CHAPTER – 3

METHODOLOGY

The study is experimental and exploratory in nature. The main aim of the study was to utilize the hygrowaste that is Lotus petioles for fiber extraction and its application for different methods of manufacturing textiles like woven, knitting and non-woven. The research started with the collection of Lotus petioles from Lotus flower suppliers and vendors of Vadodara district of Gujarat. In the study, researcher developed the varieties of hand extracted yarns by varieting the number of petioles and further spinning in Ambar charkha. The major problem was time consumption for hand extraction and spinning process. To overcome this problem researcher designed and fabricated the machine with different mechanisms. Ply yarn by twisting it with other natural fibers was explored. Open end yarns in different proportions were developed. Totally 12 different types of yarns were developed. 14 woven fabrics with different compositions were prepared in handloom and power loom. For the commercial application in woven textiles the dyeability and fastness properties are also important so the researcher experimented dyeing of Lotus fiber with natural and reactive dyes and assessed its fastness properties. The fiber possessed inherent softness, elasticity, pliability and other functional properties so the machine extracted yarns were also experimented for circular knitted structure. Leftover fibers from the petioles after extracting the long length of fibers were explored for developing nonwoven web. The study also intended to test and analyze the properties of all the structures that is woven, knitted and nonwoven. In the woven fabric category, the best fabrics were evaluated in KAWABATA system for exploring the end uses. To imply the results for the betterment of society, group of ladies were trained for fiber extraction and spinning so that they can make it as a source of earning. This chapter deals with materials and methods developed and followed for fulfilling the objectives.

The experimental procedure of the study has been further subdivided and discussed under various phases:

3.1. Procurement of raw material: Lotus Petioles

3.2. Extraction of fiber (by hand/manual)

3.2.1. Extraction of fiber for yarn making (by varieting number of petioles)

3.2.2. Extraction of fiber for making non-woven web (loose fiber extraction from leftover)

3.2.3. Testing of the extracted fiber

3.3. Spinning of hand extracted fibers

3.4. Testing of hand spun yarns

a) Determination of yarn fineness
b) Determination of tensile strength
c) Determination of twist

3.5. Development of Machines

3.5.1. Machine –1:-for extraction and spinning yarn

3.5.1.1.Designing of machine

3.5.1.2. Fabrication of machine

3.5.1.3. Working of machine for fiber extraction and yarn making

3.5.1.4. Fiber yield by machine

3.5.1.5. Testing of machine extracted yarn

a) Determination of yarn fineness
b) Determination of tensile strength
c) Determination of twist

3.5.2. Machine -2:-Development of machine for extracting raw fibers

3.5.2.1.Designing of machine

3.5.2.2.Fabrication of machine

3.5.2.3.Working of machine for fiber extraction

3.5.2.4. Fiber yield by machine

3.6. Development of blended yarn and its testing

3.6.1. Blending in fiber stage (Open end spinning/Rotor spinning)

3.6.2. Blending in Yarn stage (Plying mechanism)

3.6.3. Testing of blended yarn

a) Determination of yarn fineness
b) Determination of tensile strength
c) Determination of twist

3.7. Dyeing of Lotus yarn

a) Dyeing of Lotus yarn with natural dyes
b) Dyeing of Lotus yarn with reactive dyes

3.7.1. Testing of dyed yarns

a) Determination of Colour strength
b) Determination of Washing fastness
c) Determination of Light fastness

3.8. Construction of woven fabrics

a) Khadi fabrics
b) Handloom fabrics
c) Power loom fabrics

3.8.1. Testing of woven fabrics

a) Determination of fabric thickness
b) Determination of fabric count
c) Determination of cover factor
d) Determination of weight per unit area of fabric (GSM)
e) Determination of stiffness/bending length
f) Determination of drape co-efficient
g) Determination of tensile strength
h) Determination of abrasion resistance
i) Determination of tearing strength
j) Determination of pilling
k) Determination of shrinkage
l) KAWABATA analysis of the fabrics

3.9. Development of Knitted fabrics

3.9.1. Testing of knitted fabrics

a) Determination of knitted fabric count (Assessment of Wales and coarses)
b) Determination of bursting strength
c) Determination of pilling
d) Determination of stretch and recovery properties of knitted fabrics.
e) Determination of thickness
f) Determination of weight per unit area of fabric (GSM)

3.9.2. Development of knitted product

3.10. Testing of fibers for functional properties

a) Absorbency

b) pH

c) Antibacterial test

d) Cytotoxicity

3.11. Development of nonwoven fabric

3.11.1. Testing of nonwoven fabric

a). Determination of thickness

b). Determination of weight per unit area of the fabric (GSM)

3.12. Development of hygiene products from nonwoven sheet.

3.13. Testing of hygiene product.

3.14. Training group of women for fiber extraction and spinning

a) Interaction with NGO

b) Locale of the training programme

c) Training for fiber extraction and spinning

d) Workshop for fiber extraction and spinning.

e) Weaving of handwoven stoles

f) Exhibition of the developed fabrics

3.15. SWOC Analysis

3.16. Research Design : Page no – 114 and 115.

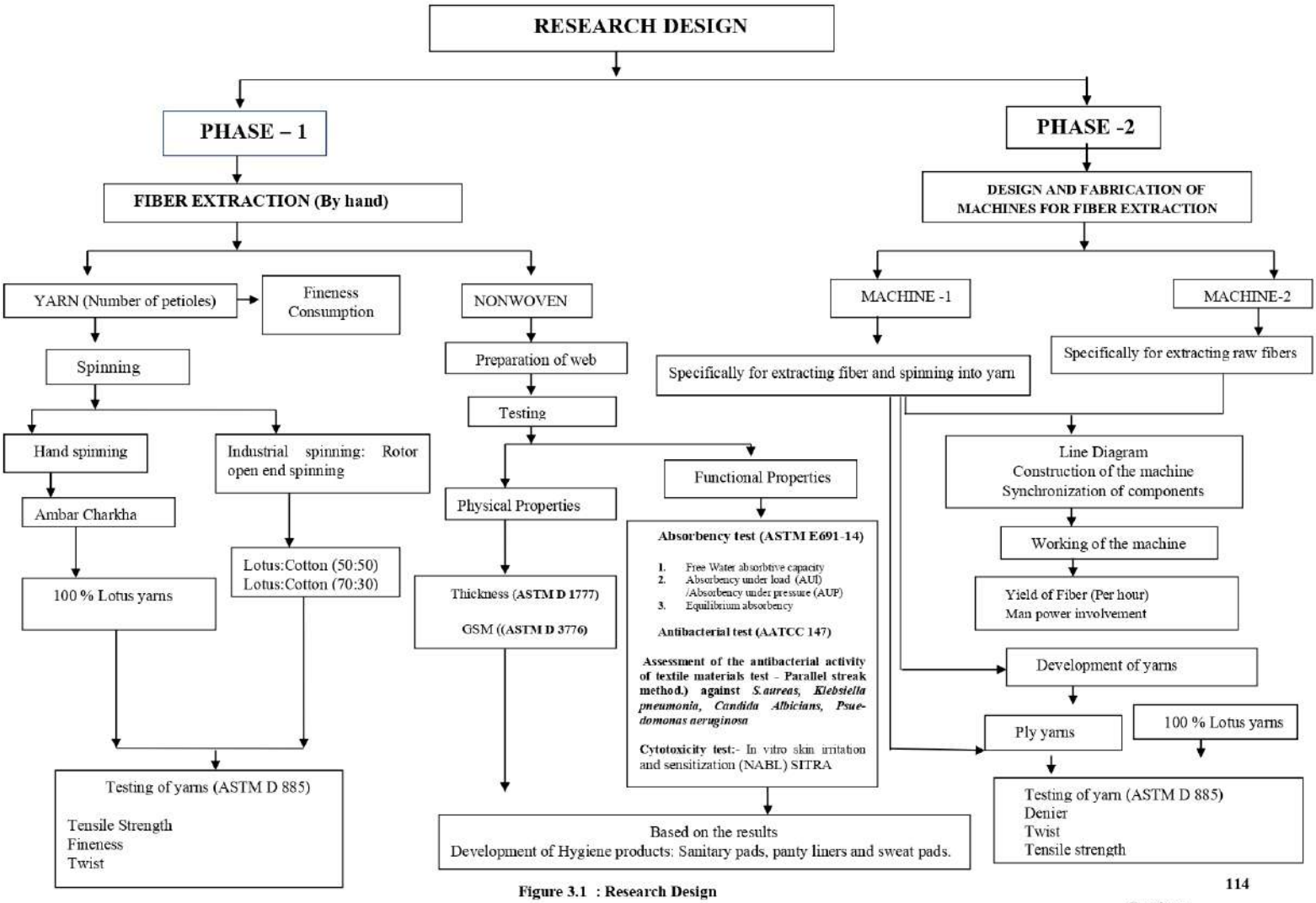

Figure 3.1 : Research Design

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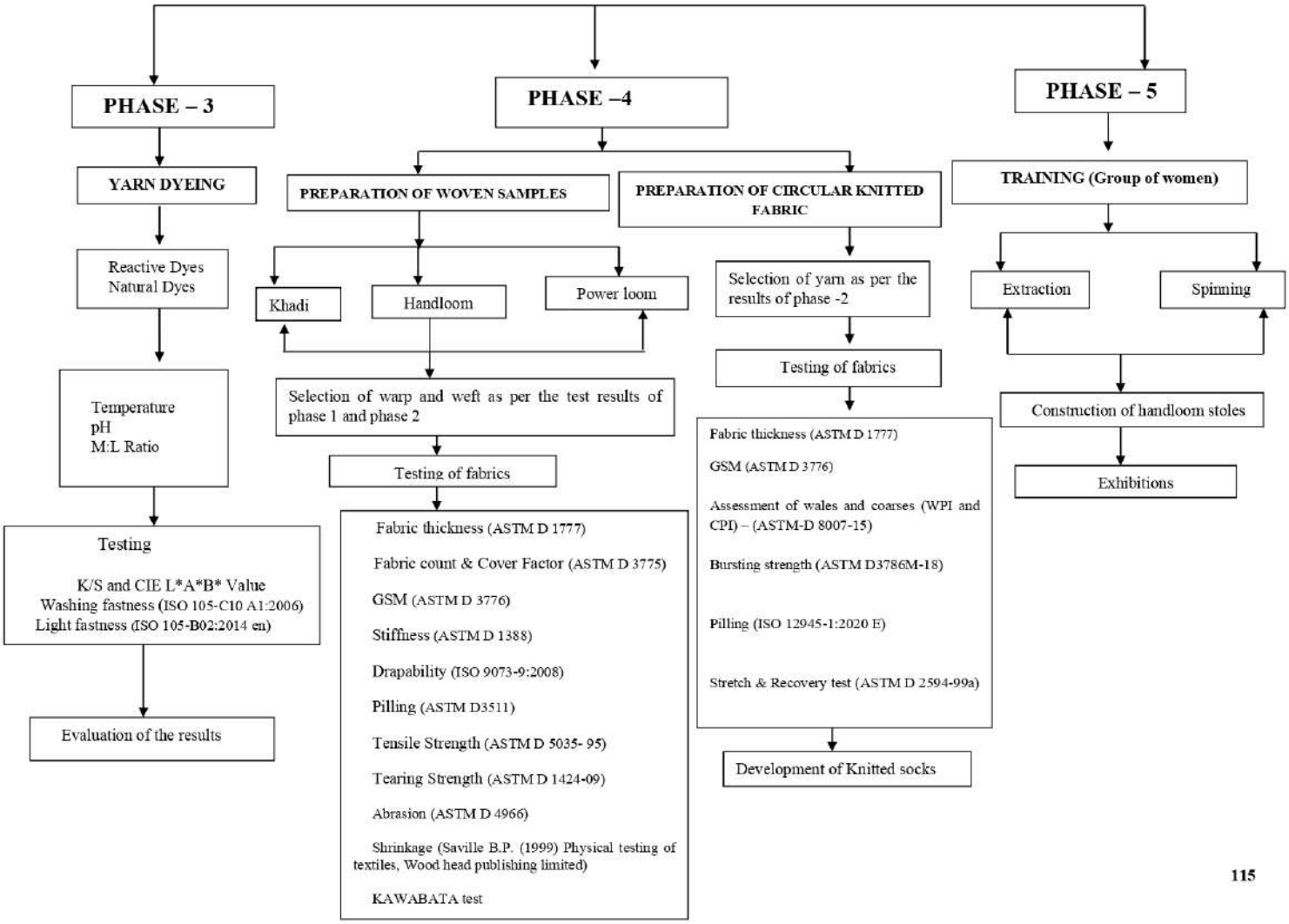

PHASE – 3
YARN DYEING
Reactive Dyes
Natural Dyes
Temperature
pH
M:L Ratio
Testing
K/S and CIE L*A*B* Value
Washing fastness (ISO 105-C10 A1:2006)
Light fastness (ISO 105-B02:2014 en)
Evaluation of the results
PHASE –4
PREPARATION OF WOVEN SAMPLES
Khadi
Handloom
Power loom
Selection of warp and weft as per the test results of phase 1 and phase 2
Testing of fabrics
Fabric thickness (ASTM D 1777)
Fabric count & Cover Factor (ASTM D 3775)
GSM (ASTM D 3776)
Stiffness (ASTM D 1388)
Drapability (ISO 9073-9:2008)
Pilling (ASTM D3511)
Tensile Strength (ASTM D 5035- 95)
Tearing Strength (ASTM D 1424-09)
Abrasion (ASTM D 4966)
Shrinkage (Saville B.P. (1999) Physical testing of textiles, Wood head publishing limited)
KAWABATA test
PREPARATION OF CIRCULAR KNITTED FABRIC
Selection of yarn as per the results of phase -2
Testing of fabrics
Fabric thickness (ASTM D 1777)
GSM (ASTM D 3776)
Assessment of wales and coarses (WPI and CPI) – (ASTM-D 8007-15)
Bursting strength (ASTM D3786M-18)
Pilling (ISO 12945-1:2020 E)
Stretch & Recovery test (ASTM D 2594-99a)
Development of Knitted socks
PHASE – 5
TRAINING (Group of women)
Extraction
Spinning
Construction of handloom stoles
Exhibitions

3.1. Procurement of raw material: Lotus Petiole

In this study, *Nelumbo Nucifera Gaertn*. species that is a petiole of pink Lotus was used. This species is the national flower of India and Vietnam. The petiole is the part between flower and rhizome (underground stem) of the Lotus plant. After the flower plucking, the petioles are either left in the pond as a waste or if it is taken out with the flower then cultivators keep only small length of petiole with flower for selling, the rest long length of petiole is thrown away as a waste. Waste Lotus petioles were procured from Mr. Isabbhai Rathod (Lotus Flower Supplier) and flower vendors of Khanderao market of Vadodara district of Gujarat.

Plate 3.1. Procurement of Lotus petioles

The average length of the petiole varies from 50- 115 Cm. The diameter of the petiole varies from 0.5 -2.5 Cm. The length and diameter vary as per the maturity level of the plant and season. The colour of the petiole ranges from light green to dark green with the thin and tiny spikes on the surface. After the petioles are taken out from the pond it is wrapped with the wet cloth and sprinkled with water to prevent it from rapid drying

and can be kept for five days. After five days, petioles get dry and uniform length of fibers cannot be extracted.

Plate 3.2. Wrapping the bundle of Lotus petioles in wet cloth

3.2. Extraction of fibers (Manual method)

3.2.1. Extraction of fiber for yarn making

For producing different counts of yarn and checking its feasibility in hand spinning and weaving , extraction was done manually by varieting the number of petioles. Three different types of unspun yarns were prepared using one, two and three petiole for extraction manually.

Plate 3.3. Extraction of fiber for yarn making (Manual method)

3.2.2. Extraction of fiber for making non-woven web and blended yarn (loose fiber extraction from leftover)

While extracting fibers manually in the unspun yarn form by joining end to end points, there was a small piece of petiole as a leftover which still contained fibers. These fibers were extracted manually and collected over the woolen felt. By pressing, sheet was formed which could be transferred easily from felt fabric.

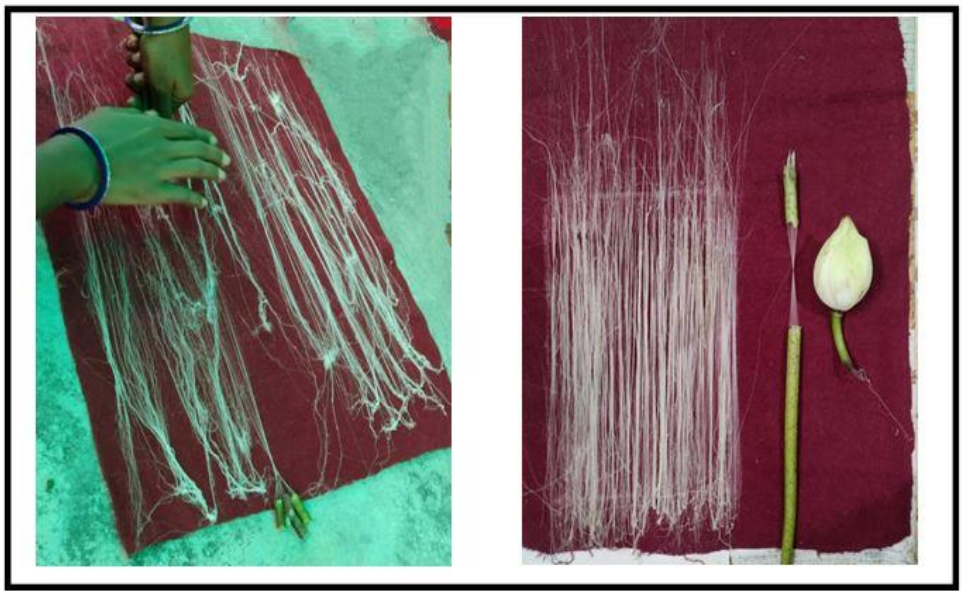


Plate 3.4. Extraction process of Lotus fiber for developing nonwoven web and blended yarn (loose fiber extraction from leftover)

3.2.3. Testing of fiber

Physical properties like fiber length, fiber diameter, fiber fineness (ASTM D 7025-09), moisture regain and content Booth, J.E. (1996) and Fiber strength (ASTM D 3822-07) were tested. Fibers were also subjected for XRD analysis at laboratory of Bharat Ratna Prof. CNR RAO Research Centre, Avinashillingam Institute of Home Science and Higher Education for Women, Coimbatore, Tamilnadu.

Colour of the fiber

Colour of the raw Lotus fiber was determined using TAPPI 452 / ISO 2470 standard on spectrophotometer instrument using D65 illumination. Whiteness, brightness and yellowness index was tested. The test was conducted at Bharat Ratna Prof. CNR RAO

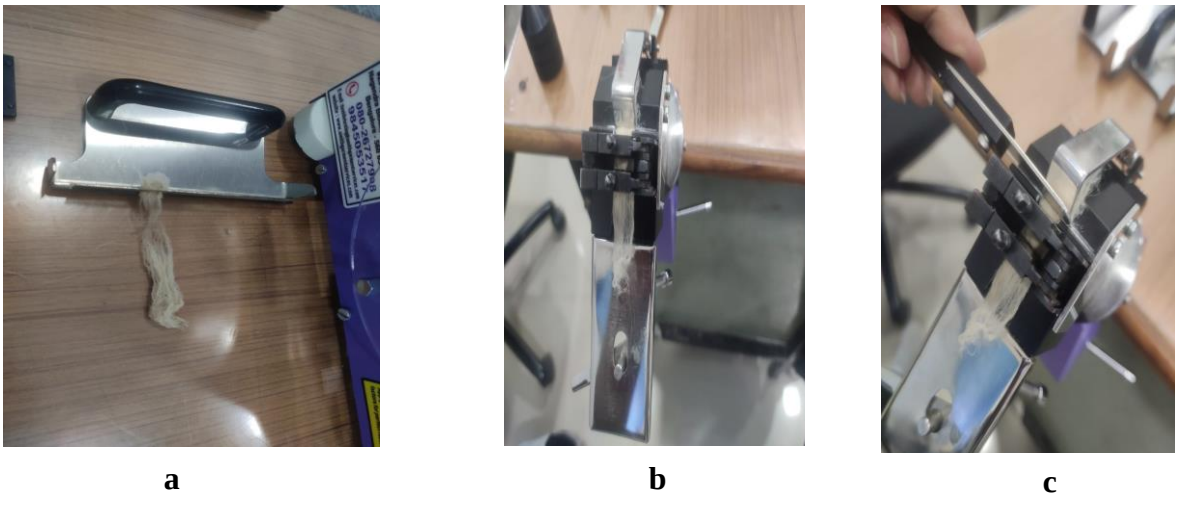
Research Centre, Avinashillingam Institute of Home Science and Higher Education for Women, Coimbatore, Tamilnadu.

Determination of Bundle Strength

Following ASTM D 1445-05, bundle strength of the fiber was tested using Stelometer. The test was conducted in Textile testing lab of Department of Clothing and textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda.

The instrument consists of pendulum, beam, combs, clamps, jaws, tweezers and cutters. First and foremost step is placement of the fibers in the jaw. For the test, weighted bundle of the combed Lotus fibers was taken and set between two jaws. The fiber specimen was weighed before the test. After the fiber specimen preparation one of the jaw was mounted on the adjustable jaw holder carried by the beam and another jaw is mounted at the top end of the pendulum. The rate of the loading is constant in the test. The center of the gravity of the beam is at the right side of its axis of rotation. The beam rotates in clockwise direction. The rotation of the beam is controlled by special dash pot like device. Load of the fibre bundle is directly proportional to the sine of the angle through which the pendulum has moved. Once the fiber specimen is adjusted in the jaws the pointer is also adjusted at zero and dashpot is pressed. The breaking load is indicated by the pointer which moves on the graduated scale ranging from 2 to 7 Kg. Bundle of the fiber broken is collected and weighted (Booth, J.E.1996). From the values of the breaking load and weight of the fiber sample before and after, tenacity is calculated using the formula:

$$\text{Tenacity in grams per tex} = \frac{\text{Breaking load in Kg} \times 1.5 \times 10}{\text{Sample Weight in Milligrams (Mg)}}$$



a **b** **c**

d **e**

Plate 3.5. Bundle strength test on Stelometer a). Combing of fibers b). Placement of fiber in the jaws c). Cutting of extra fibers from the jaw d). Placement of jaw in instrument e). Pressing the knob of pendulum for measuring bundle strength

X- Ray Diffraction (XRD)

X diffract grams (Scan range 2θ = 10 - 79º) of Lotus fiber were obtained using X-Ray diffractometer. The test identifies height of the peak at 2θ, amorphous and crystallinity index.

3.3. Spinning of hand extracted unspun yarn

The unspun yarns developed by manual extraction method were initially experimented for twisting on drop spindle, *peti* (Box) charkha and Ambar charkha. Finally the entire spinning was carried out in 2 spindle Ambar Charkha. The entire hand spinning was done by the researcher with the assistance of Mr. Bakul Shah (Expert spinner) at Bhumi Pujan Office, Fatehpura, Vadodara, Gujarat.

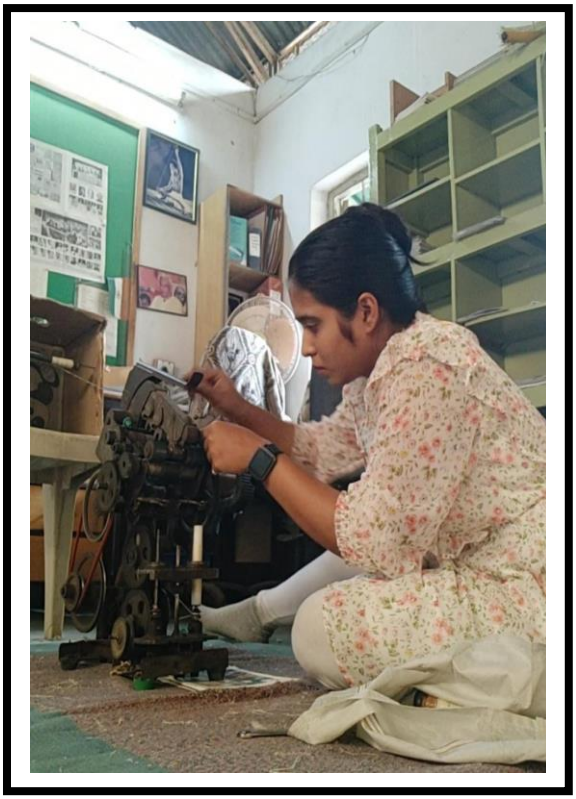


Plate 3.6. Spinning of Lotus yarn on 2-Spindle Ambar Charkha

3.4. Testing of Yarns

a). Determination of Yarn Fineness

Fiber fineness was tested as per ASTM D 7025 standard. In the direct system of yarn numbering, Denier was determined by taking the average weight of 20 readings of 100 cm length of the fiber and calculation was done using the formula:

$$\text{Denier} = \frac{WX\ l}{L}$$

Where, W= Weight of the fiber

L= Length of the sample

l = unit length of the system

The count of the fibers was also determined by indirect system of yarn numbering by using Beesley's yarn balance. The instrument consist of hook at one end and the pointer at other end. A standard weight (0.040 gm) was hung on the notch of the beam. Template was used to cut the length of fibers based on cotton count system. The fibers were kept on the hook until the pointer reaches the datum line. The count is the number of short length filament fibers used to balance the beam.

b). Determination of tensile strength of yarn

Following ASTM 885, Tensile strength of the yarns was determined on Lloyd tensile tester . The instrument works on (CRE) Constant Rate of Elongation Principle For the test the yarn of known denier was clipped between two jaws with the gauge length 500 mm (50 cm) and the pulling speed was 500mm/min. An average of 20 readings was taken.

Plate 3.7 :Lloyd tensile Tester

c). Determination of Yarn Twist

Following ASTM D 885, the amount of twist was calculated on twist tester. The sample length was 10 inch test length with tension arrangement. An average of 10 readings was taken.

3.5. Development of machines

3.5.1. Machine 1: This machine was specifically designed for extracting fiber and simultaneously developing yarn.

The main drawback of the Lotus fiber was its time consuming manual extraction process which hinders the mass production. The mechanization of the entire extraction process was also found difficult due to the delicate appearance of the fiber. Researcher in collaboration with the Mechanical Engineer- Mr. Dhaval Raval worked on the entire designing and development of apparatus. Apparatus was designed in such a way that both extraction along with spinning can be done together at the same time. The apparatus has got an Indian patent grant (IN201921032058).

3.5.1.1. Designing of Apparatus

On the basis of different steps in the manual extraction method:- slitting of petioles, holding of petioles together, twisting of fibers along with stretching and winding on the pern , researcher in collaboration with the mechanical engineer worked on different designs for the apparatus of Lotus fiber extraction and spinning . Later one of the designs was finalized and apparatus was fabricated. The line diagram of the apparatus was prepared in CAD software.

3.5.1.2. Fabrication of Apparatus

The apparatus was constructed by engineer Mr. Dhaval Raval in his work shop - The Best Project Maker, 893/3/1, (1^{st} Floor), Makarpura, GIDC Near Krishna Engineers, Purohit Chokdi, Vadodara, Gujarat. The apparatus consists of two sections that is input and output device. The input device comprises of the long PVC pipe in which Lotus

petioles are fed and later with the rotation of PVC pipe, the fibers were extracted and twisted. The output device consists of entire assembly of fixing bobbin in which the twisted yarns are winded. Machine consists of two motors, SMPS expansion connection, speed regulator and sharp knife.

3.5.1.3. Working of Apparatus

Fresh Lotus petioles are fed in the PVC pipe. In the opening side of PVC pipe there is a sharp knife attached to slit the petioles. The knife slit the petioles and the extracted fibers are first initially winded in the bobbin. Later with the rotation of the PVC pipe and stretching speed of bobbin winding device the yarns are winded evenly in the pern which can be directly proceeded for weaving. Yarns with different counts were optimized by regulating the speed of both the rollers present in the device. Speed of the machine was analyzed by the Tachometer device.

3.5.1.4. Yield of yarn by machine

The yarns winded on the perns were weighted. Time taken to obtain the yarns was noted. Consumption of the petioles was also calculated.

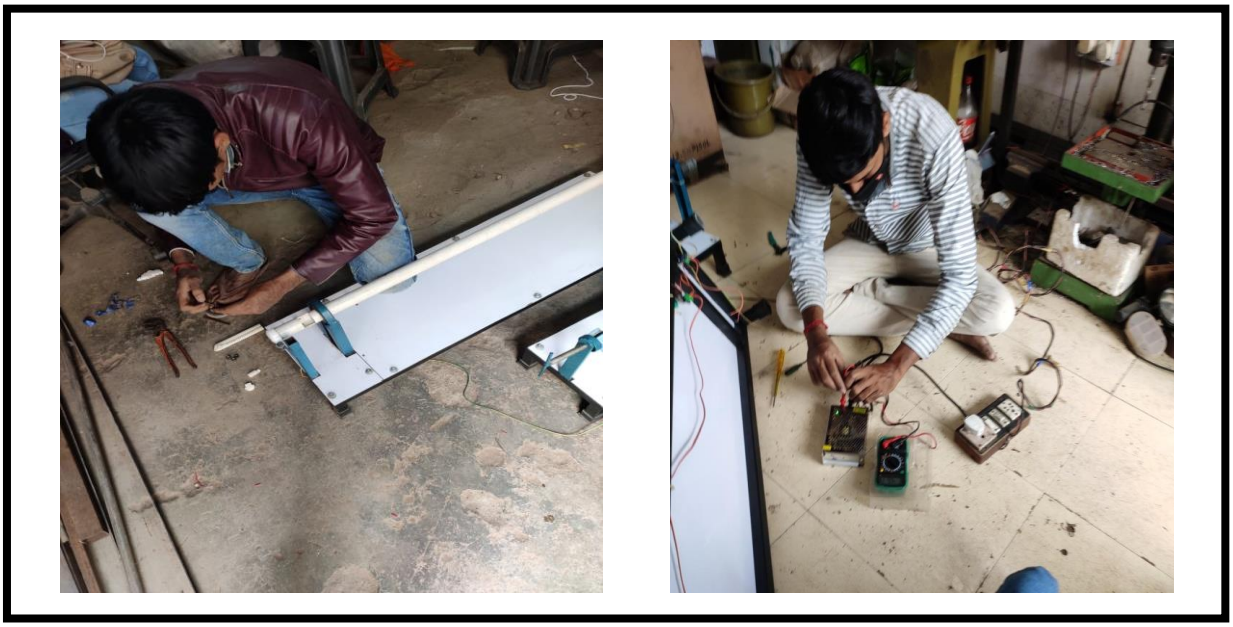


Plate 3.8 : Construction of Machine-1 for extraction and spinning for yarn making

3.5.1.5. Testing of machine extracted yarn

a). Determination of yarn count: -The test has been done as per 3.4 (a) mentioned in page no. 122 and 123.

b). Determination of tensile strength: - The test has been done as per 3.4 (b) mentioned in page no. 123.

c). Determination of yarn twist: - The test has been done as per 3.4 (c) mentioned in page no.124.

3.5.2. Machine – 2: -This machine was specifically designed for extracting raw fibers (specifically for nonwoven web preparation and development of rotor yarns)

In the case of nonwoven sheet, rotor and ring yarn preparation there is a requirement of raw fibers. So, the researcher in collaboration with Robotic engineer Mr. Shreyash Patel from Vadodara district of Gujarat designed and constructed the machine for extracted raw fibers.

3.5.2.1. Designing of machine

On the basis of different steps in the manual extraction method: slitting the petioles, holding of petioles together, laying the fibers over the felt, researcher in collaboration with the robotic engineer worked on different designs for the apparatus of Lotus fiber extraction specifically for extracting raw fiber in the loose form which will be beneficial for developing nonwoven and rotor spun yarn. Later one of the designs was finalized and apparatus was fabricated. The line diagram of the apparatus was prepared in CAD software. All the operations of the machine were controlled by programming software – Arduino IDE.

3.5.2.2. Construction of machine

The machine consists of three sections: First and main section consists of petiole loader, sorter, two rollers and blades. There are two adjusting knobs to adjust the petioles in the loader. In the front area of machine there are two blades in upper and in lower side. Second section consists of gripper which performs a jaw movement to grip the petiole. Third section consists of comb like device to collect the raw fiber.

3.5.2.3. Working of apparatus

The entire machine works on programming. Firstly the petioles are arranged manually in the loader as per the diameter. There are two sharp blades in the front of loader which slits the petiole from upper and lower sides. After slitting, the gripper grips the slited petioles and takes the fibers in the comb like winder. With the rotation of winder, fibers were extracted. Once the winder is filled with the fibers the slit is made one side and entire collected fiber is taken out. The emptied winder is again placed in the machine for next extraction.

3.5.2.4. Yield of fiber by the machine

Extracted fibers from the machine were weighed. Time taken to extract the fibers and consumption of the petioles were calculated.

3.6. Development of blended yarn and its testing

Lotus is a natural cellulosic fiber comprising all the excellent properties- it is inherently soft, lustrous, moderate strength, good elongation, high moisture absorbency and inherently antibacterial. The entire fiber preparation process doesnot contain any chemical treatments. Focusing on the economic factor, properties and sustainability researcher tried to blend the Lotus fiber only with other natural fibers – Cotton, Silk and Wool. Blending was done by two methods:

3.6.1. Blending in the fiber stage

This is also called as “intimate blending”. It combines two or more fiber substances which is further spun together into a single yarn. The blending and spinning process was done at Textile production lab of Avinashillingam Institute for Home Science and Higher Education for Women, Coimbatore Tamilnadu. Spinning of yarns was done by Rotor spinning system/Open end spinning technique.

3.6.2. Blending in the Yarn Stage (Plying Technique)

Ply yarn combines two or more single yarn to increase the diameter, length and strength. The plying was done in 2-spindle *Ambar Charkha* by the researcher with the assistance taken from Mr. Bakul Shah (Expert spinner) at Bhumi Pujan Office, Fatehpura, Vadodara. Plying of Lotus yarn was done with three different natural fibers – Cotton, Silk and Wool. For plying, Cotton and Wool yarns were procured from Artisian Weaver Pachan Premji from Bhujodi, Kutch, Gujarat. Mulberry Silk yarns were procured from Aliya Silk traders from Sidlaghatta, Karnataka. Count of both the yarns in the ply was taken into the consideration.

Plate 3.9 : Plying of Lotus yarn with other natural fibers (Cotton, Wool and Silk) in 2-spindle *Ambar Charkha*

3.6.3. Testing of blended yarns

a). Determination of yarn count : The test has been done as per 3.4 (a) mentioned in page no. 122 and 123.

b). Determination of tensile strength: The test has been done as per 3.4 (b) mentioned in page no.123.

c). Determination of yarn twist: The test has been done as per 3.4 (c) mentioned in page no. 124.

3.7. Dyeing of yarn and its testing

a). Dyeing of yarn with natural dyes

Lotus yarn was experimented for dyeing using nine different natural dyes mentioned in Table : 3.1.

Aqueous extraction method was used. Before dyeing, Lotus yarns were pre-mordanted using Alum. Dyeing was done in open bath. Self pH was used. Dyeing was done in 4 % shade.

Table 3.1. Parameters of dyeing (Natural dyes)

	M:L Ratio	**Temperature (Celsius)**	**Time (in minutes)**
Extraction of dyes	1:40	60ºC	30
Pre-Mordanting	1:30	Room temperature	30
Dyeing	1:40	60ºC	45

Table 3.2. Sources of Natural dyes

Sr.No	Dye Source	Botanical names of dye source	Obtained as
1	Marigold	*TageteseretaL.*	Flower Petals
2	Madder	*Rubia tinctorum.*	Powdered form
3	Lac	*Kerria Lacca.*	Crystal form
4	Sappan Wood	*Caesalpinia sappan L.*	Powdered form
5	Katho	*Acacia Catechu.*	Powdered form
6	Indian Berries	*Anamirta cocculus.*	Powdered form
7	Annato	*Bixa orellana.*	Powdered form
8	Pomegranate rind	*Punica granatum.*	Dry form
9	Natural Indigo	*Indigofera tinctoria.*	Indigo cake

b). Dyeing of Lotus yarn with Reactive dyes

Hot reactive dyes were used: - Reactofix blue, Reactofix dark pink, Procion Brilliant orange, Procion yellow, Procion Brilliant yellow, Procion orange, Procion black, Procion pink and Procion turquoise. Lotus yarns were dyed with nine colours of reactive dyes.

Dyeing Procedure

The dye powder was taken in the beaker containing distilled water and dissolved by continuous stirring at the temperature of 60ºC for 15 minutes. Then Sodium Carbonate was added to dye liquor and yarn sample was kept in the solution. After 15 minutes common salt was added in the liquor and kept for more 15 minutes. After dyeing, yarn sample were washed in the running cold water for 10 minutes followed by washing with the 2 gpl neutral soap solution and finally washing with the cold water, rinsing and drying.

Table 3.3. Parameters of Reactive Dyeing

Percentage shade (%)	Material to liquor Ratio	Sodium Carbonate (Na_2CO_3)	Common Salt (NaCl)	Temperature	Dyeing time
2	1:30	20 gpl	30 gpl	60ºC	45 Minutes

Plate3.10. Dyeing of Lotus yarn with natural and reactive dyes

3.7.1. Testing of dyed yarns

a). Determination of Colour Strength

Spectrophotometer analysis was done by using Premier Colourscan SS5100A spectrophotometer to measure K/S and C.I.E values of dyed samples. D65 illuminate having a colour temperature of 65000k equivalent to average day light and 10° visual angle were selected to obtain the values. The k/s values of the dyed samples were measured at the visual spectrum (360-700nm). The percent transmission curve of control (undyed Lotus yarn) and dyed samples used were evaluated. Every dye has its own transmission values. The wavelength at which maximum transmission occur indicates the colour present in the dye. The L*a*b* values and reflectance curve of control and dyed samples was obtained. The values k/s indicate the strength of the

colour, L* indicate the (lightness and darkness of colour) , a* indicate (redness – greenness of the colour), b* indicate (yellowness –blueness of the colour). The testing was conducted at Textile Testing Lab of Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda.

Plate 3.11. Spectrophotometer analysis of dyed Lotus yarn

b). Washing Fastness test

Following ISO standard test no. II (IS: 764: 1979), colourfastness to washing was evaluated. Dyed Lotus yarn was braided with the undyed Lotus yarn. The composite specimen was placed in a glass jar containing 5 gpl soap solution and 2 gpl soda ash solution, keeping material to liquor ratio 1:50. Jars were then closed and placed in Launder -O- meter. Machine was then run for 30 minutes at 60 ± 2 C°. Then samples were removed and washed with water, squeezed and dried in air. By using Grey scale, the change in shade was assessed and graded from 1 to 5 (1 means poor and 5 means excellent fastness to washing. The test was performed in Textile Chemistry lab of Department of Textile Chemistry, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda.

Plate 3.12. Washing fastness test of dyed Lotus yarn

c). Light fastness test

Following AATCC test method 16-B- 1977, colourfastness to light was evaluated by exposing the dyed samples to sunlight for 8 hours to see the effect of fading of colour due to sunlight. Dyed Lotus yarns were wrapped evenly in the black sheet. Light fastness was evaluated by comparison of exposed portion with the unexposed portion of the material. They were graded from 1 to 8 (1 means poor and 8 means excellent fastness to light). The test was performed in textile chemistry lab of Department of Textile Chemistry, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda.

3.8. Construction of woven fabrics

12 different types of yarns were developed and tested. Based on the properties, 14 different types of woven fabrics were prepared. The weaves were kept plain for all the fabrics.

a). Construction of Khadi fabrics

Two Khadi fabrics was developed using two different count of 100 % Lotus handspun yarns as a weft and 100 % Cotton handspun yarn as a warp.
Fabrics were developed by the handloom weavers of Udyog Bharti Bhavan, Gondal, Rajkot, Gujarat.

b). Construction of handloom fabrics

Four different types of handloom fabrics were developed. In which one was Fine Lotus: Silk union fabric was developed by Mr. Vithal bhai Vaghela on treadle loom. He has an expertise in silk weaving and Patola fabrics. The fabric was developed in the workshop of the weaver - Aadesh Patola house at village Somasar, Surendranagar.

Another three different woven fabrics was developed from Lotus ply yarns (Cotton, silk and wool) in warp and 100 % Lotus in weft respectively. Fabrics were developed in sample loom at Weaver's Service Center (WSC) Shahibhag Ahmedabad. The width of the loom was 34 inches.

c). Construction of Power loom fabrics

Seven different types of power loom fabrics were developed in various compositions at Coimbatore, Tamilnadu. Five union fabrics in different yarn counts were developed using 100 % Cotton yarn in warp and 100 % Lotus yarn in weft. 100 % Lotus fabric was developed using 100 % Lotus fine yarn in both warp and weft direction. Two blended fabrics were developed using two different proportions of Lotus: Cotton blended rotor yarn. The speed of the powerloom was 27 picks/minute. The width of the loom was 34 inches

Plate 3.13. Weaving of Fine Lotus: Silk union fabric at Aadesh Patola house at village Somasar, Surendranagar, Gujarat

Plate 3.14. Weaving of Lotus: Cotton Ply yarn fabric at Weaver Service Center, Ahmedabad, Gujarat

Plate 3.15. Weaving of Lotus: Silk ply yarn fabric at Weaver Service Center, Ahmedabad, Gujarat

Plate 3.16. Weaving of Lotus: Wool ply yarn fabric at Weaver Service Center, Ahmedabad, Gujarat

Plate 3.17. Powerloom Weaving of Lotus yarn at Coimbatore, Tamilnadu

3.8.1. Testing of constructed fabrics

a). Determination of Fabric thickness

Thickness is the distance between the upper and lower surface of the material measured under the specified pressure, expressed in mm. The specimen chosen were free from folds, crushing or distortion and wrinkles. Specimen was tested on Universal thickness tester as per ASTM D 1777-96.

b). Determination of Fabric count

Fabric count in woven textile material is the number of ends and picks per unit area. Following ASTM D 3775-98, the number of warp and weft yarns in one square inch of the fabrics was counted with the help of pick glass at five randomed selected places across the width and along the length of the test specimens. The region near the selvedge was avoided because the spacing of the thread is often a little different than the body of the cloth.

c). Determination of Cover Factor

Cover factor is a numerical value indicating the extent to which area of the fabric is covered by the component yarn. Cover factor was calculated with the following formula:

$$\text{Fabric Cover Factor (K)} = K_1 + K_2 - \frac{K_1 K_2}{28}$$

Where,

$$K_1 = \frac{EPI}{\sqrt{\text{Warp Count}}}$$

$$K_2 = \frac{PPI}{\sqrt{\text{Weft Count}}}$$

d). Determination of Fabric weight (GSM)

Cloth weight is expressed as mass per unit area in g/sq.mt. A sample of 5x5 cm was cut and weighted on an electronic weighing balance to determine the weight per sq.m. GSM was calculated using the formula: -

$$GSM = \frac{\text{Weight in grams of sample} \times 100 \times 100}{5 \times 5}$$

e). Determination of stiffness (Bending length)

Fabric stiffness/Bending length is the resistance of the fabric to bending. The samples were tested as per ASTM D 1388- 18 using Shirley's stiffness tester. Rectangular strip of fabric, 6 inch × 1 inch (15 cm × 2.5 cm) was mounted on a horizontal platform in such a way that it hangs as a cantilever and bends downwards. The strip of the fabric was slided with the template until the tip of the specimen viewed in the mirror cuts both index lines. Bending length was read off from the scale mark opposite a zero-line engraved on the side of the platform.

f). Determination of Drape properties of fabric

The instrument drapemeter is used to measure fall and drape of the fabric under the exposure of halogen lamp. The purpose of the instrument is used to determine the drape co-efficient of the fabric by tracing the shadow obtained. The fabric sample was cut as per the large disc of the drape tester. The diameter of the large disc of the drape tester was 25 cm which was supported on the circular disc of 12.5 Cm in diameter. Once the sample was placed it had a folded configuration. The shape of the projected area should not be circular but it should be curved and wavy. Ammonia paper was placed below the specimen holder disc in the drape meter cabinet. Test specimen was mounted below the small support disc in the drape meter cabinet before closing the door. Lamp was switched on for 5 minutes. After 5 minutes, ammonia paper from the cabinet was removed. The small cabinet and lid of the flask containing ammonia solution was opened. Ammonia paper was kept in the cabinet for 10 to 15 minutes to let the image develop on the paper. Paper was cut as per the developed impression and traced on a graph paper to measure its area.

Area of the drape pattern is calculated as mentioned below:

Area of Drape pattern (D) = K×w/W

Where,

K = Correction factor

w = Mass of drape pattern

W = Mass of Ammonia process paper in grams per square cm.

From the value D obtained from the above formula, drape co-efficient (F) of the test sample was calculated as per the formula mentioned below:

$$\text{Drape Coefficent} = \frac{\text{Area of the draped specimen (D)} - \text{Area of the support disc(a)}}{\text{Area of the specimen (A)} - \text{Area of the support disc (a)}}$$

Area of supporting stand of 12.5 diameter (a) = 122.8 cm^2

Area of test specimen of 25 cm diameter (A) = 491.1cm^2

Plate 3.18. Drape Co-efficient test of developed fabrics

g). Determination of Tensile strength

Tensile strength of the fabrics was tested on Universal tensile tester by ravelled strip test method using ASTM D 5035- 95. The instrument works on the principle of constant rate of extension. Specimen size of 150 mm x 25 mm (15 cm x 2.5 cm) was cut. Gauge length was kept 75 mm ± 1 mm (7.5 cm) and speed of 300mm/min. Average of 10 readings from both warp and weft direction respectively was taken.

h). Determination of Abrasion resistance

Following ASTM D 3884, abrasion of the fabrics was tested using TABER Rotary Platform Abraser machine. The machine had a double head tester. Taber tests involve mounting a specimen (typically less than 12.5 mm thickness) to a round platform that rotates at a fixed speed. Two abrasive wheels, which are applied at a specific pressure, are lowered onto the specimen surface. As the turntable rotates, the wheels are driven by the sample in opposite directions about a horizontal axis displaced tangentially from the axis of the sample. One abrading wheel rubs the specimen outward toward the periphery and the other, inward toward the center while a vacuum system removes loose debris during testing. The sample size of 6 by 6 inches was mounted on a round platform.

The evaluation was done by counting the number of cycles until two threads were broken. The weight of the pressure arms was 1 Kg. There was a sensor connected to the machine which gave the details of number of cycles.

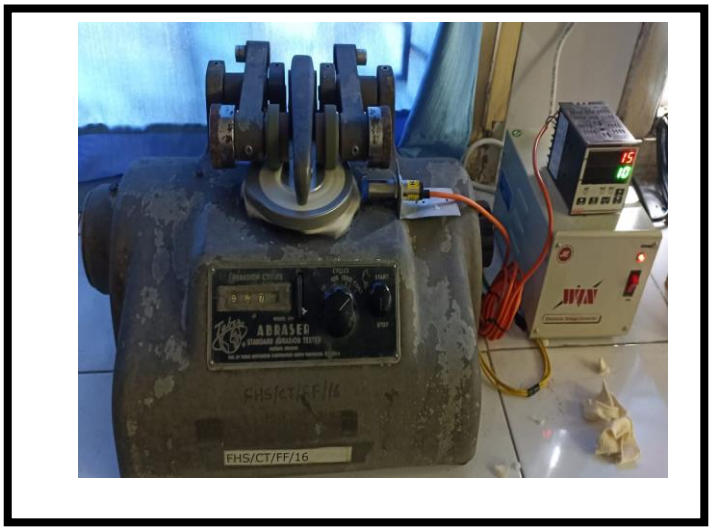


Plate 3.19. Abrasion test of constructed fabrics in Taber Rotary Platform Abraser machine

i). Determination of Tearing strength:

Following ASTM D 1424-09, tearing strength of the fabrics was tested. The test determines the force required to propagate a single rip tear starting from the cut in a fabric using a falling pendulum type Elmendorf apparatus. The cut size of the sample was 100 mm x 63 mm. Firstly the pendulum was raised to the starting position. The

pointer of the pendulum was set against the dial. Then fabric sample was clamped in the jaws. Fabric was clamped and both the jaws of the machine were tightly closed maintaining same tension. After clamping, a small slit was made in the bottom edge of the fabric using a knife blade and leaving rest of the fabric length of 42 mm ± 0.15 mm for tearing test. Then the pendulum was released as far as it goes. Once the tearing was completed the pendulum was set without disturbing the position of the pointer. Final reading was taken. The scale of pendulum is graduated to determine the percentage of the potential energy of the pendulum required to tear the sample , the reading observed in the scale was multiplied by the augmented weight. The augmented weight was 6400 gf.

Plate 3.20. Tearing test of constructed fabrics in falling pendulum type Elmendorf apparatus

j). Determination of Pilling

Pilling was determined based on the standard ISO 12945-1:2020 (E) using ICI pilling box. For the test, three fabric samples each of 125mm X 125mm (12.5 Cm x 12.5 Cm) was cut from the fabric. Each fabric sample was then folded face to face and on the marked seam line was done. Then each sample was turned inside out so the face of the fabric formed the outer portion of the tube. After stitching of the fabric tube, 6mm fabric was cut at the top and bottom side to remove any sewing distortion. The fabric tubes were mounted on rubber tubes. Care was taken that the seamed portion lies as flat as possible. Each of the loose ends of the fabric sample was taped with the PVC

tape so that the test specimen is fixed on the center of the rubber tube. Fabric specimen of each category was placed in one pilling box. The tumbling of the fabrics samples was done in a cork-lined box. The tumbling took around 5 hours to complete 18,000 rotations. After the completion of rotations, tubes were taken out from the box. The fabric specimens were removed from the rubber tube and placed under the light for the evaluation of pills. The pilling of the fabric surface was evaluated against standard swatch as per the standard. The rating for the pilling is given as per the Table 3.4.

Table 3.4 Rating of Pilling

Rating	Appearance of pills
5	No pilling
4	Slight pilling
3	Moderate pilling
2	Severe pilling
1	Very severe pilling

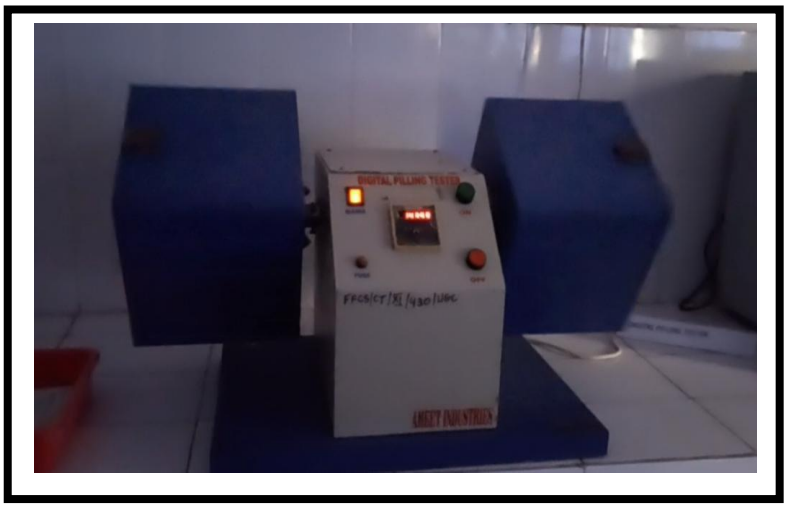


Plate 3.21. Pilling test of constructed fabrics in ICI Pilling Box

k). Determination of Shrinkage

The sample size of 350 mm × 350 mm was cut from both warp and weft way. The samples were marked with three sets of marks in each direction. The marks of 50 mm were made apart from all the edges. After marking, samples were soaked flat in the vessel containing water with the wetting agents for 24 hours. After 24 hours the samples were taken out from the water and placed flat on the tissue paper without unnecessary handling and allowed to dry flat Saville, B.P. (1999).

Relaxation shrinkage was calculated using the formula: -

$$\frac{\text{(Original measurement – Final measurement)}}{\text{Original Measurement}}$$

l). Kawabata analysis of the selected fabrics

Kawabata test was conducted at Central Institute for Research on Cotton Technology, (CIRCOT), Adenwala Road, Matunga, Mumbai. Kawabata test consists of two stages:

1. Subjective evaluation of the fabric
2. Objective evaluation of the fabric

Subjective evaluation of the fabric includes - Primary hand values such as Koshi (Stiffness), Numeri (Smoothness), Fukurami (fullness and softness) and Sofutosa (soft touch) was conducted.

The primary hand values are rated on the ten point scale in which ten is the highest value and one is the lowest value. The primary hand values of the fabric are combined to achieve the overall rating of the fabric. This is known as total hand value (THV). To determine the specific category, the fabric samples were compared with the standard reference book produced by the Hand Evaluation and Standardization Committee (HESC). The book consists of the standard samples of total hand values in each categories: Men's winter/autumn suiting, Men's summer

suiting for a tropical climate, Ladies' thin dress fabrics, Men's dress shirt fabrics and Knitted fabrics for undershirts.

Objective evaluation of the fabric includes the set of instruments which measure the appropriate fabric properties. This system is known as KESF system which consists of four major specific instruments for analyzing following properties:

FBI - Tensile and shearing

FB2 -Bending

FB3- Compression

FB4- Surface friction and variation

All the properties are tested in the following ways ;

Measurement of the tensile properties are done by plotting the force extension curve between zero and maximum force 500 gf/cm. For the recovery curve the sample is allowed to return back to its original length and then its graph is plotted. Following values are calculated using the formula:

$$\text{Tensile energy WT} = \frac{\text{the area under the load strain curve}}{\text{(load increasing)}}$$

$$\text{Linearity LT} = \frac{\text{WT}}{\text{Area of OAB}}$$

$$\text{Resilience RT} = \frac{\text{Area under load decreasing curve}}{\text{WT}} \times 100$$

For measuring the bending properties, the sample is bent between the curvatures of -2.5 and 2.5 Cm^{-1}. The radius of the bend is 1/curvature. The following properties are measured from the curve that is

Bending rigidity B = slope of the bending moment – curvature curve

Moment of hysteresis 2HB = hysteresis width of the curve.

Measurement of the compression properties is done by placing the fabric sample between two plates and simultaneously increasing the pressure by continuously observing the sample thickness upto the maximum pressure of 50 gf/Cm^2.

For the measurement of the shear properties, fabric sample of 5Cm X 20 Cm is sheared parallel to the longitudinal axis maintaining the constant tension of l0gf/cm on the clamp. From the curve following quantities are measured:

Shear stiffness G = slope of shear force-shear strain curve

Force hysteresis at shear angle of 0.5° 2HG = hysteresis width of curve at 0.5°

Force hysteresis at shear angle of 5° 2HG5 = hysteresis width of curve at 5°

Measurement of the surface roughness is done by pulling the fabric across the surface a steel wire of 0.5 mm in diameter is bent into a U shape. The contact force between the wire and the surface is 10 gf. The value that is measured for the surface roughness is SMD (mean deviation of surface roughness). In the similar way the measurement of the surface friction is calculated using contactor which contains ten pieces of the same wire. 5g of contact force was used. Friction against the distance travelled is plotted from which following values are measured:

MIU = mean value of coefficient of friction

MMD = mean deviation of coefficient of friction

In the KAWABATA system 16 parameters are measured which shows mechanical and surface properties of fabrics:

Table:3.5 Parameters of Kawabata System

Properties	Terminology	Description
Tensile	LT	Linearity of load extension curve
	WT	Tensile energy
	RT	Tensile resilience
Shear	G	Shear rigidity
	2HG	Hysteresis of shear force at 0.5°
Bending	2HG5	Hysteresis of shear force at 5°
	B	Bending rigidity
	2HB	Hysteresis of bending moment
Lateral compression	LC	Linearity of compression thickness curve
	WC	Compressional energy
	RC	Compressional resilience
Surface characteristics of the fabric	MIU	Coefficient of friction
	MMD	Mean deviation of MIL
	SMD	Geometrical roughness of the fabric
Fabric construction	W	Fabric weight per unit area
	T_O	Fabric thickness

3.9. Development of Knitted fabrics

Initially for experimenting the feasibility of Lotus yarn in knitting, the researcher tried to develop knitted structure using 70:30 Lotus: Cotton blended rotor yarn in the knitting lab of South Indian Textile Research Association, Coimbatore, Tamilnadu. 100 % Lotus yarn was also experimented for knitting at Knitting Lab of Department of Textile Technology, PSG College of technology, Coimbatore. It was observed that there was great possibility of using lotus yarn (both in pure & blended form) in knitted structure.
Further for making final knitted samples, researcher collaborated with Angel Knitting industry at Surat, Gujarat. With the assistance from the industry chairman and knitting technicians, two different types of knitted fabrics were developed in the circular knitting machine

Plate 3.22. Winding of Lotus yarn for developing circular knitted fabric

Plate 3.23. Development of 100 % Lotus circular knit structure

Plate 3.24. Development of Lotus: Cotton blended circular knit structure

Plate 3.25. Machine setting for developing 100 % Lotus knit structure on industrial circular knitting machine

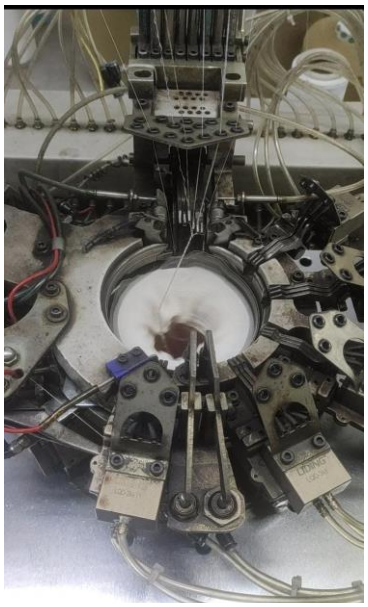


Plate 3.26. Circular knitting of 100 % Lotus yarn on industrial circular knitting machine

Plate 3.27. Heat press of 100 % Lotus circular knitted structure

3.9.1. Testing of Knitted fab

The developed fabric was subjected for the testing of fabric count, thickness, bursting strength, air permeability, pilling and stretch and Recovery properties. The tests were performed in textile testing lab of Department of Textile Technology, Faculty of Technology and engineering and Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda.

a). Determination of knitted fabric count (assessment of wales and coarses)

Following ASTM-D 8007-15, fabric count of the knitted fabrics was determined. This test method is only applicable to weft knitted fabrics – circular, flat bed and double knit fabric categories. Fabric count was assessed by calculating number of wales (wpi) and courses (cpi) per inch. For the test, fabric was first laid on table. Pick glass, ruler and pick needle were used for the test. Average of 10 readings were taken.

b). Determination of Bursting strength

Bursting strength of the knitted fabrics was tested as per ASTM D3786M-18. The test was done on hydraulic bursting tester consist of elastic diaphragm. Knitted fabric was clamped by a ring over a very thin rubber diaphragm which itself clamped over a circular hole in the upper face of reservoir. The operating fluid in the reservoir was oil. After clamping the fabric specimen, the hydraulic pressure is increased by the screw driven piston and the diaphragm distends till the fabric bursts. In the break point the strength is measured in kg/cm^2.

Plate 3.28. Bursting strength test of developed knitted fabrics in hydraulic bursting tester

c). Determination of Pilling

The test has been done as per 3.8.1 (j) mentioned in page no.142 and 143.

d). Determination of Stretch and Recovery

Following ASTM D 2594-99a, stretch and recovery property of the developed knitted fabrics were tested. For the test, three fabric sample of each category were cut in both directions that is wale wise (lengthwise) and course wise (widthwise).

The sample size was 125± 3 mm by 500 ± 10 mm. After cutting the fabric specimen, each sample was fold into half in lengthwise direction. The cut edge was sewed so that it forms a loop like structure.

For performing the test, entire hanger assembly was developed. The assembly consists of hangers, hanger stand, tensiometer (weights), ruler, marker and timer. After arranging the hanger assembly, fabric specimens were laid in the flat surface without tension. Bench mark was made in the central area in lengthwise direction in one side of the fabric specimen. After marking, the fabric specimen was placed between the upper hanger and lower hanger. The folded portion (stitched seam) of the fabric specimen was secured in the lower hanger. The upper hanger was attached in the slot of hanger stand and meanwhile weight was secured in the lower hanger by the means of chain. For loose fitting (comfort apparel), specified weight of 0 to 2.27 kgf (0 to 5 lbf) was used. For form fitting (semi support apparel), specified weight of 0 and 4.54 kgf (0 and 10 lbf) was used.

Calculation for fabric growth and stretch properties was determined using the equation mentioned below:

Fabric $\text{Growth}_{60s} = 100 \times (B-A)/A$

Fabric $\text{Growth}_{1h} = 100 \times (C-A)/A$

Fabric Stretch, $\% = 100 \times (D-A)/A$

Where,

A = original distance between bench marks prior to tension force, mm (in.).

B = distance between bench marks, mm (in.) measured after release of the tension, force following 60 s recovery.

C = distance between bench marks, mm (in.) measured after release of the tension, force following 1 h recovery.

D = distance between bench marks, mm (in.) measured while specimen is under tension force.

Averages of five readings were taken for each fabric sample.

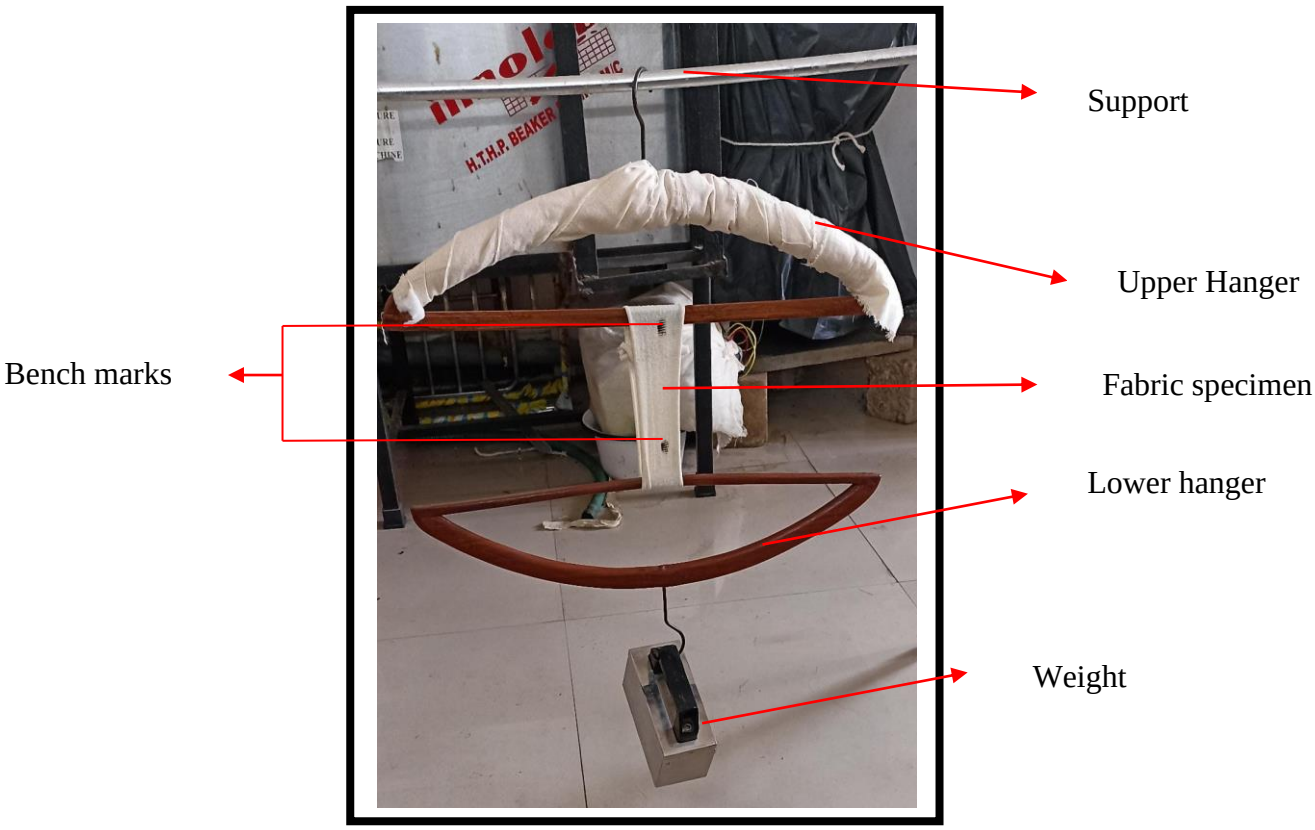


Plate 3.29. Hanger assembly for stretch and recovery test

e). Determination of thickness

The test has been done as per 3.8.1 (a) mentioned in page no.137.

f). Determination of Weight per unit area of the fabric (GSM)

The test has been done as per 3.8.1 (d) mentioned in page no.138.

3.9.2. Development of knitted product

Based on the results of knitted fabrics, 100 % Lotus knitted socks were developed at Angel Knitting Industry, Surat, Gujarat.

3.10. Testing of fibers for functional properties

a). Absorbency of Lotus fiber

Three different types of absorbency test were conducted: -

Free Swell absorptive capacity

Free Swell absorptive capacity of Lotus fiber was tested as per WSP 240.3-2011 standard. The test was conducted in the CoE medical textiles laboratory of SITRA South Indian Textiles Research Institute, Coimbatore.

Absorbency under Load/Pressure (AUL/AUP)

2 gms of raw Lotus fibers were finely chopped and spread evenly on 400 micron stainless steel mesh that is fixed at the bottom of acrylic cylinder having the diameter of 6.0 cm. Load of 21 g/cm^2 was placed in the acrylic cylinder. A porous ceramic plate of the diameter of 8.5 cm and thickness of 5 mm was placed on petri dish of diameter 9.5 cm. The test solution of 0.9 % aqueous Sodium Chloride (NaCl) was taken in the petri dish. Filter paper of diameter 7 cm comprising the pore size of < 25 µm was placed at the top of ceramic plate and allowed it to wet with Sodium Chloride solution. The acrylic cylinder was placed in the center of filter paper to allow fibers to absorb the test solution for 60 minutes. For the accuracy of the results, the experiments were repeated five times and average was calculated Yadav, S. et.al (2016).

The AUP/AUL was calculated using formula –

$$Q = \frac{W2-W1}{W1} \times 100$$

Here Q is the absorbency percentage.

W2= Wet weight/Final Weight

W1= Dry weight/Initial Weight

Plate 3.30. Load for absorbency under load test

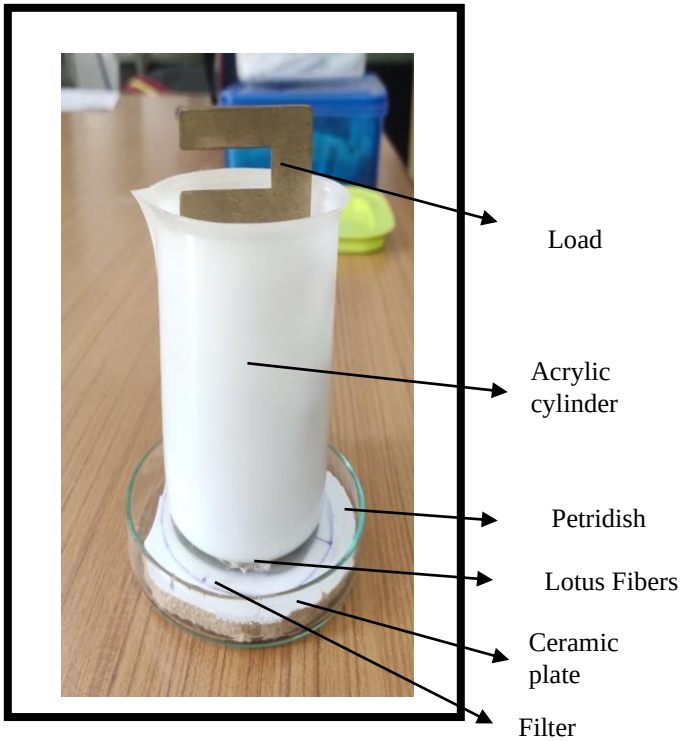


Plate 3.31. Assembly for absorbency under pressure/Load test

Equilibrium Absorbency

A specified weight of 0.168 gm of raw Lotus fibers was placed in the tea bag (lxw). Specified weight of the fibers was taken in 8 individual tea bags. The top of the tea bags were sealed and the paperclip hanger was inserted in each tea bag for hanging in the titration stands. 8 tea bag containing the fibers were soaked in the beaker containing 150 ml of distilled water for the time interval of 24 hours to determine the maximum absorptive capacity of the fibers. After 24 hours, fibers were taken out from the tea bags and squeezed Yadav, E.S. et.al. (2016). Equilibrium Absorbency was calculated using the formula:

$$Q' = \frac{W2-W1}{W1} \times 100$$

Here Q' is the percent equilibrium absorbency.

W2= Wet weight/ Final weight of the sample after immersion in the solution.

W1= Dry weight/Initial Weight of the sample before immersion in the solution.

Plate 3.32. Equilibrium Absorbency test of Lotus fiber

b). pH of the Lotus Fibers

The pH value of the Lotus fibers was measured using pH meter. pH meter was calibrated before measuring the values. 2 gms of Lotus fiber were chopped and immersed in a beaker containing 400 ml of distilled water. The beaker was manually stirred and shaked till the fiber disintegrated completely. Electrode was inserted in the beaker and the measurement was observed and recorded. Average of five readings was taken Kamaruddin, Z. et.al. (2016).

c). Antibacterial test

100 percent Lotus fiber (in the nonwoven web form) without any treatment was subjected for assessment of the antibacterial activity of textile materials test as per AATCC 147- 2016 Parallel streak method. It is a qualitative antibacterial test. The test was done in Microbiology lab of Bombay Textile Research Association (BITRA) Bombay, India. The test was performed against four organisms:

1. *Staphylococcus Aureas.* (ATCC 6538)
2. *Klebsiella Pneumonia.* (ATCC 6352)
3. *Candida Albicians.*
4. *Pseudomonas aeruginosa.*

Test method: Test specimens (non sterile) were cut into pieces (25mm x 50mm). The sterilization of the fabric specimen was done by steam flow method. Sterile AATCC bacteriostasis agar plates were prepared. Using sterile 4 mm inoculating loop, one loop full of cultured was transferred to the surface of the agar plate by making five parallel inoculum streaks spaced 10mm covering the central area of the petri dish without refilling the loop. The test specimen was gently pressed transversely, across the five inoculums of streaks to ensure intimate contact with agar surface. The plates were incubated at 37ºC for 24 hours. The inoculated plates were examined for the interruption of growth along the streaks of inoculum beneath the fabric and for a clear zone of inhibition beyond the fabric edge.

d). Cytotoxicity test (Indirect Method)

Following ISO 10993-5: 2009, Biological reactivity of the L929 mouse fibroblast cell culture is quantitatively determined in response to an extract of the test material in triplicate. The cells are allowed to grow to sub-confluency in tissue culture plates. An extract of the test material is prepared in Minimum Essential Media (MEM) which is transferred onto the cell layer in triplicate. The plates are incubated for 48 h at 37 degree Celsius in a 5 % CO_2 incubator, and scored for reactivity at 24 and 48 h on a scale from Grade 0 (no reactivity) to Grade 4 (severe reactivity). The test item is considered non-cytotoxic if none of the cultures exposed to the test item shows greater than mild reactivity (Grade 2).

3.11. Development of nonwoven fabric

To check the possibility of developing nonwoven sheet from Lotus fibers, lab scale method was developed. This experiment was done in Textile chemistry Lab of Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara. Later the final nonwoven sheet

was developed in Textile production lab of Avinashillingam Institute for Home Science and Higher Education for Women, Coimbatore Tamilnadu. The developed nonwoven sheet was tested for thickness and GSM.

Plate 3.33. Development of Lotus Nonwoven fabric

3.11.1. Testing of nonwoven fabric

a). Thickness of the nonwoven fabric

The test has been done as per 3.8.1 (a) mentioned in page no. 137.

b). GSM of the nonwoven fabric

The test has been done as per 3.8.1 (d) mentioned in page no. 138.

3.12. Development of hygiene products from nonwoven sheet.

The prototypes were developed in the Incubation Lab of SITRA – South Indian Textile Research Association Coimbatore, Tamilnadu. The hygiene products – sanitary napkin, sweat pads and panty liners was developed as per the standard size and template provided by SITRA. First and second layer of all the hygiene products was kept same as used commercially. The stitching of the hygiene products was done in the Ultrasonic machine. The description of the layers of the hygiene products are mentioned below:

a). The upper layers consist of polypropylene spun lace sheet.

b). The absorbent core consists of 100 % Lotus nonwoven sheet.

c). The bottom layer consists of water resistant polyethylene sheet.

a). Tri folding of Lotus nonwoven sheet for applications in sanitary napkin

b). Cutting of Lotus core layer as per the standard template

Plate c). Stitching of Sanitary napkin on Ultrasonic machine

Plate 3.34. Development of Sanitary napkin

3.13. Testing of hygiene product

Absorbency under load

Ability to withstand pressure after absorption was determined as per IS 5405:2019 Annex B. The test was conducted in CoE medical textiles laboratory of SITRA South Indian Textiles Research Institute, Coimbatore, Tamilnadu. For the test, the titration stand was arranged. In the bottom side of titration stand the transparent plastic tray was placed. The auto burette unit was connected in the titration stand. The flow rate of auto burette unit was 5 ml per minute. The height between the point of auto burette unit and sanitary napkin was 22 mm. The sanitary napkin was placed over the flat tray. Reason behind using the flat transparent tray was to have the easy visualization of leakage from

back and sides of sanitary napkin. For the artificial blood, .02 mol Bromocresol purple was dissolved in 1000 ml of analytical distilled water. Stop watch was used for time evaluation. Once the entire experimental set up was arranged the beaker containing the artificial blood was poured in the auto burette unit which falls on sanitary napkin. 5 ml of artificial blood was poured per 1 minute in the auto burette unit. Totally 6 minute was allowed to absorb the entire 30 ml liquid. After 6 minutes, the observation regarding leakages was done.

If no leakage is observed from back and sides of sanitary napkin then further testing was done by keeping standard weight of 1 kg over the same sample of sanitary napkin for 1 min and the observation was done regarding leakages. Evaluation of the wetness was checked by placing the white tissue paper over the same sample of sanitary napkin. If the tissue doesnot get completely wet and no leakages are observed then sanitary napkin is considered satisfactory for the use.

3.14. Training group of women for fiber extraction and spinning

For any research to be useful to society it should be shared with people so that they also get benefit. So training for fiber extraction and spinning were done. For conducting training programme, researcher searched on internet about different NGOs working in Vadodara District of Gujarat. Researcher purposively selected NGO Happy Faces ,Vadodara.

a). Interaction with NGO

Happy Faces started on 10th May, 2015 is the voluntary public welfare organization in Vadodara working for the betterment of the livelihood of semi urban peoples including health, education for children, nutrition and infra structure. Founder of NGO - Mr. Piyush Khare showed interest to start women empowerment activities and suggested to train the ladies of Zadeshwar village at Akshar Chowk, Atladara, Vadodara. So the entire training programme was done in collaboration with NGO Happy Faces, Vadodara. The training programme was named as “Project Sulbha”.

b) Locale of the training programme

Zadeshwar is the area near Sun Pharma Road, near BAPS Swaminarayan Temple Narayanwadi Atladara, Vadodara. The NGO has developed the street school in the Zadeshwar area. In this school poor children gets the free education in the morning time and in afternoon session parents of these children specially the mothers and young girls (above 18 years of age) were trained for Lotus fiber extraction. The training programme was done in the school in their vicinity only so that women can save time for transport and meanwhile they can take care of their family members.

c). Training for fiber extraction and spinning.

The training session started with the general introduction about the training programme by the founder of the NGO and researcher. After introduction the researcher demonstrated the entire fiber extraction process and also given the chance to the ladies to practice the extraction process. Training in spinning was given to ladies. Training was given by the expert Mr. Bakul Shah. Two week training was given to the women. The timing of the training programme was for 3 hours that is 3.00 to 6.00 PM. After two weeks training the researcher purposively selected 8 ladies as per the quality of fiber extracted by them, quality of spinning, productivity and dedication towards the work. Copy of Aadhar cards of all the 8 ladies was collected by the researcher. It was taken care of that all the 8 ladies selected were above 18 years. Consent of all the ladies were taken.

d). Workshop for fiber extraction and spinning

After development of the cluster for training the entire schedule was prepared for fiber extraction on the basis of duration, time and fund. All the necessary equipments were purchased before starting the project. The entire project was funded by NGO Happy Faces Vadodara. The duration of the project was for three months that is July to September, 2021. In this project ladies were trained to extract fibers from Lotus petiole. After finishing this three month project, the researcher also got the another project from GARGI – “Center for holistic development for women” research scholarship by Dr. Babasaheb Ambedkar Open University, Ahmedabad. The project was for six months.

The duration of the project was from November 2021 – May 2022. In this project ladies were trained for extraction and spinning of Lotus yarns. The researcher and mentor decided to develop handwoven stoles from the handspun lotus yarn developed by the ladies.

Plate 3.35. Training group of Women for fiber extraction

f). Weaving of handwoven stoles

For weaving researcher visited Bhujodi, Kutch. Weaving of the stoles was done by Artisian weaver Mr. Pachan Premji. Stoles were prepared using 100 % Lotus yarn in weft and 100 % cotton yarn in warp on handloom. Fabric was dyed with natural dyes: sappan wood and indigo.

Plate 3.36. Weaving of hand woven stoles at Bhujodi Kutch

f). Exhibition of the developed fabrics

Developed fabrics were exhibited in three different exhibitions. First exhibition was held on International Women's Day on 8 March, 2022 at Eva Mall Manjalpur, Vadodara, Gujarat. Second exhibition was at "Agripreneurs conclave – 2022" at GTU campus, Chandkheda, Gujarat. Third exhibition was done at "Weave Knit 2022" (The complete fabric show) 2nd Edition at Sarsana, Surat conducted by SGCCL (Southern Gujarat Chamber of Ministry and Chamber of Commerce and Industry).

3.15. SWOC Analysis of the fabrics

SWOC analysis is a widespread method and powerful tool used to identify factors like internal (strengths and weakness) and external (opportunities and challenges). In India Lotus is a novel fiber and it is in inception stage. Hence the SWOC analysis of fiber, yarn and fabric will give a perspective sight for future researches.