

Chapter – 4

RESULTS AND DISCUSSIONS

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 hygrowaste that is Lotus petioles for textile applications. In the present study, fibers were extracted manually by varying number of petioles and further spinning it using Ambar Charkha. 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 nonwoven sheet and rotor. Total 12 different types of yarns were developed. Based on the testing results of yarn, 14 different types of woven fabrics were constructed which comprises of 2 khadi fabrics, 5 handloom fabrics and 7 powerloom fabrics. Selected woven fabrics were subjected for KAWABATA analysis. As the Lotus fiber was extremely soft, has a good elongation property, excellent pliability and inherent antibacterial properties so the attempt was made to develop circular knitted structure. Two different varieties of 100 % Lotus circular knitted structure were developed. Based on the testing results of fabric, 100 % Lotus socks were developed. Lotus fibers were tested for its functional properties like absorbency, antibacterial property, Cytotoxicity and pH. Based on the positive testing results, further nonwoven fabric was developed and hygiene products: - sanitary napkin, sweat pads and pantyliners were developed and tested. Color is the major concern when selling the fabrics in the market. Hence the 100 % Lotus yarns were dyed with 9 different types of natural and reactive dyes. The dyed yarns were tested for color strength and fastness properties. To take the research from lab to community, researcher conducted the training programme in collaboration with HAPPY FACES NGO, Vadodara. Group of ladies were trained for fiber extraction and spinning. Handwoven stoles were prepared from the developed yarn and exhibited.

The results have been given, analyzed and discussed under following section: -

- 4.1.Extraction of fibers for yarn making and nonwoven sheet preparation
- 4.2. Testing of fiber
- 4.3.Spinning of hand extracted yarn using Ambar Charkha, testing of its properties and yield analysis
- 4.4. Designing and fabrication of machine -1
- 4.5.Development of yarns from machine - 1, testing of its properties and yield analysis
- 4.6. Designing and fabrication of machine -2
- 4.7. Extraction of fibers from machine -2
- 4.8.Development of blended yarns and its properties
- 4.9.Analysis of dyed yarns (Color strength and fastness properties)
- 4.10.Construction of woven fabrics and its properties
- 4.11.Construction of knitted fabrics and its properties
- 4.12.Development of knitted product
- 4.13.Functional properties of Lotus fibers
- 4.14. Construction of nonwoven fabric and its properties
- 4.15. Development of hygiene products and its properties
- 4.16. Training the women force for extraction and spinning.
- 4.17. SWOC Analysis

4.1. Extraction of fibers

a). Extraction of fibers for yarn making.

For yarn making several trails were done by varieting the number of petioles. The main reason behind varieting the number of petioles is to obtain different counts of yarns and further checking its feasibility for spinning and weaving. Another reason behind continuing the manual extraction process – it is full of art and skillful task which needs to be preserved and further it will be helpful to the Khadi sector. The

other advantage is the rural peoples can start this work of extraction without acquiring heavy equipments.

The process of extraction is mentioned stepwise:

Step 1: The required petiole (1-3) was taken over the wooden slab (Plate 4.1 - a).

Step 2: Petioles was slit into 5-7 sections as per the length with a sharp knife (Plate 4.1 - b).

Step 3: After each slit, petioles were slowly stretched and extracted fibers were laid in the wooden slab (Plate 4.1 - c).

Step 4: The extracted fibers were directly winded on the pern joining end to end points by palm twisting (Plate 4.1 - d).

It was observed that more concentration and skill is required for extracting fiber from one petiole and the extraction from two and three petioles were easy manageable. The output obtained by the manual extraction process was “unspun Lotus yarn”. (Plate 4.1- e).

b). Extraction of raw fibers for developing nonwoven sheet and rotor spun yarns

While extracting fibers for yarn making, it was observed that the leftover pieces of petioles also contain fibers. So, the following extraction method was developed for extracting fibers from leftover petioles.

Step 1: Felt fabric of (53Lx41W) cms was laid on the floor (Plate 4.2 - a).

Step 2: Bunch of four to five leftover lotus petioles were taken together was slited with the help of sharp knife (Plate 4.2 - b).

Step 3: After one slit, a bunch of petiole were slowly stretched apart to extract the fibers. Extracted fibers were sticked on the felt. (Plate 4.2 - b).

The collected fibers were used for developing nonwoven sheet and rotor spun yarn shown in (Plate 4.2 - c).

Due to the nature cohesiveness of the fibers it forms a yarn like structure when extracted from petiole. In this method, care should be taken that fibers should not

form a yarn like structure otherwise it will face difficulty in opening operation of carding process while developing nonwoven sheet and rotor spun yarn. This is an alternative method for extraction with its limitations of non-woven sheet and rotor spun yarn.



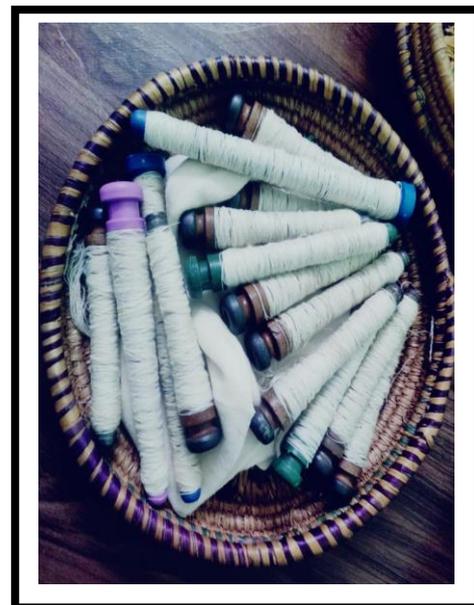
a). Holding the petiole together

b). Slitting the petiole with sharp knife

c). Stretching the petiole along with twisting



d). Winding the unspun Lotus yarn on pern



e). Lotus Unspun yarns

Plate 4.1: Manual extraction process for Lotus fiber a). Holding the petiole together, b). Slitting the petiole with sharp knife c). Stretching the petiole along with twisting d). Winding the unspun Lotus yarn on pern e). Lotus Unspun yarns



a). Felt fabric

b). Laying the fibers on the felt while extraction

c). 100 % Lotus raw fiber

Plate 4.2: Extraction of fibers for developing nonwoven sheet and rotor spun yarns

4.2. Preliminary data of the fiber

Properties of fibers – length, diameter, length to breadth ratio, fineness, strength, moisture regain, moisture content and color is mentioned in Table 4.1.

Table 4.1: Properties of Lotus Fibers

Property	Measurement
Fiber Length (Bundle)	60 to 105 cm
Fiber Diameter (Bundle)	2-6 μm
Length to breadth ratio (Bundle)	269000:1
Fineness (Bundle)	
Denier	32
Tex	3.5
Cotton count (Ne)	166s
Fineness (Single Unit)	1.06 Denier
Strength (Bundle)	
Maximum load (gf)	161.5
Extension at maximum (mm)	6.5589
Stress gm/den	5.0476
Bundle strength	18.5 g/tex
Fiber Moisture	
Moisture content	10.6 %
Moisture regain	11.8 %
Brightness index	41.130
Whiteness index	38.198
Yellowness index	15.028

Microscopical structure of the fiber - It was observed (Plate: 4.3) that single unit was smooth and fine. It was observed that the bundle has a wavy structure. Several individual fibers are conglomerated together into one bundle. From the cross sectional view it was observed that fiber has circular or similar to circular shape.

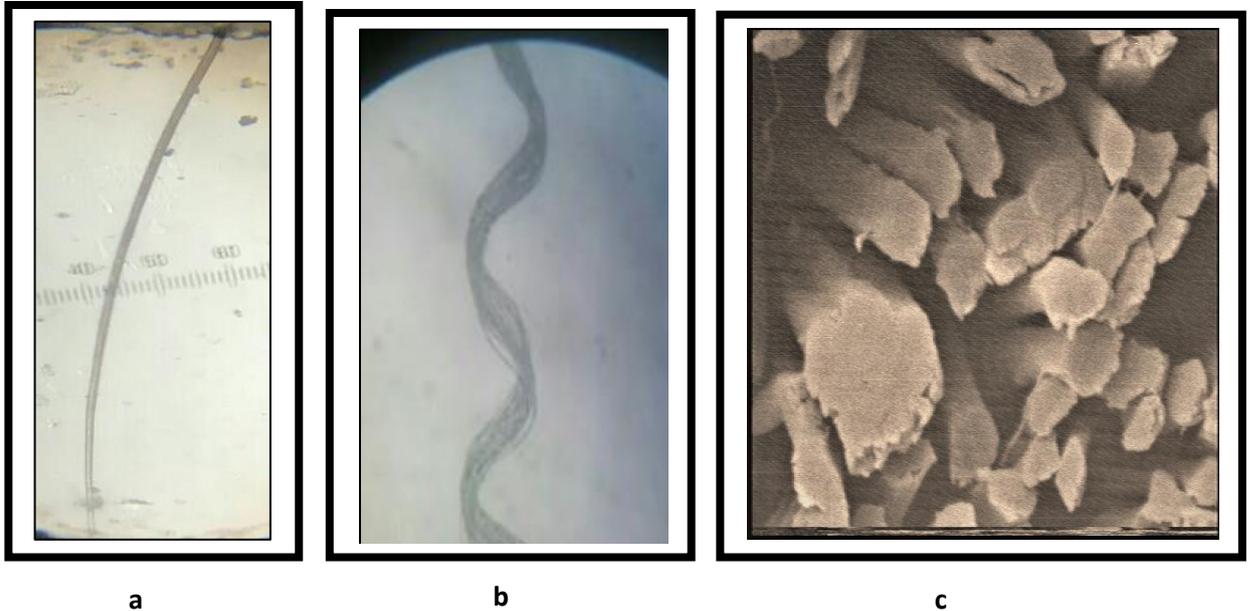
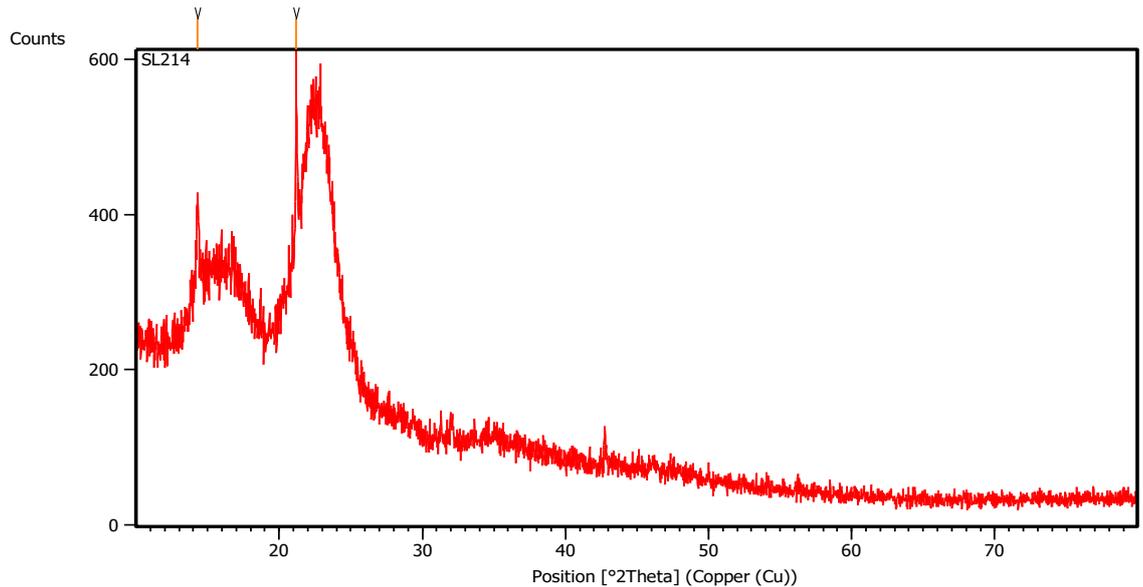


Plate 4.3. a). Longitudinal view of single Lotus fiber (single unit) -10 X b). Longitudinal view of Lotus Fiber (Bundle form) – 10 X c). Cross section view of Lotus Fiber -3500 X

XRD analysis of Lotus fiber

XRD analysis shows the amorphous and crystallinity index of the fibers. From Graph 4.1, it was observed that sharp peak was observed at 14° with the height 129.74 and broader peak was observed in 21° with the height of 254.42. The Crystallinity index (C.I) of the Lotus fiber was 40 %. Hence Lotus fiber has more amorphous regions. Peaks were not very sharp resembling to more amorphous regions of the Lotus fibers.



Graph 4.1: XRD analysis of Lotus Fiber

4.3. Spinning of hand extracted yarn using *Ambar Charkha* and analysis of its properties.

In the pilot work, the spinning was tried on *Takli* (Drop spindle) and *Peti* (box) *Charkha* also. But the output of the spinned yarn was very less. Hence the *Ambar Charkha* was used for twisting of Lotus yarn consists of 2 spindles shown in (Plate 4.4). Basically, the raw material used for spinning in *Ambar Charkha* is “rover”. But due to the nature of manual extraction method Lotus fiber the raw material achieved is in “unspun yarn” form that only requires twisting for strength and withstand in loom to develop a fabric.

For developing twisted Lotus yarn, the feed roller that decides the rate of feeding was removed from the basic *Ambar Charkha*. For the continuous spinning without any breakage, the assembly (Creel) was developed for the smooth supply of raw material. The smooth supply of raw material plays a major role in good quality twisting and increasing production rate. For developing the assembly, the small cartoon box was taken. In the cartoon box, holes were made in both left and right side at the same equal points in three rows. The thin cycle spokes were attached in the holes. Bobbins consists of unspun yarns were put in the spokes.

Strand of unspun yarn was taken from bobbin and passed through plastic funnel – throw roller pair – traverse ring – spindle. Spinning was done by rotating the hand wheel. Further hanks of 1000 meters were prepared on the winder of *Peti* (box) *Charkha* shown in (Plate 4.5).

It was observed that all the category of hand extracted (unspun yarns) from one, two and three petioles can withstand in spinning on *Ambar Charkha* without any frequent breakages. For the smooth production in spinning, the raw material that is the Lotus unspun yarn should be extracted in a proper manner with all these aspects that is: the fiber should be extracted in a uniform manner, proper joining of end to endpoints with enough strength.

Technically good spinning of yarns is due the following properties: a). Inherent property of cohesiveness. Cohesion is the property of the fiber that helps in spinning. Cohesiveness is the capacity of the constituent fibers to hold together in a mass. b). Natural crimp that is waviness along the fiber length. Crimp assist to generate the cohesion in the fibers during the carding, combing and drawing stages. However, the level of crimp should be optimum. Higher level of crimp will cause difficulty it will cause entanglement during the manufacturing process Lawrence, C.A. (2003). These properties are present in the Lotus fiber that is high cohesiveness due to fats and waxes present in the fibers and also in the cells in which fibers are arranged in the petioles. The fine microfibers are present in the xylem cells which is conglutinated together into a one bundle which has a natural helical configuration, waviness and crimp. Due to the high cohesion property the addition care was taken during uniform winding and rewinding from perns filled with extracted fibers. Addition care and attention is also taken during the Lotus hank formation and filling the perns for inserting Lotus weft during weaving.

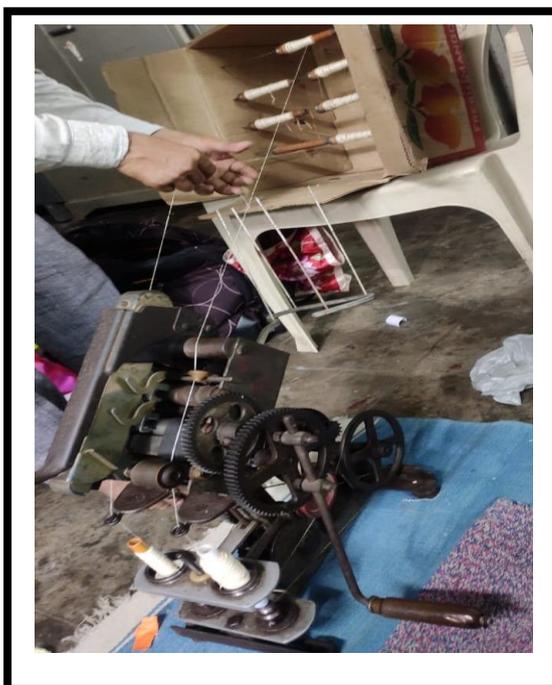


Plate 4.4 : Spinning of Lotus unspun yarn on Ambar charkha



Plate 4.5: Winding of Lotus spun yarn from spindle (for hank formation)

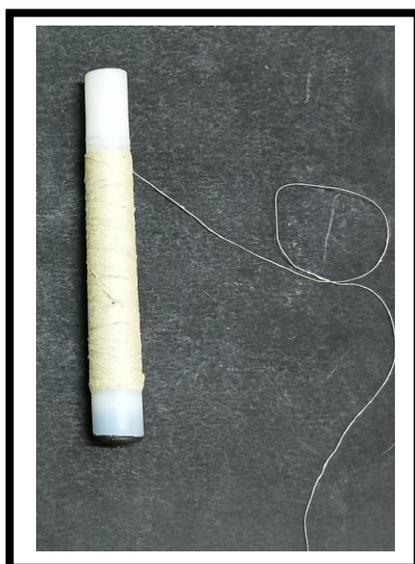


Plate 4.6 : L1A (Lotus yarn , 1 petiole extracted , Ambar charkha spun yarn)

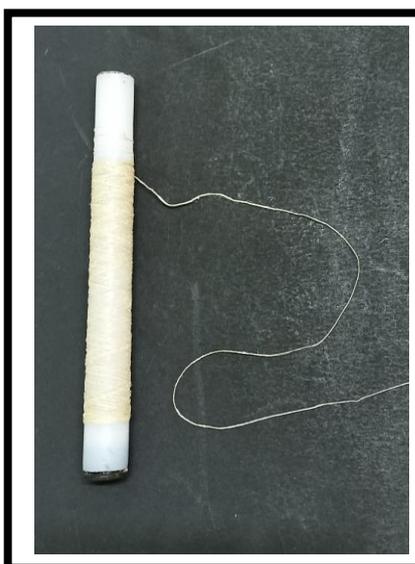


Plate 4.7 : L2A (Lotus yarn , 2 petiole extracted , Ambar charkha spun yarn)



Plate 4.8 : L3A (Lotus yarn , 3 petiole extracted , Ambar charkha spun yarn)



Plate 4.9 : L1A (*Lotus yarn , 1 petiole extracted , Ambar charkha spun yarn*) -96's
(Hank form)



Plate 4.10 : L2A (*Lotus yarn , 2 petiole extracted , Ambar charkha spun yarn*) -2/86's
(Hank form)



Plate 4.11 : : L3A (*Lotus yarn , 3 petiole extracted , Ambar charkha spun yarn*) – 3/28's
(Hank form)

Analysis of the properties of Lotus hand spun yarns

a). Fineness

Fineness is one of the most important properties of the yarn. Fine yarns are considered as a highly prized commodity which enables the fabric to be made luxurious and soft handle. In the natural fiber category, Silk and Cashmere are prized higher and cater the niche clientele due to the extreme fineness. Hence in the natural fibers achieving the fine yarns is commercially important and highly valued.

Table 4.2: Fineness of Lotus handspun yarns

Yarn	Denier	Tex	Cotton Count (Ne)
L1A	55	6	96's
L2A	63.09	7	86's
L3A	185	7	28's

L1A : Lotus yarn , 1 petiole extracted , Ambar Charkha spun yarn

L2A : Lotus yarn , 2 petiole extracted , Ambar Charkha spun yarn

L3A : Lotus yarn , 3 petiole extracted , Ambar Charkha spun yarn

Table 4.3: Fineness of Lotus handspun yarns - ANOVA Table (between Variables)

Variables		Mean	SD	SE	F-value	Sig
Yarn	L1A	55.00	1.58	0.71	206.912	.000**
	L2A	63.09	0.02	0.01		
	L3A	185	0.02	0.01		

****= Significant at 1% level**

L1A : Lotus yarn , 1 petiole extracted , Ambar Charkha spun yarn

L2A : Lotus yarn , 2 petiole extracted , Ambar Charkha spun yarn

L3A : Lotus yarn , 3 petiole extracted , Ambar Charkha spun yarn

As shown in Table 4.3 to find the association between Denier of different Yarns the researcher used One-way ANOVA and the result were presented in the above table, it is clear that there is an association between the yarns as the significance (p- value) value is 0.000, there is statistically significant (at 1% level). From the mean value it is noted that sample L3A (Lotus Yarn, 3 petiole extracted, *Ambar Charkha Spun Yarn*) got more denier when compared to other yarns. Thus, the result shows there is a statistical association between sample yarns.

Three different hand spun yarns were obtained that is L1A, L2A, L3A. From the Table 4.2, it was observed that most finer yarn was L1A having a count of 96's (55 Denier) followed by L2A that is 86's (63.09 Denier) and L3A (185 denier) that is 28's. Direct system of yarn describes that lower the denier finer is the yarn and higher the denier coarser is the yarn. Indirect system of yarn numbering describes that lower the count coarser is the yarn higher the count finer is the yarn. Hence the fiber extracted from one petiole was extremely fine which can be used in combination with other natural fine fibers like Silk because it has a similar appearance and feel like Silk. Nowadays the fashion industry is moving more towards vegan Silk. These fine Lotus yarns (L1A & L2A) due to the fineness can be used in the vegan Silk category. The manufacturing process of these handspun Lotus yarns requires lot of skill and time. Hence the cost increases. Handspun Lotus yarn will be a novel material for Khadi sector, luxury and premium market. As per the studies reported that in few places of the World – Myanmar, Cambodia, Vietnam, Manipur they practiced the extraction process only by taking the bunch of 3-8 petioles together. But in this study the efforts

has been made to extract and spin the fine quality 96's count Lotus yarn from single petiole.

b). Twist

Twist gives coherence and strength to the yarns. It is a measurement of the spiral turns imparted to the yarns in order to hold the constituent fibers together. The variation in the level of twist has an impact on yarn strength and softness.

It was observed and analyzed from Table 4.4, all the handspun Lotus yarns consist of S-direction twist. L2A that is Lotus yarn developed from two petiole has obtained higher twist of 130 tpi, L1A that is Lotus yarn developed from one petiole has obtained twist of 121 tpi followed by L3A that is Lotus yarn developed from three petiole has obtained twist of 63 tpi. The yarn having the twist of 60-75 tpi or more is considered as crepe twist and high twist yarn Hollen, N., & Saddler, J. (1955). Higher twist in the Lotus handspun yarns may be due to the inherent cohesion property of the Lotus fibers which helps in proper holding the constituent fibers together during extraction and spinning.

Technically the amount of the twist in the yarn should be optimum. As the twist increases beyond its maximum value, the yarn strength decreases. From the Table 4.4 and 4.5, it was observed that L2A Lotus yarn obtained from 2 petiole has obtained higher twist of 130 tpi but its tenacity was very low (1.832 gf/tex) amongst all the three handspun yarns which may be due to higher amount of twist imparted during the spinning process.

Table 4.4: Twist of the Lotus handspun yarn

Sr.No.	Twist per inch (tpi)	Twist per meter (tpm)	Twist Direction
L1A	121	4763	S
L2A	130	5118	S
L3A	63	2480	S

L1A : Lotus yarn , 1 petiole extracted , Ambar Charkha spun yarn

L2A : Lotus yarn , 2 petiole extracted , Ambar Charkha spun yarn

L3A : Lotus yarn , 3 petiole extracted , Ambar Charkha spun yarn

c). Tensile strength

Yarn should have adequate strength for handling during weaving. Lotus yarn has a moderate tensile strength. From the Table 4.5, it was observed that L1A that is yarn developed from one petiole has obtained highest tenacity of (36.531 gf/tex) followed by L3A (18.537 gf/tex) and L2A (1.832 gf/tex).

Lotus yarn developed from one petiole has obtained higher tensile strength because while stretching and extracting it naturally forms an inbound yarn like structure. Tenacity of the Lotus handspun yarn majorly depends on quality extraction of fibers.

Variability is the beauty of the natural fiber. The developed yarn has a soft feel and there was a slight variation in color ranging from off white to light yellow. But as compared to other minor cellulosic fibers, it does not require any pre-treatment for increasing strength, fineness and softness. Without any treatment it was suitable for extraction and spinning which lead to sustainability aspect of saving water and without the use of chemicals in the processing.

The major drawback of developing the Lotus handspun yarn was time-consuming extraction and spinning process which hinders to take this precious fiber in the mass scale production. The manual technique of extraction restricts to hand spinning and hand weaving. Thus, machine with different mechanisms was developed which had added new dimension in acquiring this novel aquatic fiber for different manufacturing techniques of textiles.

Table 4.5: Tensile Strength of Lotus handspun yarns

Sr. No	Yarn	Maximum Load (gf)	Extension at Max. (mm)	Stress (gm/den)	Strain (%)	Tenacity (gf/tex)
1	L1A	219.188	2.7	3.94	2.7	36.531
2	L2A	115.618	2.71	1.82	2.71	1.832
3	L3A	129.763	3.93	0.71	3.93	18.537

L1A : Lotus yarn , 1 petiole extracted , Ambar Charkha spun yarn

L2A : Lotus yarn , 2 petiole extracted , Ambar Charkha spun yarn

L3A : Lotus yarn , 3 petiole extracted , Ambar Charkha spun yarn

Yield analysis of hand extracted and handspun yarns

Hand extraction process was very time consuming. 25 gms of L3A yarn developed from three petiole can be produced in 7 hours. The length of the unspun yarn obtained from each slit is same with decreasing number of petioles. The time of extraction and spinning required for one petiole, two petiole and three petiole was same. But the weight of the developed hank decreases. For the construction of 1 meter fabric using Lotus yarn in weft, only 1 hank of L3A (Lotus yarn, three petiole, *Ambar Charkha*) is required. But in case of fabric construction from L1A (Lotus yarn, one petiole, *Ambar Charkha*) and L2A (Lotus yarn, two petiole, *Ambar Charkha*) more number of hank will be required because they are finer in count.

Table 4.6. Yield analysis of L1A yarn

Extracted unspun yarn for making one hank (gm)	9 grams
Extraction time for 9 grams unspun yarn(hours)	6 hours
Time for spinning 9 grams unspun yarn (hours)	1 hour
Weight of hank after spinning (gm)	6 gm
Weight of petioles (gm)	270g

*1 hank = 1000m

Table 4.7. Yield analysis of L2A yarn

Extracted unspun yarn for making one hank (gm)	15 grams
Extraction time for 15 grams unspun yarn(hours)	6 hours
Time for spinning 15 grams unspun yarn (hours)	1 hour
Weight of hank after spinning (gm)	12 grams
Weight of petioles (gm)	500 g

*1 hank = 1000m

Table 4.8. Yield analysis of L3A yarn

Extracted unspun yarn for making one hank (gm)	30 grams
Extraction time for 30 grams unspun yarn (hours)	6 hour
Time for spinning 30 grams unspun yarn(hours)	1 hour
Weight of hank after spinning (gm)	25 grams
Weight of petioles (kg)	1 Kg

***1 hank = 1000m**

4.4. Designing and fabrication of machine -1

Focusing on the nature of manual extraction process and simultaneously developing the unspun yarn like structure which further needs to be twisted in *Ambar Charkha* to withstand strength on loom. The extraction of the fibers manually is a tedious process and further twisting it in the *Ambar Charkha* also takes time which will helpful for mass production. The manual extraction process also needs high amount of manpower for extracting and spinning yarns. This is reason Lotus fiber is restricted only to handmade fabrics.

The major problems in implementing the mechanical process in the Lotus fiber extraction is the delicate appearance of the fiber and arrangement of the fibers in the petiole. The fibers are stretched out not from one single section of the petiole. The fibers are in the xylem cells and also in the side walls of the petioles.

The machine was developed in such a way that it can extract fibers, spin it into yam and wind it into the pern which can be directly used in the weft direction in weaving. The line diagram of the machine is shown in Figure 4.1 and Figure 4.2. The 3D diagram of the machine is shown in Figure: 4.3

The machine is semi-automatic. It consists of two sections that is – a). Input device (Feeding device) b). Output device (winding device).

Input device

The dimension of the input device/feeding device is (99 L×30W×35 H). The input device consists of wooden base. Over the wooden base there is sheet of sun mica. Device has three different iron stands. Over the three stands the long PVC pipe of 96 Cm is attached. The diameter of the PVC pipe is 3 Cm. 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. The entire machine is connected with the SMPS (Switch Mode Power supply).

Output Device

The dimension of output device (winding device) is – (32 L× 21W × 31 H). The winding device consists of wooden base. Over a wooden base there is sheet of sun mica. There are two iron stands in the winding device. Between the two rods, the entire assembly for attaching the pern is made. One side consists of round knob and another side consists of handle which is used to tighten and loosen the pern.

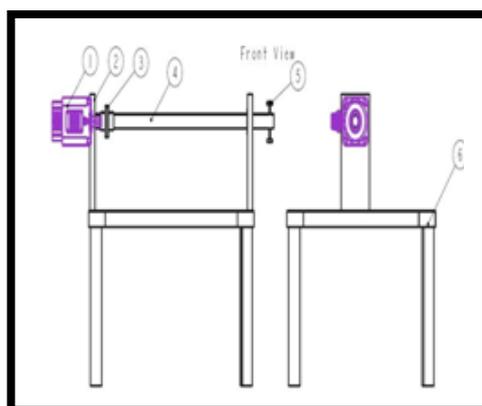


Figure: 4.1 Line Diagram of the Machine – 1 specifically for extracting and yarn making – Front view

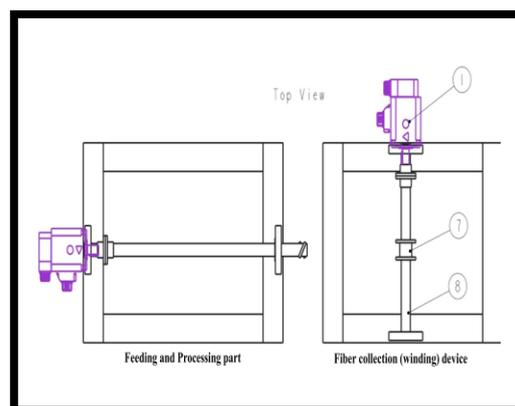


Figure: 4.2 Line Diagram of the Machine – 1 specifically for extracting and yarn making – Top view

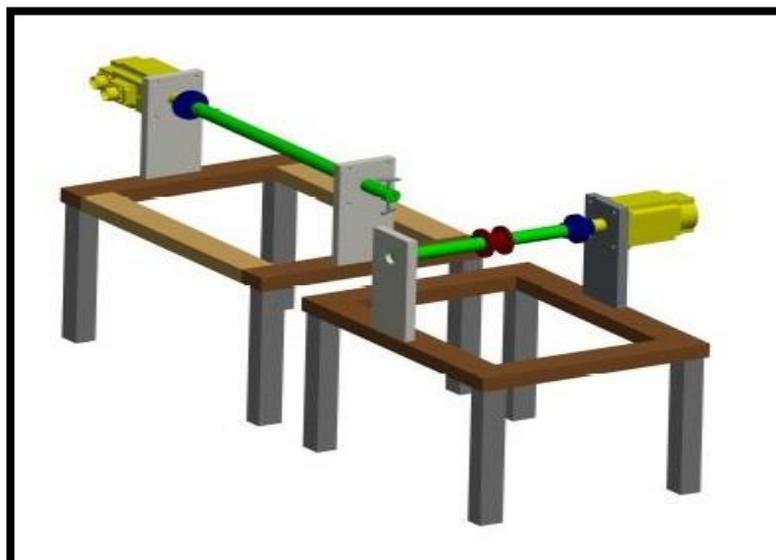


Figure: 4.3 Three-dimensional diagram of Machine – 1 specifically for extracting and yarn making

4.5. Development of yarns from machine-1

Step 1: Firstly, the cap of the PVC pipe is opened. The PVC pipe has an ability to hold 4 petioles together. But for extraction of fibers from this machine, only three petioles were taken. Bunch of three petioles were inserted in the PVC pipe and then cap of the PVC pipe was closed (Plate 4.12).

Step 2: In the opening/front area of PVC pipe, the plastic clip is attached to hold the petioles shown in (Plate 4.13). Holding the petioles together is one of the important and critical operations in extraction process and developing it into yarns

Step 3: Before extraction, the perns was slit with hezo blade in one end for the proper attachment in the winding device (Plate 4.18). After slitting, the pern was attached to the winding device (Plate 4.14). Meanwhile the inserted petioles were slited with the sharp knife (Plate 4.15).

Step 4: After slitting the petioles, the speed regulator of the feeding device is switched on whose task is to revolve the PVC pipe (Plate 4.16). The revolution of the PVC pipe can be manipulated and controlled by the speed regulator of the feeding device. Extracted fibers were wound on the pern initially for the starting operation. The power supply of the winding/output device is switched on whose task is to stretch

and wind the yarn simultaneously with the revolution of the PVC pipe the extracted fibers are twisted into yarn structure (Plate 4.17).

Step 5: Once the pern is filled with the yarn it is taken out and another pern is attached for the next extraction.



Plate 4.12: Feeding the Lotus petioles in the PVC pipe



Plate 4.13: Attaching the clip to hold the petioles together



Plate 4.14: Attaching the pern in the feeding device



Plate 4.15: Slitting the petioles

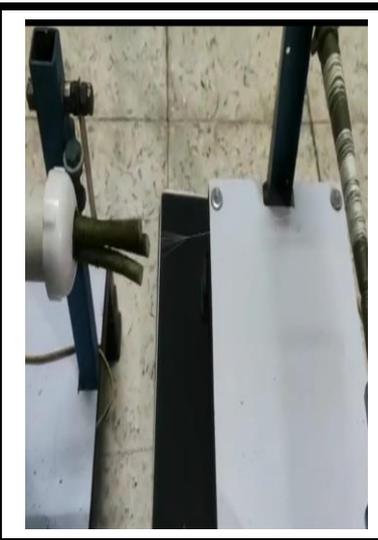


Plate 4.16: Rotation of the PVC pipe along with stretching of fibers and twisting

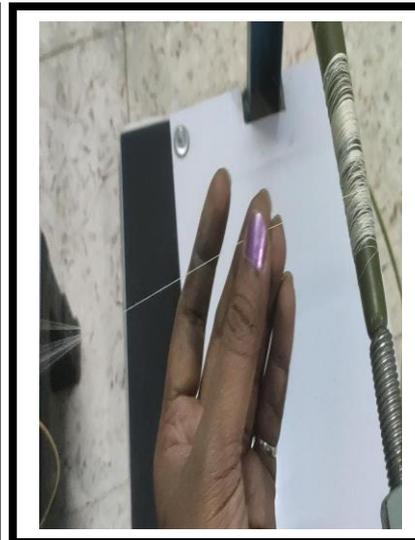


Plate 4.17: Pern with machine extracted and spinned Lotus yarn



Plate 4.18: Slitting the perns with hezo blade

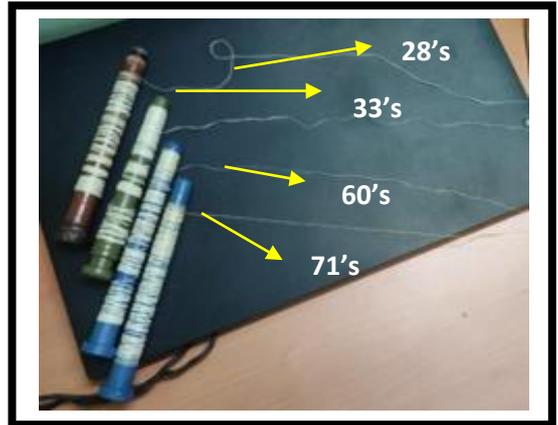


Plate 4.19: Machine extracted and spun Lotus yarns (Initial pilot work)



Plate: 4.20 MYHS1 – (Machine yarn high speed 1)-3/ 71's



Plate :4.21 MYHS2 – (Machine yarn high speed 2)-3/ 60's



Plate: 4.22 MYMS – (Machine yarn moderate speed 1)-3/ 33's



Plate: 4.23 MYHS – (Machine yarn Low speed 1)-3/28's

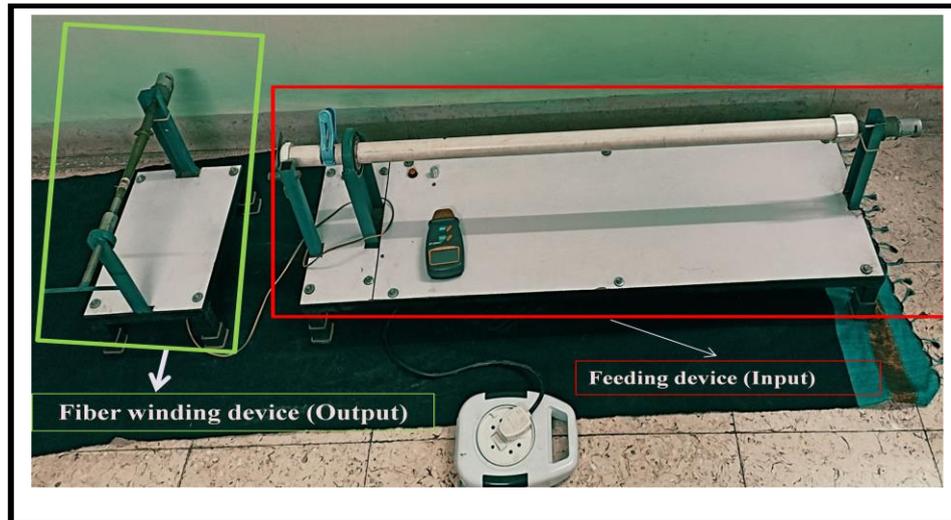


Plate 4.24: Fabricated machine 1 – for extraction and spinning of yarns

Optimization of speed in fabricated machine

The machine majorly consists of two rollers. The quality of the yarn depends on balancing the speed of both the rollers. For balancing the speed, several trails were taken.

- a) It was observed that when both the rollers rotate in extremely high speed, then the yarn formation is not even more of the hairiness is seen in the yarn structure.
- b) It was analyzed that when both the rollers rotate in low speed then the fibers extracted from the petiole form a yarn which has an open and loose structure.
- c) It was found that when the speed of feeding device is extremely high and speed of winding device is low. Due to the extremely fast revolution of feeding device the extracted fiber will result into a high twist yarn. The twist beyond limit leads to breakage and causes difficulty in handling during weaving process.
- d) It was found that when the speed of feeding device is extremely low and speed of winding roller is high than it causes frequent breakages due to improper twist.

For detecting the speed, Tachometer was used. 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. Speed (RPMs) were classified into: Low, Moderate, High 2 and High 1 shown in Table 4.9. In the fabricated machine only three petioles are used.

Table 4.9: Speed categorization of machine for obtaining different fineness of Lotus yarns

Sr. No.	RPMs	Codes of machine extracted yarn	RPMs of Feeding roller	RPMs of Winding roller	Cotton Count (Ne) achieved in particular speed
1	High -1	MYHS1	517	92	71
2	High – 2	MYHS2	470	87	60
3	Moderate	MYMS	315	80	33
4	Low	MYLS	270	75	28

MYHS1 - Machine yarn high speed 1

MYHS2 - Machine yarn high speed 2

MYMS - Machine yarn moderate speed

MYLS - Machine yarn low speed

Table 4.10: Quantity of Lotus yarn developed from fabricated machine

Sr.No.	Speed	Quantity of developed yarn (in grams) per hour	Petioles (in Kg)
1	MYLS	100	8 Kg
2	MYMS	100	8 Kg
3	MYHS2	80	6 Kg
4	MYHS1	70	5 Kg

MYHS1 - Machine yarn high speed 1

MYHS2 - Machine yarn high speed 2

MYMS - Machine yarn moderate speed

MYLS - Machine yarn low speed

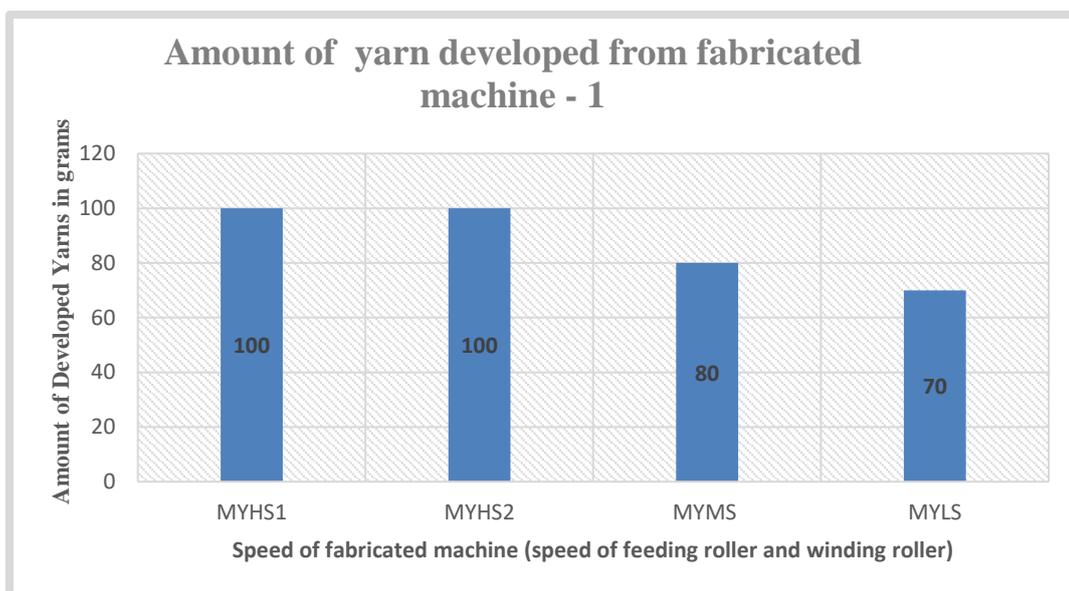
Table 4.11: Amount of Lotus yarn developed from fabricated machine - Anova table (between variables)

Variables		Mean	SD	SE	F-value	Sig
RPMs	High rpm – 1	100.00	1.58	0.71	450.000	.000**
	High rpm – 2	100.00	1.58	0.71		
	Moderate rpm	80.00	1.58	0.71		
	Low rpm	70.00	1.58	0.71		

**= Significant at 1% level

As shown in Table 4.11, to find the association between the speed of a machine and amount of developed yarn One-way ANOVA were used and the result were presented in the above table, it is clear that there is an association between the speed as the significance (p- value) value is 0.000, there is statistically significant (at 1% level). From the mean value it is noted that sample High RPM 1 got more speed and can developed more yarn when compared to other speeds. Thus, the result shows there is a statistical association between speed and yarn development process.

In fabricated machine, one manpower can produce 100 gm of developed Lotus yarn of 71's and 60's count. The role of the operator is to feed the petioles in the feeding device, placing the perns the winding device and regulating the speed. As the speed decreases, the amount of the yarn obtained is low. Winding is done by the machine so there were no issues regarding the entanglement. Uniform winding of developed yarn on the pern was possible. As compare to the manual method, more amount of yarn can be achieved can from fabricated machine.



Graph 4.2 : Amount of yarn developed from the fabricated machine

MYHS1 - Machine yarn high speed 1

MYHS2 - Machine yarn high speed 2

MYMS - Machine yarn moderate speed

MYLS - Machine yarn low speed

Analysis of the properties of yarn developed from fabricated machine-1

a). Fineness

Fineness of the Lotus yarn developed from the fabricated machine are mentioned in Table 4.12. Fineness of the machine extracted and spinned yarn depends on the speed of both the rollers that is feeding roller and winding roller of the fabricated machine. In the optimized high speed that is (RPM of feeding roller – 517) and (RPM of winding roller – 92), finer quality of the Lotus yarn (MYHS-1) was achieved that is of 71’s count. With the slight decrease of speed (RPM of feeding roller – 470) and (RPM of winding roller – 87) a slight decrease in fineness was observed which is categorized as (MYHS2) yarn of 60’s count. In the moderate speed that is (RPM of feeding roller – 315) and (RPM of winding roller – 80) yarn of 33’s count was achieved. 28’s count yarn was achieved in the low speed ((RPM of feeding roller – 270) and (RPM of winding roller – 75). Only three petioles were used in the fabricated machine. In machine extraction and spinning variation in fineness is due to the number of fine microfibers stretching out from the petioles and twisting together

into the yarn. Yarns with the fineness ranging from 7.5 to 40 tex can be used successfully for textiles specifically for the apparel purpose Lawrence C.A. (2003). Hence all the four categories of the Lotus yarns obtained from the machine can be used in apparels.

Table 4.12: Fineness of machine extracted and spinned Lotus yarn

Sr. No.	Yarn type	Denier	Tex	Cotton count (Ne)
1	MYHS1	189	21	71
2	MYHS2	158	17.55	60
3	MYMS	79	8.77	33
4	MYLS	74	8.22	28

MYHS1 - Machine yarn high speed 1

MYHS2 - Machine yarn high speed 2

MYMS - Machine yarn moderate speed

MYLS - Machine yarn low speed

Table 4.13: Fineness of machine extracted and spinned lotus yarn - Anova table (between variables)

Variables		Mean	SD	SE	F-value	Sig
Yarn Type	MYLS	189.00	1.58	0.71	6601.333	.000**
	MYMS	158.00	1.58	0.71		
	MYHS2	79.00	1.58	0.71		
	MYHS1	74.00	1.58	0.71		

****= Significant at 1% level**

As shown in Table 4.13, to find the association between Denier of different Yarns extracted by machine the researcher used One-way ANOVA and the result were presented in the above table, it is clear that there is an association between the denier as the significance (p- value) value is 0.000, there is statistically significant (at 1% level). From the mean value it is noted that sample MYLS (Machine Yarn Low Speed) got more denier (Coarser) when compared to other yarns. Thus, the result shows there is a statistical association between sample yarns.

b). Twist

The amount of twist expressed in tpi, tpm and twist direction were tested and mentioned in Table 4.14. The amount of the twist plays a key role in developing yarns from the fabricated machine. The amount of twist majorly depends on the speed of the feeding roller which carries the petioles. All the yarns consist of S- direction twist. MYHS1 (Machine yarn high speed 1) and MYHS2 (Machine yarn high speed 2) has obtained a high twist of 100 tpi followed by MYMS (Machine yarn moderate speed 2) has obtained 76 tpi and MYLS (Machine yarn low speed) consist of lower twist of 40 tpi. Technically yarns with the range of 40-60tpi and greater than this range are considered as high twist yarn Hollen, N., & Saddler, J. (1955). Hence the tpi of MYHS1, MYHS2, MYMS and MYLS were in the range of high twist.

Table 4.14: Twist of machine extracted and spinned Lotus yarn

Sr. No.	Yarn type	Twist per inch (TPI)	Twist per meter (TPM)	Twist Direction
1	MYHS1	100	3937	S
2	MYHS2	100	3937	S
3	MYMS	76	2992	S
4	MYLS	41	1614	S

MYHS1 - Machine yarn high speed 1

MYHS2 - Machine yarn high speed 2

MYMS - Machine yarn moderate speed

MYLS - Machine yarn low speed

c). Tensile strength

The tensile strength of machine extracted and spinned Lotus yarns were tested and values are mentioned in Table: 4.15. 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. It was analyzed from Table 4.15, MYHS1 (Machine

yarn high speed 1) has obtained highest maximum load of 883.41 gf having the tenacity of 42.06 gf/tex. With the slight decrease in speed of the fabricated machine the tenacity dropped to 16.77 gf/tex in MYHS2 (Machine yarn high speed 2). The tenacity was found low in MYMS (Machine yarn moderate speed) and MYLS yarns (Machine yarn low speed) but the extension was higher in both the yarns that is 4.64 mm and 6 mm respectively as compared to the yarns developed in high speed. MYHS1 and MYHS2 possess higher tenacity due to the higher speed and higher amount of twist imparted in the yarns. It was analyzed that tensile strength of the machine extracted yarn in high speed (MYHS1) – [Maximum load – 883.41 gf, Tenacity -42.06 gf/tex] was more than the L3A that is (Lotus yarn, 3 petiole extracted, *Ambar Charkha* spun yarn) - [Maximum load – 129.763 gf, Tenacity – 18.537 gf/tex]. Hence the machine extracted yarn has higher strength.

Table 4.15 : Tensile strength of machine extracted and spinned Lotus yarn

Sr.No	Yarn type	Maximum Load (gf)	Extension at maximum (mm)	Stress(gm/den)	Strain (%)	Tenacity (gf/tex)
1	MYHS1	883.41	2.697	5.909	2.697	42.06
2	MYHS2	294.46	3.326	0.720	3.326	16.77
3	MYMS	81.454	4.64	1.230	4.64	9.28
4	MYLS	78.028	6	1.181	6	9.49

MYHS1 - Machine yarn high speed 1

MYHS2 - Machine yarn high speed 2

MYMS - Machine yarn moderate speed

MYLS - Machine yarn low speed

4.6. Designing and fabrication of machine – 2

Machine 1 is designed in such a way that it can extract the fiber in a continuous form joining end to end points. The output material obtained is in the yarn form which can be further used for weaving and knitting. But in case of developing nonwoven structure, preparation of rotor and ring spun yarns the basic raw material is the fiber

form. So, the machine was designed and fabricated with the specific structure. The line diagram of the machine -2 is shown in Figure 4.4.

The machine is semi - automatic works on programming. The dimension of the machine is (65L×45W×23H) Cms.

The machine consists of three sections –

- a). Feeding device
- b). Gripping device
- c). Fiber collection device

a). Feeding device: - As shown in Figure 4.5, It is a rectangular slab of following dimension (37L×16W×15H). The rectangular slab is made of Mild steel. In the front area of the rectangular slab, there is an assembly of one rubber roller coated with Polypropylene. To reset the rubber roller, there is a screw mechanism in both the sides of roller. Behind the rubber roller, there are two mild steel rods which are arranged horizontally. Behind the two mild steel rods there is a connection of two sharp blades in upper and lower sides. There is a conveyer belt assembly in both the sides of the feeding device in front area.

b). Gripping device: - As shown in Figure 4.6, The gripper assembly is made of mild steel. In the middle area of gripper assembly there is a rectangular shape holding mechanism.

c). Fiber collection device: Between the two sections: feeding and gripping there is an assembly made for collecting fibers. The vertical stand is connected in the front side of the feeding device. In that vertical stand, a horizontal rod is connected from upper side making a perpendicular axis. In the horizontal rod, there is a provision made to attach the comb like device for fiber collection.

The comb like device for fiber collection is made of Poly Lactic Acid (Pro). In the comb like device, a thin polypropylene spikes attached for smooth collection of fibers from petioles.

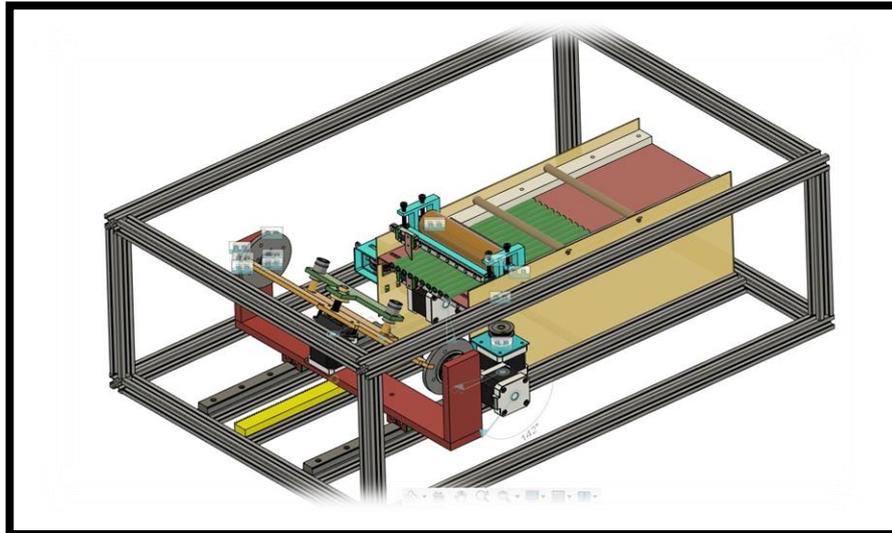


Figure : 4.4 Diagram of Machine-2 for extracting raw fibers from the Lotus petals

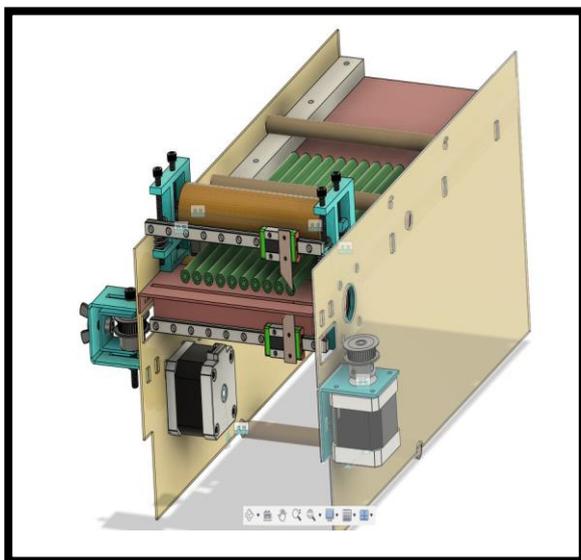


Figure: 4.5 Feeding device of Machine -2

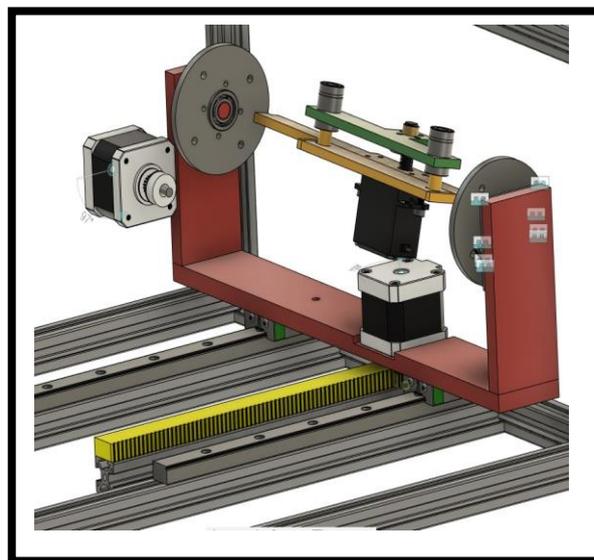


Figure: 4.6 Gripping and winding device

4.7. Extraction of fibers from machine -2

Before starting the extraction process, all the components of the machine is set in their home position.

Step 1: Five to six petioles were arranged in the feeding device or rectangular slab horizontally.

The petioles were set below the rubber roller and horizontal rods. The role of the roller is to slide the petiole forward for extraction. The role of the two horizontal rods is to hold the petiole together in the proper alignment for correct slitting from upper and lower sides.

Step 2: After arranging the petioles, the blades slits petioles from upper and lower sides.

Step 3: After slitting the petioles, the gripper mechanism comes forward, grips the slitted petioles.

Step 4: The gripper winds the slitted petiole over the comb like device.

Step 5: With the rotation of comb –like device, the fibers are collected over the toothed surface.

Step 6: Once the comb like device is filled with the fibers. From one side it is slit with the sharp blade and extracted fiber is taken out. The comb is emptied and connected to the horizontal rod of the fiber collection device for next extraction.

All the steps are controlled automatically via switch board only the petioles are fed in the machine manually. In the back side of rectangular slab of feeding device there is a circuit board to operate the entire extraction process of fiber. The machine has the capacity to extract 130 gms if fiber in 1 hour.



Plate 4.25: Machine -2 for extracting raw fiber



Plate 4.26: Lotus fiber extracted in raw form from machine -2

4.8. Development of blended yarns and its properties

a). Fiber stage blending – Preparation of blended rotor spun yarns

Lotus fiber has a numerous inherent property – it is extremely soft, lustrous and has a moderate strength. Till date, Lotus fibers are only extracted by manual process which restrict its use only to handmade fabrics. The hand extracted yarn leads to more cost. The attempt was made to blend the Lotus fiber with natural cellulosic fibers like Cotton by industrial spinning system that is rotor spinning. The blended yarn developed by the fiber blending process consists of inherent properties of both the fibers.

For blending, Lotus fibers used were extracted on the woollen felt. Initially 50:50 (Lotus: Cotton) was tried for spinning. It was observed that it was successful to achieve the yarn in the proportion of 50:50 (Lotus: Cotton). Later the proportion of Lotus fibers increased and 70:30 blend proportion was achieved. During the processing of 70:30 Lotus: Cotton spinning, it was observed that there were little cracks seen in lap formation which may be due to the increase of Lotus fiber in the blend proportion. The process of developing open end yarn is shown in Plate 4.28.

Step -1: Firstly, the Lotus and Cotton fibers were weighted for obtaining the blend proportions. Plate: 4.28 (a)

Step -2: After weighting fibers, initially the 100 % Cotton fibers were passed for opening and carding, two Cotton laps were produced. Between the two Cotton laps, Lotus fibers were sandwiched, arranged and processed further for opening as shown in Plate 4.28 (b). In opening operation, compressed fibers open up into very small tufts. Dust particles and contamination were removed from the fibers.

Step 3: After opening, the Lotus: Cotton carded web were produced over the drum shown in Plate 4.28 (c). The carded web of 50:50 Lotus: Cotton proportion was even in appearance whereas 70:30 Lotus: Cotton web contains little cracks and non-uniformity.

Step 4: The sliver was slowly pulled in lengthwise direction from the carded web and the initial starting point was passed through the funnel and sliver was collected over the plastic tub. It was observed that in both the blend proportion, the slivers were smooth, strong and evenly drawn shown in Plate 4.28 (b)

Step 5: After drawing the slivers, it was subjected for rotor spinning. One end of the sliver is inserted inside the rotor assembly and various technical parameters – Rotor, delivery, feed and opening was set and spinning was carried out. The spun yarn was automatically wined in a criss-cross manner over the bobbin. It was observed that there were negligible breakages during spinning in both the blend proportion which may be due to the inherent good strength of both the fibers. Open end yarns developed in both the proportion is shown in Plate 4.27.

Table : 4.16 Technical specification of carding machine

Sr. No	Operations	Speed (mm/min)	Speed (mm/min)
		50:50 Lotus: Cotton	70:30 Lotus: Cotton
1	Feeding	0.83	0.50
2	Main Cylinder	504.9	704.9
3	Doffer	3.51	4.55

Table: 4.17 Technical specification of Rotor

Sr. No	Operations	Speed (mm/min)	Speed (mm/min)
		50:50 Lotus: Cotton	70:30 Lotus: Cotton
1	Rotor	15000	19500
2	Delivery	13.7	17.5
3	Feed	5.06	4.84
4	Opening	6499	6156



Plate 4.27: a). 50:50 Lotus: Cotton Rotor spun yarn b). 70:30 Lotus: Cotton Rotor spun yarn

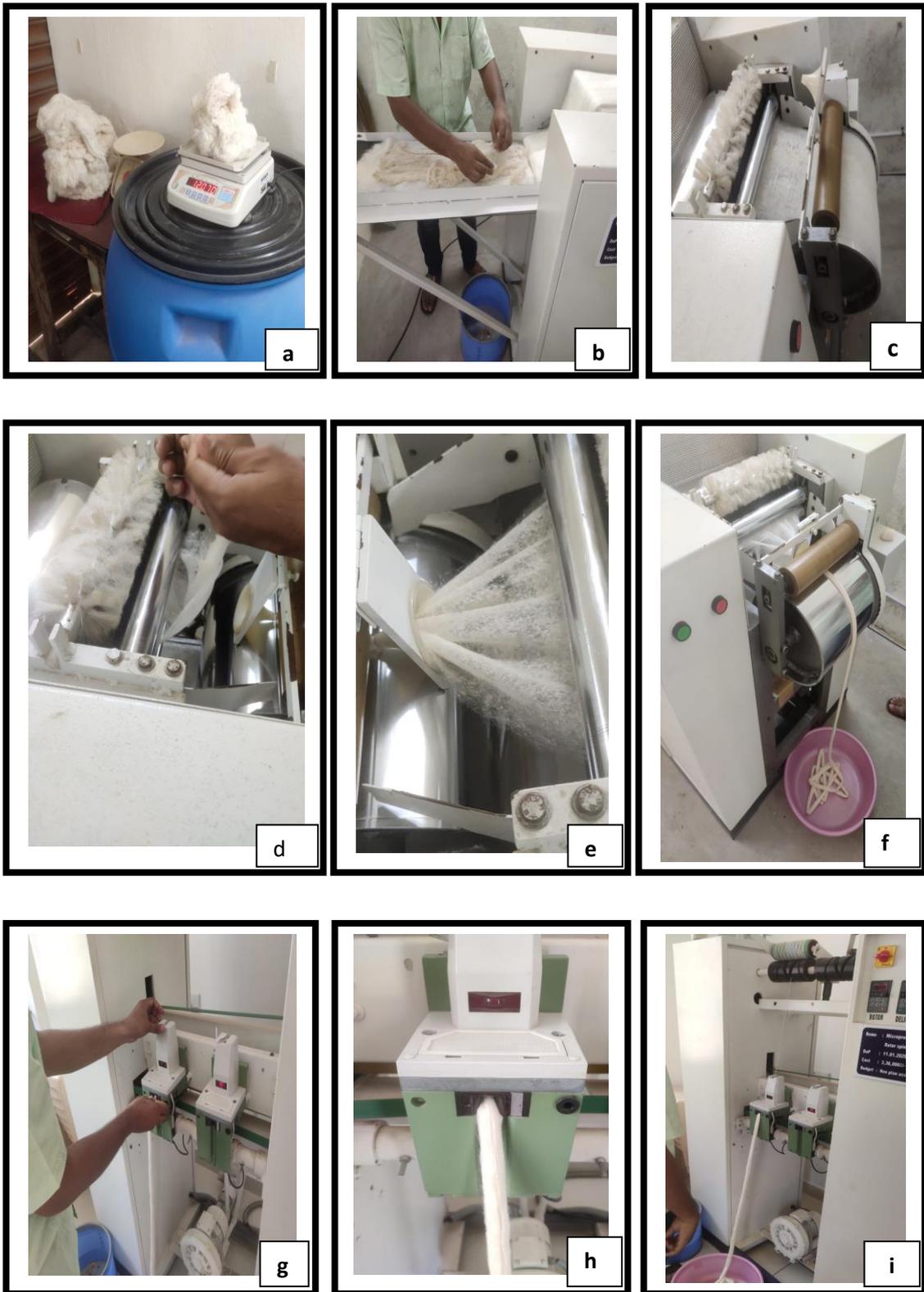


Plate 4.28: Open-end Rotor spinning of blended Lotus yarn a). Weighing of Lotus and Cotton fibers b). Lotus fibers were put between the two laps of Cotton c). Development of blended laps d). Preparation for sliver e). Sliver formation (close image) f). Sliver formation and collecting it into a plastic tub g). Putting the sliver in the rotor h). Lotus cotton blended sliver in the rotor (Close view) i). Spinning of Rotor yarns

Testing and analysis of Lotus: Cotton rotor yarn

Analysis of the properties of Lotus: Cotton rotor yarn

a). Fineness

From Table 4.18, it was observed that Lotus: Cotton blended open end yarns were coarser. LCRY (70:30) - 3's was coarser than LCRY (50:50) -5's. This may be due to increase of the Lotus fiber in the blend proportion. These yarns can be used to develop heavy weight fabrics for the applications in jackets, coats and household textiles.

Table: 4.18 Fineness of the Lotus: Cotton rotor yarn

Sr. No	Yarn	Denier	Tex	Cotton Count (Ne)
1	LCRY (50:50)	1009	112	5's
2	LCRY (70:30)	1290	143	3's

LCRY (70:30)- Lotus : Cotton Rotor spun yarn

b). Twist

It was analyzed from Table 4.19, that twist of Lotus: Cotton blended open end yarns were higher which may due to the good cohesion property and natural crimp of Lotus fiber. Tpi of LCRY (50:50) was higher than tpi of LCRY (70:30). Twist direction of both the yarns were in Z-direction.

Table: 4.19 Twist of the Lotus: Cotton rotor yarn

Sr. No	Yarn	Twist per inch (TPI)	Twist per meter (TPM)	Twist Direction
1	LCRY (50:50)	94	3700.78	Z
2	LCRY (70:30)	82	3228.34	Z

LCRY (50:50) - Lotus: Cotton Rotor spun yarn

LCRY (70:30)- Lotus: Cotton Rotor spun yarn

c). Tensile strength

It was observed from Table 4. 20 that there was slight difference in tenacity of both the yarns. The extension of LCRY (50:50) - 30.5 mm was higher than LCRY (70:30) – 32 mm. This may be due to the increase of Lotus fiber in the blend proportion of LCRY (70:30) and natural elongation property of the Lotus fiber in the yarn structure.

Table :4.20 Tensile strength of the Lotus: Cotton rotor yarn

Sr. No	Yarn	Max Load (gf)	Extension (mm)	Tenacity(gf/tex)
1	LCRY (50:50)	528	30.5	4.71
2	LCRY (70:30)	656	32	4.58

LCRY (50:50) - Lotus: Cotton Rotor spun yarn

LCRY (70:30) - Lotus: Cotton Rotor spun yarn

b). Yarn stage blending

Blending in yarn stage was done by plying technique. Twisting two or more singles yarns is called as called ply twisting, doubling and folding. In plying, the yarns are twisted in the direction opposite to the singles yarn twist to develop a torque balanced yarn Mayers, R. (2001). The main motto of ply twisting is to enhance the strength, luster, elongation, smoothness and abrasion resistance to achieve the high stability against the wear, improvement to fabric cover and visual appearance. Ply yarn increases the durability and flexibility Lord, P. (2003). The balance of twist in both the singles yarn is important to obtain the good quality ply yarn. Otherwise, the fabrics developed from it will have a tendency to coil or kink Mayers, R. (2001).

Lotus fiber has a superior quality of long length. Instead of cutting it into a staple length for blending, an attempt was made to ply the Lotus yarn with other natural fibers like – Cotton, Silk and Wool. During weaving, 100 % Lotus yarn is unable to withstand strength in warp direction so plying the Lotus yarn with other natural fibers will help to increase the production and weft was 100 % machine extracted Lotus yarn.

The fabrics produced from these ply yarns were durable with different textures. The Lotus yarn itself has a silk like smooth appearance hence plying the Lotus yarn with Mulberry Silk was done. Wool and Lotus both has a natural crimp in the structure, hence plying was done with the Wool yarns. For plying, only the machine extracted Lotus yarns were used.

The most important and advantageous quality of Lotus fiber in developing ply yarn is its cohesiveness and crimp, it fastly conglomerate with the other yarns in twisting operation.

Preparation of Ply yarns

Plying was done in the two-spindle Ambar Charkha. The major and component yarns were winded on separate pern. These perns were placed in the creel for the smooth supply of both the yarns for maintaining the tension in plying. The specification of major and component yarns is shown in Table 4.21, it was observed that Lotus fiber due to its good cohesion property and luster, it bounds well in all the ply structure. After plying, all the yarns had a textured appearance due to the characteristic of different fibers used (Cotton, Silk, Wool) and variation in counts implemented in the ply structures

Table :4.21 Specification of Lotus Ply yarns

Sr. No	Ply yarns	Major yarn	Count (Ne)	Type of Lotus yarn	Twist Direction	Component yarn	Count (Ne)	Twist Direction	Twist Direction of Ply
1	YLCP	Lotus	3/60's	MYMS	S	Cotton	70	S	Z
2	YLSP	Lotus	3/71's	MYHS 1	S	Mulberry Silk	100	S	Z
3	YLWP	Lotus	3/28's	MYLS	S	Australian Wool	9	S	Z

YLCP - Yarn Lotus cotton ply

YLSP - Yarn Lotus Silk Ply

YLWP - Yarn Lotus Wool Ply

Analysis of the properties of the Lotus Ply yarns

a). Fineness

Fineness values of ply yarns are mentioned in Table 4.22 It was found YLWP (Yarn Lotus Wool Ply) yarns were coarser that is 14.40's due to the Wool yarn and lower count of Lotus yarn (3/28's) used in the Ply structure. YLSP yarns were finer that is 23.10's amongst all the three yarns due to the finer Mulberry Silk and Lotus yarn used in the Ply structure.

Table 4.22: Fineness of Lotus Ply yarns

Yarn	Denier	Tex	Cotton Count (Ne)
YLCP	275	30.55	19.32
YLSP	230	25.55	23.10
YLWP	369	41	14.40

YLCP – Yarn Lotus cotton ply

YLSP - Yarn Lotus Silk Ply

YLWP – Yarn Lotus Wool Ply

b). Twist

Proper plying holds the yarn together. It was observed and checked that yarns should not get separate out and form a loose structure after plying that will further face difficulty in peg warping and weaving on loom. It was also taken care of that optimum twist is imparted in the yarn structure because high twist form crimp in entire length of the yarn structure that will further face issues during handling these ply yarn in weaving process. Hence the amount of twist plays a critical role in the ply structure. Twist per inch (tpi), Twist per meter (tpm) and twist direction were tested and values are mentioned in Table 4.23. It was observed that all the ply yarns has obtain higher twist which has a correlation with inherent nature of Lotus fiber, type of constituent yarn, variation in fineness of major and constituent yarns. It was analyzed that YLSP (Yarn Lotus Silk Ply) has obtained high twist (90 tpi) followed by YLWP (70 tpi) and YLCP (60 tpi). The tpi of YLSP is higher due to the stickiness of Lotus yarn with Silk because both the yarns has Silk like appearance and feel. Wool and Lotus yarn both has natural waviness and it sticks properly in the ply structure. Lotus

yarn due to the cohesion property it sticks very fastly with the rough surface of the wool yarns. All the yarn has obtained the Z direction twist.

Table:4.23 Twist of Lotus Ply yarns

Yarn	Twist per inch (tpi)	Twist per meter (tpm)	Twist Direction
YLCP	60	2362.2	Z
YLSP	90	3543.3	Z
YLWP	70	2755.9	Z

YLCP – Yarn Lotus cotton ply

YLSP - Yarn Lotus Silk Ply

YLWP – Yarn Lotus Wool Ply

c). Tensile strength of Lotus ply yarns

The main aim of developing ply yarns was to use Lotus fiber in warp direction with the assistance of other natural fibers in the yarn structure. Technically the process of plying increases strength and the resultant fabric is durable in nature. From Table 4.24, it was analyzed that strength of YLCP (Yarn Lotus Cotton Ply) was higher that is 13.158 gf/tex followed by YLSP (Yarn Lotus Silk Ply) that is 8.050 gf/tex and YLWP (Yarn Lotus Wool Ply) that is 6.781 gf/tex.

Table :4.24 Tensile strength of Lotus ply yarns

Yarn	Max Load (gf)	Extension at Max. (mm)	Tenacity (gf/tex)	Stress (gm/den)	Strain (%)
YLCP	402.48	7.354	13.158	7.29	7.354
YLSP	205.68	2.79	8.050	0.89	2.79
YLWP	278.056	3.758	6.781	0.74	3.758

YLCP – Yarn Lotus cotton ply

YLSP - Yarn Lotus Silk Ply

YLWP – Yarn Lotus Wool Ply



Plate 4.29: YLCP – Yarn Lotus Cotton ply – 4/19’s



Plate 4.30: YLSP - Yarn Lotus Silk Ply – 4/23’s



Plate 4.31: YLWP – Yarn Lotus Wool Ply -4/14’s

4.9. Analysis of the Lotus dyed yarn

CIE $L^*a^*b^*$ contain three-dimensional color space with three axis in which L^* determines light and dark axis representing 0 means no reflection that is black and 100 representing high reflection that is white. a^* refers to green and red axis in which positive a^* value indicates red color and negative a^* value represents green color. b^* refers to yellow to blue axis in which positive b^* value indicates yellow color and negative b^* value indicates blue color. C^* refers to Chroma (+ = brighter and - = duller). Chroma is defined as amount of saturation of a color. Color with higher chroma refers to clear, brighter and brilliant color and lower chroma refers to duller side in the color axis. H^* means hue of the particular color.

Color strength of Lotus yarns dyed with natural dyes

The values of Color strength are measured in terms of $L^*a^*b^*$ color scale. The tabulated values are given in Table 4.25. L^* value of all the dyed samples were high

that were in the range of 63-79 except Indigo (LNI). Lotus yarn dyed with Indigo has a less L* value of 30.055 which is more towards darker side. Lotus yarn dyed with Sappan wood (LNS) and Madder (LNM) has a high a* value that is 18.339 and 15.314 respectively means these dyed samples were more towards redder side. Samples dyed with Marigold (LNMG): 0.392, Katho (LNK):1.889, Lac (LNL): 2.990, Pomegranate rind (LNP) :7.605 and Indian berries (LNIB) : 9.583 has achieved low a* value means these dyed samples were less red . Lotus yarns dyed with Indian Berries (LNIB) has a high b* value that is 14.966 followed by Marigold (LNMG): 13.500 and Pomegranate (LNP): 12.178.

Lotus yarn dyed with Indian berries has achieved a lighter and bright yellow color, marigold has obtained darker yellow color and pomegranate was towards yellowish brown color. Samples dyed with Marigold (LNMG) and Madder (LNM) was bright and brilliant with the higher C* value of 18.91 and 18.03. Lotus yarns dyed with Indian Berries (LNIB) has obtained lower C* value that is 10.172. Lotus yarn dyed with Indigo dye has obtained negative a* value that is -7.577 which is more towards greener side in the color axis and the b* value was also negative that is -14.807 which is more towards blue color. The K/S value of Lotus yarn dyed with Indigo dyes (LNI) was higher that is 89.58 amongst all the dyed samples means the absorption of this dye was more. Lotus yarn dyed with Katho (LNK) has obtained lower K/S value of 2.109 from all the dyed samples. The swatches of Lotus yarn dyed with natural dyes are shown in Plate: 4.32 (Page no: 295).

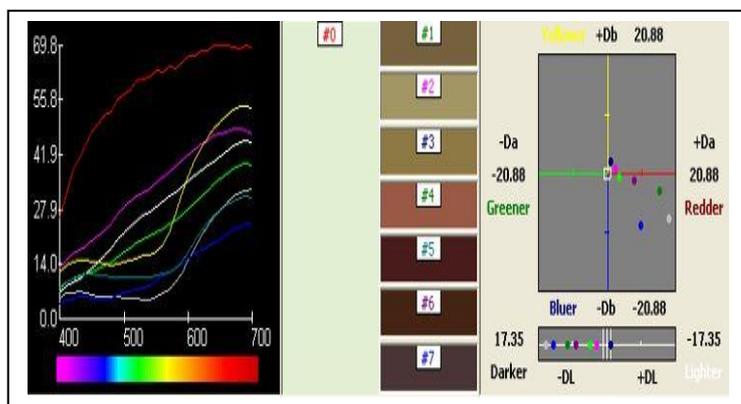
Table 4.25: Color strength K/S value of Lotus yarn dyed with natural dyes

Sr.No		Control	LNL	LNK	LNS	LNM	LNMG	LNP	LNIB	LNI
1	L*	78.765	74.551	76.191	79.694	68.888	63.420	70.841	65.312	30.055
2	a*	-0.539	2.990	1.889	18.339	15.314	0.392	7.605	9.583	-7.577
3	b*	12.673	4.622	11.436	3.411	9.527	13.500	12.178	14.966	-14.807
4	C*	12.684	12.540	13.632	14.971	18.036	18.912	13.734	10.172	16.633
5	H*	92.471	76.175	82.002	88.464	31.873	14.140	56.353	19.585	85.545
6	K/S	0.515	4.019	2.109	4.586	2.564	6.587	8.677	4.099	89.582

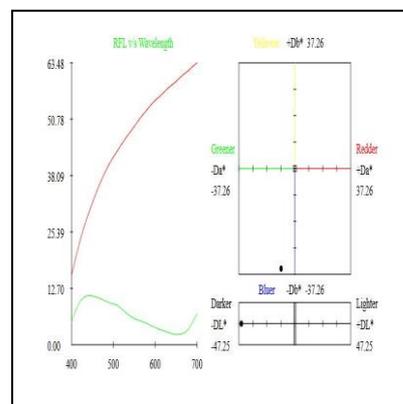
LNL - Lotus natural Lac

LNK – Lotus natural Katho

LNS - Lotus natural Sappan Wood
 LNM - Lotus natural Madder
 LNMG - Lotus natural Marigold
 LNP - Lotus natural Pomegranate
 LNIB - Lotus natural Indian Berries
 LNID – Lotus natural Indigo



Graph 4.3 : Reflectance curves of Lotus yarns dyed with Natural dyes



Graph 4.4 : Reflectance curve of Lotus yarns dyed with Indigo dye

Color strength of Lotus yarns dyed with reactive dyes

The tabulated value of Lotus yarns dyed with Reactive dyes are shown in Table 4.26. Samples dyed with Reactive dye Yellow (LRY) and Reactive dye Light Yellow (LRLY) has obtained high L* value that is 89.988 and 83.38 means it is more towards lighter side in the color axis.

The L* value of all the dyed samples were in the range of 50-89. a* value of samples dyed with Reactive dark pink (LRDP), Reactive orange (LRO) and Reactive light pink (LRLP) were 30.896, 26.601 and 23.047 respectively. Hence it can be inferred that these dyed samples are more towards redder side in the color axis.

Lotus yarn dyed with Reactive dye turquoise (LRT) has obtained high negative a* value that is -23.225 means it is more towards greener side in the color axis. The a* value of all the dyed samples were in the range of -0 to +30. The b* value of samples dyed with Reactive dye yellow (LRY) and Reactive dye light yellow (LRLY) was 26.474 and 22.807 means they are more towards yellower sides and the values were higher as compare to b* value of controlled sample (un dyed lotus yarn) that is 12.673. The K/S value of samples dyed with Reactive dye light pink (LRLP) and Reactive dye Black (LRBL) was high that is 21.028 and 20.836. C* value of Lotus yarn dyed with Reactive dye dark pink (LRDP) was high that is 32.586 means it has achieved brighter color whereas the samples dyed with Reactive dye black color

(LRBL) has obtained low chroma value of 3.280 means they are dull. The k/s value of the samples dyed with Reactive dye orange bright (LROB) and Reactive dye black (LRBL) was high that is 21.028 and 20.836 respectively means the absorption of these dyes was more. The swatches of Lotus yarn dyed with natural dyes are shown in Plate: 4.33 (Page no: 296).

Table : 4.26 Color strength K/S value of Lotus yarn dyed with reactive dyes

Sr.No		Control	LRO	LRYL	LRT	LROB	LRLP	LRB	LRBL	LRY	LRDP
1	L*	78.765	69.253	83.382	58.602	80.289	59.066	50.087	60.104	89.988	58.103
2	a*	-0.539	26.601	-0.382	-23.225	11.820	23.047	-0.539	-1.176	3.069	30.896
3	b*	12.673	9.711	22.807	16.627	22.258	3.181	-18.775	-1.157	26.474	-3.593
4	C*	12.684	28.318	22.261	28.563	25.688	23.265	18.812	3.280	27.159	32.586
5	H*	92.471	20.047	91.019	215.585	62.579	352.145	266.375	339.352	102.928	353.672
6	K/S	0.515	4.878	4.497	3.032	21.028	3.059	5.781	20.836	15.239	12.470
7	RFL	37.683	8.569	9.172	12.598	2.271	12.512	7.414	2.291	3.082	3.717

LRO - Lotus Reactive orange

LRYL - Lotus Reactive light yellow

LRT - Lotus Reactive turquoise

LROB- Lotus Reactive orange bright

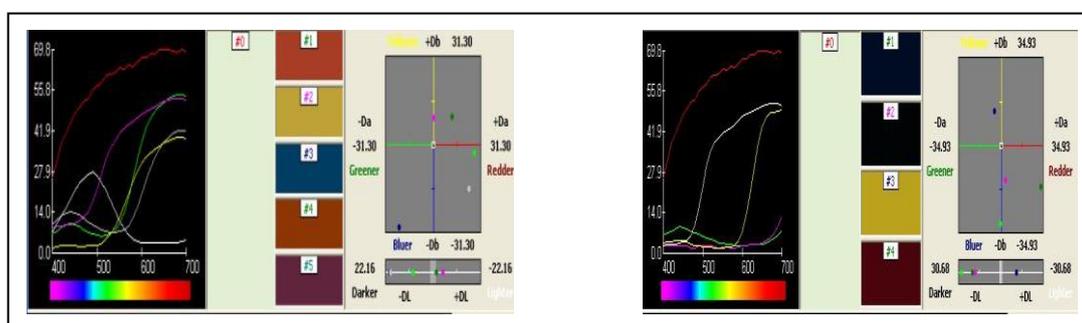
LRLP - Lotus Reactive light pink

LRB - Lotus Reactive blue

LRBL - Lotus Reactive black

LRY - Lotus Reactive yellow

LRDP - Lotus Reactive dark pink



Graph: 4.5 Reflectance curves of Lotus yarns dyed with Reactive dyes

Fastness properties of Lotus dyed yarns

Colorfastness, as defined by the American Association of Textile Chemists and Colorists (AATCC), is the resistance of a textile material to changes in color

properties, migration of dye to adjacent materials, or both as a result of exposure of the textile material to any environment that might be encountered during the testing, processing, storage and applications. Color fastness is the fabric ability to retain its color throughout its entire lifecycle. Issues regarding low colorfastness are one of the biggest problems in textiles. Color is universal it is a prime factor which is attracted by the customers. Any new fiber for the application in woven and knitted applications should be check for the fastness property. Two common fastness property that is light and washing was tested for Lotus dyed yarns with natural and reactive dyes.

Natural Dyes

Nature has gifted many color yielding sources from plants and animals Gokhale, S.B. et.al. (2004). Though natural dyed products are not marketed in the huge amount due the issues related to longer time needed for extraction, high usage of energy and improper fixation of color into the fabric. Till date, Indian handloom weavers and printers practice the art of natural dyeing. The newer minor cellulosic fibers and natural dyes are preferred by specified niche consumers. Hence Lotus dyed yarns were experimented with few known natural dyes and further its fastness properties were also assessed.

Light fastness property of Lotus yarn dyed with natural dyes

It can be inferred from Table 4.27, Lotus yarn dyed with Katho (LNK), Madder (LNM), Marigold (LNMG), Indian berries (LNIB), Sappan Wood (LNS) and Lac (LNL) has obtained very good to excellent light fastness property. Lotus yarns dyed with Indigo dyes (LNI) has obtained fair light fastness property.

Washing fastness rating of Lotus dyed yarns with natural dyes

It can be inferred and analyzed from Table 4.28, Lotus yarn dyed with Indigo dye that is (LNI) has obtained very good to excellent washing fastness property with the rating 4/5. Indigo dyeing has its prestigious place in Indian traditional textiles from the ancient times in India. Thus, this will be a novel fiber in the Indigo dyed textiles. Lotus yarns dyed with Lac (LNL)-3, Katho (LNK)-4, Sappan Wood (LNS)-3, Madder (LNM)-3/4, Marigold flower petals (LNMG)-3, Indian Berries (LNIB)-3 has obtained

good to very good washing fastness property which may be due to the pre-mordanting with Alum and Lotus fiber inherent property of water absorbency and fine microfiber structure.

Table :4.27 Light fastness property of Lotus yarn dyed with Natural dyes

Sr.no	Sample name	Result out of 7 rating
1	LNL	6/7
2	LNK	7
3	LNS	6/7
4	LNM	7
5	LNMG	7
6	LNP	7
7	LNIB	7
8	LNI	4

LNL - Lotus natural Lac

LNK – Lotus natural Katho

LNS - Lotus natural Sappan Wood

LNM - Lotus natural Madder

LNMG - Lotus natural Marigold

LNP - Lotus natural Pomegranate

LNIB - Lotus natural Indian Berries

LNI – Lotus natural Indigo

Table : 4.28 Washing fastness rating of Lotus dyed yarns with Natural dyes

Sr.no	Sample name	Result out of 5 rating
1	LNL	3
2	LNK	4
3	LNS	3
4	LNM	3/4
5	LNMG	3
6	LNP	4
7	LNIB	3
8	LNI	4/5

LNL - Lotus natural Lac

LNK – Lotus natural Katho

LNS - Lotus natural Sappan Wood

LNM - Lotus natural Madder
LNMG - Lotus natural Marigold
LNP - Lotus natural Pomegranate
LNIB - Lotus natural Indian Berries
LNI - Lotus natural Indigo

Reactive Dyes

Reactive dyes are anionic dyes, it forms chemical covalent bonds with the hydroxyl groups of cellulosic fiber Gohl, E.P.G & Vilensky, L.D. (1987). It is popular dye used in textile industry. Due to the faster production, demand and strong fixation, reactive dyes are widely used.

Light fastness property of Lotus yarn dyed with reactive dyes

It was found that Lotus yarns dyed with the reactive dyes has obtained very good to excellent Light fastness property with the rating ranging from 6/7 to 7 as shown in Table 4.29.

Washing fastness property of Lotus yarn dyed with reactive dyes

It was observed that washing fastness property of the Lotus yarn dyed with reactive dyes has obtained very good to excellent washing fastness property with the rating ranging from 3/4 to 4 shown in Table 4.30. The washing fastness property may be due to inherent property of the reactive dye bonding with the cellulosic and high-water absorbency property of Lotus fiber.

Table: 4.29 Light fastness property of Lotus yarn dyed with Reactive dyes

Sr.no	Sample name	Result out of 7 rating
1	LRO	7
2	LRYL	7
3	LRT	6/7
4	LROB	6/7
5	LRLP	6/7
6	LRB	7
7	LRBL	7
8	LRY	7
9	LRDP	7

LRO - Lotus Reactive orange
LRYL - Lotus Reactive light yellow
LRT - Lotus Reactive turquoise
LROB - Lotus Reactive orange bright
LRLP - Lotus Reactive light pink
LRB - Lotus Reactive blue

LRBL - Lotus Reactive black

LRY - Lotus Reactive yellow

LRDP - Lotus Reactive dark pink

Table : 4.30 Washing fastness property of Lotus yarn dyed with Reactive dyes

Sr.no	Sample name	Result out of 7 rating
1	LRO	3/4
2	LRYL	4
3	LRT	3/4
4	LROB	4
5	LRLP	3/4
6	LRB	4
7	LRBL	4
8	LRY	4
9	LRDP	4

LRO - Lotus Reactive orange

LRYL - Lotus Reactive light yellow

LRT - Lotus Reactive turquoise

LROB - Lotus Reactive orange bright

LRLP - Lotus Reactive light pink

LRB - Lotus Reactive blue

LRBL - Lotus Reactive black

LRY - Lotus Reactive yellow

LRDP - Lotus Reactive dark pink

4.10. Construction of woven fabrics and its properties

Based upon the testing results of the 12 different types of Lotus yarns, woven fabrics were prepared in different compositions. Specification of the constructed fabrics are shown in Table 4.31. Weave was constant for all the fabrics that is plain weave. Images of all the developed fabrics are shown in Plate 4.34. In the present research, using 14 different types of Lotus fabrics - union, blended and pure fabrics were developed in handloom and powerloom on the basis of following parameters –

- a). End use
- b). Texture
- c). Time for preparation

d). Handling in production

e). Cost

f). Market

Handspun yarn that is L2A (Lotus yarn, two petiole, *Ambar Charkha*) and L3A (Lotus yarn, two petiole, *Ambar Charkha*) were used in developing Khadi fabrics because these yarns has a natural uneven appearance and shaded color that varies from off white to cream. Beauty of the Khadi fabrics lies in their irregularity that reveals the human efforts. The appearance of the Lotus fiber resembles to fine silk. India is known for its long Silk route and Lotus is a national flower of country. Fine handspun yarn of 96's count was developed from one petiole. Due to extreme fineness, fabric was prepared with fine Mulberry Silk. All these fabrics will be cater to the niche and luxury market.

Concerning the mass production and durability factor, three Lotus ply yarns (YLCP, YLSP and YLWP) were used in developing handloom fabrics using ply yarn in warp and 100 % Lotus yarn in weft. Plying the yarns has been helpful to the weaver also for smooth handling during the warping process and ability to handle stress in weaving without any constant breakage in between. Lotus yarn (MYHS1) developed from fabricated machine was used for developing union fabric with cotton in warp on handloom.

Revolution of powerloom is one of the most important segments of textile industry Prakash, A. (2021). Around 58.4 % of the total cloth production of India is through powerloom. Focusing on the fashion world, it changes in minutes and require faster and rapid production of fabric. Implementing this minor fiber- Lotus in its pure form without any treatment in preparing powerloom fabric will add a novel fabric in fashion industry. Hence four union fabrics and one pure Lotus fabric was prepared in powerloom which has come up with the fine textures. Lotus yarns used in developing powerloom fabrics were developed from fabricated machine. Following count of Lotus yarns were used: MYHS1 (71's), MYHS2 (60's), MYMS (33's) and MYLS (28's).

The rotor/open end spinning system is cost effective and faster as compared to the ring spinning system. From the cost point of view, it eliminates the roving step. Hence Lotus rotor spun yarns (LCRY 50:50 & LCRY 70:30) were developed in combination with Cotton fiber. The yarns were strong, soft, coarser and has an excellent elongation property which was very much suitable for developing sturdy fabrics for jackets, coats and shawls. Images of the developed woven fabrics are shown in Plate: 4.34 (Page no. 297 and 298). Fabrics with the exploration of different type of weaves are shown in Plate : 4.35 (Page no. 299).

Table: 4.31 Specification of the constructed woven fabrics

Sr.No	FABRIC CODE	WARP		WEFT				
		Fiber content	Yarn count	Fiber content	Yarn count (Cotton Count Ne)	Number of petioles	Extraction method	Description of yarn making
1	HS Fabric - 1	Fine cotton hand spun yarn	120's	100 % Lotus hand spun yarn	2/ 86's	2 petiole	Manual	Hand spinning by Ambar Charkha
2	HS Fabric - 2	Fine cotton hand spun yarn	120's	100 % Lotus hand spun yarn	3/28's	3 petiole		

Continue...

HANDLOOM FABRICS								
Sr.No	FABRIC CODE	WARP			WEFT			
		Fiber content	Yarn count	Description of yarn making	Fiber content	Yarn count (Cotton Count Ne)	No. of petioles	Description of yarn making
3	HL Fabric - 3	Mulberry silk :Lotus ply yarn	100's	Machine spun mulberry silk	100 % Lotus	96's	3	Hand spinning by Ambar Charkha
4	HL Fabric - 4	Lotus:Cotton ply yarn (3 Lotus + 1 Cotton)	4/19's	Twisting by Ambar Charkha	100 % Lotus	3/60's	3	Machine extracted and machine spun from fabricated machine
5	HL Fabric - 5	Lotus:Silk ply yarn (3 Lotus + 1 Silk)	4/23's	Twisting by Ambar Charkha	100 % Lotus	3/71's		
6	HL Fabric - 6	Lotus:wool ply yarn (3 Lotus + 1 Wool)	4/14's	Twisting by Ambar Charkha	100 % Lotus	3/28's		
7	HL Fabric - 7	Handspun Cotton	120's	Handspun by Ambar Charkha	100 % Lotus	3/71's	3	Machine extracted and machine spun from fabricated machine

Continue

POWERLOOM FABRICS								
Sr. No.	FABRIC CODE	WARP			WEFT			
		Fiber content	Yarn count (Cotton count Ne)	Description of yarn making	Fiber content	Yarn count (Cotton count Ne)	Description of yarn making	Number of petioles
8	PL Fabric - 8	Cotton	80's	Machine spun	100% Lotus	3/71's	Machine extracted and machine spun from fabricated machine	3
9	PL Fabric - 9	Cotton	70's	Machine spun	100% Lotus	3/60's	Machine extracted and machine spun from fabricated machine	3
10	PL Fabric - 10	Cotton	40's	Machine spun	100% Lotus	3/33's	Machine extracted and machine spun from fabricated machine	3

Continue

11	PL Fabric - 11	Cotton	20's	Machine spun	100% Lotus	3/28's	Machine extracted and machine spun from fabricated machine	3
12	PL Fabric - 12	100 % Lotus	3/71's	Machine extracted and machine spun from fabricated machine	100% Lotus	3/71's	Machine extracted and machine spun from fabricated machine	3
13	PL Fabric - 13	70:30 Lotus: cotton blended	5's	Rotor spun yarns	70:30 Lotus: cotton blended	5's	Rotor spun yarns	Fiber extracted in the raw form
14	PL Fabric - 14	50:50 Lotus: Cotton blended	3's	Rotor spun yarns	50:50 Lotus cotton blended	3's	Rotor spun yarns	Fiber extracted in the raw form

Properties of constructed woven fabrics

a). Thickness

Fabric thickness is defined as the distance between the top and bottom surfaces of a fabric under the standard pressure. It is measured in millimeters (mm). Thickness is considered as one of the basic properties that provides basic information about warmth, heaviness and stiffness Y. Li., & Dai, XQ. (2006). Thickness of the constructed fabrics are shown in Table 4.32.

From the testing results, it was observed that there was slight difference in thickness between the two Lotus Khadi fabrics that HS Fabric -1 and HS Fabric-2. HL Fabric – 3 (fabric woven with Mulberry Silk yarn in warp and Lotus yarn developed from one petiole in weft) has showed low thickness of 0.24 mm amongst all the constructed fabrics. This is due to the finer count of both the yarns that is Mulberry silk and Lotus. Fabric developed has a light and sheer appearance. The fabric was shiny, smooth and has a yellowish to off white shaded appearance. Amongst the hand-woven fabrics developed from ply yarns, HL Fabric -6 has a highest thickness of 0.48 mm which is due to Australian Wool yarn in ply structure followed by HL Fabric -4 (0.41 mm) and HL Fabric -5 (0.38 mm). HL fabric -5 (0.38 mm) has lowest thickness due to fineness of Mulberry silk and Lotus in the ply structure. Amongst the powerloom fabrics (PL fabric - 8 & PL fabrics -9) has less thickness of 0.26 mm and 0.27 mm due to the finer varieties of yarns obtained from fabricated machine at high speed. Fabrics developed from Lotus:Cotton blended rotor spun/open end yarns that is PL fabric -13 & PL fabric – 14 has obtain higher thickness of 0.48 and 0.52 mm amongst all the constructed fabrics. This may be due to coarser count of yarns. These fabrics were thicker amongst all the fabrics which can be used for jackets, coats and shawls.

Variating the number of petioles, type of fiber in the blend structure, spinning systems, type of yarn structure has direct association with the developed yarn and thickness of the fabric achieved.

Table 4.33 shows the association between thickness of different fabric the researcher used One-way ANOVA and the result was presented in the above table, The estimated f-value was 139.090 and the p-value is .000 which shows that there is an association within thickness of fabric. From the mean value it is noted that sample PL Fabric 14 got

more thickness when compared to other fabrics. Thus, the result shows there is a statistical association within thicknesses of fabrics.

Table 4.32: Thickness of the woven fabrics

Sr. No.	Fabric code	Thickness(mm)
1	HS Fabric – 1	0.34
2	HS Fabric – 2	0.36
3	HL Fabric – 3	0.24
4	HL Fabric – 4	0.41
5	HL Fabric – 5	0.38
6	HL Fabric – 6	0.48
7	HL Fabric – 7	0.41
8	PL Fabric – 8	0.26
9	PL Fabric – 9	0.27
10	PL Fabric – 10	0.36
11	PL Fabric – 11	0.38
12	PL Fabric – 12	0.37
13	PL Fabric – 13	0.48
14	PL Fabric – 14	0.52

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric – 3 -Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100's ; Weft – Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric – 4 - Handloom fabric (Warp –Lotus: Cotton ply yarn –4/19's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole-3/71's)

HL Fabric – 5- Handloom fabric (Warp – Lotus: Silk ply yarn –4/23's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole -3/60's)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn –4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric – 7 -Handloom fabric (Warp - handspun Cotton yarn – 120's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole- 3/71's)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)

PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71's)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

Table :4.33. Thickness of the constructed fabrics ANOVA Table (between Variables)

Variables		Mean	SD	SE	F-value	Sig
Thickness	HS Fabric - 1	0.34	0.02	0.01	139.090	.000**
	HS Fabric - 2	0.36	0.02	0.01		
	HL Fabric - 3	0.24	0.02	0.01		
	HL Fabric - 4	0.41	0.02	0.01		
	HL Fabric - 5	0.38	0.02	0.01		
	HL Fabric - 6	0.48	0.02	0.01		
	HL Fabric - 7	0.41	0.02	0.01		
	PL Fabric - 8	0.26	0.02	0.01		
	PL Fabric - 9	0.27	0.02	0.01		
	PL Fabric - 10	0.36	0.02	0.01		
	PL Fabric - 11	0.38	0.02	0.01		
	PL Fabric - 12	0.37	0.02	0.01		
	PL Fabric - 13	0.48	0.02	0.01		
	PL Fabric - 14	0.52	0.02	0.01		

****= Significant at 1% level**

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric – 3 -Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100's ; Weft – Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric – 4 - Handloom fabric (Warp –Lotus: Cotton ply yarn –4/19's ; Weft – Machine extracted and spun Lotus yarn : 3 petiole-3/71's)

HL Fabric – 5- Handloom fabric (Warp – Lotus: Silk ply yarn –4/23's ; Weft – Machine extracted and spun Lotus yarn : 3 petiole -3/60's)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn – 4/14's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

HL Fabric – 7 -Handloom fabric (Warp - handspun Cotton yarn – 120's ; Weft – Machine extracted and spun Lotus yarn : 3 petiole- 3/71's)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's)

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)

PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71's)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

b). Fabric count and cover factor

Fabric count is defined as number of warp and weft threads per square inch of fabric. It is indicative to quality and superiority of the constructed fabrics. It indicates that how tightly the particular fabric has been woven. When fabric count is higher than it is an indicator of good quality fabrics for the applications in suiting, bedsheets and work wear.

The fabric count also influence and affect the breathability properties and it is directly associated with the comfort of the wearer. Yarn fineness, fabric count and type of material influence the breathability of the fabric. Synthetic material leads to poor breathability. Spun yarns has a higher breathability as compare to continuous filament yarns. Microfibers possess higher breathability as compare the ordinary fiber.

Cover factor is the number that shows the extent to which the area of the fabric is covered by one set of threads. Covering power means the ability of the material to occupy space or to cover an area. A fabric with the better cover factor will be warmer, look and feel more durable. In a woven fabric there are two cover factors: a warp cover factor and weft cover factor. It is also based on thread count and thread density. As the cover factor increases the fabric has a closer structure and denser appearance and when the cover factor decreases the resultant fabric has an open structure.

As shown in Table 4.34 and Graph 4.6, Amongst all the constructed fabrics, HL fabric -3 has low cover factor of 2.8 K which is due to the handspun Lotus yarn of 96's count (L1A) was used in weft direction which results into open, uneven and sheer appearance in the fabric.

Cover factor of PL fabric -13 and PL fabric -14 was higher that is 19 K and 21 K as compared to all the other constructed fabrics which is due to the same count and density of coarser blended yarn used in both warp and weft direction which has lead to the compact structure. PL fabric – 12 (that is 100 % Lotus yarns of 71's used in both warp and weft direction) has obtained low cover factor that is 8.3 K amongst the category of powerloom fabrics which may be due to the inability in maintaining tension and stress during weaving another reason may be due to use of 100 % Lotus yarn in warp and weft direction on powerloom which has resulted into open structure.

In the category of handloom fabrics developed from ply yarns, the cover factor of HL fabric-6 developed from Lotus: Wool ply yarns in warp and 100 % Lotus yarn in weft

consists of higher cover factor that is 15 K followed by HL fabric-4 (14 K) and HL fabric -5 (12.8 K) which may be due to the bulkiness of Wool in the ply structure. The fabric developed from Lotus: Silk ply yarn in warp and 100 % Lotus in weft has an open structure amongst all the fabric developed from ply yarn.

The cover factor of handspun Khadi fabrics that is HS fabric – 1 and HS Fabric -2 was lower than all the powerloom union and pure fabrics which is due to the quality of Lotus yarn used in the weft structure. Both HS fabric – 1 and HS fabric -2 contains the yarn that is extracted manually from 2 and 3 petioles which leads the weaver to beat carefully on handloom to avoid breakage in between and results into an open structure as compared to powerloom union fabrics.

Table 4.35 shows the result of One-Way ANOVA analysis the cover factor within of selected fabrics. The estimated f-value were 189.436 and the p-value is .000 which shows that there is an association within fabrics cover factor of selected fabrics. From the mean value it is noted that sample PL Fabric 14 got more cover factor when compared to other fabrics. Thus, the result shows there is a statistical association within cover factors of fabrics.

Table :4.34 Fabric count and Cover factor of the woven fabrics

Sr.No.	Fabric code	Fabric count	Cover Factor
1	HS Fabric - 1	52×34	7.7
2	HS Fabric - 2	50 × 32	7.4
3	HL Fabric - 3	53 × 28	2.8
4	HL Fabric - 4	50×46	14
5	HL Fabric - 5	32×23	12.8
6	HL Fabric - 6	31×26	15
7	HL Fabric - 7	32×23	5.5
8	PL Fabric - 8	53×35	9.4
9	PL Fabric - 9	48×55	11
10	PL Fabric - 10	56×61	14.8
11	PL Fabric - 11	52×58	15.5
12	PL Fabric - 12	42 × 34	8.3
13	PL Fabric - 13	22×31	19
14	PL Fabric - 14	19×31	21.9

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 - Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp - Lotus: Cotton ply yarn - 4/19's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/71's)

HL Fabric - 5 - Handloom fabric (Warp - Lotus: Silk ply yarn - 4/23's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/60's)

HL Fabric - 6 - Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7 - Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric - 11 - Powerloom fabric (Warp - Machine spun Cotton yarn - 20's; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

PL Fabric - 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn; 3 petiole - 3/71's)

PL Fabric - 13 - Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric - 14 - Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

Table :4.35 Cover factor the constructed fabrics - ANOVA Table (Within Variables)

Variables		Mean	SD	SE	F-value	Sig
Fabric Cover Factor	HS.Fabric - 1	7.70	0.16	0.07	189.436	.000**
	HS Fabric - 2	7.40	0.16	0.07		
	HL Fabric - 3	2.80	0.16	0.07		
	HL Fabric - 4	14.00	1.58	0.71		
	HL Fabric - 5	12.80	0.16	0.07		
	HL Fabric - 6	15.00	1.58	0.71		
	HL Fabric - 7	5.50	0.16	0.07		
	PL Fabric - 8	9.40	0.16	0.07		
	PL Fabric - 9	11.00	1.58	0.71		
	PL Fabric - 10	14.80	0.16	0.07		
	PL Fabric - 11	15.50	0.16	0.07		
	PL Fabric - 12	8.30	0.16	0.07		
	PL Fabric - 13	19.00	1.58	0.71		
	PL Fabric - 14	21.70	0.35	0.16		

**= Significant at 1% level



Graph: 4.6 Cover factor of the constructed woven fabrics

c). Weight per unit area (GSM)

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 buyers also. From the Table 4.36 and Graph 4.7, it was observed that in the Khadi fabric category, HS Fabric-1 was light in weight as compared to HS Fabric-2 which may be due to the finer yarn used in HS Fabric -1 that is developed from two petioles. HL Fabric-3 was lighter in weight amongst all the handloom fabrics which may be due to extremely finer Lotus yarn developed from only one petiole in weft direction and Mulberry silk in warp direction. Amongst all the fabric constructed from ply yarns, HL Fabric-6 has a higher GSM due to the Australian wool yarn in the ply structure. HL Fabric -5 has a lower GSM due to the Mulberry Silk in the ply structure followed by HL Fabric-4. In the powerloom fabric category, PL Fabric -8 was lighter in weight that is 64 GSM due to extremely fine yarn extracted from fabricated machine in high speed followed by PL Fabric-9 (74 GSM), PL Fabric-10 (82 GSM) and PL Fabric -12 (94 GSM). Fabric developed from open end yarns that is PL Fabric -13 (323 GSM) and PL fabric -14 (336) was heavier in GSM amongst all the constructed fabrics due to the coarser open end yarn structure of Lotus: Cotton blended yarns Table: 4.36. shows the classification of Weight of fabrics and its appropriate end use Young, D. (2015). As per this classification all the constructed fabrics excluding PL fabric-13 and PL Fabric -14 can be used in Blouses, Shirting and light summer dresses. Fabrics developed from open end yarns that is PL Fabric -13 and PL fabric-14 can be used in blankets, heavier coats and denims.

The Table 4.37, shows the result of One-Way ANOVA analysis the GSM in grams within of selected fabrics. The estimated f-value was 189.436 and the p-value is .000 which shows that there is an association within GSM in grams of selected fabrics. From the mean value it is noted that sample PL Fabric 14 got more GSM when compared to other fabrics. Thus, the result shows there is a statistical association within GSM of fabrics.

Table4.36: GSM of the constructed fabrics

Sr.No.	Fabric code	GSM (grams)	GSM (in Ounces)
1	HS Fabric - 1	80	2.35
2	HS Fabric - 2	84	2.47
3	HL Fabric - 3	71	2
4	HL Fabric - 4	117	3.45
5	HL Fabric - 5	101	2.97
6	HL Fabric - 6	140	4
7	HL Fabric - 7	125	3.68
8	PL Fabric - 8	64	1.88
9	PL Fabric - 9	74	2
10	PL Fabric - 10	82	2.41
11	PL Fabric - 11	113	3.33
12	PL Fabric - 12	94	2.77
13	PL Fabric - 13	323	9.52
14	PL Fabric - 14	336	9.90

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 - Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp - Lotus: Cotton ply yarn - 4/19's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

HL Fabric - 5 - Handloom fabric (Warp - Lotus: Silk ply yarn - 4/23's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

HL Fabric - 6 - Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7 - Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric - 11 - Powerloom fabric (Warp - Machine spun Cotton yarn - 20's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

PL Fabric - 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole - 3/71's)

PL Fabric - 13 - Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric - 14 - Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

Table : 4.37 GSM of the constructed fabrics -ANOVA Table (Within Variables)

Variables		Mean	SD	SE	F-value	Sig
GSM Gram	HS Fabric - 1	80.00	1.58	0.71	1779.591	.000**
	HS Fabric - 2	84.00	1.58	0.71		
	HL Fabric - 3	75.00	7.91	3.54		
	HL Fabric - 4	117.00	1.58	0.71		
	HL Fabric - 5	101.00	1.58	0.71		
	HL Fabric - 6	4.00	1.58	0.71		
	HL Fabric - 7	3.68	0.02	0.01		
	PL Fabric - 8	1.88	0.02	0.01		
	PL Fabric - 9	2.00	1.58	0.71		
	PL Fabric - 10	2.41	0.02	0.01		
	PL Fabric - 11	3.33	0.02	0.01		
	PL Fabric - 12	2.77	0.02	0.01		
	PL Fabric - 13	9.52	0.02	0.01		
	PL Fabric - 14	9.90	0.02	0.01		

****= Significant at 1% level**

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 -Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp -Lotus: Cotton ply yarn -4/19's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole-3/71's)

HL Fabric - 5- Handloom fabric (Warp - Lotus: Silk ply yarn -4/23's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole -3/60's)

HL Fabric - 6- Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7-Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole- 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

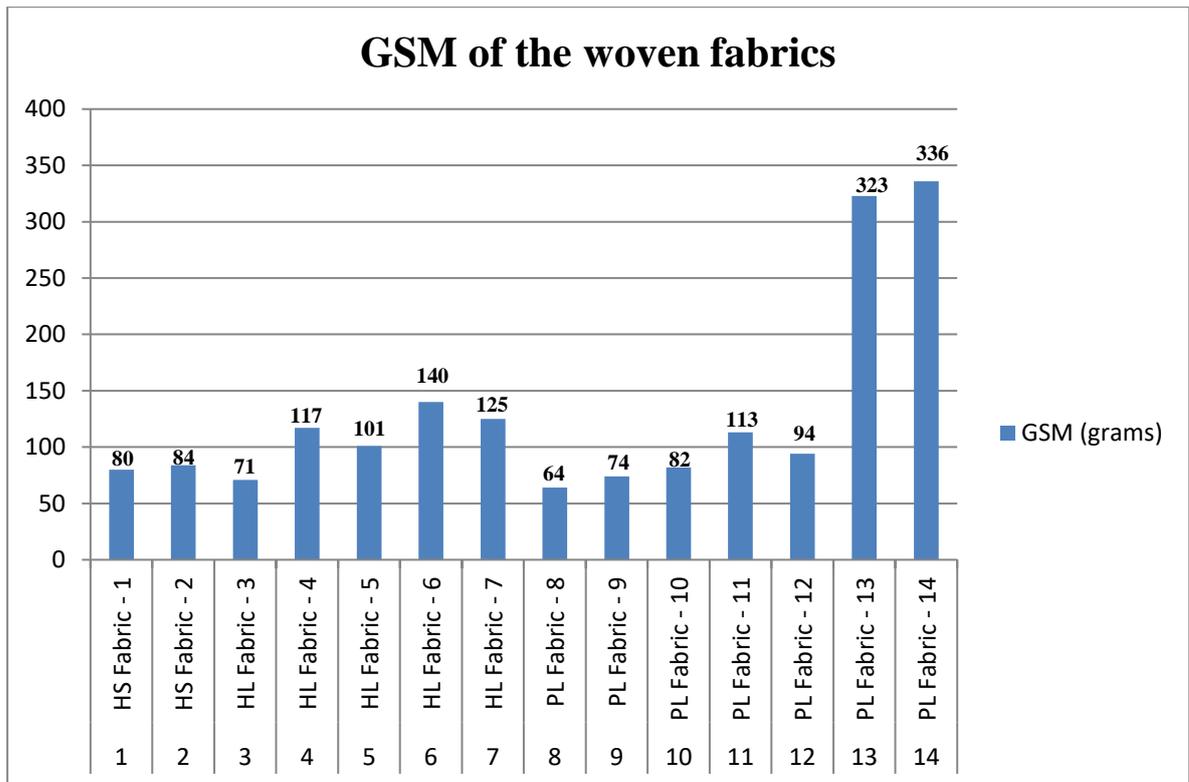
PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric - 11 - Powerloom fabric (Warp - Machine spun Cotton yarn - 20's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

PL Fabric - 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole - 3/71's)

PL Fabric - 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric - 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)



Graph :4.7 GSM of the constructed woven fabrics

Table : 4.38 Classification of the fabrics as per weight

Category	Ounces (oz)	Appropriate End Uses
Extremely Light weight	0-1	Chiffon, tulle, sheers, some laces
Light weight	1-4	louses, Shirting and light summer dresses
Medium Weight	4-7	Heavier tops, lighter bottoms and slacks
Medium to heavy weight	7-9	Bottom weight slacks suiting and light weight summer dresses
Heavy weight	> 9	Blankets, heavier coats and denims

Source : Young, D.E (2015) Swatch reference guide for fashion fabrics Bloomsburg publications.

d). Stiffness/Bending length of the constructed fabrics

Stiffness or flexural rigidity is one of the essential physical properties of the textile materials and it is widely used to assess the bending rigidity and fabric handling. The bending behaviour of the woven fabric is very essential for designers, fabric producers and also for apparel production Eryuruk, S.H. et.al. (2015). Stiffness determines the suitability for specific applications. Fabrics with the higher bending length are stiffer, lack in drape property and consist of less flexibility. Properties of the yarn: type of the spinning system, fineness of the yarn and type of the yarn that is filament or staple has a influence on bending length of the fabrics.

From Table 4.39 and Graph 4.8, amongst the Khadi fabrics, the bending length of HS Fabric-1 was found lower than HS Fabric-2 which may be due to the fineness of the yarns achieved by varieting the number of petioles. The bending length of HL Fabric- 3 was lower amongst all the constructed fabrics due to the finer lotus yarn developed from one petiole used in weft direction and fine mulberry silk used in warp direction. There was no maximum difference observed in the bending length of the fabrics developed from ply yarns. In the powerloom union fabrics category, the bending length of PL fabric- 8 has obtained lower bending length which may be due to the finer Lotus yarn used in weft direction developed from the fabricated machine in high speed. PL fabric - 11 has a higher bending length amongst the union powerloom fabrics which may be due to the 28's count Lotus yarn developed from fabricated machine in low speed. PL Fabric -13 and PL Fabric -14 has a higher bending length amongst all the constructed fabrics due to the coarser yarn produced by the open end/rotor spinning system that is clearly visible in graph -

Table 4.40 shows the result of One-Way ANOVA analysis. Stiffness (warp) (face-to-face) within the selected fabrics. The estimated f-value was 13.827 and the p-value is .000 which shows that there is an association within Stiffness (warp) of selected fabrics. From the mean value it is noted that sample PL Fabric 14 got more Stiffness (warp) when compared to other fabrics. Thus, the result shows there is a statistical association within stiffness (warp) of fabrics.

The Table 4.41, shows the result of One-Way ANOVA analysis. Stiffness (weft) (face-to-face) within the selected fabrics. The estimated f-value were 9.037 and the p-value is .000 which shows that there is an association within Stiffness (weft) of selected fabrics.

From the mean value it is noted that sample PL Fabric 13 was more stiffer along weft direction when compared to other fabrics. Thus, the result shows there is a statistical association within stiffness (weft) of fabrics

Table: 4.39 Bending length of the constructed woven fabrics

Sr.No.	Fabric code	Warp (Cm)		Weft (Cm)	
		Face to face	Back to back	Face to face	Back to back
1	HS Fabric - 1	3.5	3.2	3	2.7
2	HS Fabric - 2	3.7	3.5	3.2	3
3	HL Fabric - 3	2.3	2.3	1.7	2
4	HL Fabric - 4	4	4.5	4.5	5
5	HL Fabric - 5	3.8	4	4.5	4.4
6	HL Fabric - 6	4	4.5	3.5	3.6
7	HL Fabric - 7	4.8	4.5	4	3.8
8	PL Fabric - 8	2.6	3	2	1.8
9	PL Fabric - 9	3.5	4	2.6	2.4
10	PL Fabric - 10	4.8	4.5	3.8	3.6
11	PL Fabric - 11	5.1	4.5	4.3	4.5
12	PL Fabric - 12	2.3	3	2.3	3.2
13	PL Fabric - 13	4.5	4.5	4.7	5.6
14	PL Fabric - 14	5.7	5.6	4.3	4.4

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 - Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp - Lotus: Cotton ply yarn - 4/19's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/71's)

HL Fabric - 5 - Handloom fabric (Warp - Lotus: Silk ply yarn - 4/23's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/60's)

HL Fabric - 6 - Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7 - Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric - 11 - Powerloom fabric (Warp - Machine spun Cotton yarn - 20's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

PL Fabric - 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole - 3/71's)

PL Fabric - 13 - Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric - 14 - Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3'

Table : 4.40 Bending length stiffness of the fabrics - Anova table (within variables) -Warp

Variables		Mean	SD	SE	F-value	Sig
Stiffness Warp	HS Fabric - 1	3.50	0.16	0.07	13.827	.000**
	HS Fabric - 2	3.70	0.16	0.07		
	HL Fabric - 3	2.30	0.16	0.07		
	HL Fabric - 4	4.00	1.58	0.71		
	HL Fabric - 5	3.80	0.16	0.07		
	HL Fabric - 6	4.00	1.58	0.71		
	HL Fabric - 7	4.80	0.16	0.07		
	PL Fabric - 8	2.70	0.16	0.07		
	PL Fabric - 9	3.50	0.16	0.07		
	PL Fabric - 10	4.80	0.16	0.07		
	PL Fabric - 11	5.10	0.16	0.07		
	PL Fabric - 12	2.30	0.16	0.07		
	PL Fabric - 13	4.50	0.16	0.07		
	PL Fabric - 14	5.70	0.16	0.07		

****= Significant at 1% level**

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric – 3 -Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100's ; Weft – Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric – 4 - Handloom fabric (Warp –Lotus: Cotton ply yarn – 4/19's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole-3/71's)

HL Fabric – 5 - Handloom fabric (Warp – Lotus: Silk ply yarn – 4/23's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole -3/60's)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn – 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric – 7 -Handloom fabric (Warp - handspun Cotton yarn – 120's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole- 3/71's)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)

PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71's)

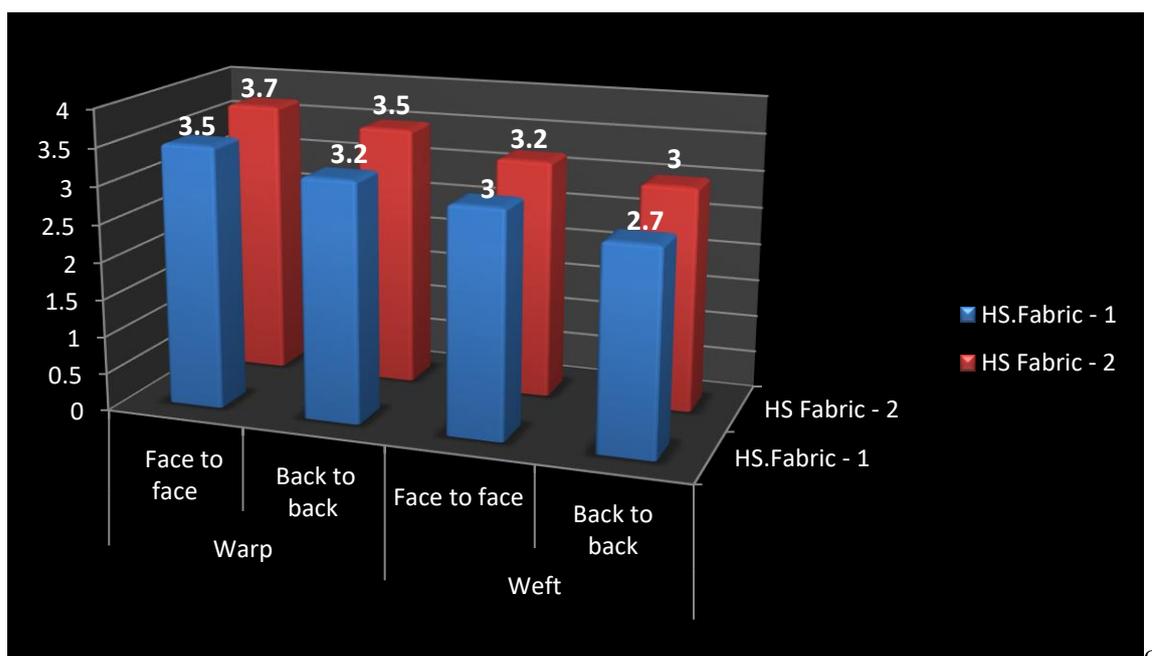
PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3'

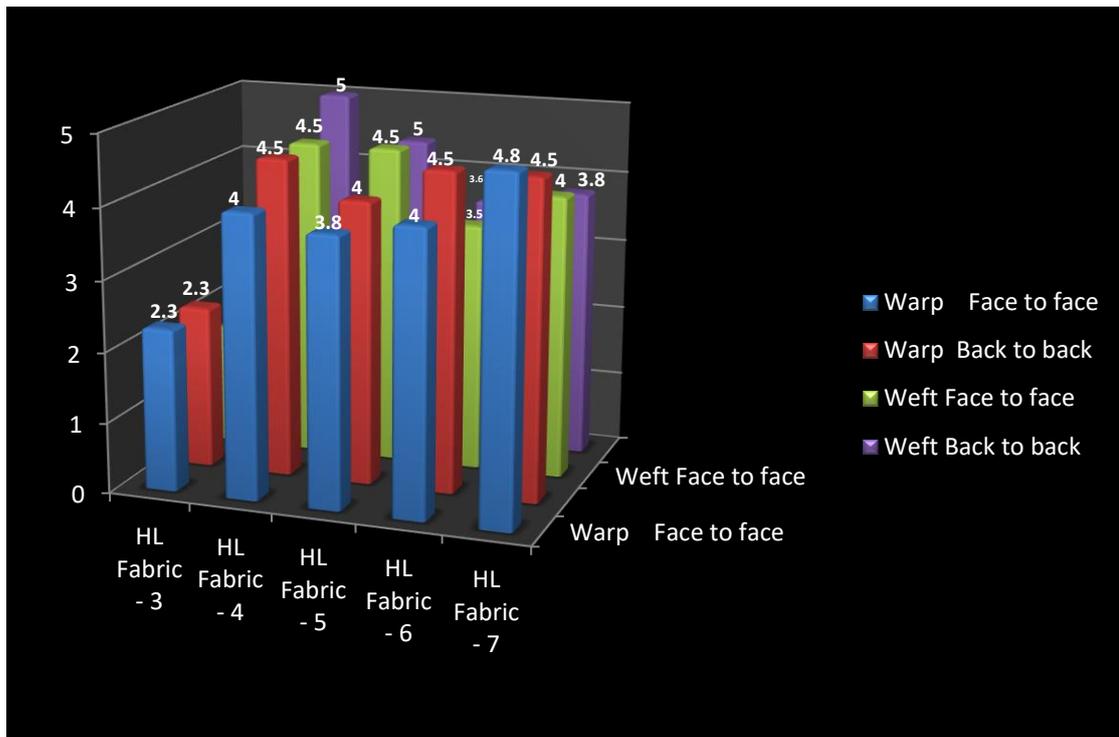
Table :4.41 Bending length stiffness of the fabrics - Anova table (within variables) -Weft

Variables		Mean	SD	SE	F-value	Sig
Stiffness Weft	HS Fabric - 1	3.00	1.58	0.71	9.037	.000**
	HS Fabric - 2	3.20	0.16	0.07		
	HL Fabric - 3	1.70	0.16	0.07		
	HL Fabric - 4	4.52	0.15	0.07		
	HL Fabric - 5	4.46	0.21	0.09		
	HL Fabric - 6	3.50	0.16	0.07		
	HL Fabric - 7	4.00	1.58	0.71		
	PL Fabric - 8	2.00	1.58	0.71		
	PL Fabric - 9	2.60	0.16	0.07		
	PL Fabric - 10	3.80	0.16	0.07		
	PL Fabric - 11	4.30	0.16	0.07		
	PL Fabric - 12	2.30	0.16	0.07		
	PL Fabric - 13	4.70	0.16	0.07		
	PL Fabric - 14	4.30	0.16	0.07		

**= Significant at 1% level

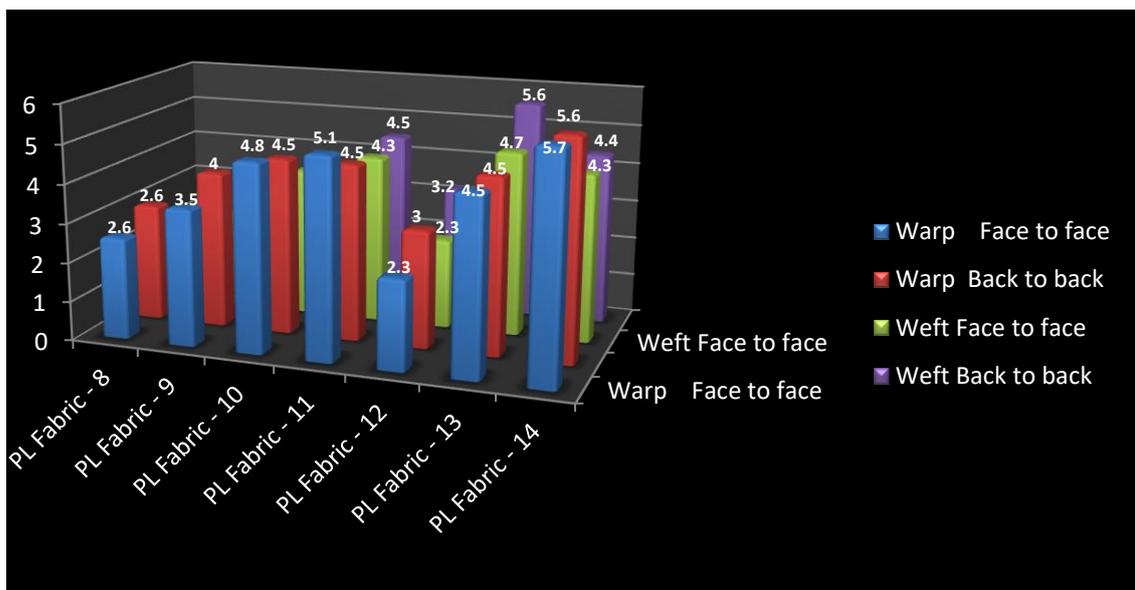


Graph:4.8 Bending length/stiffness of the Handspun/Khadi Fabrics



ccc

Graph : 4.9 Bending length/stiffness of the handloom fabric



Graph: 4.10 Bending length/stiffness of the powerloom fabric

e). Drape co-efficient of constructed fabrics

The term drape is used to describe the way a fabric hangs under its own weight. It is an important factor from the aesthetic point of view. The property of drape plays a very essential role for the designer as it influences the appearance of garment. Women's

clothing needs to have a good drape and appearance. Measurement of fabric's drape leads to the ability to hang in graceful curves. 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. Few other parameters like number of nodes and node dimensions also assess the drape quality Wang, S., & Deakin, C.H. (2008). The drape co-efficient of all the constructed fabrics are shown in Table 4.42 and Graph 4.11, HL Fabric- 3 has a lower drape co-efficient means the fabric will drape very well, the property may be due to the inherent softness of the Lotus fiber, excellent pliability of the yarn and extremely finer yarn developed from one petiole which is used in the weft direction of the fabric with the fine mulberry silk in warp. PL Fabric-14 showed a higher drape co-efficient which may be due to the coarser appearance of 70:30 Lotus: Cotton blended open end/ Rotor yarn. In the powerloom fabric category, the drape coefficient of PL Fabric -8 and PL Fabric -9 was lower that is 23 % and 29 % respectively which may be due to the finer Lotus yarn developed from the fabricated machine in high speed. All the constructed fabrics were very well drapable excluding the fabrics developed from open end yarn.

The Table 4.43 shows the result of One-Way ANOVA analysis Drape Co-efficient within the selected fabrics. The estimated f-value was 226.901 and the p-value is .000 which shows that there is an association within Drape Co-efficient of selected fabrics. From the mean value it is noted that sample PL Fabric 14 got more co-efficient when compared to other fabrics. Thus, the result shows there is a statistical association within drape co-efficient of fabrics.

Table :4.42 Drape Co-efficient (%) of the woven fabrics

Sr.No.	Fabric code	Drape Co-efficient (%)
1	HS Fabric - 1	29
2	HS Fabric - 2	32
3	HL Fabric - 3	18
4	HL Fabric - 4	38
5	HL Fabric - 5	33
6	HL Fabric - 6	29
7	HL Fabric - 7	36
8	PL Fabric - 8	23
9	PL Fabric - 9	29
10	PL Fabric - 10	33
11	PL Fabric - 11	35
12	PL Fabric - 12	38
13	PL Fabric - 13	43
14	PL Fabric - 14	64

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric – 3 -Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100's ; Weft – Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric – 4 - Handloom fabric (Warp –Lotus: Cotton ply yarn – 4/19's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole-3/71's)

HL Fabric – 5- Handloom fabric (Warp – Lotus: Silk ply yarn – 4/23's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole -3/60's)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn – 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric – 7 -Handloom fabric (Warp - handspun Cotton yarn – 120's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole- 3/71's)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)

PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71's)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3'

Table :4.43 Drape co-efficient of the constructed woven fabrics - ANOVA Table (Within Variables)

Variables		Mean	SD	SE	F-value	Sig
Drape Co-efficient	HS Fabric - 1	29.00	1.58	0.71	226.901	.000**
	HS Fabric - 2	32.00	1.58	0.71		
	HL Fabric - 3	18.00	1.58	0.71		
	HL Fabric - 4	38.00	1.58	0.71		
	HL Fabric - 5	33.00	1.58	0.71		
	HL Fabric - 6	29.00	1.58	0.71		
	HL Fabric - 7	36.00	1.58	0.71		
	PL Fabric - 8	23.00	1.58	0.71		
	PL Fabric - 9	29.00	1.58	0.71		
	PL Fabric - 10	33.00	1.58	0.71		
	PL Fabric - 11	35.00	1.58	0.71		
	PL Fabric - 12	38.00	1.58	0.71		
	PL Fabric - 13	43.00	1.58	0.71		
	PL Fabric - 14	64.00	1.58	0.71		

****= Significant at 1% level**

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120’s ; Weft – Handspun Lotus yarn : 2 petiole - 2/86’s)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120’s ; Weft – Handspun Lotus yarn: 3 petiole - 3/28’s)

HL Fabric – 3 -Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100’s ; Weft – Handspun Lotus yarn : 1 petiole - 96’s)

HL Fabric – 4 - Handloom fabric (Warp –Lotus: Cotton ply yarn –4/19’s ; Weft – Machine extracted and spun Lotus yarn : 3 petiole-3/71’s)

HL Fabric – 5- Handloom fabric (Warp – Lotus: Silk ply yarn –4/23’s ; Weft – Machine extracted and spun Lotus yarn : 3 petiole -3/60’s)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn –4/14’s ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/28’s)

HL Fabric – 7 -Handloom fabric (Warp - handspun Cotton yarn – 120’s ; Weft – Machine extracted and spun Lotus yarn : 3 petiole- 3/71’s)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71’s

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60’s)

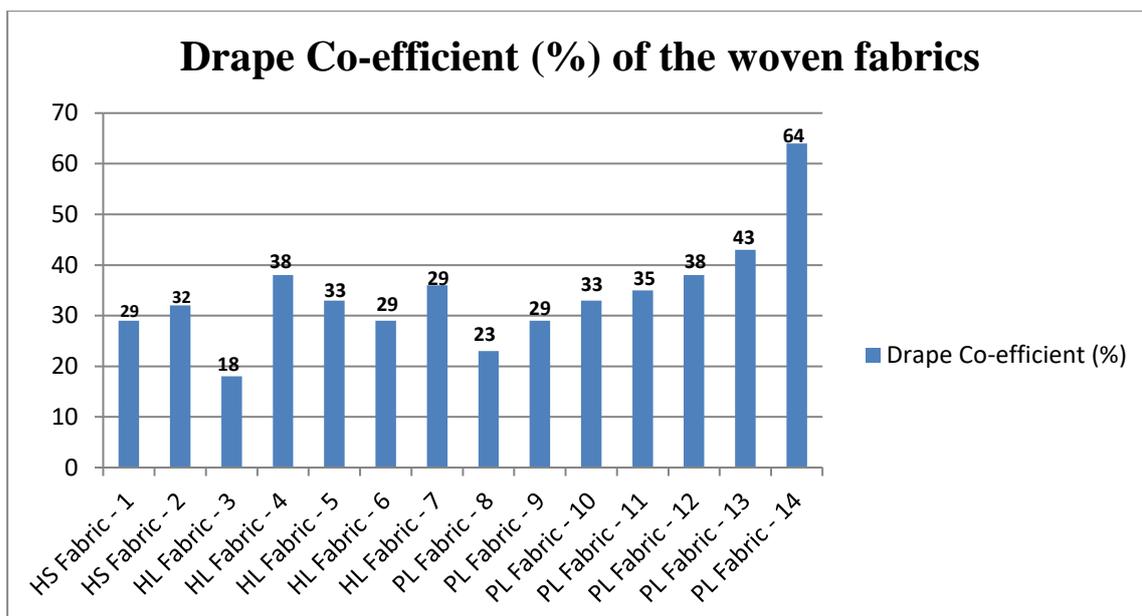
PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33’s)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28’s)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71’s)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5’s)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3’s)



Graph : 4.11 Drape Co-efficient of the constructed woven fabrics

f). Tensile strength of the constructed fabrics

Tensile strength is a most vital aspect for the fabric durability and performance. Tensile strength is the maximum stress that the textile material can withstand while being stretched before breaking. Tensile strength depends on – type of fiber, blend ratio, twist, fineness, fabric density and fabric structure. The tensile strength of the constructed fabrics is shown in Table 4.54.

From the Table 4.44, it was found that HL fabric -3 has obtained low load value in weft direction that is 2.41 Kgf which may be due to the finer Lotus hand extracted and handspun yarn of 96’s count extracted from one petiole used in weft direction amongst all the constructed fabrics.

The load value of HL- Fabric -7 (warp- Cotton & weft – machine extracted and spinned 71’s Lotus yarn) was high in weft direction as compare to the load values of HS fabric -2 (warp – Cotton & weft – hand extracted and hand spinned 28’s Lotus yarn) in weft direction. Both the category yarns that is manual and machine contains same number of petioles. But the load value of HL fabric -7 in weft direction was high due to the higher tenacity of machine extracted and spinned yarn developed in high speed from the fabricated machine.

The load values of the handloom fabrics (HL fabric -4, HL fabric -5 & HL fabric -6) developed from ply yarns increased in weft direction as compare to warp which is due to the higher tenacity of the machine extracted and spinned Lotus yarns used in all the three fabrics. In warp direction, HL fabric -5 has achieved high load value of 16.17 Kgf as compare rest two fabrics due to the high tenacity of the Lotus yarns MYHS1 (42.06 gf/tex) of 71's count used in the ply structure.

The load value of PL fabric-12 (Warp and weft -100 % Lotus MYHS1 machine extracted and spinned yarn of 71's) was low (12.84 Kgf) in warp direction as compared all the 14 constructed fabrics due difficulty handling maintaining tension of Lotus yarn in both warp and weft direction on powerloom. Though the yarn MYHS1 has a high tenacity (42.06 gf/tex) but due the higher cohesive ness it creates difficulty in handling during weaving in both warp and weft direction.

In the powerloom union fabric category, the load value of PL fabric -8 was high 32.55Kgf due to the higher tenacity (42.06 gf/tex) of Lotus yarn MYHS1 (machine extracted and spinned yarn of 71's) used in weft direction.

Table: 4.44 Tensile strength of the constructed woven fabrics

Sr.No.	Fabric code	Maximum Load (kgf)		Extension (mm)	
		Warp	Weft	Warp	Weft
1	HS Fabric - 1	19.39	6.50	15.14	10.5
2	HS Fabric - 2	15.35	5.50	12.15	10.8
3	HL Fabric - 3	14.17	2.41	13.89	8.30
4	HL Fabric - 4	13.75	15.47	12.83	20.25
5	HL Fabric - 5	16.17	16.71	13.07	22.70
6	HL Fabric - 6	13.10	28.02	12.73	32.93
7	HL Fabric - 7	15.55	26.11	19.00	12.00
8	PL Fabric - 8	19.79	32.55	14.70	10.48
9	PL Fabric - 9	15.07	30.86	18.87	12.36
10	PL Fabric - 10	13.37	26.23	22.02	16.03
11	PL Fabric - 11	15.55	19.97	13.07	27.82
12	PL Fabric - 12	12.84	18.19	15.74	11.50
13	PL Fabric - 13	26.64	23.34	40.63	35.65
14	PL Fabric - 14	19.75	19.89	38.86	27.82

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 -Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp -Lotus: Cotton ply yarn -4/19's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole-3/71's)

HL Fabric - 5- Handloom fabric (Warp - Lotus: Silk ply yarn -4/23's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole -3/60's)

HL Fabric - 6- Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7 -Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole- 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28’s)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71’s)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5’s)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3’s)

g). Tearing strength

As per ASTM D 1682, Tearing strength is defined as the force required to start or continue to tear the particular fabric in both warp and weft direction under the specific condition Hunter, L., & Fan, J. (2015). It is the important mechanical property of the woven fabrics. It is very essential property for the garment items like – uniforms, outdoor clothing and overalls. It plays an important role in personal protective clothing. Triki, E. et.al. (2011). Fabrics which has higher tearing strength leads to better resistance to tearing that is suitable for many applications that include frequent stress. The tearing strength of the constructed fabrics is shown in Table 4.45 and Graph 4.12.

It was observed that amongst all the constructed fabric, tearing strength of HL Fabric – 3(Warp – Machine spun Mulberry Silk yarn - 100’s; Weft – Handspun Lotus yarn: - 96’s) was low that is 1600 kgf/cm in weft direction which may be due to the finer count of Lotus yarn developed from one petiole. This developed fabric has a sheer appearance and since it is handspun Lotus yarn it has an uneven appearance throughout the fabric with loose and compact effects in weaving which may have lead to lower tearing strength.

In the powerloom union fabric category, tearing strength of PL Fabric -8(Warp – Machine spun Cotton yarn – 80’s ; Weft – machine extracted and spun Lotus yarn : 3/71’s) & PL Fabric -9 (Warp – Machine spun Cotton yarn – 70’s ; Weft – machine extracted and spun Lotus yarn : 3/60’s) was high that is 5760 kgf/cm & 5504 kgf/cm in weft direction which may be due to machine extracted and spinned yarn used in weft direction that is MYHS1 (Machine extracted and spinned – 71’s) and MYHS2 (Machine extracted and spinned-60’s) Both also possess high tensile strength that is 42.06 gf/tex& 16.77 gf/tex respectively.

PL fabric -12 (warp and weft machine extracted and spinned Lotus yarn -71’s) has obtained low tearing strength that is 5056 kgf/cm in weft direction as compare to PL fabric -8 (warp - Machine spun Cotton yarn – 80’s; weft – machine extracted and spun

Lotus yarn 3/71's) that is 5760 kgf/cm. Both the fabric comprising same fineness of yarn in weft direction but there is a difference in tearing strength is due to the 100 % fine Lotus yarn used in both warp and weft direction in PL fabric -12 which has caused difficulty in weaving.

In the rotor spun Lotus: Cotton blended fabric category, tearing strength in weft direction of PL Fabric – 13 was high (5760 kgf) as compare to PL fabric -14 (4512kgf) which may be due to the LCRY: 50:50 (Lotus: Cotton rotor spun yarn) which contain high proportion of Cotton fiber as compare to LCRY: 70:30 (Lotus: Cotton rotor spun yarn).

In the fabric category consists of Ply yarns, tearing strength of HL fabric – 4 was high in warp direction that is 5888 which may be due to the high tenacity of YLCP yarn that is 13.158gf/tex followed by HL fabric -5 (5760kgf) and HL fabric – 6 (4800kgf). In the weft direction the tearing strength of HL fabric -4 and HL fabric -5 was high due to higher tenacity of machine extracted and spinned yarns (MYHS1 & MYHS2) that is 42.06gf/tex and 16.77 gf/tex.

Table :4.45 Tearing strength of the woven fabrics

Sr. No	Fabric code	Tearing Strength (Kgf/cm)	
		Warp wise	Weft wise
1	HS Fabric - 1	4800	4480
2	HS Fabric - 2	4480	4032
3	HL Fabric - 3	2496	1600
4	HL Fabric - 4	5888	5760
5	HL Fabric - 5	5760	5980
6	HL Fabric - 6	4800	3520
7	HL Fabric - 7	4470	5120
8	PL Fabric - 8	5760	5760
9	PL Fabric - 9	5680	5504
10	PL Fabric - 10	4544	4192
11	PL Fabric - 11	3200	2560
12	PL Fabric - 12	4864	5056
13	PL Fabric - 13	5310	5760
14	PL Fabric - 14	2474	4512

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric – 3 - Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100's ; Weft – Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric – 4 - Handloom fabric (Warp – Lotus: Cotton ply yarn –4/19's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole-3/71's)

HL Fabric – 5- Handloom fabric (Warp – Lotus: Silk ply yarn –4/23's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole -3/60's)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn – 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric – 7- Handloom fabric (Warp - handspun Cotton yarn – 120's ; Weft – Machine extracted and spinned Lotus yarn : 3 petiole- 3/71's)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's)

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)

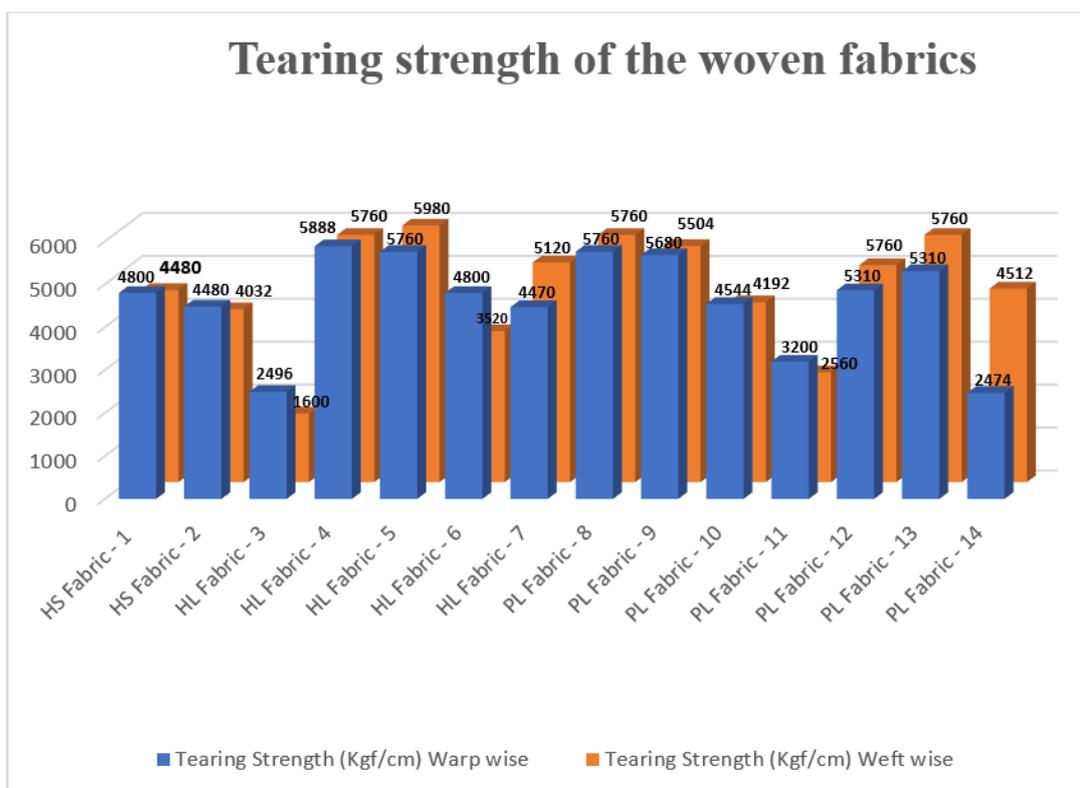
PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71's)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)



Graph : 4.12 Tearing strength of constructed woven fabrics

h). Serviceability property of the constructed fabrics

Serviceability is very important factor for the apparels. Particular apparel is considered as serviceable when it is appropriate for specific end use. After being used for a certain length of time the apparel ceases to be serviceable when it no longer fulfills its intended use in the manner that it did when it was new. Apparel which is used for the particular work wear should withstand the good deal of hard usage during their entire life. Abrasion and pilling are the serviceability properties of fabrics. Lotus fiber has an inherent property of softness, moderate strength, good elongation and possesses high water absorbency. Lotus yarns and fabrics developed has a soft appearance and has an excellent tensile strength but focusing on mass production and in today's fast world consumers rely more on the serviceability factor. Hence the constructed fabrics were tested for pilling and abrasion property.

Pilling

Pilling is considered as a performance and aesthetic property of the woven fabric. It is a state that arises in wear due to the formation of tiny “pills” of entangled fiber clinging to the surface of the fabric that results into an uneven appearance. Pills are developed by the rubbing action of loose fibers which are present on the surface of the fabrics. Pills occur during the wear, washing due to abrasion, area influencing the appearance, handle and touch of textiles. From the Table 4.46, it was observed that all the constructed fabrics has the rating (4-5). The major reason for good pilling property is due to the following properties: Lotus fiber has a long length, highly cohesive and it is water absorbent fiber. Pilling results of the constructed woven fabrics are shown in Table 4.46. HL fabric- 4 and HL fabric - 6 has slight pilling due to the few protruding fibers in Lotus: Cotton and Lotus: Wool yarn ply structures. Slight pilling was observed in PL fabric – 13 and PL fabric -14 because the yarns are made by rotor spinning technique in which contains short length of Lotus and Cotton fibers in the blend proportion. Slight tendency of pilling was found in PL fabric – 10 and PL fabric -11 which is due to loose structure of yarns obtained in moderate and lower speed from the fabricated machine.

Table :4.46 Pilling test of constructed woven fabrics

Sr.No.	Fabric code	Pilling Rating	Appearance
1	HS Fabric – 1	5	No Pilling
2	HS Fabric – 2	5	No Pilling
3	HL Fabric – 3	5	No Pilling
4	HL Fabric – 4	4	Slight pilling
5	HL Fabric – 5	5	No Pilling
6	HL Fabric – 6	4	Slight pilling
7	HL Fabric – 7	5	No Pilling
8	PL Fabric – 8	5	No Pilling
9	PL Fabric – 9	5	No Pilling
10	PL Fabric – 10	4	Slight pilling
11	PL Fabric – 11	4	Slight pilling
12	PL Fabric – 12	5	No Pilling
13	PL Fabric – 13	4	Slight pilling
14	PL Fabric – 14	4	Slight pilling

HS Fabric – 1 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric – 3 -Handloom fabric (Warp – Machine spun Mulberry Silk yarn - 100's ; Weft – Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric – 4 - Handloom fabric (Warp –Lotus: Cotton ply yarn –4/19's ; Weft – Machine extracted and spun Lotus yarn : 3 petiole-3/71's)

HL Fabric – 5- Handloom fabric (Warp – Lotus: Silk ply yarn –4/23's ; Weft – Machine extracted and spun Lotus yarn : 3 petiole -3/60's)

HL Fabric – 6- Handloom fabric (Warp – Lotus: Wool ply yarn – 4/14's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

HL Fabric – 7 -Handloom fabric (Warp - handspun Cotton yarn – 120's ; Weft – Machine extracted and spun Lotus yarn : 3 petiole- 3/71's)

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

PL Fabric – 9 - Powerloom fabric (Warp – Machine spun Cotton yarn – 70's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/60's)

PL Fabric – 10 - Powerloom fabric (Warp – Machine spun Cotton yarn – 40's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/33's)

PL Fabric – 11 - Powerloom fabric (Warp – Machine spun Cotton yarn – 20's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/28's)

PL Fabric – 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole – 3/71's)

PL Fabric – 13- Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric – 14- Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

Abrasion

Abrasion refers to gradual removal of fibers from the yarn structure. Abrasion resistance is very complex phenomenon and it affected by many factors: fiber, yarn, fabric properties and finishing. Few of these parameters affect the surface of the fabrics whereas some of them has an effect on internal structures of the fabric Ozdil,

N.et.al. (2012). Ability of a surface to resist being worn away by rubbing of friction is defined as abrasion resistance.

Test was done in Taber Rotary platform abraser machine. There are various methods of evaluation. Here in the present study for the woven fabric, evaluation was done by finding out the endpoints which assess the number of cycles until two or more yarns have broken or a hole appears Ozdil., N. et.al. (2012).

Technically, abrasion resistance of longer fibers is better than shorter fibers. Fibers are harder to remove from yarns containing longer fibers Saville, B.P. (1999). It can be concluded from Table: 4.47. HS fabric- 1 and HS fabric -2 has achieved lower number of cycles that is 200 as compare to all the constructed fabric. The production method also influences the abrasion resistance property Ozdil., N. et.al. (2012). The Lotus yarns used in both the fabrics were extracted manually and handspun that causes some unevenness and slubs in the fabrics which may have lead to lower abrasion cycles.

Abrasion property also depends on number of plies. In the yarn structure, when the number of ply increases the thickness and mass per unit area also increases that leads to improvement in the abrasion property of the fabric Ozdil, N. et.al. (2012). It was observed and analyzed from Table 4.47. HL fabric- 6 has achieved a greater number of cycles as compare to HL fabric- 4 and HL fabric- 5. This is because of coarser count (14's) of Lotus: Wool Ply yarns which make the yarn thicker. Hence the fabric developed has a higher abrasion resistance characteristic in the category of fabrics developed from ply yarns.

HS fabric - 7 has obtained 700 cycles which was more as compare to HS fabric – 2 that has obtained 200 cycles. Technically the production process of yarn is also a concern for the abrasion property. Hence the weft yarn used in HS fabric -7 was made from the fabricated machine in high speed consists of 71's count which has undergone more smooth production during weaving process which has result into more even fabric as compare to HS fabric -2. Lotus yarns used in both the fabrics consists of three petioles but due to the difference in the production process the abrasion resistance of HS fabric -7 was high as compare to HS fabric -2.

In the powerloom union fabric category, the abrasion cycle of PL fabric- 8 has obtained more of cycles (400) as compare to PL fabric – 9, PL fabric -10 and PL fabric -11 (300) respectively. This may be due to the structure of yarn developed in different speeds from the fabricated machine. As the speed decreased the yarn has loose structure and few protruding fibers through the surface. Hence the PL fabric -8 consists of Lotus yarn developed in high speed which has lead to better abrasion resistance as compare to all other powerloom union fabrics.

PL fabric -14 has obtained highest cycles (1000) as compare to all the constructed fabrics which may be due to higher thickness of fabrics (0.52 mm) and coarser count (3's) developed by rotor spinning technique used in both warp and weft direction. PL fabric -13 has lower number of cycles (800) as compare to Pl fabric – 14 (1000) which may be due to the more proportion of Lotus fiber used in the blend. Technically the yarn comprising of finer fibers causes increment in number of fibers in the cross section which results into higher cohesion that leads to better abrasion resistance characteristic. Hence the Lotus fiber bundle is made of many fine microfibers and also possess cohesiveness property. Thus, PL fabric -14 developed from LCRY-70:30 yarn has obtained a greater number of cycles.

Table 4.48, shows the result of One-Way ANOVA analysis Abrasion (No. of cycles) within the selected fabrics. The estimated f-value were 11.647and the p-value is .000 which shows that there is an association within Abrasion of selected fabrics. From the mean value it is noted that sample PL Fabric 14 got more abrasion and increased cycles when compared to other fabrics. Thus, the result shows there is a statistical association within fabrics.

Table: 4.47 Abrasion property of the woven fabrics

Sr.No.	Fabric code	No of Cycles to form a pin hole
1	HS Fabric - 1	200
2	HS Fabric - 2	200
3	HL Fabric - 3	500
4	HL Fabric - 4	500
5	HL Fabric - 5	500
6	HL Fabric - 6	600
7	HL Fabric - 7	700
8	PL Fabric - 8	400
9	PL Fabric - 9	300
10	PL Fabric - 10	300
11	PL Fabric - 11	300
12	PL Fabric - 12	600
13	PL Fabric - 13	800
14	PL Fabric - 14	1000

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 - Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp - Lotus: Cotton ply yarn - 4/19's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

HL Fabric - 5 - Handloom fabric (Warp - Lotus: Silk ply yarn - 4/23's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

HL Fabric - 6 - Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7 - Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric - 11 - Powerloom fabric (Warp - Machine spun Cotton yarn - 20's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

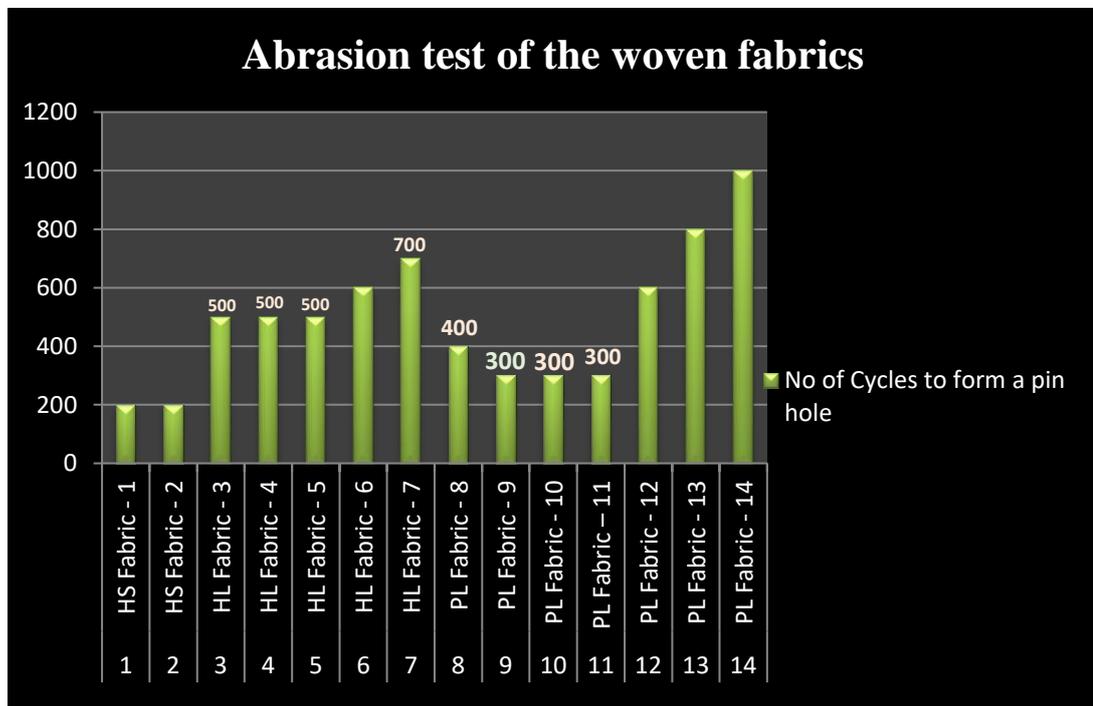
PL Fabric - 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole - 3/71's)

PL Fabric - 13 - Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric - 14 - Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

Table:4.48. Abrasion property of the woven fabrics - Anova table (within variables)

Variables		Mean	SD	SE	F-value	Sig
Abrasion	HS.Fabric - 1	218.00	132.74	59.36	11.647	.000**
	HS Fabric - 2	216.00	135.20	60.46		
	HL Fabric - 3	500.00	158.11	70.71		
	HL Fabric - 4	520.00	148.32	66.33		
	HL Fabric - 5	460.00	181.66	81.24		
	HL Fabric - 6	560.00	114.02	50.99		
	HL Fabric - 7	700.00	158.11	70.71		
	PL Fabric - 8	400.00	158.11	70.71		
	PL Fabric - 9	300.00	158.11	70.71		
	PL Fabric - 10	280.00	148.32	66.33		
	PL Fabric - 11	340.00	114.02	50.99		
	PL Fabric - 12	600.00	158.11	70.71		
	PL Fabric - 13	800.00	158.11	70.71		
	PL Fabric - 14	1000.00	158.11	70.71		



Graph 4.13: Number of cycles obtained in abrasion testing

i). Dimensional stability – Shrinkage

According to the AATCC definition, relaxation shrinkage is the determination of dimensional changes of fabric immersed in cold water, but not agitated. It occurs due to the release of the strains that is introduced into the fabric structure during the process of manufacturing Rippon, J.A. (2008). When the fibers absorb water, the diameter of the weft yarns increases and the warp yarn is stretched to accommodate them. Because the fabric is no longer under tension, however, the warp yarn is free to move and crimp more to relieve the stress thus shortening the distance between adjacent filling yarns. Because they are under more tension from the weaving process than are filling yarns, warp yarns ordinarily relax more during laundering and possess more shrinkage. Shrinkage not only causes change in fabric dimension but when it is used in apparels it causes other issues like seam puckering, torquing and also it affects the entire fit of the apparel.

Shrinkage also depends upon the fiber type used in the blended structure. It was observed from Table : 4.49, that fabric made from open end yarns that is PL Fabric – 13 (warp and weft – 50:50 Lotus: Cotton) and 14 (warp and weft – 70:30 Lotus: Cotton) has 0.3 % shrinkage in both warp and weft direction which may be due to the Cotton fibers used in blended yarn because Cotton fibers has a property to shrink.

PL Fabric – 11(warp –Cotton (20's) and weft – Lotus (28's) developed loom has 5 % shrinkage in warp direction and 3 % shrinkage in weft direction. The shrinkage is more in the warp direction (5%) due to the use of Cotton yarn in the warp direction. The shrinkage in this category of Lotus yarn that is MYLS (Machine extracted and spinned Lotus yarn in Low RPM) of 3/28's used in the fabric structure was loose in structure and has lesser tensile strength which has caused breakage and maintaining tension during weaving.

Wool fiber is more susceptible to relaxation shrinkage due to the scales present in the fiber surface. HL Fabric 6 (Warp – Lotus: Wool ply yarn –4/9's; Weft - Machine extracted and spinned Lotus yarn: 3/28's) has also observed negligible shrinkage. Implementing Lotus yarn in the woollen fabrics will solve the drawback of Wool.

All the natural cellulosic fibers are hydrophilic in nature which has a higher propensity of shrinkage. To reduce shrinkage from washing, certain finishing like

sanforization is been done. All the fabric excluding PL Fabric 12, PL Fabric 13 and PL fabric 14 has negligible shrinkage due to the use of Lotus yarns in the weft direction. Lotus yarn has 0 % shrinkage as per the test conducted by ASTM D 885. The reason behind negligible shrinkage is each Lotus yarn consists of natural microfibers and microfibers has a property to shrink less. These developed fabrics will have an advantage over other natural fibers which have the property to shrinkage. These fabrics will save the resources required to provide anti-shrink finishing which will also add to the aspect of sustainability and finally it will satisfy the consumers.

Table : 4.49 Shrinkage of the woven fabrics

Sr.No.	Fabric code	Warp shrinkage (%)	Weft Shrinkage (%)
1	HS Fabric - 1	0	0
2	HS Fabric - 2	0	0
3	HL Fabric - 3	0	0
4	HL Fabric - 4	0	0
5	HL Fabric - 5	0	0
6	HL Fabric - 6	0	0
7	HL Fabric - 7	0	0
8	PL Fabric - 8	0	0
9	PL Fabric - 9	0	0
10	PL Fabric - 10	0	0
11	PL Fabric - 11	5	3
12	PL Fabric - 12	0	0
13	PL Fabric - 13	0.3	0.3
14	PL Fabric - 14	0.3	0.3

HS Fabric - 1 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn : 2 petiole - 2/86's)

HS Fabric - 2 - Handspun fabric (Warp - Handspun Cotton yarn - 120's ; Weft - Handspun Lotus yarn: 3 petiole - 3/28's)

HL Fabric - 3 - Handloom fabric (Warp - Machine spun Mulberry Silk yarn - 100's ; Weft - Handspun Lotus yarn : 1 petiole - 96's)

HL Fabric - 4 - Handloom fabric (Warp - Lotus: Cotton ply yarn - 4/19's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/71's)

HL Fabric - 5 - Handloom fabric (Warp - Lotus: Silk ply yarn - 4/23's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/60's)

HL Fabric - 6 - Handloom fabric (Warp - Lotus: Wool ply yarn - 4/14's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/28's)

HL Fabric - 7 - Handloom fabric (Warp - handspun Cotton yarn - 120's ; Weft - Machine extracted and spinned Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 8 - Powerloom fabric (Warp - Machine spun Cotton yarn - 80's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/71's)

PL Fabric - 9 - Powerloom fabric (Warp - Machine spun Cotton yarn - 70's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/60's)

PL Fabric - 10 - Powerloom fabric (Warp - Machine spun Cotton yarn - 40's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/33's)

PL Fabric - 11 - Powerloom fabric (Warp - Machine spun Cotton yarn - 20's ; Weft - machine extracted and spun Lotus yarn : 3 petiole - 3/28's)

PL Fabric - 12 - Powerloom fabric (Warp and Weft machine extracted and spun Lotus yarn ; 3 petiole - 3/71's)

PL Fabric - 13 - Powerloom fabric (Warp and Weft ; 50:50 Lotus: Cotton Rotor yarn 5's)

PL Fabric - 14 - Powerloom fabric (Warp and Weft ; 70:30 Lotus: Cotton Rotor yarn 3's)

j). Kawabata test of selected woven fabrics

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 (Total hand value) is a consolidated index graded using a scale of 0-5 which was women's suiting for the present research. The value ranging between 0-5 shows the varying levels of suitability of the fabrics for the proposed applications. THV value 5 indicates that the fabric is for the good for the intended applications whereas THV value 0 means it is unsuitable for the particular applications.

Amongst the 14 woven fabrics, 2 fabrics were selected and subjected for Kawabata test. One fabric was HS Fabric -2 and another was PL Fabric -8 (Powerloom fabric - Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's). Both the fabric were selected on the basis of extraction method, spinning system and type of weaving. Both the fabric has its own essence and qualities. Moving to the sustainability and consumer perception towards eco-friendly fabrics, HS Fabric -2 that is Khadi fabric will be a novel fabric in the entire Khadi and Village industry. Looking to the fashion world and bulk production point of view, PL Fabric -8 will be beneficial.

From the Table: 4.50, it was observed that the Koshi (stiffness) value was less for PL fabric -8 (Powerloom fabric: Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's) as compare to HS fabric -2 (Handspun fabric :Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's) . The reason behind this is the finer, stronger, high twist, machine extracted and spinned yarn used for developing fabric on powerloom. HS fabric-2 (Handspun fabric :Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's) has high Koshi value because of the coarser, hand extracted and spinned yarn used in the weft.

Numeri (Smoothness) value of PL Fabric -8 (Powerloom fabric - Warp – Machine spun Cotton yarn – 80's; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's) was higher than HS Fabric-2 (Handspun fabric - Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's) . The smoothness of the powerloom fabric was higher than Handspun Khadi fabric the reason behind this is extraction and

spinning process of the fiber. HS Fabric contains hand extracted and handspun Lotus yarns which shows some slubs and unevenness in the entire fabric surface whereas the PL- Fabric -8 contains Lotus yarns which is extracted and spinned in the fabricated machine. From the visual analysis also, it was observed that, Lotus yarns developed from the fabricated machine was uniform which gives the even appearance in the entire fabric surface.

Fukurami (Fullness & Softness) is the bulky, rich and well-formed feeling and it mainly depends on fabric bulk and compression properties. Fukurami means warm feeling of the fabric. The Fukurami value of PL Fabric -8 (Powerloom fabric: Warp – Machine spun Cotton yarn – 80’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71’s) was higher than HS fabric -2 (Handspun fabric :Warp – Handspun Cotton yarn - 120’s ; Weft – Handspun Lotus yarn: 3 petiole - 3/28’s) . Hence the fabric developed from the machine extracted and spinned yarn was more softer than hand extracted and spinned yarn.

Overall the total hand value (THV) of the PL fabric -8 (Powerloom fabric (Warp – Machine spun Cotton yarn – 80’s; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71’s) was more than HS fabric -2 (Handspun fabric :Warp – Handspun Cotton yarn - 120’s ; Weft – Handspun Lotus yarn: 3 petiole - 3/28’s) . Hence it can be concluded that yarns developed from the fabricated machine leads to fine fabric with better handle property.

Table : 4.50 Primary and Total Hand values of the selected woven fabrics

Sr. No.	Fabric sample	PRIMARY HAND VALUES KN-201 W- MDY – Women’s Suiting				THV
		Koshi (Stiffness)	Numeri (Smoothness)	Fukurami (Softness)	Sofutosa (Fullness and softness)	KN-301 W- MDY
1	PL Fabric-8	3.07	8.26	6.22	5.86	4.68
2	HS Fabric -2	3.53	3.26	3.20	2.30	1.96

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80’s ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71’s

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120’s ; Weft – Handspun Lotus yarn: 3 petiole - 3/28’s)

Fabric weight and thickness of all the constructed fabrics has been discussed earlier. However, for the fabric sample for which KAWABATA was done is mentioned in

Table 4.51, Fabric thickness and thickness at compression was low for the HS Fabric – 2 as compare to PL Fabric -8. The fabric weight of PL fabric -8 was lower than HS fabric -2 which may be due to the finer Lotus yarn used in weft direction.

The compressional properties of fabrics are measured by placing the sample between two plates and monitoring its thickness with increasing pressure. Compressional properties of fabrics are mentioned in Table 4.52. The linearity of compression (LC) mainly depends on the fabric thickness and compressional characteristics of the yarn. Compressional energy (WC) depends upon the LC and the amount of compression. The compressional resilience (RC) mainly depends upon fabric thickness and compressional characteristics of yarn. During wearing garments and ironing compression property plays an important role. It was observed that compressional resilience (RC) and linearity of compression (LC) was high for HS Fabric -2 and lower for PL Fabric – 8.

Tensile properties are shown in Table : 4.53, it was observed that tensile strain (EMT) affects the slim slippage and tailorability. Greater value of EMT provides comfort properties to the wear but on another side it creates issues during seam pressing and stitching. EMT values of both the fabrics in warp direction is higher than weft direction. The WT (tensile energy value) was more in HS Fabric -2 as compare to PL Fabric -8 this may be due to the stress of powerloom. The tensile Resilience (RT) indicates recovery after tensile deformation. There was very slight difference in RT values of both the fabrics. This may be due to inherent property of elongation and recovery of the Lotus fiber. Tensile resilience (RT) values are higher for tighter construction because of crimp removal, which leads to a better recovery in tight fabrics. Both the fabric has a compact appearance with high fabric count and cover factor.

Shear properties are shown in Table: 4.54. Greater values of shear causes problems in stitching and it is uncomfortable for the wearer. Shear rigidity depends on the mobility of warp and weft yarns within the fabric. The compact fabric consists of higher pick density and consists of higher shear values and hysteresis of shear. The shear values of HS Fabric-2 was higher than PL Fabric-8. 2HG and 2HG5 indicate the hysteresis of shear force at 0.5° and 5° respectively. Hysteresis for shear at 2HG and 2HG5 was higher for HS Fabric – 2 as compare to PL fabric -8. This may be due to finer yarn of 120's count used in the warp direction of HS fabric -2.

Surface properties of the fabric are shown in Table 4.55. It was found that Coefficient of friction (MIU) was higher in HS Fabric -2 and lower for PL Fabric -8. The mean deviation of coefficient of friction (MMD) notes the surface smoothness as perceived while moving the fingers on the fabric surface. Coefficient of friction (MMD) was higher in PL Fabric -8 and lower in HS Fabric -2. The increased smoothness of PL fabric -8 is due to the High twist yarn of 100 tpi used in weft direction of the fabric that is developed from the fabricated machine. Geometrical Roughness was high for HS Fabric -8 and low for PL Fabric -8. There was a huge difference in geometrical roughness values between both the fabrics. This is due to the coarser, hand extracted and hand spun yarn used in the HS Fabric – 2 that leads to the rough appearance. Finer, high twist yarn extracted and developed from the fabricated machine has lead to less geometrical roughness.

Bending rigidity (B) of a fabric depends upon the bending rigidity of the threads and the mobility of warp and weft threads within the fabric. Bending rigidity is defined as a characteristic of ease or difficulty encountered in bending a fabric. Bending hysteresis is a measure of fabric's ability to recover from bending.

Bending properties of the fabric are shown in Table 4.56, Bending rigidity of the PL Fabric -8 was higher than HS Fabric -2. PL fabric -8 is difficult to bend and slightly stiffer as compare to HS Fabric -2. Bending rigidity is higher in weft direction than in warp direction. Hysteresis of bending moment (2HB) is high for HS fabric -2 and lower for PL fabric -8. Hence HS Fabric -2 can fastly recover from bending moment as compared to PL fabric -8.

Table : 4.51 Fabric Weight and thickness of the selected woven fabrics

Sr. No.	Fabric sample	Fabric Thickness (mm) (To mm)	Fabric thickness at compression (Tm mm)	Fabric weight (mg/cm²)
1	PL Fabric-8	0.685	0.366	9.875
2	HS Fabric -2	0.609	0.358	10.15

To: Thickness at 0.5gf/cm²

Tm: Thickness at 5gf/cm²

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

Table : 4.52 Compression properties using compression tester

Sr. No.	Fabric sample	LC	WC g.cm/cm²	RC (%)
1	PL Fabric-8	0.239	0.190	35.17
2	HS Fabric -2	0.273	0.171	38.97

LC : Linearity of compression –thickness curve

WC : Compressional energy

RC :Compressional Resilience

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

Table :4.53 Tensile properties using Tensile tester

Sr. No.	Fabric sample		LT	WT Gf/cm/cm ²	RT (%)	EMT (%)
1	PL Fabric-8	Warp	0.617	8.25	49.39	5.35
		Weft	0.640	6.65	45.35	4.16
		Average	0.628	7.45	47.37	4.75
2	HS Fabric -2	Warp	0.656	8.58	48.35	5.23
		Weft	0.674	6.97	47.02	4.13
		Average	0.665	7.78	47.68	4.68

LT : Linearity of load- extension curve

WT : Tensile energy

RT: Tensile resilience

EMT : Extensibility

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

Table : 4.54 Shear Properties using shear tester (KES-FB1) of the selected woven fabrics

Sr. No.	Fabric sample		G gf/cm.deg	2HG gf/cm	2HG5 gf/cm
1	PL Fabric-8	Warp	0.37	0.33	0.48
		Weft	0.24	0.30	0.32
		Average	0.30	0.31	0.40
2	HS Fabric -2	Warp	0.54	0.83	1.43
		Weft	0.46	0.77	1.20
		Average	0.50	0.80	1.32

G: Shear Hysteresis

2HG: Hysteresis of shear force at 0.5 degree shear angle

2HG5 : Hysteresis of shear force at 5 degree shear angle

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

Table : 4.55 Surface properties using surface tester (KES-FB4)

Sr. No.	Fabric sample		MIU	MMD	SMD (μm)
1	PL Fabric-8	Warp	0.105	0.0077	1.792
		Weft	0.115	0.0076	4.550
		Average	0.110	0.0077	3.171
2	HS Fabric -2	Warp	0.198	0.0554	14.318
		Weft	0.178	0.0228	14.338
		Average	0.188	0.0391	14.328

MIU: Coefficient of friction
MMD: Mean deviation of MIU
SMD : Geometrical Roughness

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

Table : 4.56 Bending properties using Pure bending tester (KES –FB2)

Sr. No.	Fabric sample		B gf.cm ² /cm	2HB gf.cm ² /cm
1	PL Fabric-8	Warp	0.0521	0.0681
		Weft	0.0393	0.0354
		Average	0.0457	0.0518
2	HS Fabric -2	Warp	0.0612	0.0593
		Weft	0.0213	0.0489
		Average	0.0412	0.0541

PL Fabric – 8 - Powerloom fabric (Warp – Machine spun Cotton yarn – 80's ; Weft – machine extracted and spun Lotus yarn : 3 petiole – 3/71's

HS Fabric – 2 - Handspun fabric (Warp – Handspun Cotton yarn - 120's ; Weft – Handspun Lotus yarn: 3 petiole - 3/28's)

4.11. Construction of Knitted fabrics and its properties

Knitting is second most used technique for fabric production after weaving. The knitting process is higher in productivity because it eliminates many of the pre- preparatory process like sizing, warping, drawing and di-sizing.

Though it is the growing sector nowadays but it is restricted to commodity fibers like Cotton, Organic Cotton, Wool, Viscose rayon, Modal, Tencel, Excel, Acrylic, Nylon and Polyester etc. Focusing on the area of the minor cellulosic fibers, due to properties like harshness, less elongation and unevenness doesnot work successfully in knitted sector.

Few minor cellulosic fibers are on the inception stage in the knitting sector. Fibers like Hemp, Banana, Milkweed, Jute etc are used but they have to undergo certain pretreatment for softening and luster to work successfully in the knitted structure. The another limitation is these fibers has to blended with some other fibers while developing yarn for achieving smooth production in the knitting machines.

Globally knitted fabrics and natural fibers are preferred by the consumers. The advantage of Lotus fiber in developing knitted structures are:

The fiber is inherently soft, lustrous, pliable, inherently antibacterial and possess a good elasticity due the spiral arrangement of fine microfibers in the bundle. Due to the excellent characteristics of the fiber it doesnot require any treatments which leads to sustainability.

Knitted fabrics has a wide array of applications due to its mechanical properties and characteristics obtained from the constituent yarns. In machine knitting the yarn has to pass through several needles so the quality of the yarn especially strength, pliability and evenness plays a major role in obtaining a good quality knitted fabric. The invention of the fabricated machine in the research has lead to the development of 100 % Lotus yarn which was found successfully in developing 100 % Lotus knitted structure. The major advantage is the Lotus yarn was used in its pure form for knitting. Hence this will be a novel sustainable material for the entire knitting sector especially in the inner garments (Underwears& Camisoles) and Socks. Due to the comfort characteristics consumer pay more for the inner garments. Distinct properties are built in the inner garments and

specialized socks using special fibers, yarns and fabric structures and finishes. Softness along with the functional properties like antibacterial properties plays a very important role in inner garments. Our human body consist of odor that is caused by the mix of bacterias and sweat on the skin. This fibers will be helpful as it consist all the mechanical and functional properties – softness, high absorbency, antibacterial, good elasticity and strength and it doesnot consist any chemicals in the entire manufacturing process.

Initially for experimenting the capacity of the yarn to withstand strength in the circular knitting machine blended yarn of 70:30 (Lotus: Cotton) yarn was used in developing fabric shown in Plate :4.36: It was observed that it works very well in the circular knitting machine in terms of strength and smooth production. Later 100 % Lotus yarn (71’s count) fabricated from the machine was experimented in the circular knitting machine that was also successful in terms of strength in developing circular knitting structure shown in Plate 4.37. These both fabrics were developed in the miniature circular knitting machine without the use of Elastane. Later for the final sample, amongst all the 12 yarns, only two finer yarns (MYHS1 & MYHS2). Developed from fabricated machine was subjected for final fabric preparation in industrial circular knitting machines . Two different types of 100 % Lotus circular knitted fabrics were developed in Automatic circular knitting machine shown in Plate : 4.38 and Plate 4.39.

Table : 4.57 Technical Details of the circular knitting

Machine Speed	250 to 275 RPM
Diameter of Cylinder	3.75 inches
Number of Needles in the circular cylinder	168

Table : 4.58 Specification of the developed knitted structures

Sr. No	Fabric Type	Description of yarn used in the knitted structures	
		Lotus yarn	Elastane
1	LK1 -71	Lotus yarn (Machine extracted and spinned 3/71's count yarn)	20 Denier
2	LK2- 60	Lotus yarn (Machine extracted and spinned 3/60's count yarn)	



Plate :4.36 Lotus: Cotton (70:30 Circular Knitted structure) without Elastane



Plate : 4.37 100 % Lotus Knitted structure without



Plate : 4.38 LK1 -71 (Lotus yarn (Machine extracted and spinned 3/71's count yarn)



Plate: 4.39 LK2- 60 (Lotus yarn Machine extracted and spinned 3/60's count yarn)

Testing and analysis of Knitted fabrics

a). Preliminary data of the constructed fabrics - Fabric count, Thickness and GSM of the knitted fabrics

From the Table :4.59, fabric count , thickness and GSM of LK1-60 was found higher as compare to LK1-60 fabric due to the variation of fineness in the yarns used in developing knitting structures. The GSM ranging from 1-4 oz is considered in the category of light weight fabrics Young, D. (2015). Hence the GSM of both the developed knitted fabrics fall under the light weight fabrics which can be used in blouses, shirting and light summer dress.

Table : 4.59 Preliminary data of the constructed knitted fabrics

Sr. No	Fabric Type	Fabric Count		Thickness (mm)	GSM (in grams)	GSM (in ounces)
		Coarses	Wales			
1	LK1-71	28	21	0.12	80	2.35
2	LK2-60	32	25	0.97	83	2.47

LK1-71 : Lotus yarn (Machine extracted and spinned 3/71's count yarn)

LK2 -60 : Lotus yarn (Machine extracted and spinned 3/60's count yarn)

b). Bursting strength

Bursting strength is an important physical indicator for assessing the quality and durability of the knitted fabrics. Bursting strength is defined as three-dimensional strain applied to the fabric until it ruptures Islam, A. et.al. (2023). It is one of the essential mechanical properties of the knitted fabrics Hoque, M.M.U. et.al. (2022). Knitted apparels which cover the following areas like elbows, knees and the toes specially in case of socks gets deformed over a certain period of time. In such cases, the measurement of the bursting strength plays a pivotal role. Bursting strength depends on many factors: raw material that is type of the fiber, pattern used in knitted structure, yarn fineness, yarn strength, ratio of elastomer used Islam, A et.al. (2022). For the study, yarn fineness and strength were taken into the consideration. From the Table :4.60 and Graph : 4.14, it was analyzed

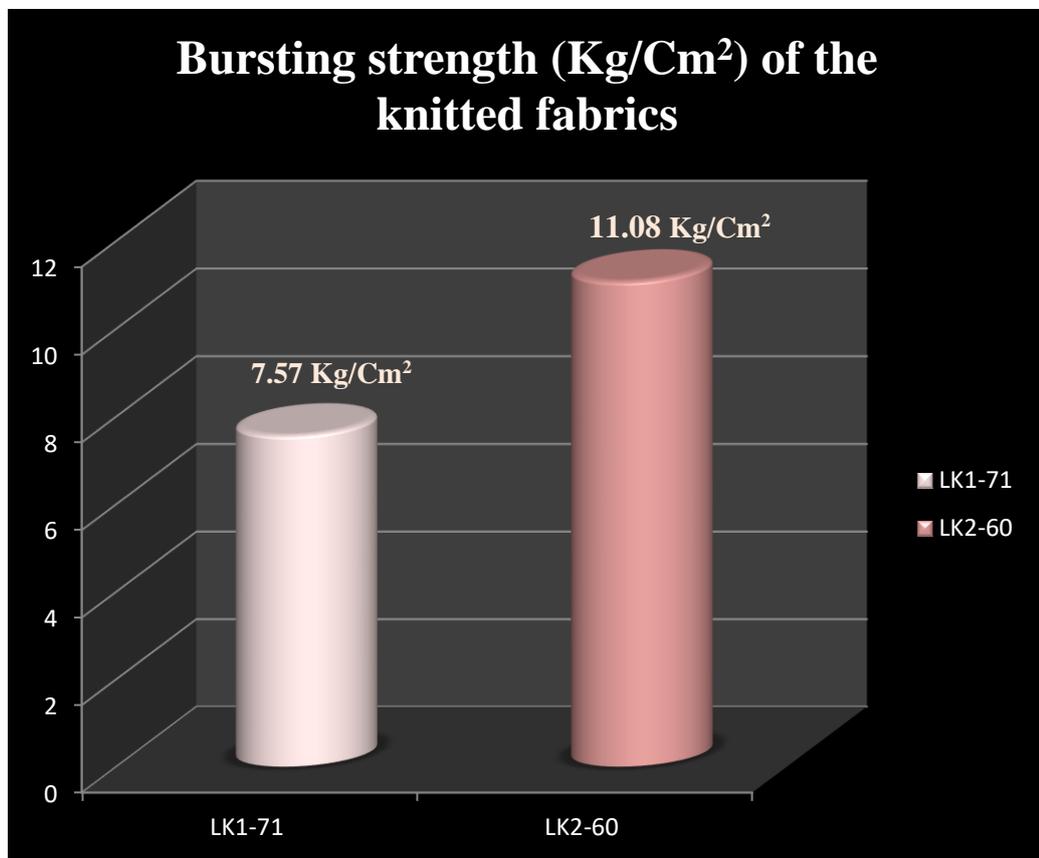
that, the bursting strength of LK2-60 fabric was found higher that is 11.08 Kg/Cm² as compare to LK1-71 fabric that is 7.57 Kg/Cm² . The reason behind this is may be due to the higher tenacity of the MYHS2 yarn (g/f den.) The higher thickness of LK2-60 fabric that is 0.97 mm also leads to higher bursting strength.

Table : 4.60 Bursting strength of the constructed Knitted fabrics

Fabric type	Bursting strength Kg/cm ²	Bursting strength pounds/inch ²
LK1-71	7.57	107.670
LK2-60	11.08	157.594

LK1-71 : Lotus yarn (Machine extracted and spinned 3/71's count yarn)

LK2 -60 : Lotus yarn (Machine extracted and spinned 3/60's count yarn)



Graph : 4.14 Bursting strength of the constructed Knitted fabrics

LK1-71 : Lotus yarn (Machine extracted and spinned 3/71's count yarn)

LK2 -60 : Lotus yarn (Machine extracted and spinned 3/60's count yarn)

c). Pilling

Pilling of the fabric is the multifaceted issue influenced by the various technical factors. It significantly affects the quality of fabric, aesthetics and comfort. Any novel fiber should be tested for pilling tendency because it plays a vital role in care of textiles. Due to the fast life, consumers are more focused towards the wear and tear as well as longevity of the fabrics.

Selection of the fiber is the paramount when it comes to fabric pilling. It was observed that LK1-71 fabric has no pilling with the rating 5 (no pilling) and LK2-60 fabric has slight pilling with the rating 4. The slight difference in the rating was seen in both the fabrics due to the variation of yarn fineness. LK1-71 fabric is developed from the finer Lotus yarn (MYHS1) of 71's count that is prepared in the high speed during yarn preparation in the fabricated machines. Due to the high speed it fastly gets twist with the less breakage of the short fibers in between whereas LK2-60 fabric is developed from the Lotus yarn (MYHS2) of 60's count that is prepared in high moderate speed during yarn preparation in the fabricated machines. Due to the lower speed in yarn preparation and lower count has lead to slight pilling in LK2-60 fabric.

The problem of pilling is less in the developed knitted structure due to the inherent property of fiber, method of extraction and construction of yarn making. Yarns used in developing the knitted structure plays a crucial role. Both the yarns used in the developed knitted structure has a high twist of 100 TPI that leads to satisfactory results in pilling. Low and soft twisted yarns leads to excess pilling whereas high twist yarns exhibit lower propensity to pilling.

Satisfactory results of pilling leads to the nature of the extraction process because the fibers are extracted in the filament form in the fabricated machine only end to end points are joined. Fibers of shorter length are more prone to pilling as compare to longer counterparts. Long length fibers possess greater resistance to friction and less likely to form pills.

Another important property of the fiber is when it is extracted from the bunch of petioles due to the water, fats and waxes present in the petioles leads to cohesiveness as it form an inbound, compact and intact yarn structure which

cannot be segregated later. Results of the pilling are also attributed to the smoothness of the yarns with the less protruding fibers. The Lotus fiber has high water absorbency that also leads to less pilling.

d). Stretch and Recovery property of the constructed knitted fabrics

Knitted fabrics that return to its original size after stretching is called recovery whereas some fabrics are unable to revert back to their original position is called as growth. It is also defined as maximum stretching of the fabric without causing any deformation.

This property is imparted by using different fiber content with Lycra. Requirement of recovery properties varies as per the end use. Good recovery property play an essential role in more fitted knitted garments like in Active wear and lingerie.

It was observed from the Table : 4.61 and Graph : 4.15, Stretch percentage points (recovery percentage) of LK1-71 fabric was 40 % in the wale direction and 90 % in the coarses direction. Hence this type of structure can be suitable for the application in form-fitting (semi-support apparel) as per ASTM D 2594-99a standard shown in Table : 4.62. This knitted structure can be further used in swimwear, sportswear and anchored slacks. This knitted structure will be useful in the garments that are close fitted to the body because firstly the fabric should have a capacity to accommodate donning and removal of clothing and secondly it should withstand its shape and stretch during any physical activities. The fabric after wear should not lead to the baggy appearance. The stretch has to follow complete recovery from original positions Saville, B.P. (1999).

Stretch percentage points (recovery percentage) of LK2 -60 was 20 % in the wale direction and 40 % in the coarses direction. Hence this type of structure can be suitable for the application in Loose Fitting (Comfort Stretch) apparel type as per ASTM - D 2594-99a standard shown in Table 4 : This type of knitted structure can be used in chunky sweaters.

Stretch and recovery percentage of LK1-71 fabric was higher as compare to LK2-60 fabric but both fulfills two categories of knitted apparels that is form fitting

and loose fitting as per ASTM- D 2594-99a. The satisfactory stretch and recovery percentage is obtained due to the characteristic of both the Lotus yarn (MYHS1 & MYHS2) used in the developing knitted structures along with the Lycra yarn used in addition with the Lotus yarn while preparing fabrics. Stretch and recovery percentage (%) of LK1-71 fabric was higher than LK2-60 due to the higher extension (6 mm) and fineness (71's) of MYHS1 yarn used in developing LK1-71 Fabric. The appearance of MYHS1 yarn was more smoother with less protruding fibers in the surface as compared to MYHS2 yarn that may lead to higher stretch and recovery property.

Table :4.61 Stretch and Recovery percentage of the constructed knitted fabrics

Fabric type	Wale direction	Course direction
LK1-71	40	90
LK2-60	20	40

LK1-71: Lotus yarn (Machine extracted and spinned 3/71's count yarn)

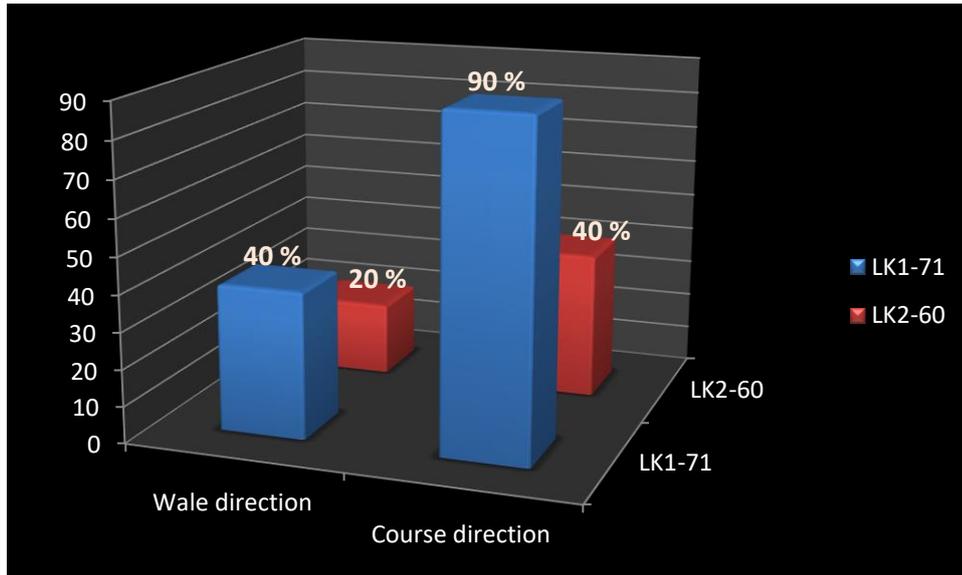
LK2 -60: Lotus yarn (Machine extracted and spinned 3/60's count yarn)

Table : 4.62 Stretch and recovery percentage of the knitted fabrics as per ASTM- D 2594-99a

Apparel Type	Wale Direction	Course Direction
Form Fitting (Semi Support)	35	60
Loose Fitting(Comfort Stretch)	15	30

LK1-71 : Lotus yarn (Machine extracted and spinned 3/71's count yarn)

LK2 -60 : Lotus yarn (Machine extracted and spinned 3/60's count yarn)



Graph : 4.15 Stretch and recovery percentage of Lotus knitted fabrics.

4.12. Development of knitted product

After the successful trail of Lotus yarn in developing circular knitted structure. Testing results of the developed fabrics showed better results for stretch and recovery properties, bursting strength and pilling properties. Lotus fiber itself is soft, moisture absorbent, antibacterial and light in weight. Focusing on all these properties, socks were developed from 100 % machine extracted and spinned Lotus yarns (Plate 4.40) & (Plate 4.41). Socks was selected because it is utility product that is used by people of all the ages. In the study, it is considered as a small representative product of apparel. Developed socks were soft in feel and comfortable to wear.



Plate : 4.40 100 % Lotus socks developed from Lotus yarn (Machine extracted and spinned 3/71's count) yarn)



Plate : 4.41 100 % Lotus socks developed from Lotus yarn (Machine extracted and spinned 3/60's count)

Functional properties play an important role for the application in technical textiles especially in the medical textiles.

a). pH of Lotus fibers

pH value of textiles refers to acidic and alkaline components of the fibers that is one of the indicators of the harmful substances affecting the health of the human being. pH of the human skin ranges from 5.5 to 7. Higher value of pH damages the weakly acidic environment on the surface of the human body that further causes itching and growth of pathogenic bacterias that leads to dermatitis and other symptoms.

Textile materials are considered as a pointer of infections in vaginal area. Malheiro, J.N.M & Salvado, L.R.S (2009). It was tested that pH value of the Lotus fiber was 6.9. As per ISO:5405 pH value of the absorbent material used in sanitary napkin should range between 6 to 8.5 to fulfill the purpose without causing any skin irritation and comfort. The acidic pH leads to the growth of common bacteria – *Staphylococcus aureas*. Pidwill, G.R. et.al. (2021).

Hence in terms of pH Lotus fibers can be successfully used in absorbent material for various hygiene products.

b). Antibacterial activity of the Lotus fibers

Lotus plant is widely known for its medicinal properties. Many pharmaceutical researches revealed that the extracts of different part of the Lotus has many health benefits. Hence the raw Lotus fibers without any treatment was tested against these organisms: *Staphylococcus aureas*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Candida Albicans*. According to Kara, S. (2021) the most essential functional properties of the sanitary napkins is the antibacterial activity. The absorbent layer should be majorly focused for antibacterial activity to inhibit the growth of bacteria instead of upper layers which is in direct contact with the vaginal skin. It was found that Lotus fibers has a positive antibacterial activity with Bacteriostatic effect against four microorganisms mentioned in Table: 4.63. Bacteriostatic is defined as any substance that prevents the growth of bacteria or the reproduction of Bacteria. Removal of bacteriostatic compound leads to

bacteria growth immediately or after a certain period of time. Hence the antibacterial activity is inbuilt in the Lotus fiber. In case of hygiene for the prevention of bacterial development the textile material should possess bacteriostatic activity instead of bactericidal or diffusible activity that significantly kills the bacteria. Any textile material should not lead to destruction of the skin flora. Positive immune defences or the good bacterias should not be decreased by the textile material Kara, S. (2021). This inbuilt antibacterial activity of the Lotus fibers may be due to the bio-active agents present in the plant. Hence the Lotus fibers in its pure form can be successfully used in absorbent core layers of the various hygiene products. Currently the issues in the sanitary napkin is it contain synthetic fibers, regenerated fibers , dioxins due to the bleaching of the core fibers , antibacterial finish and perfumes which causes health issues and leads to environmental hazards. In the vaginal ecosystem, *Staphylococcus aureas* is most frequently found. All the four microorganisms are responsible for Urinary tract infections (UTI). *Klebsiella pneumonia* appears in blood stream infections also found in the Catheters of the patients (<https://www.bio-services.org/urinary-tract-infection/>). *Candida Albicans* is a yeast that is found in GI tract, mouth and vagina. *Albicans* means white in latin. This microorganism causes abnormal vagina discharge and causes rash around the vaginal area. Candid infection is very common in women (Source : <https://www.medicalnewstoday.com/articles/322722>).

Pseudomonas aeruginosa. causes infection in soft tissues, burns, patients suffering from cancer and AIDS Wu, M., & Xuefeng, L. (2015). Hence the advantages of the Lotus fiber are it can be used in its pure form with the inbuilt antibacterial activity against the four microorganisms frequently responsible for vaginal and Urinary tract infection.

Table : 4.63 Antibacterial activity of Lotus fibers

Sr. No.	Organisms	Growth under specimen	Zone of Inhibition
1	<i>Staphylococcus aureas.</i>	Absent	Absent
2	<i>Klebsiella Pneumonia.</i>	Absent	Absent
3	<i>Candida Albicians.</i>	Absent	Absent
4	<i>Pseudomonas Aeruginosa.</i>	Absent	Absent

Table : 4.64 Antibacterial Effect

Sr. No.	Growth	Description	Assessment
1	No Growth	Zone of inhibition is seen	Diffusible antibacterial activity
2	No Growth	Zone of inhibition is absent	Bacteriostatic antibacterial activity
3	Growth	Zone of inhibition is absent	No antibacterial activity

c). Cytotoxicity

Textile material should be non-cytotoxic for the applications in the medical textiles. The term cyto means “cell” and toxicity means “poison”. Cytotoxicity is an in-vitro test that is done outside the living organisms. Cell viability refers to number of healthy cells in a test sample. The test was done in the mouse fibroblasts cells. It evaluates that how the particular test sample that is fiber affects the cell either it destroys the healthy cell completely or no destruction in cell is observed. From the Table : 65, it was observed that Lotus fiber has a 20 % cytotoxic value and possess slight reactivity against the cell means there are some degenerated or malformed cells observed in the specimen. As per ISO 10993:5:2009, reduction of the cell viability more than 30 % is considered as harmful and cytotoxic. Hence the Lotus fiber is non-cytotoxic means it will not create any toxicity to the cells. Non-cytotoxicity may be due to the bioactive agents present in the plant. The reasons of the slight toxicity may be due to the environmental and geographical conditions where the plant grows. Another reason may be that the Lotus plant has a capacity to accumulate heavy metals from the environment Leong, E.S., et.al. (2012).

Table : 4.65 Cytotoxicity of Lotus Fibers

Concentration (μg)	Cytotoxicity (%)	Cell Viability (%)	Cytotoxic Reactivity
Pbs (Phosphate buffered saline) extract	-		
Sample (Lotus fiber)	20	80	Slight
Cotton seed oil	-		
Sample (Lotus fiber)	20	80	Slight

d). Absorbency of the Lotus fibers

(i). Absorbency under Load or pressure (AUL/AUP)

For the application of the Lotus fiber in the core layer of the hygiene products, absorbency under load parameter plays an important role because the human body undergo through many physical activities like walking, sitting, driving etc so there is certain pressure which is exerted. The hygiene product should be functional and it should adapt with the movement and shape of the body. In such cases, the fiber should have an ability to hold the fluid. It was found that absorbency under load percentage of the Lotus fiber was 16.01 % in 60 minutes. Hence the fibers can be used in the core layers of the hygiene products.

(ii). Equilibrium Absorbency

It was found that the highest equilibrium absorbency of the Lotus fibers was 40 % in 24 hours. Hygiene products made from Lotus fiber can be used for the prolonged time.

(iii). Free swell absorptive capacity

It is a measure of the ability of the textile fiber to absorb and hold the fluids such as water, oil and blood. This property is essential in the healthcare and personal hygiene products like diapers, sanitary napkins, wound dressings and many other products in which fluid absorption plays an essential role. In sanitary napkins and diapers high free swell absorbency is needed.

Lotus fibers possess free swell absorptive capacity of 35.17 % which is more than the regenerated fibers, few natural and protein fibers. The free swell capacity of the core layer made of fibers: Lyocell (30.82 %), Modal (20.21 %) and Lyocell/Modal blended (22.43 %) reported by Dhinakaran, M., Kumar, S., & Kumar, S.T. (2017). Free swell absorptive capacity of Banana fiber is 28.75 %. Sreekumar, S. et.al. (2018). Cotton and Viscose fibers has absorptive capacity of 30 % Kalebek, A.N., & Babaarslan, O. (2016). Flax (unbleached) fiber has an absorptive capacity of 14 % and bleached fibers has a absorptive capacity of 20.79 %. Mishra, S., Pandey, R., & Singh, M.K.

(2016). High free swell absorbency leads to larger amount of fluid absorbency and meanwhile it decreases the risk of leakage and discomfort for the users. Hence Lotus fibers can be used in the core layer of the hygiene products.

In commercial hygiene products to increase the absorbency the fibers in the core layers are bleached which is harmful to the health and leads to environmental hazards. Lotus fibers without any treatment leads to satisfactory results in absorbency. The high absorbency of the Lotus fiber is due to the fine microfibers that are arranged in the helical form in the xylem cells of the Lotus petioles. Microfibers are superabsorbent and it consists of higher surface area that leads high absorbency Ravandi, H.S., & Valizadeh, M. (2011).

4.14. Development of Nonwoven fabric and its testing

To check the possibility for making the nonwoven sheet from Lotus fibers, lab scale method was developed. Fibers were extracted on the woolen felt (Plate : 4.42) horizontally and vertically direction (Plate: 4.43) that forms a web like structure due to the natural cohesiveness properties of fiber (Plate : 4.44). To develop more compact structure the web was further taken from woolen felt to A4 size paper. Water was sprinkled on the web. Then the A-4 size sheet comprising of extracted fibers was covered with the polypropylene mesh (Plate : 4.45). To get the compact structure sheet was passed through padding mangle in 3 psi pressure. Then sheet was kept to dry in moisture oven for 1 hour at 100° C. After drying the compact nonwoven structure was formed (Plate 4.46). The thickness of the developed nonwoven fabric was 0.72 mm and the GSM was 90.

Finally for the applications in medical textiles, final nonwoven sheet was developed in machine. For that fibers extracted in the raw form was weighted and passed through the carding machine. The carding machine opens up the individual fibers. Finally the 100 % Lotus nonwoven web was developed (Plate 4.47). It was observed that the web prepared was thin and lightweight. The entanglement of fibers was also good. Since the application of the nonwoven sheet was in absorbent core material of hygiene products so it was not proceeded further for needle punching. Thickness of the nonwoven fabric was 0.47 mm.

GSM of the nonwoven fabric was 58. This nonwoven fabric was used further in the core layer of sanitary napkins.



Plate : 4.42
Extracted fibers
taken on felt fabric



Plate :4.43
Alignment of fibers
in vertical and
horizontal



Plate 4.44 Web
separated from
the felt fabric



Plate 4.45: Web laid
on the A-4 size sheet
and covered with
polypropylene sheet



Plate :4.46 100 % Lotus Nonwoven fabric
(Lab-scale method)



Plate :4.47 100 % Lotus Nonwoven
fabric (developed in machine)

4.15. Development of hygiene products and its testing

The entire lotus plant is endowed with numerous medicinal properties. It was observed that Lotus fibers has functional properties like inherent antibacterial properties without any finishing, excellent free swell capacity and absorbency under load. The main component of hygiene medical textiles is its absorbent core layer. Moving to the sustainability there is a demand of eco-friendly fibers for the

application in the core layers. Hence it was decided to implement these fibers in the core layers of hygiene medical textiles.

Initially the layers of sanitary napkin were cut according to the standard template. The size of the Lotus nonwoven sheet developed in the machine was 62L×23W Cm. After cutting, the Lotus nonwoven sheet for absorbent core of sanitary napkin it was observed that there was small leftover pieces. Hence these leftover pieces were implemented in the absorbent core layer of sweat pads and panty liners (Plate:4.51) and (Plate:4.52) First all the layers were cut according to the standard template. All the layers were arranged. The stitching of the hygiene products was done in the Ultrasonic machine. The sanitary napkin was developed in all the sizes – regular, large and extra large (Plate 4.48), (Plate 4.49) and (Plate 4.50). Weight and thickness of the sanitary napkin are mentioned in Table: 4.66, As per ISO 5405-1980 standard, thickness of the sanitary napkin should be 15± 2 mm but as per current standard that is ISO 5405-2019, specific measurement of thickness is excluded and it is not a major concern. Developed sanitary napkins were extremely light in weight and low in thickness value also. Light weight and low thickness in sanitary napkin is a major choice of the today’s users.

Table : 4.67 Weight and thickness of the developed sanitary napkin with Lotus core

Sr.No	Size of Pad	Weight (in gms)	Thickness (mm)
1	Regular	5	3
2	Large	5.5	5
3	Extra large	6.2	7.5



Plate : 4.48 Sanitary napkin with Lotus core (Regular size)



Plate :4.49 Sanitary napkin with Lotus core (Medium size)



Plate : 4.50 Sanitary napkin with Lotus core (Large size)



Plate : 4.51 Sweat pad with Lotus Core



Plate : 4.52 Pantyliner with Lotus Core

Absorbency under load / Absorbency under pressure test (AUL)

A women undergoes many physical activities like walking, sitting, driving etc so there is certain pressure which is exerted. The sanitary napkin should be designed in such a way that it should have a capacity to hold the menstrual fluids without any back and side leakages.

To test the ability of the absorbent core the sanitary napkin was subjected for the absorbency under load test. It was found that developed sanitary napkin can absorbed 30 ml colored liquid within 6 minutes and there was no leakage observed at bottom and sides of the sanitary napkin (Plate 4.53).



Plate : 4.53 Absorbency under load test of Lotus sanitary napkin

Core layer comprises one of the major parts in the sanitary napkin. Commercial sanitary napkins contain synthetic fibers, regenerated fibers, superabsorbent polymers (SAP) and dioxin (group of toxic chemical compounds) are used which are harmful to the environment and health. Focusing on health consciousness and sustainability,

consumers today are moving towards organic sanitary napkin. Synthetic sanitary napkin also causes difficulty in disposal. As per guidelines for waste management of sanitary waste under solid waste management rules -2016 the sanitary napkins should consists of highly cellulosic fibers not a super absorbent polymers Jingang, W. et.al (2019) researchers has done a systematic review on various chemicals present in commercial sanitary pads. They mentioned that as per French Agency for Food, Environmental and Occupational Health and safety revealed the list of VOCs in the female hygiene products these are Butylphenyl methyl propional, Polycyclic aromatic hydrocarbon, pesticides, di-n-octyl phthalate. Dioxins which consist of Polychlorinated dibenzodioxins (PCDFs), Polychlorobiphenyls (PCBs) are been detected in the sanitary napkins.

Hence with these functional properties of high absorbency, positive antibacterial activity and non- Cytotoxicity of Lotus fibers will lead to the novel material in the area of hygiene medical textiles. The process of fiber extraction and manufacturing into the nonwoven does not contain any treatment.

4.16. Training the women force for extraction and spinning

Researchers interacted the founder of HAPPY FACES NGO Mr. Piyush Khare for the project. He suggested to train the ladies of the Zadeshwar area, Atladara, Vadodara. Initially the researcher trained twenty ladies for extraction. In the first day of training researcher gave the knowledge about the waste and what will be the end product made from it. While demonstrating the fiber extraction process the researcher explained all the major quality aspects in the extraction process mentioned below:

Important quality aspects in extracting fibers :

- 1). Tension should be maintained during stretching of fibers from the petioles.
- 2). The balance between stretching and winding should be maintained.
- 3). Proper slitting of petioles should be done otherwise it will cut the fibers.
- 4). Uniform winding of the yarns in bobbins is essential because these fibers are cohesive in nature it fastly gets entangled during the winding process. So even winding should be done.
- 5). Bunding of petioles should be hold together properly during the extraction.
- 6). As the end where the winding of the bobbin is finished the small piece of the paper should be attached so that it becomes easy to the get the end point. The reason behind this is due to the high cohesive nature of the fiber end points get entangled.
- 7). Cleanliness should be maintained while extracting the fibers so that color of the fibers does not become dull.
- 8). Joining of end-to-end points should be done properly so that it doesnot gets opened up in the spinning and weaving process.
- 9). Care should be taken that the extracted fibers should have a uniform fineness it should not be very thin that will lead to the breakages in spinning.
- 10). The focus was more given to the extraction process because it the fiber is not extracted properly it will create problem in spinning in getting high quality yarn.
- 11). The bundle of the petiole should be covered with the wet cloth so that it doesnot get dry fastly with atmospheric heat and air.



Plate : 4.54 Interaction with the group of women for training

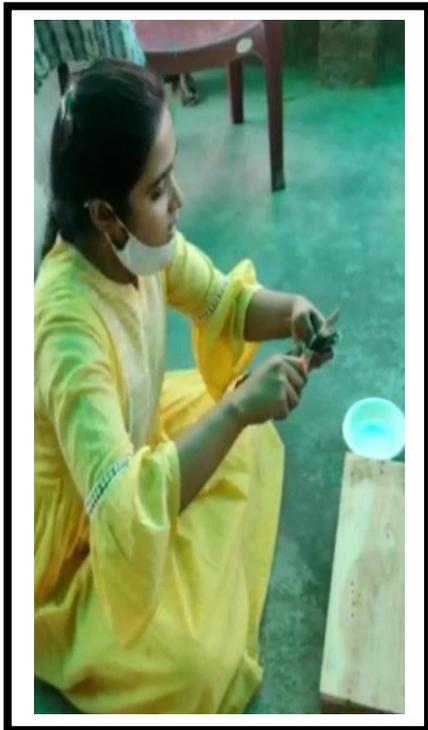


Plate: 4.56 Demonstration for Fiber Extraction

After one week training, the researcher selected 8 ladies purposively as per their productivity, quality of the fiber extracted and dedication towards the work. List of the 8 ladies are mentioned in Table : 4.67.

Copy of Aadhar cards from all the ladies were taken. Attendance sheet was prepared for the daily signature of ladies. Consent of all the ladies were also taken and attached in the Annexure portion of the thesis.

Table : 4.67 Names of women selected for final extraction and spinning workshop

Sr.No	Name	Age	Aadhar No.
1	Kavithiya Nimubehen	37	974553893017
2	Gauriben Mali	42	539158291522
3	Narangiben Devipujak	39	758346403633
4	Kavithiya Bharti	21	904786474921
5	Ambaliya Sunita	22	202633109165
6	Ambaliya Manjuben	41	855968713460
7	Gangdiya Kankuben	45	257365996934
8	Kanchan Gangdiya	21	345055993646

Mr. Bakul Shah (Expert spinner) was invited to train the ladies for spinning of Lotus yarns. He has a wide knowledge of recognizing different types of *Charkha* and keen interest in spinning different types of new eco-friendly yarns. The ladies who were earlier selected for extraction were trained for spinning.

For spinning, Mr. Bakul Shah together with the researcher explained the following points mentioned below:

1. Importance of spinning was explained to ladies that spinning imparts strength to the extracted unspun yarns.
2. Explanation was given about the different parts of *Charkha*.
3. Explanation about the optimum twist with respect to Lotus fiber spinning was given.
4. Explanation regarding the smooth supply of unspun yarn during spinning process was given.
5. The speed of rotating the wheels of *Charkha* was explained.
6. Sitting position was also explained while working on *Charkha*.

7. Initially the ladies were trained to work on *Peti Charkha* then the final spinning was done in *Ambar Charkha*.

Important quality aspects in spinning process were also explained to the ladies mentioned below:

1. Care should be taken of that spindle should be corrected placed in the Charkha.
2. Initial winding of thread in the spindle should be right direction.
3. Supply of unspun yarn should be smooth and in right direction.
4. While spinning, the concentration of the spinner is very important in all the points of *Charkha* right from supply of thread till final winded spindle with yarn.
5. It should be taken care of that threads should not entangle in the spindle.
6. If the thread breaks in between, it should be joined properly at that time only because if it is not joined properly then it will further break during the hank making and also in weaving.

Preparation of schedule for extraction and spinning workshop

From the NGO support, the space of training was provided for the project that is the Street School of Zadeshwar, Atladara, Vadodara.

Time for workshop was - 3:00 to 6:00 PM. Lotus petioles were transported by auto to workshop venue. Ladies used to keep all the equipments in the storehouse of the school. They reach to work at 2:45 PM set all the equipments and start the work at 3:00 PM. The target of the daily work output was given by the researcher.

As per the wages of year 2021, payment of the extraction and spinning was decided by the researcher, mentor and NGO founder. For the extraction process for 3 hours per day, Rs.150 was paid and for spinning process for 3 hours per day, Rs.100 was paid to the ladies.

Extraction and spinning Workshop (From waste- fiber-yarn)

1. Lotus petioles were first sent to the work shop venue (Plate 4.56).
2. Bundle of three to four petioles were taken together and wiped with the cloth.
3. Then the bundle of three petioles were slited with the sharp knife at 5 to 6 places throughout the entire length of the petioles (Plate :4.57)
4. From one slit, 100 to 150 cm thread is obtained. End to end points were joined and then the continuous extracted fibers were winded in the bobbin (Plate :4.60) and (Plate: 4.61).
5. Winded bobbins are then proceeded further for spinning.
6. Initially the spinning was done in box (*peti*) *Charkha* later for the faster production and to achieve the uniform quality of twist, spinning was done in Ambar Charkha. Yarn of 28's Count was developed by the ladies (Plate: 4.62).



Plate : 4.56 Waste Lotus petioles transported in workshop venue



Plate : 4.57 Holding the petioles together and slitting it with sharp knife

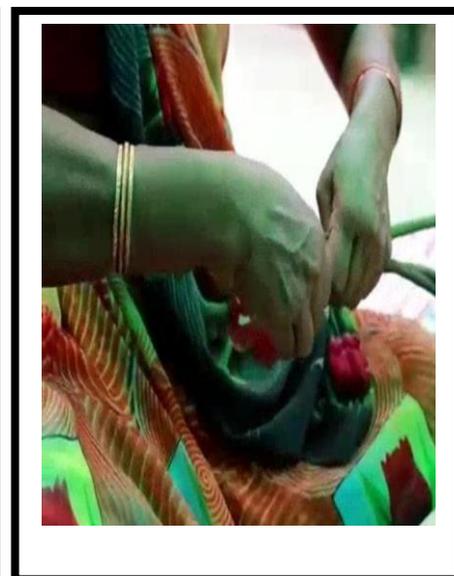


Plate : 4.58 Stretching the petioles along with pulling the fibers

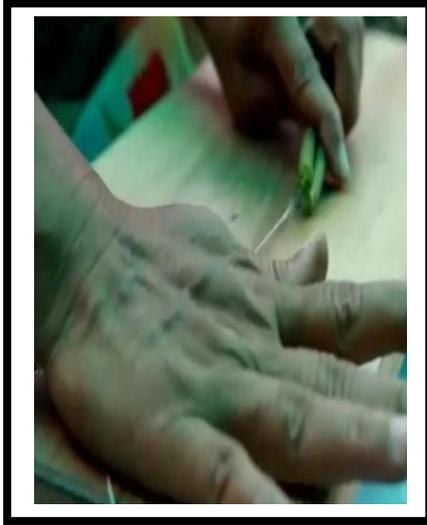


Plate : 4.59 Slight twisting of fibers



Plate : 4.60 End to end joining of fibers



Plate: 4.61 Winding of yarns on bobbins



Plate : 4.62 Spinning of 100 % Lotus handspun yarn



Plate : 4.63 Unspun Lotus yarn developed by the ladies



Plate: 4.64 100 % Lotus handspun yarn developed by ladies



Plate : 4.65 Workshop for fiber extraction and spinning of Lotus yarns



Plate: 4.66 Entire team of women of the project

Construction of the handwoven stoles from the yarn developed by the ladies

To check the final appearance of the prepared yarns in the fabric researcher moved Bhujodi Kutch for weaving. Weaving was done in collaboration with Three threads handicrafts by Mr. Pachan Premji, Artisian designer. Union fabric (100 % Lotus yarn in weft and 100 % Cotton yarn in warp) was prepared on handloom using extra –weft designing. It was observed that Lotus yarns possess enough strength to be used easily in weft without any treatment. Total nine stoles were prepared. All the stoles were dyed with the natural dyes like – Indigo, Sappan wood and onion peels. Specifications of fabric are mentioned in Table : 4.68.

Table : 4.68 Specification of the constructed Lotus Hand woven Stole

Sr.No	Hand woven stole specification	
1	Fabric count	50x44
2	GSM	75.6
3	Weave type	Plain weave with extra weft design
4	Thickness (mm)	0.29
5	Warp yarn count	70's 100% Cotton yarn
6	Weft yarn count	28's 100% Lotus yarn handspun yarn
7	Length of the stole	2m (78 inch)
8	Width of the stole	20 inch



Plate : 4.67 Interaction with the weaver



Plate : 4.68 Winding of yarn on pern from hank

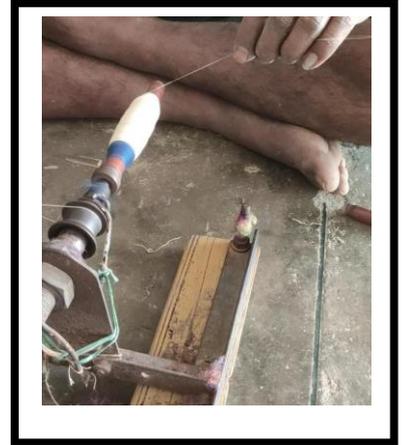


Plate 4.69 Lotus handspun yarn pern



Plate : 4.70 Loom Set up

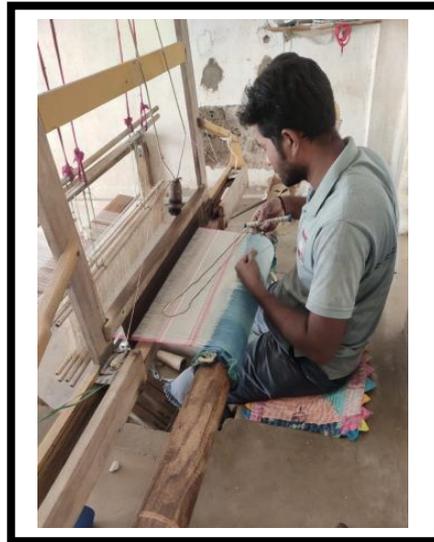


Plate : 4.71 Weaving of Stole



Plate : 4.72 Woven stole with extra weft figuring



Plate : 4.73 Woven stole washed and dried on sunlight



Plate : 4.74 Woven fabric appearance after ironing



Plate : 4.75 Dyeing of stole with Indigo dyes



Plate : 4.76 Dyeing of stole with Sappan wood



Plate : 4.77 Dyed fabrics in sunlight



Plate : 4.78 Lotus Stole (Undyed)

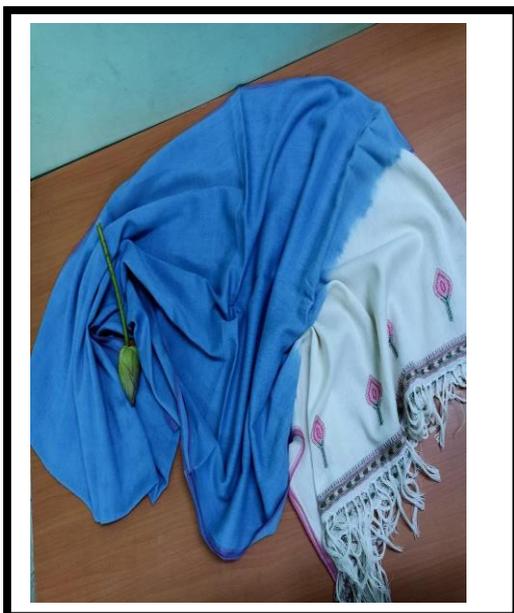


Plate: 4.79 Lotus stoles Indigo dyed

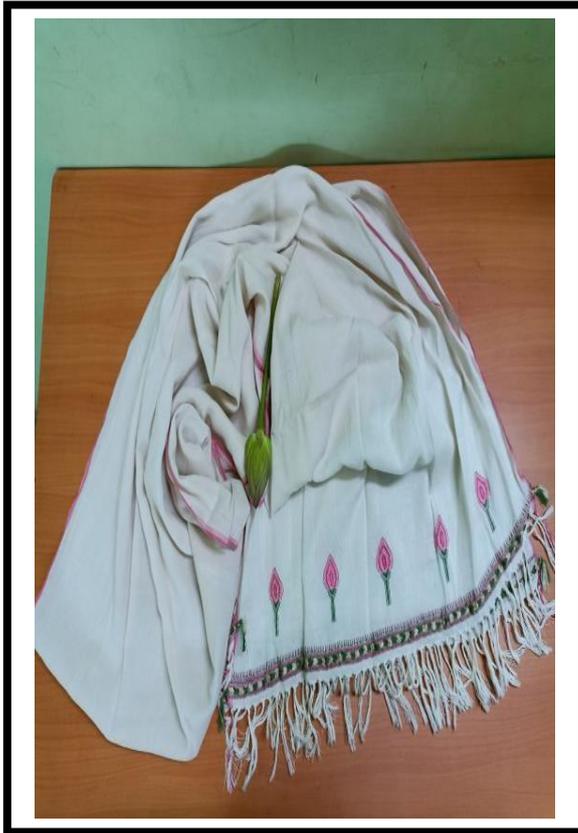


Plate:4.80 Lotus stoles Sappan wood dyed



Plate 4.81 Lotus stole dyed with onion peels

Exhibition of the developed fabrics

Any novel product should reach to the society. To give the awareness about the Lotus fabrics, researcher exhibited the fabrics in three different exhibitions.

Exhibition -1

To bring the hard work of all the ladies in the limelight. Researchers planned to display the fabrics on International Women's Day = 8 March, 2022. The Happy faces NGO Vadodara already had planned some other programmes on that day so the founder and researchers both decided to showcase the fabrics. Exhibition was conducted at Eva Mall, Manjalpur, Vadodara. The ladies who have done the extraction and spinning were also invited and they were appreciated for their hard work in the stage. Exhibition was not for sale it was just to introduce the concept and promote the novel fabric.

Ladies said that we are very lucky to learn such kind of skill in our life and it has helped to manage some of the financial crisis. They quoted that earning the money by their own hard work has a different charm and it gives a great satisfaction. They are ready to continue this work in coming future. Total 100 peoples visited the stall, they like the texture and feel of the fabric.

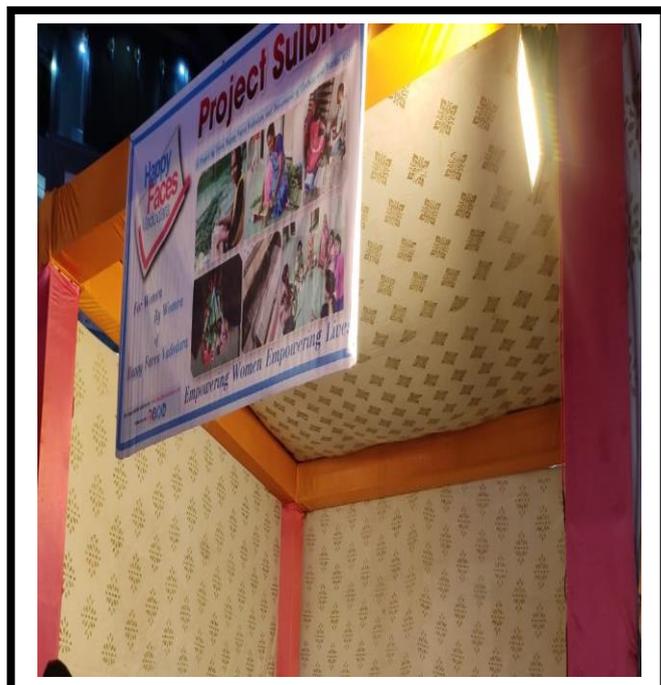


Plate 4.82 Exhibition of the Lotus fabrics on International women's day



Plate : 4.83 Appreciation to the women for the outcome of the entire project

Exhibition -2

Gujarat Technological University start up and innovation center in collaboration with AIC (Atal Incubation Center) and ACCWF (Ahmedabad Chamber of Commerce Welfare Foundation) jointly conducted “Agripreneurs conclave” (Agri – startups exhibition). The programme was held on 21-22 July, 2022 at GTU campus,

Chandkheda, Gujarat. Through social media coverages the vice-chancellor of Gujarat Technological University approached the researcher to present the work in the exhibition. The name of the stall was – “Agrowaste to Eco-Textiles: - Lotus Petiole finds a new place in Fashion Industry”. The soul objective of exhibition was filling up the gaps, branding and sector specific sustainable growth for Agri based startups. The areas included in the exhibition were the products developed from agriculture waste and also the products which are beneficial in increasing the plant growth. Different start up agencies, people associated with the agriculture, textiles, fashion and robotics visited this stall.



Plate 4.84 Exhibited Lotus fibers, yarns and fabrics at Agripreneurs Conclave - 2022

Exhibition – 3

Due to wide media coverage, vice president and members of Southern Gujarat Chamber of Commerce and Industry (SGCCL) contacted and approached the researcher for exhibiting the Lotus fibers, yarns and fabrics in Weave Knit 2022 (The complete fabric show) 2nd Edition, exhibition. The stall, staying and travel expenses were entirely sponsored by the SGCCL. So the researchers presented the developed

fabrics in the exhibition. The exhibition was conducted for three days that is 23 to 25 July, 2023 at Sarsana, Surat. The name of the stall was “Padmapalash”.

Fabric manufacturing industries: - Nilkant fabrics, Vedanta fabrics, Milan textiles, Krishna Textiles, Suril textiles, Yogeshwar Textiles, Batsons Textiles, Dhanlaxmi Textiles, Knit world, Jenny Fashion, Shree Hari Tex etc from Surat, Gujarat visited the stall. Peoples from the industry like the feel, drape and texture of the fabrics. Different yarn manufacturers like Shanghvi spinners, Agarwal Fabtex private limited, Color Trendz etc. visited the stall. They liked the fineness and feel of the yarns. Peoples from CMAI – The Clothing Manufacturers Association of India of South Gujarat Region also visited the stall and well appreciated the entire concept of making fabrics from Lotus petioles. The third exhibition has given a complete shape and future path for the commercialization of the entire work.



Plate 4.85 Stall set up for the Weave Knit Exhibition - 2022

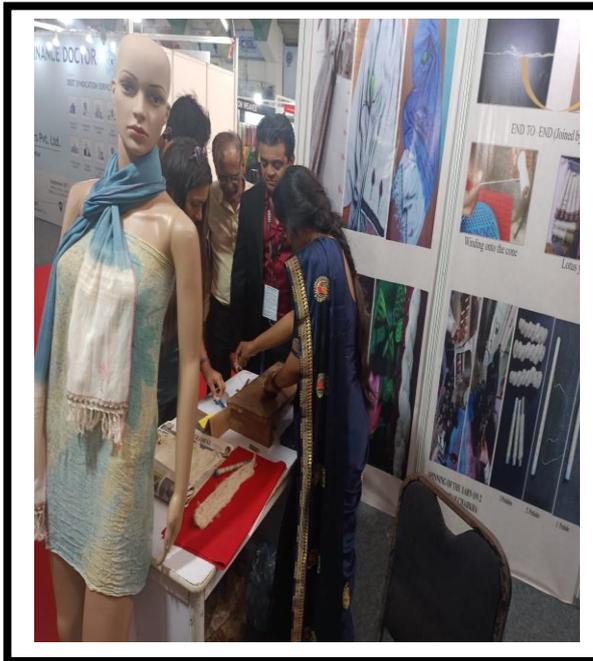
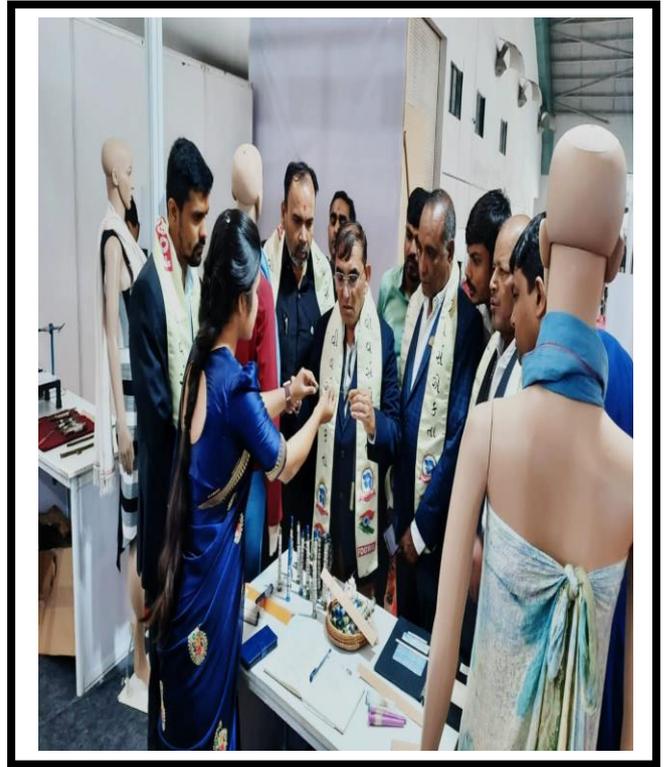


Plate 4.86 Weave knit Exhibition – 2022

By the exhibitions researcher got a future pathway to commercialize the entire concept of making fabrics from Lotus petioles and also to work on building sustainable value chain for it shown in Figure: 4.7.

National education policy (NEP) 2020 has majorly focus on new group of skilled labour, benefit to the local community directly and promoting sustainable methodologies. The upcoming future of this concept will surely contribute to build new and user friendly skills in women and as the entire manufacturing method does not use any harmful chemicals it will promote the green environment. Nature has given the wide range of sources. India is a country of wetland ecosystem. Fiber is one the basic unit of textiles. The research has come up with treasure that is hidden in the aquatic region for textile applications which follows the Honorable Prime Minister Narendra Modi call of “Local for vocal”.

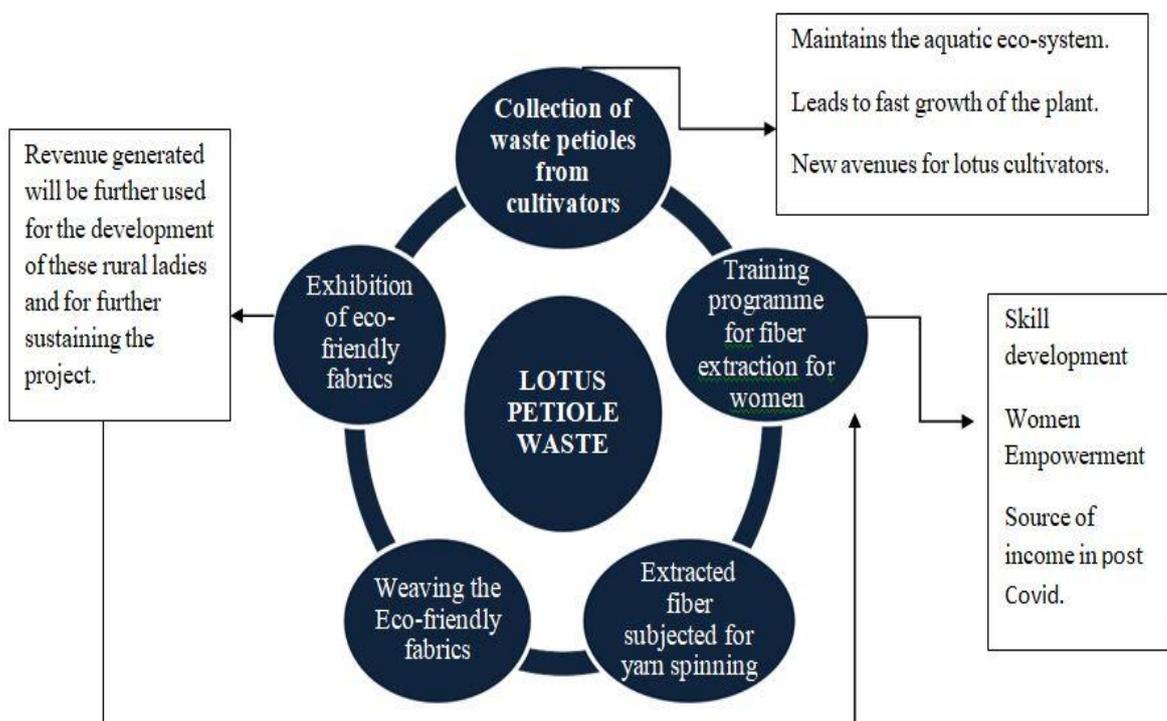


Figure : 4.7 Lotus petiole waste to fabric–Sustainable supply chain

World is constantly working on achieving the sustainable development goals by 2030 to achieve a better and more sustainable future for all. The research contributes to following Sustainable Development Goals mentioned in Figure :4.8.

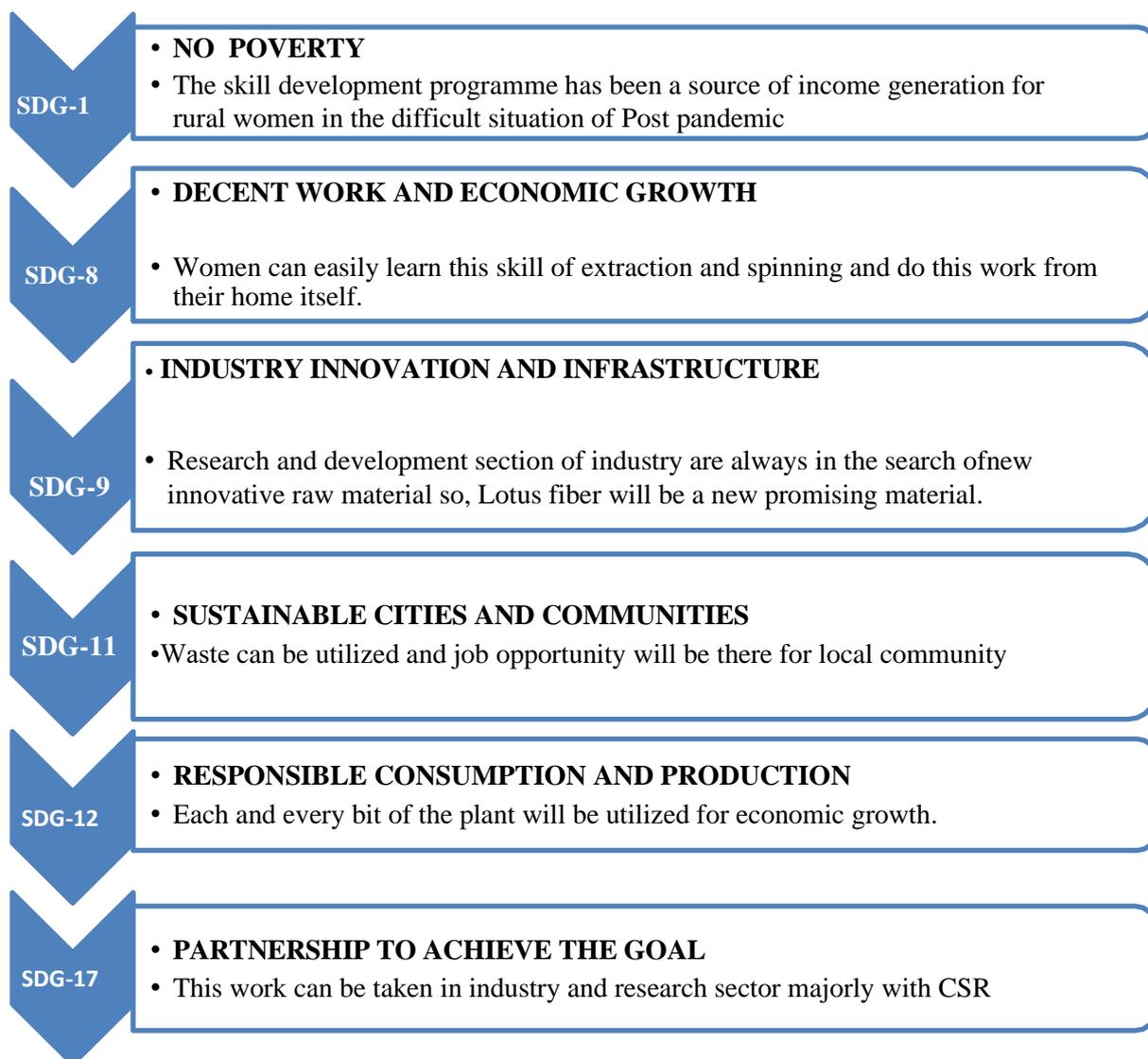


Figure 4.8 : Lotus petiole waste into fabric - contribution to Sustainable development goals (SDG)s

4.17. SWOC ANALYSIS

Strengths

1. The fabricated machine -1 has dual mechanism of extracting fibers and twisting into yarn at the same time. Hence it saves time and energy for spinning of yarns.
2. High yield and quality yarn is been achieved from the fabricated machine.
3. By the intervention of machine, Lotus fiber can be used in powerloom weaving and knitting.

4. Not a single drop of chemicals was used in the entire process of fiber extraction, yarn spinning and fabric development (woven, knitted and nonwoven) which leads to sustainability in true sense.
5. Lotus fiber without any treatment has an inherent functional property of: water absorbency, antibacterial properties and non-cytotoxicity. Thus, it is the novel sustainable material for hygiene medical textiles.
6. Lotus fiber can be alternative to Silk as the source of extracting Lotus fiber is from the waste.
7. The fabricated machine -2 was found suitable for extracting raw fibers which can be further used for nonwoven web preparation and developing industrial spun – rotor and ring yarns.
8. Rural peoples who cannot purchase heavy equipments for extraction can practice the manual extraction and spinning process. The developed yarns can be a novel material for the Khadi and Village industry.

Weakness

1. After collecting the waste petioles from the pond the extraction of the fibers has to be done within five days to obtain continuous and uniform fibers. After five days the petioles get stiff and dry.
2. During the heavy rain and flood, the availability of the waste petioles is less because it becomes very difficult for the Lotus flower pluckers to get in the pond.
3. Being a natural material, the diameter of the petioles, number of fibers in the petioles and quality of the petioles that varies in different seasons and ponds. All these variability effects on maintaining the uniform fineness of yarn throughout the extraction and spinning process.
4. In the manual extraction process, the extractor has to take out extra time to wipe the petioles from the cloth because the outer part contains some water and dirt. Due this problem, developed unspun yarn has an uneven color. Maintaining the cleanliness of the hand is also a challenging task in the manual extraction process and it affects the color of the yarn developed.

Opportunities

1. It is found that 100 % Lotus yarn developed from fabricated machine is been successfully used in developing knitted structure so there is a wide scope of developing innovative knitted seamless garments.
2. Lotus fibers can be dyed with natural dyes as it has achieved a good fastness property. So, the fabrics can be used by the consumers who are more nature friendly having the liking towards natural fiber and natural dyes. These natural dyed yarns can be used in various Indian traditional dyed textiles.
3. Lotus yarn can be dyed with reactive dyes with good light and washing fastness property. Hence there is a wide opportunity of using these yarns from industrial perspective.
4. There is a wide scope of generating job opportunities for rural peoples and SHG for fiber extraction and spinning.
5. After drawing yarn from the stems, leftover pieces also consist of fibers which can used for developing nonwoven sheet for medical textile applications.

Challenges

1. Awareness of Lotus fiber fabric in Indian market specifically to the traders, manufacturers, retailers is a biggest challenge for the commercialization.
2. Awareness regarding the properties of Lotus fiber as compare to other natural fiber is also a challenging to cater the consumers.
3. Training the group of peoples for extracting fiber and developing yarn from the fabricated machines is also challenging task because it also requires knowledge of the technical aspects
4. Due to the higher cohesiveness property of the Lotus fiber, it becomes very difficult to handle the Lotus yarns during manufacturing. Extra care is required during winding of yarns on pern, hank making and cone winding. The yarn has a property to stick thus it entangle fastly during

manufacturing. Hence extra care and patience is required during handling of Lotus fiber and yarn.

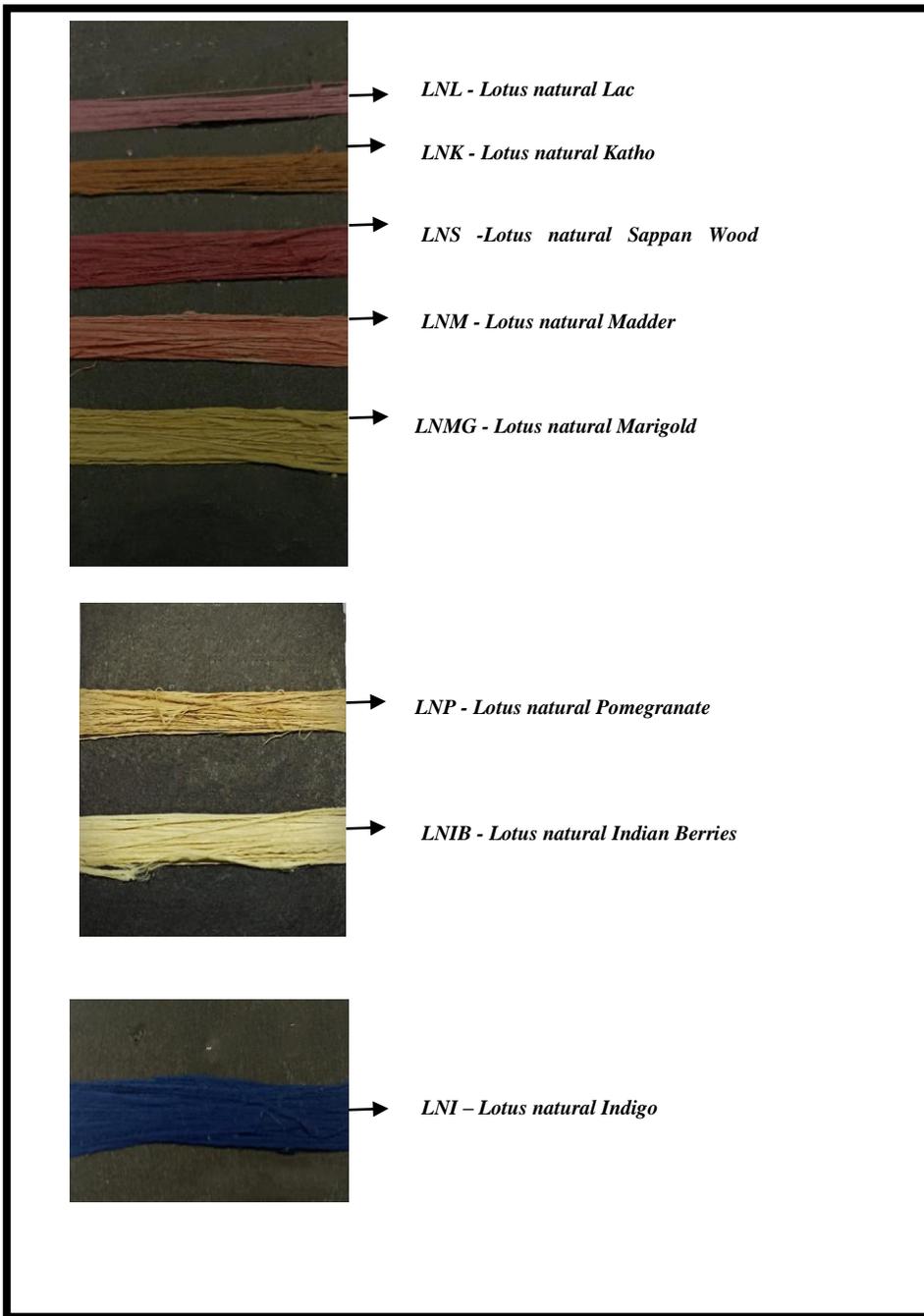
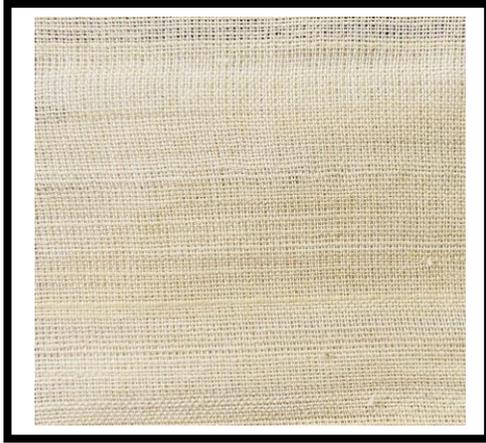


Plate : 4.32 Images of Lotus Natural dyed yarns



Plate : 4.33 Images of Lotus Reactive dyed yarns



HS Fabric – 1

Warp : 120's fine cotton hand spun yarn
Weft : 2/86's Lotus hand spun yarn



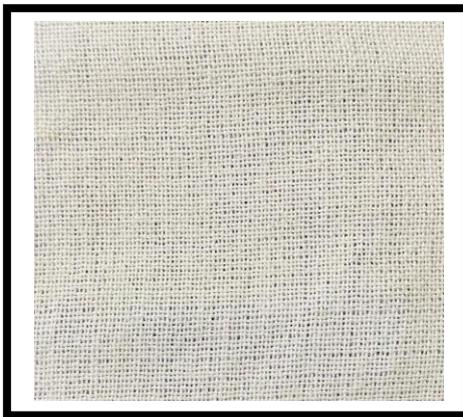
HS Fabric – 2

Warp : 120's fine cotton hand spun yarn
Weft : 3/28's Lotus hand spun yarn



HL Fabric – 3

Warp : 100's Mulberry Silk
Weft : 96's Lotus hand spun yarn



HL Fabric – 4

Warp : 4/19's Lotus: Cotton Ply yarn
Weft – 3/71's Machine extracted and spinned Lotus yarn



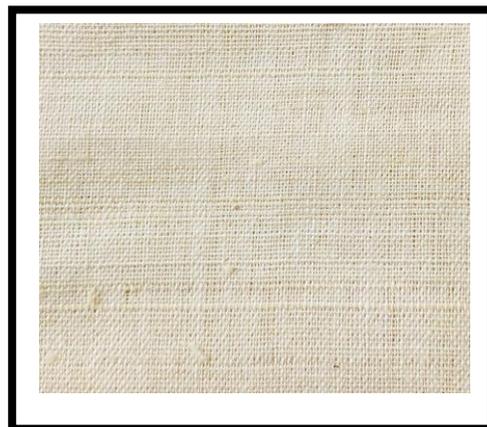
HL Fabric – 5

Warp : 4/23's Lotus: Silk Ply yarn
Weft : 3/60's Machine extracted and spinned Lotus yarn



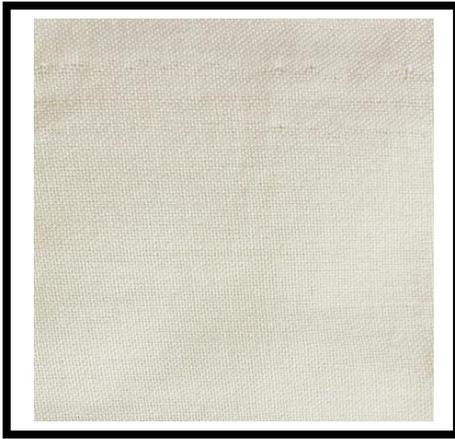
HL Fabric – 6

Warp : 4/14's Lotus: Wool Ply yarn
Weft : 3/28's Lotus machine extracted and spinned Lotus yarn



HL Fabric - 7

Warp : 120's fine Cotton yarns
Weft : 3/71's Machine extracted and spinned Lotus yarn



PL Fabric – 8

Warp : 80's Cotton yarn
Weft : 3/71's Lotus machine extracted and
spinned yarn



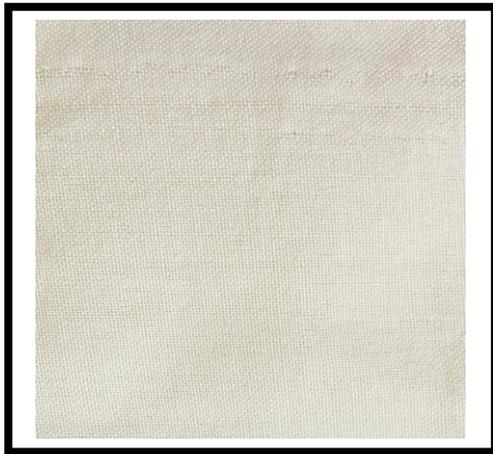
PL Fabric – 9

Warp : 70's Cotton yarn
Weft : 3/60's Lotus machine extracted and
spinned yarn



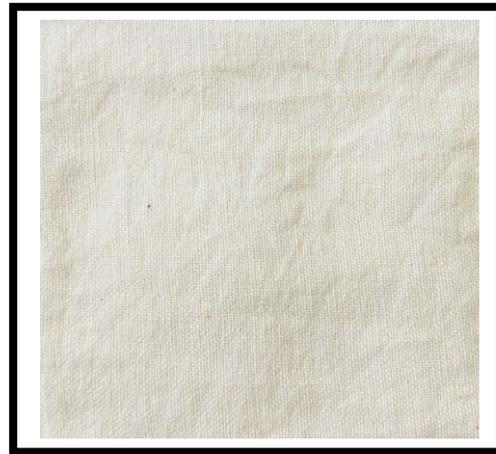
PL Fabric – 10

Warp : 40's Cotton yarn
Weft : 3/33's Lotus machine extracted and
spinned yarn



PL Fabric – 11

Warp : 20's Cotton yarn
Weft : 3/28's Lotus machine extracted and
spinned yarn



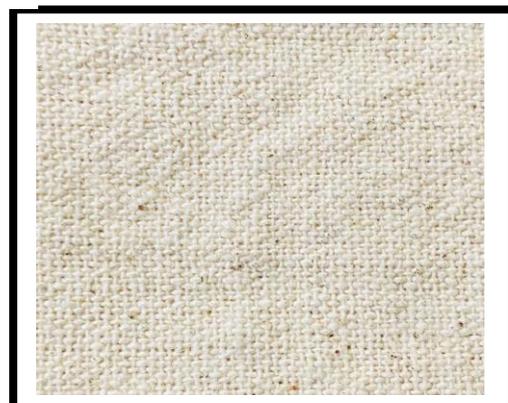
PL Fabric - 12

100 % Lotus 3/71's Machine extracted and
spinned
both in warp and weft



PL Fabric – 13

5's - 50:50 (Lotus: Cotton Rotor spun yarn in both
warp and weft)



PL Fabric – 14

3's - 70:30 (Lotus: Cotton Rotor spun yarn in both
warp and weft)

Plate : 4.34 Images of Woven fabrics



Warp : 4/19's Lotus: Cotton Ply yarn
Weft – 3/71's Machine extracted and spinned Lotus yarn

Weave : Twill

Handloom Fabric



Warp : 4/14's Lotus: Wool Ply yarn
Weft : 3/28's Lotus machine extracted and spinned Lotus yarn

Weave : Twill

Handloom Fabric



Warp : 4/19's Lotus: Cotton Ply yarn
Weft : a). One set of 3/71's machine extracted and spinned Lotus yarn
b). One set of 3's Lotus: Cotton rotor yarn
Weave : Backed fabric
Handloom Fabric



3's - 70:30 (Lotus: Cotton Rotor spun yarn in both warp and weft)
Weave : Twill
Powerloom Fabric

Plate : 4.35 Exploration of different weaves



Plate : 4.87 HS Fabric – 1 (Open view)

**Warp : 120's fine cotton hand spun yarn
Weft : 2/86's Lotus hand spun yarn**



Plate : 4.88 HL Fabric – 3 (Open view)

**Warp : 100's Mulberry Silk
Weft : 96's Lotus hand spun yarn**



Plate : 4.89 HL Fabric – 5 – Open view

Warp : 4/23's Lotus: Silk Ply yarn
Weft : 3/60's Machine extracted and spinned Lotus yarn



Plate : 4.90 HL Fabric – 6 (Open view)

Warp : 4/14's Lotus: Wool Ply yarn
Weft : 3/28's Lotus machine extracted and spinned Lotus yarn