has a softer and has a better drapability whereas when the value of drape co-efficient is higher, the fabric has a stiffer appearance. It was analysed that all the union fabrics has a lower drape coefficient means these fabrics can be used in sarees and other garments in which flow and drape is very essential. Serviceability is very important factor for the apparels. Particular apparel is considered as serviceable when it is appropriate for specific end use. Table 8 shows the serviceability properties of the constructed fabrics. Neglible pilling was seen in union fabrics: PL-1 and PL-2. Blended fabrics BL- 5 and BL-6 was found superior in abrasion testing with the higher number of cycles means it can be used in the garments in which wear and tear plays a very

important role. Negligible shrinkage was seen in union fabrics. Union fabric PL – 1 was selected and subjected for Kawabata test. Primary hand values are graded using a scale of 1-10 where 10 indicates strongest and 1 indicates weakest as per the particular descriptor. THV of the PL- 1 was 4.68 which is very much suitable for Women's Suiting. Images of the union and blended fabrics are shown in Figure 4 and Figure 5.

Table 3: Properties of yarns

Sr. No.	Type of yarn	Fineness (Cotton Count)	Tenacity (gf/tex)	Twist
1	MYHS1	70	42.06	10
2	MYHS2	60	16.77	10
3	MYMS	33	9.28	4.6
4	MYLS	28	9.49	7.6
5	LRY (50:50)	5	4.71	9.4
6	LRY (70:30)	3	4.58	8.2

MYHS1 - Machine yarn high speed 1
MYHS2 - Machine yarn high speed 2
MYMS - Machine yarn moderate speed
MYLS - Machine yarn low speed
LRY (50:50) – Lotus rotor yarn: 50 % Lotus 50% Cotton
LRY (70:30) – Lotus rotor yarn: 70 % Lotus 30 % Cotton

Table 4: Preliminary properties of the constructed fabrics

Sr. No.	Fabric	Fabric Count	Fabric Weight (GSM)	Fabric Thickness (mm0)
1	PL -1	48 ×55	74	0.27
2	PL -2	56×61	82	0.36
3	PL -3	52×58	113	0.38
4	PL -4	42 × 34	94	0.37
5	BL -5	22×31	323	0.48
6	BL -6	19×31	336	0.52

Table 5: Tensile strength of the constructed fabric

Sr. No.	Fabric	Maximum Load (Kgf)		Extension (mm)	
		Warp	Weft	Warp	Weft
1	PL -1	15.07	30.86	18.87	12.36
2	PL -2	13.37	26.23	22.02	16.03
3	PL -3	15.55	19.97	13.07	27.82
4	PL-4	12.84	18.19	15.74	11.50
5	BL -5	26.64	23.34	40.63	35.65
6	BL -6	19.75	19.89	38.86	27.82

Table 6: Tearing strength of the constructed fabrics

Sr. No.	Fabric	Tenacity (Kgf/cm)	
		Warp	Weft
1	PL -1	5680	5504
2	PL -2	4544	4192
3	PL -3	3200	2560
4	PL -4	4864	5056
5	BL -5	5310	5760
6	BL -6	2474	4512

Table 7: Drape co-efficient of the constructed fabrics

Sr. No.	Fabric name	Drape coefficient (%)
1	PL -1	23
2	PL -2	29
3	PL -3	33
4	PL -4	35
5	BL -5	43
6	BL -6	64

Table 8: Serviceability properties of the constructed fabrics

Sr. No.	Fabric	Shrinkage (%)		Pilling (Rating from 1to 5)	Abrasion (Number of turns)
		Warp	Weft		
1	PL -1	0	0	5	400
2	PL -2	0	0	5	300
3	PL -3	0	0	4	300
4	PL -4	0	0	4	300
5	BL -5	0.3	0.3	4	800
6	BL -6	0.3	0.3	4	1000

Table 9: Kawabata test of the selected fabric

Sr. No.	Fabric sample	PRIMARY HAND VALUES KN-201 W- MDY				THV
		Koshi (Stiffness)	Numeri (Smoothness)	Fukrami (Softness)	Sofutosa (Fullness and softness)	KN-301 W- MDY
1	PL Fabric-8	3.07	8.26	6.22	5.86	4.68

Figure 4: Images of Union Lotus Fabric a). PL – 1 b). PL-2 c). PL-3 d). PL-4

Figure 5: Images of Lotus Blended Fabrics: a) BL- 5 b). BL-6

6. Conclusions

In the category of natural fiber, the technological implementation and upgradation play a very important role. Technological invention in the Lotus fiber was very difficult due to following reasons: Fibers are extremely delicate to withstand strength on the machine, Fibers in the petioles are not assembled together in a single chamber. Fibers are arranged in xylem cells that is tracheids and vessels and few fibers are also assembled in the outer portion or the wall of the xylem cells. Variation in the nature and diameter of the petioles. Maintaining even tension during the extraction. All the drawbacks were kept in the mind while designing and fabricating both the apparatus. Testing results concluded that raw material developed from both the apparatus was good in quantity. Both the apparatus can produce higher production as compare to manual method. Technological invention in Lotus fiber manufacturing opens the opportunities for developing more textile materials for various applications. 70's count yarns were found more feasible for using it in the production line in terms of its strength, twist and count. In entire manufacturing systems not a single drop of chemical is been used which is a way towards sustainability in the true sense.

7. Suggestions and recommendations

Blending can be done with other natural and regenerated fibers for developing more functional and comfortable fabrics. Other spinning systems can be tried for developing different types of Lotus yarns. Small scale industry can be developed near the Lotus ponds and these fabricated machines can be installed in it for the systematic production it can generate employment to the rural sector.

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