Chapter-2

REVIEW OF LITERATURE

A literature review provides a comprehensive overview of the relevant research as it provides clear understanding of the empirical and theoretical contributions made in the field meanwhile highlighting the points that require further exploration, experimentation and investigations. Understanding the nature of the problem of the study, the relevant theoretical literature and researches were studied related to existing machines and techniques for extraction of different cellulosic minor fibers, spinning systems, development of functional nonwoven products & knitted material from minor fibers, dyeing of minor fibers with natural & reactive dyes, training the community for the skill development programmes regarding to fiber extraction, spinning and product development for uplifting the minor fibers were studied.

The literature was collected by the investigator from various renowned libraries like SITRA (South Indian Textile Research Association) Central library of PSG College of Technology, Central library of Avinashillingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamilnadu, Central library of Institute of forestry, Tribhuvan University, Pokhra, Nepal, Smt.Hansa Mehta library, Department of Science library of Faculty of Science, Prof. T.K. Gajjar library of Faculty of Technology and Engineering, Department of Clothing and Textiles library of Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat. Other sources were from the internet and interaction with the researchers involved in similar field.

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

2.1. **Theoretical Review:**

2.1.1. Global distribution of Lotus (*Nelumbo Nucifera Gaertn*.)

2.1.2. Description of Lotus Plant

2.1.3. Latest cultivation practices of Lotus plant (About waste)

b). Passive substances

Skin resident microflora

Textiles and Infection vectors

Microbes in clothing and skin

Textiles and skin

Microbial adhesion in textiles

Bacteria and hygiene

2.1.13. People practicing Lotus fiber extraction

2.2. Research Reviews

2.2.1. Machine mechanism for extracting various minor fibers.

2.2.2. Extraction process of various minor fibers

2.2.3. Spinning process of minor fibers

2.2.4. Dyeing of minor fibers with natural and reactive dyes

2.2.5. Development of knitted fabrics from minor fibers

2.2.6. Specific functional properties of minor fibers and its applications

2.2.7. Lotus fibers

2.2.8. Training the community for fiber extraction and spinning.

2.1.1. Global distribution of Lotus (Nelumbo Nucifera Gaertn.)

According to Nguyen, Q.V., & Hicks, D. (2001), Lotus is widely cultivated in many countries of the world especially India, China, Japan, Korea, South East Asia and Africa.

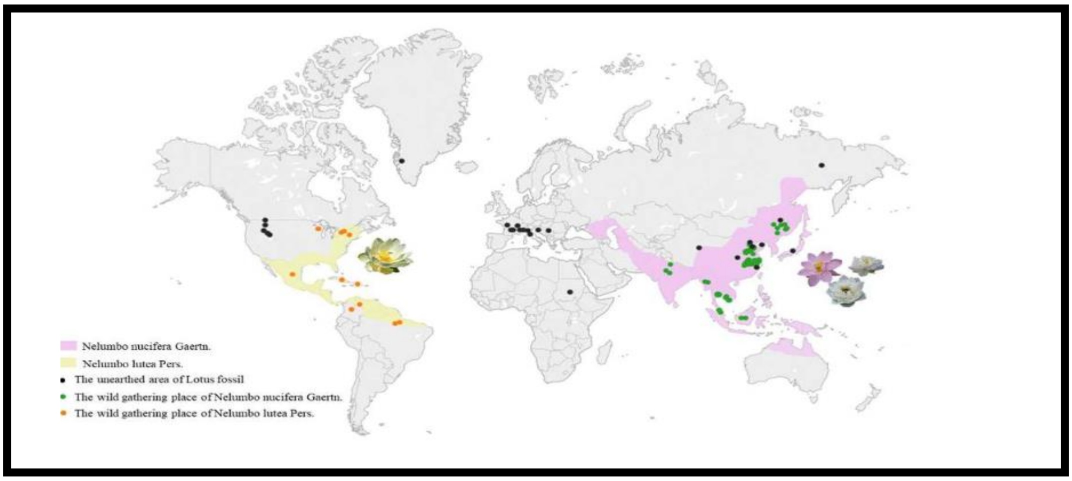


Plate 2.1: Global distribution of Lotus

Source : Zhou, P., et.al. (2022)

According to Royal Botanical gardens report, distribution of Lotus in world is mentioned in two classes that is: Native and Introduced.

Native –In the map shown in Plate 2.2, the places highlighted in green are native. Lotus is native to Amur, Assam, Bangladesh, Cambodia, China North-Cen tral, China South-Central, China Southeast, East Himalaya, Hainan, India, Iran, Japan, Jawa, Khabarovsk, Korea, Laos, Lesser Sunda Is., Malaya, Manchuria, Myanmar, Nepal, New Guinea, North Caucasus, Northern Territory, Pakistan, Philippines, Primorye, Queensland, South European Russi, Sri Lanka, Thailand, Transcaucasus, Ukraine, Vietnam, West Himalaya, Western Australia.

Introduced -In the map shown in Plate 2.2, the places highlighted in purple are introduced. Alabama, Arkansas, Benin, Cook Is., Cuba, Florida, Georgia, Italy, Kentucky, Leeward Is., Louisiana, Maryland, Massachusetts, Mississippi, Missouri, New Jersey, North Carolina, Puerto Rico, Romania, South Carolina, Tennessee, Texas, Trinidad-Tobago, West Virginia, Windward.

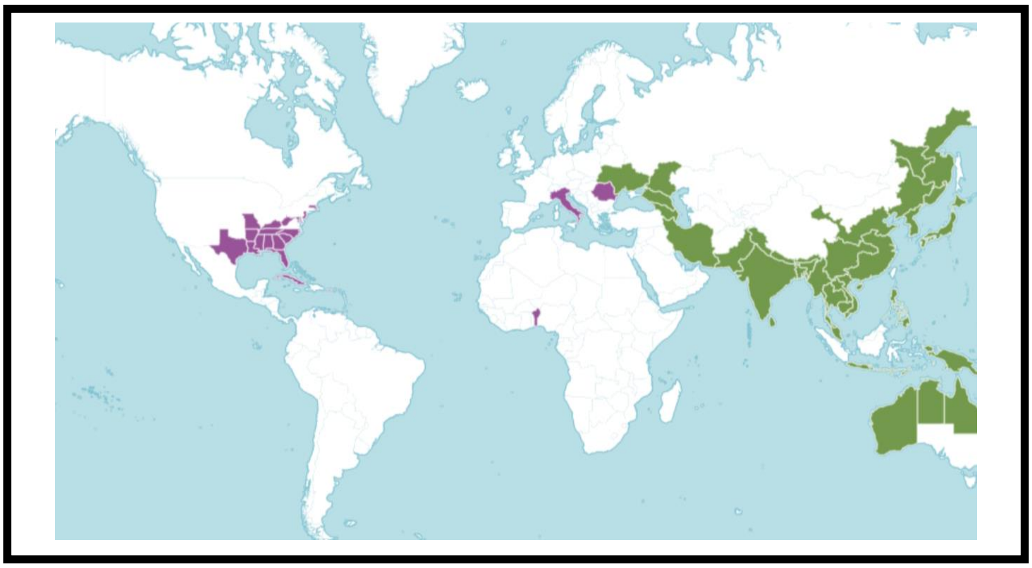


Plate 2.2 : Global distribution of Lotus : Native – Green color and Introduced – Purple color

Source: https://www.kew.org/plants/sacred-Lotus

Distribution in India

According to Barooah, C., & Ahmed, I. (2014) Assam Science and Technology council, In India Lotus is widespread in Himalayan lakes. It is native to Assam, Kashmir, Madhya Pradesh, Manipur, Odisha, Rajasthan, Tamil Nadu, Uttar Pradesh, Maharashtra, Karnataka, Mysore and Kerala.

Endemic Distribution in India: Throughout the Assam.

Distribution in Western part of the country

It is reported that some wetlands of central Gujarat like Ahmedabad, Kheda, Anand, Vadodara districts) and south Gujarat (Valsad and Navsari districts) have an impressive growth of Lotus plants (Source : https://www.dnaindia.com/ahmedabad/column-flowers-of-some-wetland-plants-elegance-personified-2748658). In Vadodara district it is widely cultivated in Ganeshpura, Savli Taluka, Kamlapura, Ruvad and Tarsali. Sharan, M., & Haldar, S. (2021).

Distribution in Northern part of the country

Dal Lake located in Srinagar city is famous for Lotus Cultivation. The surface elevation of the lake is 1,583mts. The latitude and longitude of the lake is 34 07' N and 74 52'E. There is a prime importance of Lotus in Kashmir valley due to the climate and geographical location Hussain, N.Z. et.al. (2016). Lotus is luxuriantly found in Samastipur lake of Raebareilly district of Uttar Pradesh.

Distribution in Eastern part of the country

Gohl, A., Sharma, S.C., & Sharga, A.N. (2001) reported that Lotus flower is extensively grown in Eastern Midnapur district Hooghly and Howrah district of the state. Flowers are supplied to various states of India and European countries. Bainchi village of Hooghly district is considered as a hub of Lotus farming due to the abundance of many water bodies. In the Bainchi village there are 200 farmers involved in Lotus farming. Lotus farming is widely practiced in the Bankura district of Bengal. About 13,000 Lotus flowers from Bankura are exported to London. The water bodies authorities and maintenance team of Bankura district are highly encouraging the farmers to cultivate Lotus in a big way. (Source: https://30stades.com/2022/07/25/west-bengal-Lotus-cultivation-in-bankura-increases-growers-income-exports-to-europe-australia/)

Distribution in Southern part of the country

Thirunnavaya town in Malappuram district of Kerala. is one of the major Lotus cultivation centres. There are four major Lotus farms in Thirunnavaya. About 30 families are engaged in Lotus farming in around 500 acres land. The flowers are send to all the major temples across the state. On an average 20,000 flowers are collected and distributed every day in Thirunnavaya town. (Source - http://www.markazhi.com/Lotus-farms-of-thirunnavaya)

2.1.2. Description of Lotus plant

An aquatic herb, rhizomatous, grows upto a height of about 150 cm and horizontal spread of up to 3 m. Leaves are like peltate, glaucous, dark green above and pale beneath covered with network of microscopic hairs; veins radially extended; petioles are very long rise above the water are smooth and minutely prickled. Flower solitiary to 25 cm in diameter. Sepals are elliptic or ovate, 1.5-5 × 1-3.5 cm, concave, green or pinkish green. Petals are 25(in single form) and 110 (in double form). Stamens are numerous. Receptacles are 2-4 cm across, spongy. Carpels are numerous, loosely embedded in cavities on flattened top of receptacle,1-ovuled. Fruit a nut-like achene, oblong to ovoid.

(Source: www.bsienvsis.nic.in/kidscentre/National_flower_17056.apx)

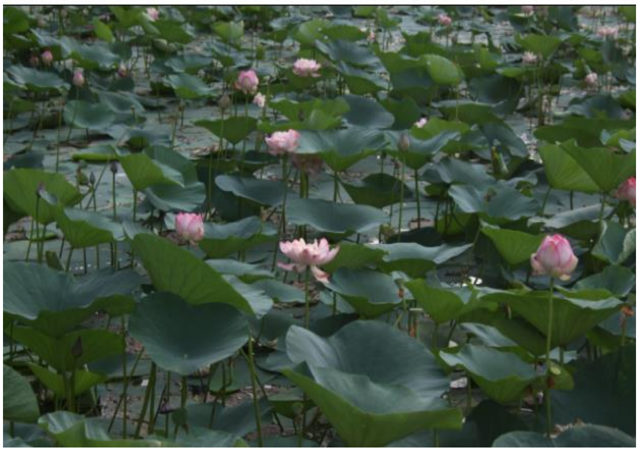


Plate 2.3: Nelumbo Nucifera Gaertn. Pink Lotus

Source:www.bsienvsis.nic.in/kidscentre/National_flower_17056.apx

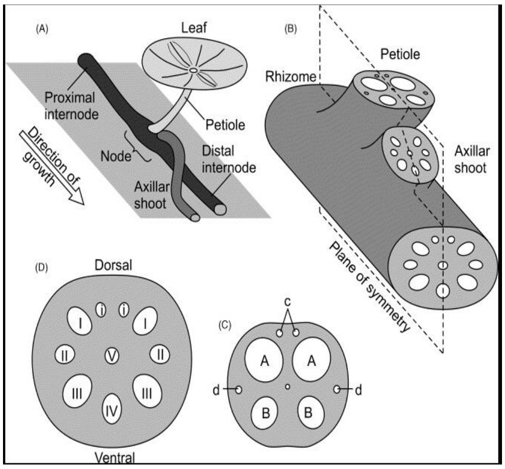


Plate 2.4: Morphological diagram of Lotus plant *(Nelumbo Nucifera Gaertn.)*

Source:https://cdn.biologydiscussion.com/wp-content/uploads/2016/12/clip_image018_thumb7-2.jpg

2.1.3. Latest cultivation practices of Lotus plant (*Nelumbo Nucifera Gaertn.*) (About waste)

Huang, J. et.al. (2022) authors mentioned that Lotus cultivation causes considerable amount of waste after harvesting. Different parts of the Lotus: leaf, seed, embryo, root and stamen are used as functional ingredients in the pharmaceutical industry. All these parts has been widely researched for their nutraceutical properties. But the Lotus petiole (*Nelumbinis Petiolus*) and seed pod (*Nelumbinis Receptaculum*) are generally thrown as a waste that causes environmental pollution.

Pan et al., (2011) reported that Lotus petiole consist of natural cellulosic fiber that can be used in textiles.

According to Chen, Y. et. al. (2015) reported that after harvesting Lotus leaf stalks (petioles) are dumped as a waste that may cause environmental hazards

Thaun reported that farmers often toil for hours to clear Lotus paddies of rotting stems, which ruin the soil and bring unwanted insects.

(Source: https://www.france24.com/en/20200828-fabric-of-success-how-lotus-silk-is-weaving-its-way-into-vietnam)

Plate 2.5 : Waste Lotus Petioles

Source : Chen, Y., et.al. (2015)

2.1.4. Medicinal properties of Lotus petioles

Whole plant possess antidiabetic, antipyretic, anti-inflammatory, anticancerous, antimicrobial, antiviral and anti-obesity properties Saraswathi, K. et.al., (2019). According to Sharma, P.D. (2019), petioles of the Lotus plant contain fibers and the gummy substance called mucilage. Mucilage is the group of polymers widely used in pharmaceutical dosages Chaudhary, M., et.al. (2017). Paste of the petioles has a capacity to maintain the body temperature. For the treatment of piles and excessive bleeding in menstruation, petioles are used Chandra, L. (2020).

2.1.5. Machinery for extracting minor cellulosic fibers.

(Source : Das, P.K., Nag, D., Debnath, S., & Nayak, L.k. (2010) Machinery for extraction and traditional spinning of plant fibers. *International Journal of Traditional Knowledge*. 9(2), 386-393)

Jute

Earlier only the long-defoliated plant stems were immersed in water in small bundles upto three weeks. Alternatively, the ribbons of green stem were subjected for retting in low water for few days. In third method, ribbons are treated chemically to speed up the retting process.

The NIRJAFT had developed manual and power operated ribboners. In the manual ribboners, vertical pole, bamboo hooks, bicycle hub are used to peel the green ribbon from defoliated stems. The capacity of the manual ribboners is 150 Kg/day of green ribbon. In the power operated ribboners, the green barks are peeled off by compression in pair of rollers. The production capacity of the power operated ribboners is 1500 Kg/day. CRIJAF developed power decorticator that strikes the stems of Jute by rotating blades and removing the ribbon by breaking the stick into pieces.

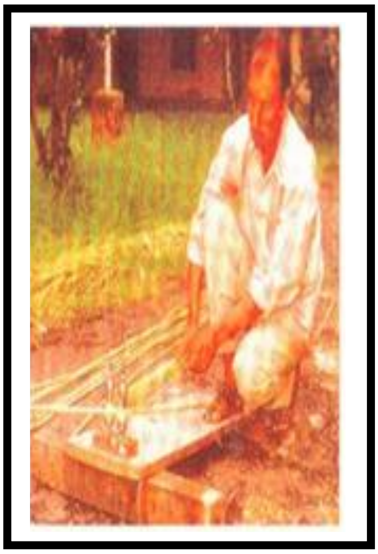


Plate 2.6: Manual ribboners for Jute

Plate 2.7: Power ribboners for Jute

Plate 2.8 : Jute Decorticator

Source : Das, P.K., et.al. (2010)

Pineapple

Fibers are obtained from green leaves by peeling and scrutching, scrapping followed by retting in the water and by mechanical decortication. This hand operated mechanical decorticator is runned by paddle operation for the removal of impervious layer of the leaf surface. The power operated decorticator consisted of rotary cylinder that is fixed on the rasp bars to remove the green matter from the leaf.

By this technique 1500 kg of green fibre is obtained per day.

Plate 2.9 : Pineapple Leaf Fiber extractor

Source : Das, P.K., et.al. (2010)

Sisal Fiber

Fibers is extracted by manual process of retting, scraping or retting and by mechanical process that is decortication using Raspador machine. In the machine leaves are crushed by rotating wheel and beaten by blunt knives to obtain the fibers.

Plate 2.10 : Sisal Decorticator

Source : Das, P.K., et.al. (2010)

Banana fiber

Decorticator machine for banana fiber includes rotating drums mounted on the shaft. In the circumference of drum there are a blade which performs the beating action as the drum is rotated by the electrical drive. When the drum rotates, the pseudostem is fed between the feeding roller/backing plate and drum. The pulpy material is removed owing to crushing, beating and pulling action. From the drum, pseudostem are slowly pushed and banana fibers are collected in the bucket. After extracting, fibers are degummed for the removal of foreign matter, washed and dried at room temperature of 27-32ºC. The capacity of the extraction machine is two tons of dry fiber per day.

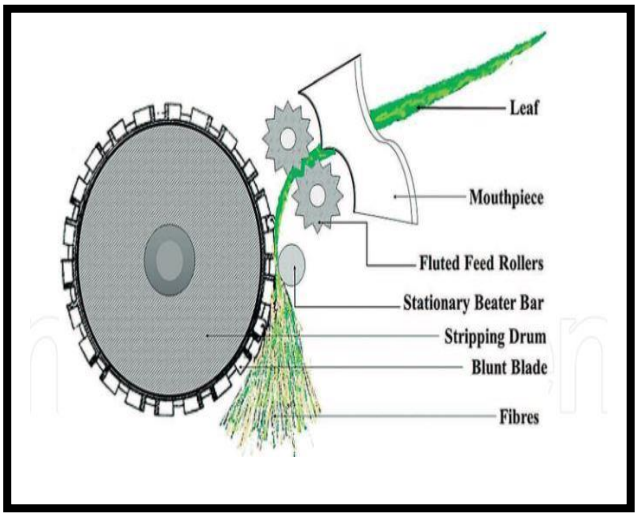


Plate 2.11: Pseudostem fiber extraction machine

Source: Subagyo, A., & Chafidz, A. (2018)

Plate 2.12: Banana Fiber extractor

Source : Das, P.K., et.al. (2010)

Flax

Scutching is the process for the removal of non-fibrous material from the retted stalks to extract the bast fibers. Sundried and retted flax is scutched to break the woody sticks and thus separate the fiber reed in the scutching machine. This scutching machine includes breaker which consists of six pairs of flutted rollers which crushes the straws and break the woody stem into small pieces. The wooden pieces are separated from the fibres by the stroke in the horizontal metal bar of scutching machine. The flax straws are passed three times through the fluted rollers repeatedly for the complete separation of fibers. After scutching, fibers are subjected for hackling. In hackling the scutched fibers are combed to parallelize the long fibers and short fibers &

extraneous matter are removed. Hackling can be done by machine or by hand. Hackling done by hand yield more fine fibers. Machine yield soft and weak fibers Pandey, R. et.al. (2014).

Plate 2.13 : Flax Scutcher **Plate 2.14 : Hackling machine**

Source : Das, P.K., et.al. (2010)

Coir

Coir dehusking machine is used to separate the husk from the coir fibers. The husks are removed and put through a machine composed of a pair of corrugated iron rollers. These semi – operated coir are further fed to the coir extractor for opening and cleaning of fibers. The strong and long fibers are washed cleaned and dried. The other methods of coir fiber extraction is decorticating the dry husks. All the processes produce three varieties of fibers based on the method of extraction- bristle fiber, mattress fiber and mat fibre (longest fibre) Velayutham, T., & Dhandapani, S. (2018).

Source : Das, P.K., et.al. (2010)

2.1.6. Spinning

2.1.6.1. Traditional spinning systems

a). Drop spindle (*Takli*)

It is one of the oldest methods for spinning fibers into yarn. With the rotation of the spindle, fibers are twisted. The spun yarn is wounded around the spindle. Drop spindle comes in different weights and sizes based on the fineness of yarn. Drop spindle consist of tapering rod or shaft and a round disk or whorl.

Shaft is made of different variety of materials such as metal, wood, bone or plastic. By the use of shaft, spinner inserts a twists by turning it between the fingers or rolling it between the hand or in the surface of thigh. The thickness of the shaft depends on how fast the spindle spins. The narrow shaft leads to faster spinning.

Whorl is the weight that is added to the spindles. The shape of the whorl can be ball shaped, disk – shaped and cross –shaped. The shape and weight of the spindle has an affect on the momentum it gives to the spindle while the yarns are spun.

(Source - https://home.nps.gov/pisp/learn/historyculture/drop-spindle.htm)

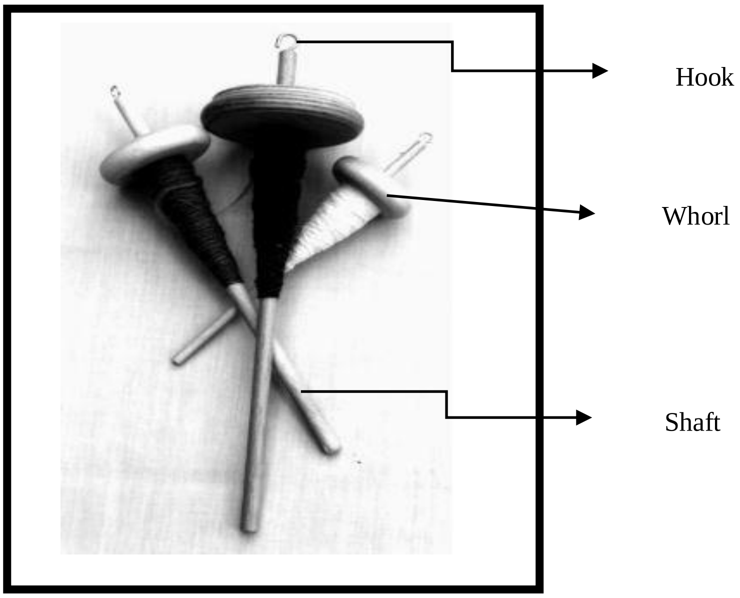


Plate 2.16 : Drop Spindle

Source:https://www.worldinaspin.com/sites/default/files/How%20to%20Spin%20on%20a%20Handspindle.pdf

b). *Ambar Charkha*

Ambar charkha was proposed, designed and improved by Mr. Amarnath from South India. It gives faster production of yarn. Ambar charkha can have two to twelve spindles. The basic raw material or input material of the spinning in the *Ambar charkha* is roving. It helps in producing the spun yarns in large quantities as compare to box charkha and drop spindle.

Ambar Charkha is composed - set of rollers with pressure arm, ring frame and cam. For spinning with the rotation of the Charkha, the movement is passed to different parts that are gears, pulleys and belts. The major parts of the charkha are:

R1: Pair of the feed roller – it confirms the rate of feeding the roving.

R2: Pair of the extender roller – it opens, stretches and aligns the fibers in the roving.

R3: Pair of the throw roller – it confirms the speed of yarn formation.

Hook for yarn guide – it facilitates the free rotation and linear movement of yarns

Traveler–it helps in twisting and winding of the yarn on bobbins.

Ring Frame–It guides and holds the traveler and helps in winding the yarn on spindle.

Cam– It confirms the follower lever to move up and down

Gears (G1, G2 & G3) – confirms the rate of production of yarn.

Drafting arrangements of *Ambar charkha*: Bottom drafting rollers made of steel are mounted on the inclined roller stand which consist of fixed brackets. The top roller consist of rubber that is mounted on a pendulum lever arm is pivoted on the machine frame. The lever is swing to lift all the rollers together. Top rollers are pressed against the bottom steel rollers by the means of spring pressure. The flexibility is required to fix the value of the draft that is required to spin the yarns of varying fineness.

Twisting: Twist is imparted by the rotation of the traveller. Each revolution of the traveler generates one turn of twist to the yarn. The traveller rotates on the surface of the ring. The traveller doesnot consist of its own drive. It is dragged by the yarn that is passed to the surface of the bobbin that is further winded on the spindle.

Package Formation: When the traveller and spindle rotate in the same direction the difference in the peripheral speeds of the traveller and spindle causes the yarn to wound on the package. The traveller acts a guide for the yarn as it oscillates back and forth across the length of the package for maintaining the yarn uniformity. The oscillating movement is imparted to the ring rail that holds the ring in which traveller runs.

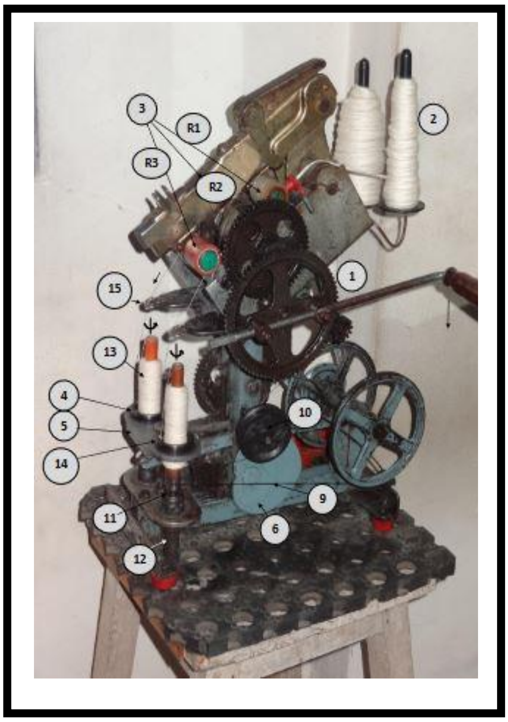


Plate 2.17. *Ambar Charkha* (Front view)

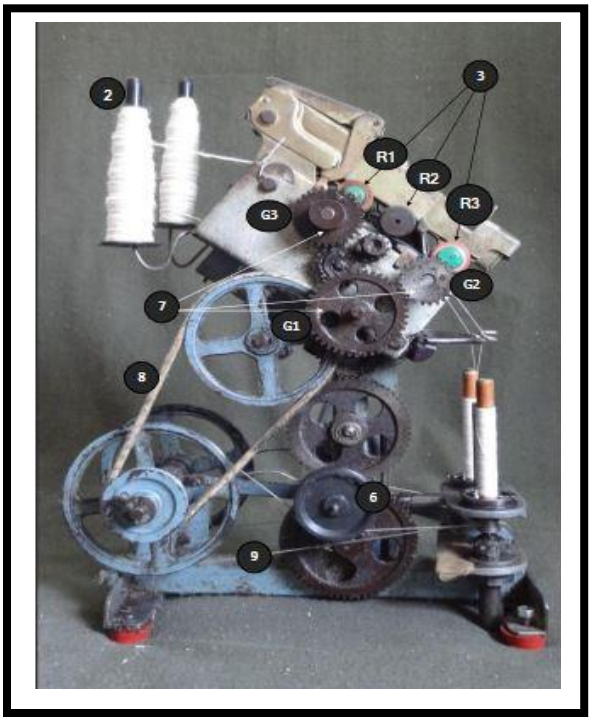


Plate 2.18. *Ambar Charkha* (Side view)

Source: https://www.mkgandhi.org/swadeshi_khadi/Charkha_Manual.pdf

Table 2.1. Major Parts of *Ambar Charkha*

Sr.No	Parts of Ambar Charkha
1	Wheel with handle
2	Rover wound on Plastic Bobbin
3	Roller pairs - R1, R2 & R3
4	Ring
5	Ring Frame
6	Cam and Cam lifter
7	G1, G2, G3 – Set of gears
8	Belt (Thick)
9	Belt (Thin)
10	Tension wheel
11	Spindle

12	Bearing in spindle
13	Bobbins
14	Traveler
15	Hook guide

Recently to increase the production of yarn, Ambar charkha are driven by the electric power and solar panels.

c). *Peti* (Box) *Charkha*

The box charkha is a portable spinning wheel that can be folded into the size of brief case and can be carried with the handle. The charkha is usually made of teak wood. It is composed of two wheels, crank, spindle and two storage compartments to keep extra spindles and fibers. The charkha works by rotating the crank which simultaneously spun the two wheels and spindle to spun the yarns.
(Source:https://artsandculture.google.com/story/charkha-the-device-that-charged-india-s-freedom-movement-mode/BAUBNSJPyMyVJg?hl=en)

Table 2.2. Major parts of Box Charkha

Sr.No	Parts of Box Charkha
1	Wheel with the handle
2	Accelerator wheel
3	Winder
4	Slide with spring
5	Fly nut
6	Stand
7	Bearing string
8	Stopper
9	Belt (Thick)
10	Belt (Thin)
11	Arm with Hook
12	a). Spindle b). Pulley
13	Leather washer
14	Yarn winded on the spindle
15	Sliver

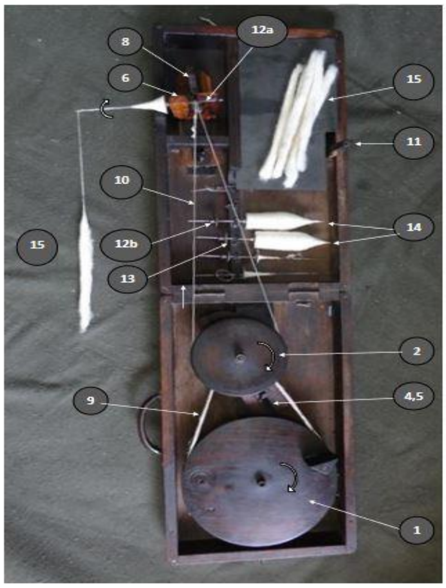


Plate 2.19: *Peti* (box) Charkha

Source: https://www.mkgandhi.org/swadeshi_khadi/Charkha_Manual.pdf

d). Phoenix *Charkha*

It is also called as *Medleri Charkha*. It is self winding foot operated spinning wheel with a bobbin attachment to collect the spun yarns. This charkha is used to spun longer and coarser fibers like Banana.

The feeding of the fibers in the phoenix charkha is done manually without any feeding units. The fineness of the yarn depends on rate of feeding which causes lot of non-uniformity in twist and fineness. For the synchronization of both the operation: twisting and feeding, a new drive mechanism was designed and developed by CIRCOT.

In Phoenix charkha at CIRCOT, both flyer and bobbin work independently. The differential in RPM determines twist per inch (TPI) imparted to the developed yarn. The twist of the yarn can be altered by changing the RPMs of the flyer, bobbin, changing the wheels in the drive mechanism. Fineness of the yarn is based on many factors: fineness of the fiber, skill of the operator and feeding rate. The attachments to the phoenix charkha was also developed by CIRCOT that helps in feeding the fibers keeping the non twisted and twisted portion separate. The modified design of phoenix charkha developed by CIRCOT can generate finer yarns of 2.9 counts with better evenness and uniformity. Desai, C.S., et.al. (2016).

Plate 2.20 : Phoenix *Charkha*

Source : Desai, C.S., et.al. (2016).

2.1.7. Spinning systems of natural fibers

For the development of yarn from minor cellulosic fiber several trails have to be taken in different spinning systems due to the properties of the fiber.

Fibers like Sunhemp, Mesta and Jute can be processed using Jute Spinning systems due to the similar mechanical properties and fibre structure. As the Jute is coarser in nature as compared to Cotton so the processing machinery for Jute is of heavy duty and robust in nature. Due to the finer nature of Cotton fiber it requires intensive and mild opening as compare to Jute. During the processing of Jute fiber it requires high amount of opening force to de-mesh and split the Jute reeds. The roller settings of yarn processing machinery (drawing to spinning) are much wider for Jute fiber as compare to Cotton spinning machine due to the higher staple length of Jute fiber. Due to the specific nature of Jute fiber, cotton spinning machines cannot be used to develop Jute yarn.

Flax and Ramie bast fibers consist a discrete filament structure. Both the fibers are much finer than Jute but they are coarser than Cotton. Thus, both the fibers are processed in the Flax spinning systems. Coir fiber has low length to breadth ratio and consists of high rigidity so it is difficult to spin but coir fibers are pliable into ropes using Coir spinning system. Pineapple fibers are fine in nature. Hence fibers are successfully spun into yarn on Jute, Cotton, Flax and semi-worsted spinning systems. There are specific spinning systems of animal fibers like wool and silk which is not suitable for plant fibers.

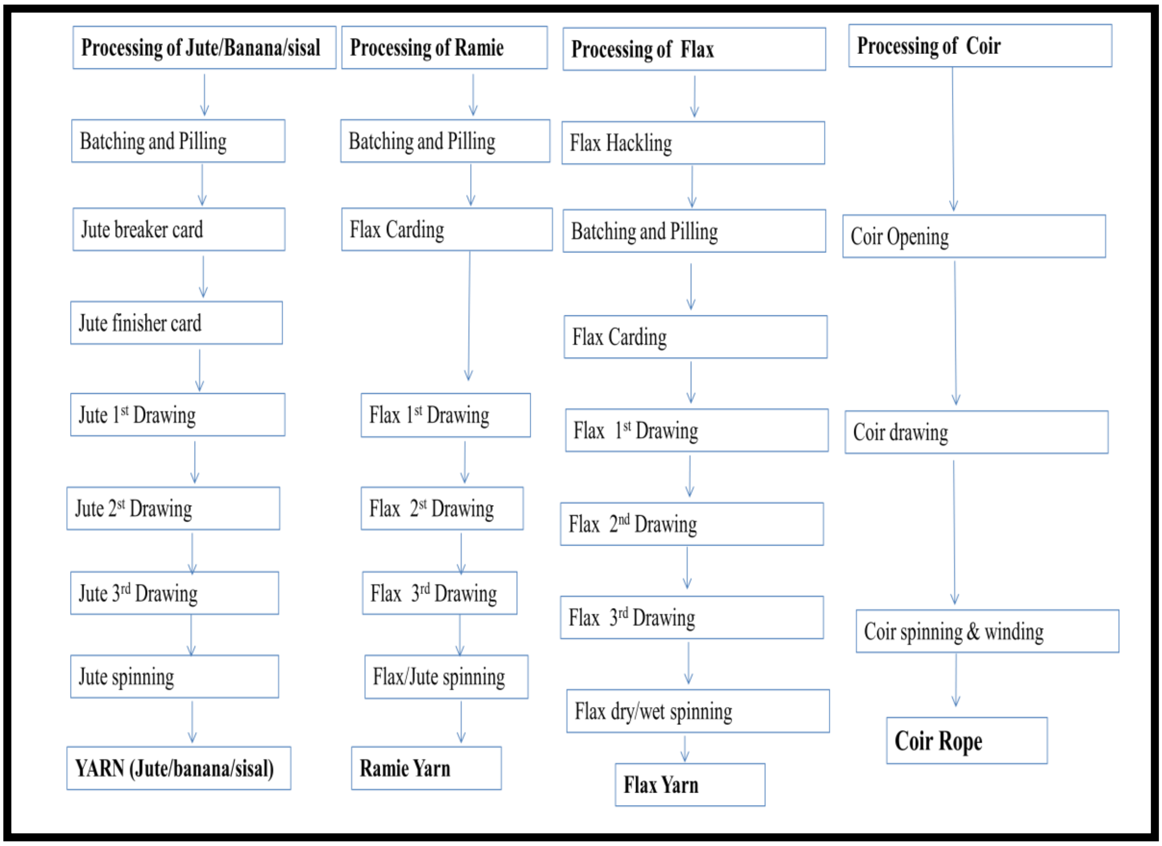


Figure 2.1 :Spinning of plant fibers

Source : Das, P.K., et.al. (2010)

a). Jute spinning system

Prior to mid 1850s, handmade ropes were developed from raw Jute fiber. Then Jute processing followed Wool and Flax since 1850s and continued till 1970s in roving system. Sliver replaced round roving prior to spinning. Later full scale spinning system of Jute was developed.

The commonly operated Jute spinning systems comprises two stages of carding followed by three stages of drawing and finally subjected to spinning stage.

In the initial carding stage, long fibers are passed through breaking cards. The role of breaking cards is to break the continuous mesh of fibers into separate fragments which is also called as "entities". The breaking cards has a provision of cleaning action which helps in removing the non-fibrous matter from the fiber properly. Sliver produced from the breaking card is passed through second or finisher card. The finisher card has a provision of specific mixing effect. Hence the number of slivers are fed in the card and finally it emerge into a single sliver. There is a cleaning action in the finisher card also for the removal of non-fibrous material.

In all the drawing process, fiber movement is controlled by the gill pins that are fixed by faller bars. The sliver obtained from the drawing stage is then passed through the spinning frames and twist are inserted. Twist in yarn is inserted by the overhung flyer universally practiced in all the Jute industry.

b). Flax spinning system

As the flax fibers are longer in length so the machinery and process flowchart is different from Jute. The process for developing flax yarn is: hackling, carding, drawing and yarn preparation. Flax fibers are extracted using various retting techniques. Retting stems are subjected for scutching machine which removes the non-fibrous material from Flax stems. After scutching, fibers are subjected for Hackling. In this process, fibers are combed in order to parallelize the long fibers and it also leads to the removal of short fibers. Hackling process can be done by hand, hackling machine and beating the fiber sample against wooden rod or mallet. Hackling done by hand produce finer and higher fiber yield as compare to hackling done by machine. After hackling fibers are degummed, scoured and bleached in order to remove the impurities. Cleaned fibers are cut into the staple length prior to carding. Before carding, batching oil and water are sprinkled over the fibers for 24 hours in order to soften the fibers and to increase the strength of yarn. After the pre-treatment, fibers are subjected for carding, drawing, roving and final yarn preparation.

c). Coir system

Coir fibers are very coarser and harsh in nature. It is extensively used in villages for developing mat of cots. General spinning systems used for Cotton and Wool fibers are not suitable for Coir because of insufficient inter-fiber friction and inherent properties of coir fibers like torsion and high flexural rigidity. Ratt spinning is the traditional method used for developing coir ropes. For developing Coir yarn opened, Coir fibers are manually fed in the hand-operated twisting wheel for imparting twist. The yarn production was very low in this technique. The technique generates low quality yarns. The Coir yarns obtained by this process are coarser, weaker and irregular. Later the motorized Coir spinning machine was developed. The spinning machine works on the basis of open end spinning system. In the machine coir fibers are individualized by the action of beater. The opened fibers are collected in the trough which is located in the bottom of beater which works on the gravity principle. 2 ply coir yarns are produced by this machine.

d). Wool spinning system

The three main routes for wool are: a). Woollen spinning system b). semi worsted spinning system c). Worsted spinning system

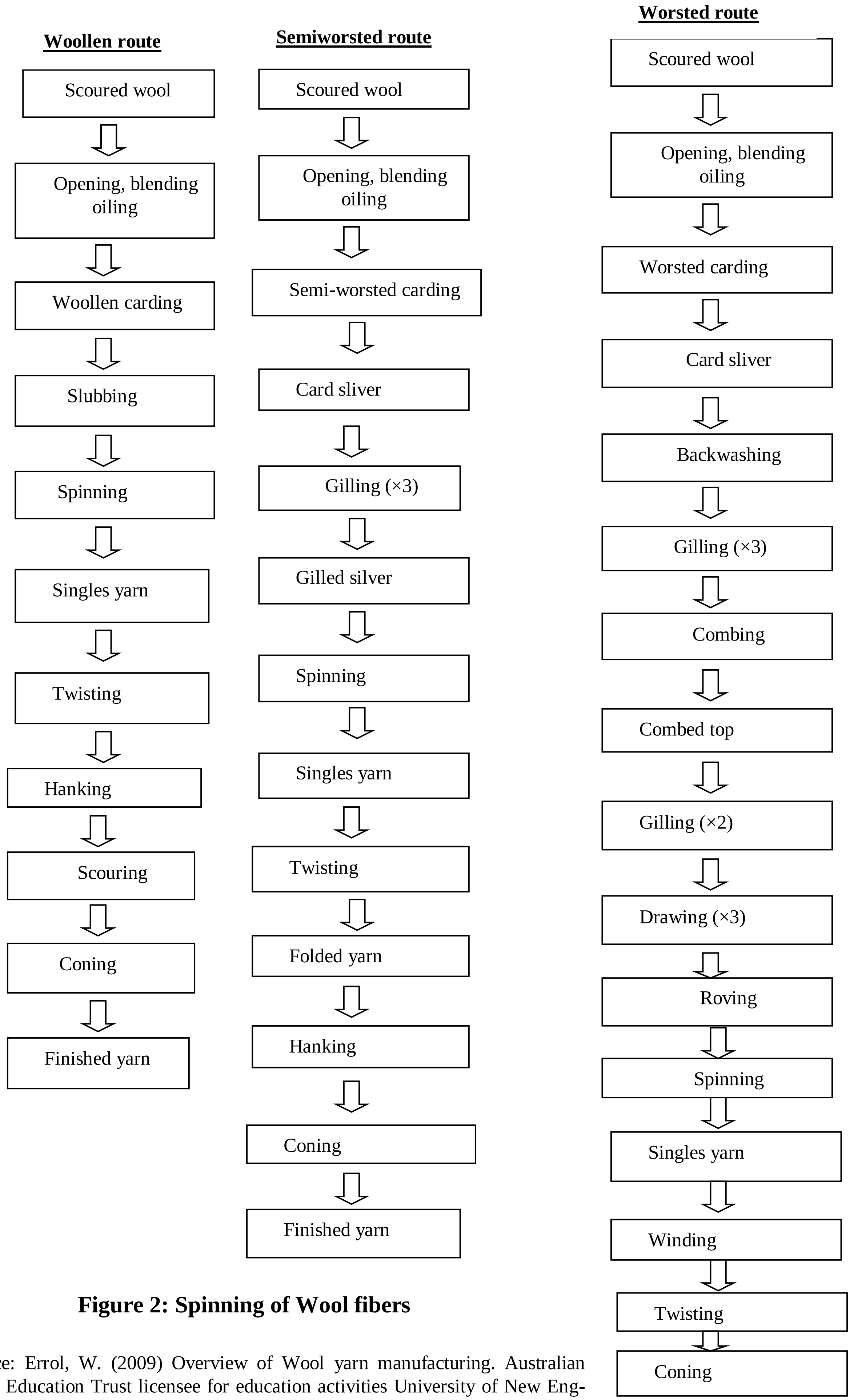


Figure 2: Spinning of Wool fibers

Source: Errol, W. (2009) Overview of Wool yarn manufacturing. Australian Wool Education Trust licensee for education activities University of New England

e). Woollen spinning system

It is one of the simplest amongst the three manufacturing process of wool. It is used to process the woollen blends which vary in fiber length and diameter. This system is used for handling the poor quality of wool, tender and shorter wool. Recycled fibers from rags and yarns and noils (combing waste) are included in woolen blends. Cross-bred wool blends that are used for carpets can be processed on the woollen system.

Woollen carding

Through the hopper feed wool generally passed through two stages of carding that is called as scribbler and carder parts respectively in ensure the opening of wool tufts, fiber mixing and removal of impurities. In the tap condenser the thin web of carded fibers is separated into a narrow strips and then consolidated through action of rubbing into a thin ribbon of fibers called as slubbing. Slubbing is similar to worsted roving, it is non-uniform, fibers are not well aligned and straight. A pair of smooth rollers called as *Peralta* crushes the vegetable matter into fragments ensuring more easy removal from the web. The slubbing developed by the carding is spun into a yarn and later twist is applied. This process is carried out in ring spinning frame.

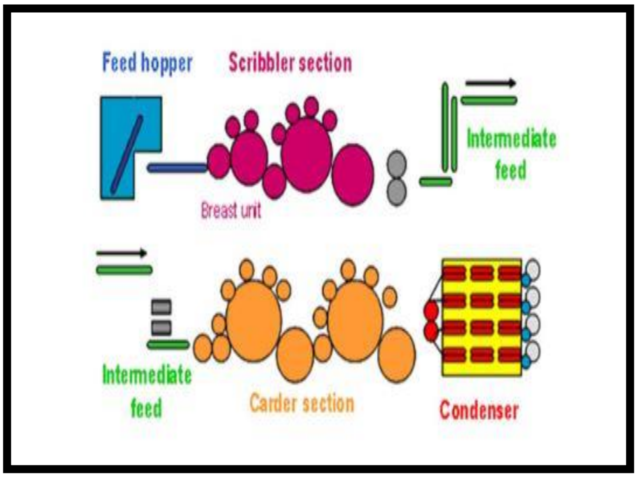


Figure 2.21: Layout of woollen card

Source : Errol, W. (2009)
https://www.woolwise.com/wp-content/uploads/2017/07/Wool-482-582-08-T-02.pdf

The developed woollen spun yarn has a high proportion of short fibers distributed randomly throughout the yarn. The ends and loops of fibers protruding from the surface has an important influence on the visual and tactile properties of woollen yarn. The yarn produced are coarser in count, spun in low twist, bulky, soft handling, hairy and less regular as compare to worsted yarn.

Woollen ring spinning frame consists of :

1). An overhead creel to hold the spools with positive let off drum feed

2). A drafting system with a false twist device

3). Collapsed balloon spindles

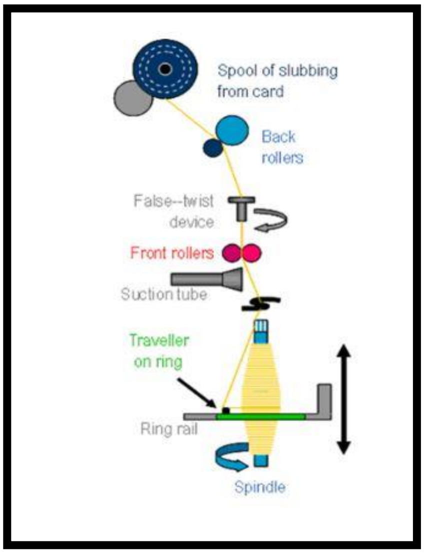


Figure 2.22 :Key parts of woollen spinning frame

Source : Errol, W. (2009) https://www.woolwise.com/wp-content/uploads/2017/07/Wool-482-582-08-T-02.pdf

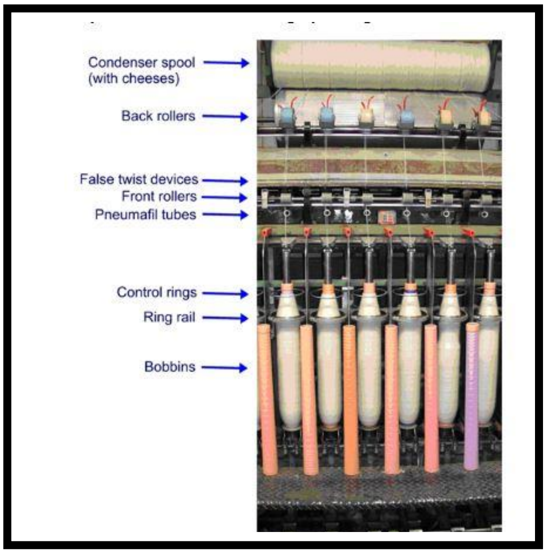


Plate 2.23. Woollen ring spinning

Source : Errol, W. (2009) https://www.woolwise.com/wp-content/uploads/2017/07/Wool-482-582-08-T-14.pdf

f). Semi-worsted system

Semi worsted system needs superior fiber of staple length (100-120 mm). This system was developed to produce yarns with the higher strength. Wool is passed through high production card, gilled several times in order to straighten the fibers and spun directly from thin sliver. Yarns produced from semi-worsted system are intermediate in quality as compare to yarn developed by worsted and woolen system. Due to greater fiber length and degree of straightening imparted in the gilling step, semi worsted yarns are less bulkier as compare to woollen yarns.

Semi worsted spinning frame

Spinning takes place directly after the third gilling step. To obtain fine yarns it is necessary to develop finer sliver that is produced on a gill box. In this process roving frame is used prior to spinning. To obtain higher drafts two-zone drafting system is used in the spinning frame.

The ratch (distance between the back and front drafting rollers) should be set so that no that fiber has both the ends nipped at the similar time. Fibers shorted than ratch will pass easily via back nip to front nip. Short fibers are not nipped at all for the significant period of their passage across the drafting zone. These “floating fibers” tend to carried forward in groups through front rollers making thin and thick places in the yarn. The main function of the drafting aprons and intermediate rollers is to control the movement of floating fibers and hence impart evenness.

Semiworsted system in lighter counts can be spun using double zone drafting system in which roller drafting system perhaps with a short apron is followed by conventional double apron system. The first initial zone applies the draft up to 8 and draft is the second zone is may be upto 25 giving the total draft of 200. Floating fibers in the zone one are controlled by soft “sampre rollers” which apply light pressure to the sliver.

Plate 2.24 : Drafting section of semi-worsted spinning system

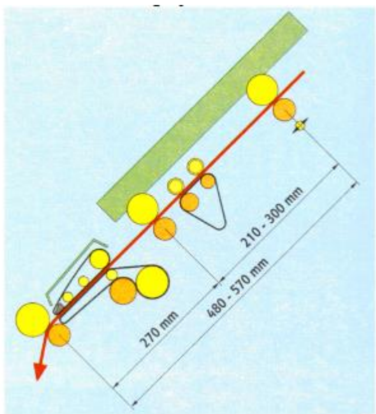


Plate 2.25: Double zone drafting system

Source : Errol, W. (2009)
https://www.woolwise.com/wp-content/uploads/2017/07/Wool-482-582-08-T-14.pdf

g). Worsted spinning system

Worsted system requires long and sound wool in order to develop efficient processing and yarn of acceptable quality. The wool is removed from the worsted card called as sliver. Worsted spinning system has more elaborative steps. The card sliver is passed through the series of gilling steps in order to straighten and align fibers into a clean parallel arrangement. Gillbox resembles to combing of hair. To remove the short fibers, neps and vegetable matter gilled sliver is combed. It is gilled again to restore the parallel alignment for the formation of top. The top is further scoured to obtain a cleaner and whiter product. Drafting of the top is done to form a thin ribbon of fibers, or roving prior to twisting and further drafted in spinning to develop a yarn. In the worsted system, first process is – carding, gilling and combing that is called top making.

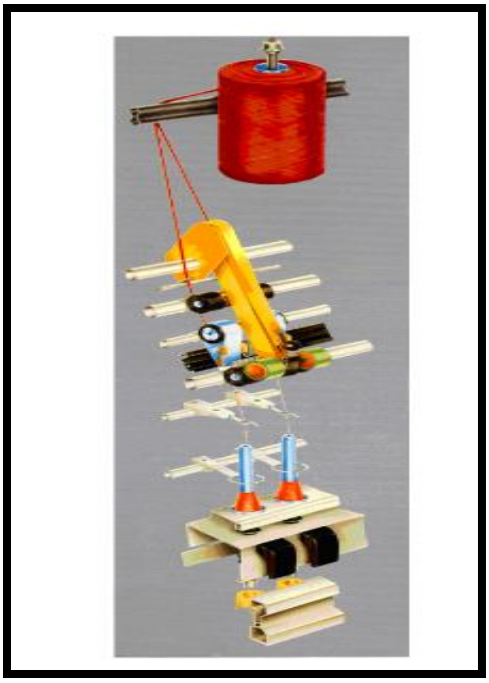
Roller drafting is done by passing a roving or sliver between two pairs of driven rollers. The front and delivery roller has a higher surface speed as compare to the feed (back) rollers. Minimal drafting is used in the woollen system. In the drafting zone, pair of aprons or secondary rollers assists in controlling the short fibers. Rovings is passed through drafting zone and the yarn is wounded on the bobbins that rotate in high speed on the spindles. Worsted spun yarns are used in woven suiting fabrics of high quality, hand and knitting yarns.

Worsted spinning frame consists of:

1). Pair of rovings wound off the package.

2). Drafting zone in combination of rollers and aprons

3). Spindles with control rings



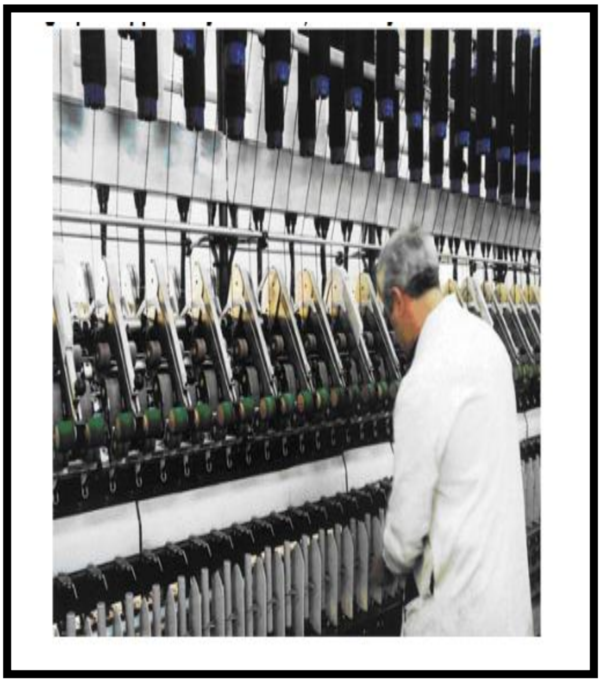


Plate 2.26 : Schematic diagram of Worsted Spinning frame

Plate 2.27 :Worsted spinning frame

Source : Errol, W. (2009)
https://www.woolwise.com/wp-content/uploads/2017/07/Wool-482-582-08-T-14.pdf

h). Silk spinning

Spun silk is developed from the threads spun from short and inferior filaments left over from the damaged cocoons and broken off in the silk production process. The process of producing spun silk yarns is called as silk spinning system.

Spun silk yarns are less lustrous, low strength and elasticity as compared to reeled silk because of short staple fibers. (https://www.fao.org/3/x2099E/x2099e09.html)

Sources to develop spun Silk:

1. Pierced cocoons, the result of breeding moths that have emerged from their cocoons;
2. Double cocoons or doupion, which result when two cocoons have been spun too closely together;
3. Floss, brushed from cocoons before reeling;

4. Friese, the coarse and uneven silk fibre at the beginning and end of each cocoon
5. Scrap, the machine waste left over from reeling.

The steps in Silk spinning are as follows:

1). Degumming

The wastes are collected and put in the machine consists of large drums filled with water. Then it is boiled for 1 hour at 90-95ºC depending upon the removal of Sericin content. After boiling, wastes are washed in a washing drum consists of wooden pad like structure which exerts pressure during washing for the removal of soap and soda. This process is called as stumping. Then it is squeezed and hydro extracted. The Silk is then dried in a hot air drying machine. After drying the silk is conditioned for 15 days. Degumming process is done by five methods: 1). Extraction with waste b). Boiling off with soap c). Degumming with alkalis d). Enzymatic degumming e). Degumming in acidic solutions

2). Mixing and ball making

To obtain a uniform silk, mixing of different types of silk wastes are done in order to get a good process performance, quality and economy aspect. In a ball making the degummed silk are weighted and 200-250 gm of Silk taken in the ball form.

3). Opening

The opening machine consist of fork like structure. The ball of the degummed silk is fed in the machine in which fork opens the tangled mass of fibers and convert it into a ribbon like structure.

4). Filling and Pegging

The web or the mat obtain from opening machine is transferred into the drum of filling or pegging machine. The surface of this drum consist of rows of combs arranged at different intervals. The output obtained from this machine is called as sliver.

5). Combing or dressing

The purpose of combing or dressing is the removal of short fibers and to parallelize the long fibers. Short fibers which are obtained in this process are used for developing noil yarns. Long fiber drafts are subjected for next process.

6). Cleaning of slivers

The dressed and combed sliver are subjected for visual cleaning on a glass. Below the glass light is provided. To obtain the good quality yarn, foreign matters are removed.

7). Drawing

The sliver is passed through six different drawing machines. In this stage, sliver is reduced to fine slubbing. In the draw frame, doubling and drafting takes place simultaneously. So blending of different fibers with the silk can be done.

8). Roving

The fine slubbing obtained from the draw frame is further subjected for attenuation, parallelization and twisting. Slightly twisted roving is wound on a bobbin which is further used for spinning frames.

9). Spinning

Rovings are converted into the yarns and wound on bobbins.

10). Winding and doubling

Two or three single spun yarns are doubled and twisted.

11). Gassing

Protruding fibers on the surface of the yarn are burnt out by the passing the yarns through a flame of 500-600 meters per minute to increase the luster and appearance of the yarn.

12). Cleaning

After gassing process, the yarns are passed between the rotating steel rollers for the complete removal of adhered burnt particles. After this process, yarns are reeled and standard hanks are prepared.

The waste obtained in the various stages of spun silk processing is used for the production of the coarser count of yarn which is called as Noil yarns. The process for the manufacturing of Noil yarn is similar to the Cotton system. Noil yarns are used for the manufacturing of carpets.

(Source : https://hbmahesh.weebly.com/uploads/3/4/2/2/3422804/silk_spinning.pdf)

2.1.8. Open End spinning

The main part of open end spinning system is rotor in which fibers are collected and drawn off into the yarn. It is also known as break spinning and rotor spinning. The production rate of rotor spinning is 6-8 times more than ring spinning. Open end spinning system has lower manufacturing cost than ring spinning system. This is generally used for Cotton carded spinning.

In open end spinning rotation of rotor generates the twisting force. Rotor consists of shallow “V” or “U” shape groove surrounding the periphery.

In open end spinning twisting force is imparted by the rotation of rotor and the friction is transferred to the fibers that builds the tail of newly developed yarn structure. This twisting tail touches with the other fibers it collects them. When this process starts then it is self sufficient and yarn can be drawn out from the rotor continuously.

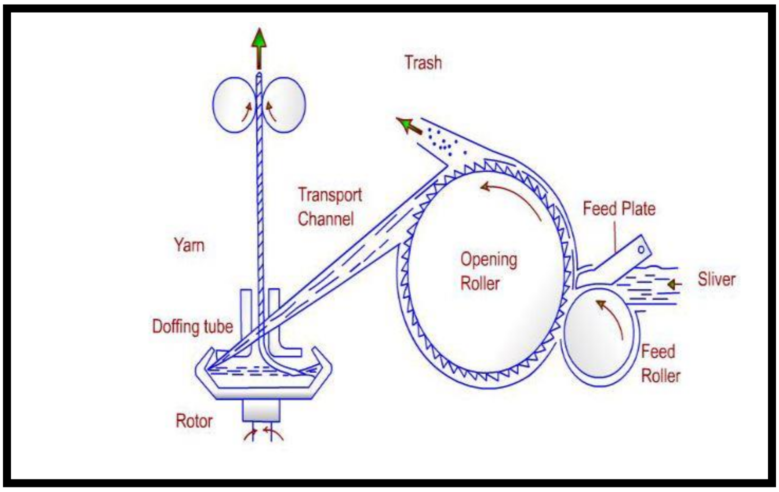


Plate 2.28 :Main features of rotor spinning systems

Source: https://textilescommittee.nic.in/sites/default/files/spin7psf

Plate 2.29 : Open end/Rotor spinning ma-

Source:https://textilelearner.net/an-overview-of-open-end-rotor-spinning/

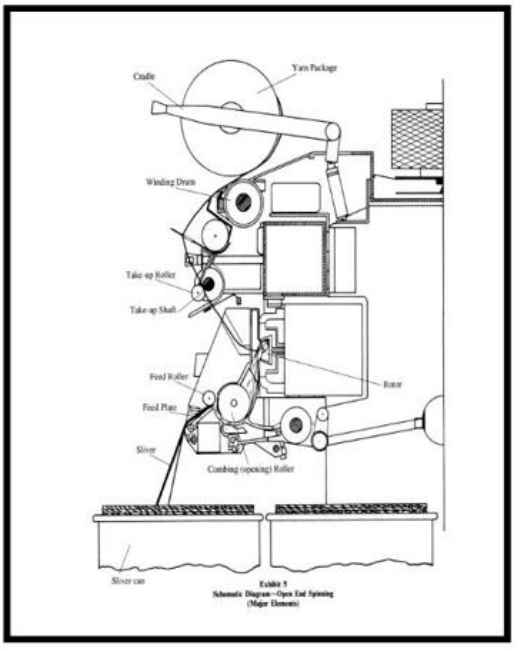


Plate 2.30: Schematic diagram of open-end spinning

Plate 2.31: Rotors

Source : https://www.cottoninc.com/wp-content/uploads/2017/12/TRI-1004-Introduction-to-Open-End-Spinning.pdf

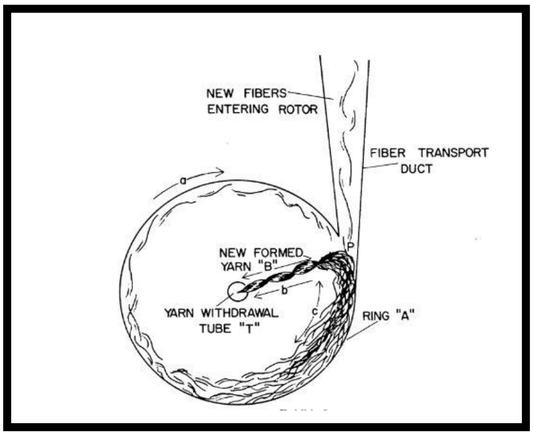


Plate 2.32 : Schematic illustration showing the formation of yarn inside the rotor of an open end

Source: https://www.cottoninc.com/wp-content/uploads/2017/12/TRI-1004-Introduction-to-Open-End-Spinning.pdf

Functions of open end spinning are:

Sliver produced from the draw frame is introduced by feeder cylinder and it is then subjected to the opener which consists of saw-toothed wiring that rotates in the speed between 6000-9000 RPM that separates the sliver into a single fibres. Then the single fibres are passed through the rotor by a vacuum channel.

Sliver from the cans is passed through a feeding roller by the means of sliver guide. The combing roller takes the sliver from feeding roller and opens up into the individual fibers and fed these fibers to the rotor by the means of fiber transfer tube. Fibers are deposited onto the rotating rollers and then slides down into a groove of rotor and it forms a ribbon of fibers. The rotor rotates in a very high speed developing a centrifugal force.

For starting the spinning length of the yarn which is wounded onto the package by the take up mechanism and threaded by the nip line of delivery rollers and then into a draw off tube. Due to the partial vacuum the tail of the yarn is sucked into a rotor due to the partial vacuum. The rotation of the rotor pulls the yarn end into a collected ribbon of fibers and at the same time inserts twist to the yarn tail. A little of the twist propagates into the portion of ribbon which is in contact with the yarn tail and further binding it into a yarn. When the tail of the yarns enters the rotor the delivery roller is set in the motion to pull the tail from the rotor. The peeling action results in peeling of the fiber ribbon from the groove. The developed yarn is winded on the package in a cylindrical or conical form by the means of winding drum.

Yarns developed by rotor spinning system are of medium to coarser count range. End applications of rotor spun yarns are: socks, denims, T-shirts, blankets and towels.

(Source: https://textilelearner.net/an-overview-of-open-end-rotor-spinning/)

2.1.9. Selection of constituents for blending

Parameters to be considered for blending : Kalanjikombil, M. (2020)

1). Type of fibre: As per the end applications of fabric the blend constituents are selected.

2). Compatibility of blend fibers: While blending it should be compatible in terms of following properties:

a). Denier and length of fibers – These are two most essential parameters which needs to be matched.

b). Extensibility – The elongation balance of the fiber is very essential with regard to yarn quality. A huge difference in breaking elongation of fibers in a blend has an adverse effect on tenacity of yarn.

The lower yarn tenacity leads to unequal sharing of load at rupture point. At the time of shed formation in weaving, breaking extension influence the weave ability of warp yarns.

c). Density- The huge difference in the density of the blend fibers leads to separation while conveying the blend stocks through the ducts under the presence of air suction in blow room. Heavier fibers falls in the lower section of duct. A large difference in blend fiber density leads to non-uniform blend.

d). Dispersion properties – it is the separation of individual fibers from the group and disperse throughout the fiber matrix of the blend to produce a homogenous blend.

Poor dispersion leads to many factors – very little or more crimp, high static accumulation and large fiber aggregates with coterminous ends.

e). Drafting properties – for example fiber like viscose rayon has a good drafting property so blending with the other fibers acts as a carriers to overcome the trouble in drafting.
f). Dyeing properties- of the individual fiber should be taken into the consideration while blending.

2.1.10. Influence of yarn on fabric properties

Ring spun yarns are softer than open end rotor yarn. Low twist yarns produces more of softer fabrics as compare to high twist yarns. Yarns made of finer fabrics will result in soft fabrics. Open end yarns developed in the machine with grooved navels will result into softer fabric. There is a correlation between the strength of yarn and fabric properties. Yarns are made stronger when longer, stronger, finer fiber are used with the optimum twist. More uniformity in yarn with few imperfections leads to stronger yarns. Fabrics are stronger when plied yarns are used. Appearance and fabric luster is influenced by the yarn. Fabric made of ring spun yarns are more lustrous than fabrics developed from open end yarns. Fabric consist of low twist are more lustrous as compare to fabrics developed from high twist yarns. Fabrics made of combed yarns are more lustrous than carded yarns. (Source:https://www.cottonworks.com/wp-content/uploads/2017/11/Textile_Yarns.pdf)

2.1.11. Circular Knitting machine

Circular knitting includes all those weft knitting machines in which needle beds are arranged in circular cylinders/dials consists of latch needles, bearded or compound needle. The machine is used to develop wide range of fabric structures, garments, hosiery or other products in varying diameter. The circular knitting machinery is of body size or larger. The machine consists of single or double cylinders with the dial arrangements in case of small diameters specifically for hosiery. The modern circular knitting machines are engineered, controlled electronically with high precision system capable of developing fabric with high quality fabrics in higher speeds. The fabric obtained from the circular knitting machine is tubular in structure.

Plate 2.33: Circular Knitting machine

Source: https://textiletutorials.com/types-of-circular-knitting-machine-used-in-textile-sector/

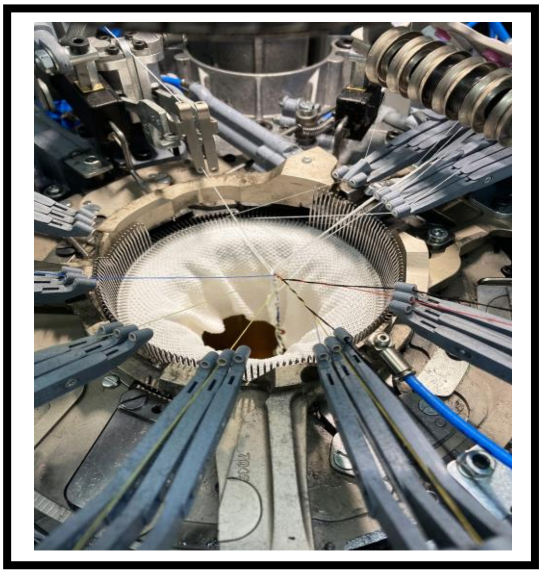


Plate 2.34: Closet view of circular knitted fabric

Source: https://www.sockeasy.com/post/knitting-machinery

Features of Circular Knitting machines

1. The body or frame is circular as per the needle bed shape that supports the majority of mechanisms of machine.
2. It consists of yarn supply systems or creel for holding the packages of yarns.
3. Yarn tensioning devices
4. Yarn feed control
5. Yarn stop motion
6. Yarn carriers or guides
7. The knitting system which consists of housing and driving of knitting elements and needle selection device.
8. Take down mechanism for fabric
9. Start, stop and inching buttons
10. The automatic lubrication system

In circular knitting machine, yarn from the package is unwounded and comes down through the guides, tensioners, stop motion to move through the needles. The developed knitted fabric is taken down inside the cylinder and then rolled on the cloth roller. The circular knitting machine begins to knit when the CAM systems on the needle beds (cylinder and dial) move along the surface Kothari, V. (2010).

Gauge is a very important parameter which shows the density of the needles in cylinder or dial of the circular knitting machine. Gauge is defined as number of needles per unit length of the cylinder or dial is defined as gauge. The gauge has a great influence on the fabric structure. All the yarn counts cannot be used in same gauge of machine. Lower needle gauge is used for heavier, bulkier and handspun yarns. Standard gauge is used for socks, fingering and baby weight yarns. Fine gauges are used for lace weight to fingering weight yarns. Gauge selection depends on – yarn count, type of fiber, yarn twist and finishing in the yarn Abedin, F. et.al. (2014).

Requirements in Knitting

1. Yarns used in knitting should be resilient, strong, bulky and good elasticity. It should have an ability to absorb moisture.
2. Yarns should be even, smooth, fine.
3. Yarns used for knitting should have lower twist and fuzzy to obtain a knitwear with more bulky appearance, softer and porous structure.
4. Folded yarns produce best results in knitted structure.
5. Textured yarns with the crimped structure produce a softer, bulkier and porous fabric.
6. Highly twisted yarns display the texture of the knitted patterns.
   (Source: https://www.woolwise.com/wp-content/uploads/2017/07/WOOL-482-582-12-T-12.pdf)

2.1.12. Textiles and microorganisms

Microbes

Microbes are the tiny creatures that are not visible by the naked eyes. There are wide variety of microorganisms like fungi, bacteria, algae and virus. Bacteria are unicellular organisms that grow very rapidly under moisture and warmth. The subdivisions of the bacterial family are – Gram positive (*Staphylococcus aureas*), gram negative (E-coli), spore bearing or non-spore bearing type. Some specific type of bacteria causes cross infection and pathogenic. Molds, mildew and fungi are complex organisms that has a slow growth rate. These organisms are the part of daily lives and they are present everywhere in the environment Boryo, D.E.A. (2013).

Antimicrobial textiles

Antimicrobial textiles are defined as textiles that act against the bacteria. In recent years, due to the increased public health awareness consumers there is demand for textiles with antimicrobial property. The importance of reducing or eliminating the growth of microbes on textiles has a high importance due to the susceptibility of textiles to microorganisms such as bacterias and fungi that is based on nutrients, temperature and moisture. Hydrophilic nature of the natural fibers and regenerated cellulosic fibers are more vulnerable to microbial growth. Thus antimicrobial characteristics plays a important role in diversified areas of uses such as medical, protective, sports, defense, home textiles, water purification systems and apparels. Antimicrobial properties are explored by using synthesized and inherent antimicrobial fibres. In industry, treatment of antimicrobial agents at the fabric stage is widely practiced.

Antimicrobial agents are incorporated in textiles using different methods: Agents are incorporated into the polymers prior to extrusion or by blending it with synthetic fibers at the time of manufacturing and production. This method provides the better durability as the active compounds are embedded in the structure of fiber and they are released slowly during application. Another methods are exhaustion, pad-dry-cure, foaming and spraying on various textiles. The newer method of incorporating antimicrobial agents is through nanotechnology such as carbon nanotubes, nanoclays, natural polymers like Chitosin, metal oxide nanoparticles and nanoencapsulated agents.

The antimicrobial application in textile should fulfill the points mentioned below:

- It should not lead to loss of performance properties and fibre degradation.
- It should reduce the formation of odour that later result into the microbial de gradation of perspiration.
- It should avoid retarding and transferring pathogens.
- It should have a durability to drycleaning, laundering and hot pressing.
- It should not destroy the good bacterias.
- It should not be harmful to user, manufacturer and environment.
- Antimicrobial agents should fulfill the requirements of regulatory agencies and have compatibility with the chemical processing.
- The method of the application should be easy.
- It should have a property of resistance towards the body fluids, disinfection and sterilizations.

Various antibacterial chemicals and fibres available in the international markets are not environment friendly. They majorly consist of synthetic base. Nowadays the consumer preferences are towards the functional fabrics with antimicrobial property. There is a huge requirement to necessitate the production of environmental friendly antimicrobial agents. India has a vast reserve of plants that consist of prominent medicinal values. Extracts from the different parts of the plants like roots, stem, leaves, flowers, fruits and seeds exhibits the antimicrobial properties. In textile finishing these plant extracts are used in the native form or in the form of microcapsules.

Mechanism of antimicrobial activity

The antimicrobial effect is referred as negative effect on the vitality of microorganisms. Two keywords are commonly associated in antimicrobial field termed as “cidal” and “static”. The term cidal (Bacteriocide) defines significant destruction of microbes and static (Bacteriostatic) refers to inhibition of microbial growth without destruction. Montazer, M., & Harifi, T. (2018)

Antimicrobial activity is based on two mechanisms:

1. Controlled release mechanism (Conventional leaching type of finish) – In this mechanism, antimicrobial agents are diffuse and poison to kill the microbes. The durability of antimicrobial agents are not strong. Between agent and textile fibers there is no chemical bonding. In this case, the leaching rate of the antimicrobial agent plays a important role affecting the efficiency. This type of mechanism has a poor durability and causes health issues.

2. Direct contact mechanism (Non-leaching or biostatic type of finish) - In this mechanism, antimicrobial agents are strongly attached to the fiber and it acts when it is contact with the microorganisms. Through this mechanism there are minimum hazardous effects of antimicrobial agents. There are more compatible with ecological and toxicological principles. This type of mechanism shows good durability and doesnot have any health issues.

The another classification of antimicrobial textiles are classified into two groups:

1. Active substrates – Active substrates are not released from the surface of the fibre so it is less effective. These substrates act only when they are in contact with microorganism.
2. Passive substrates - Passive substrates donot contain any active substances but there surface consist of negative effects on the living conditions of microorganisms. There is a anti adhesive effect on the structure and surface of the substrate.

Skin resident microflora

Skin flora should be stable. Basically 10^3–10^4 microorganisms per cm^2 are found on the skin. Specifically in the wet areas and groins the figures goes upto $10^{6-7/cm2}$. Freney, J., & Renaud, F. (2012)

Textiles and Infection vectors

Textile materials consists of infectious agents like bacteria, virus and fungi. Wattiau, P. et. al. (2008) in his study mentioned the occurrence of *Bacillus anthracis.* strains isolated in the wool cleaning factory. Spread of infection in the hospitals are majorly through clothing and textiles. Takahashi, A. et. al. (1998) mentioned in the study regarding the presence of *Streptococcus pyogenes strain.* on the vinyl undersheet of 17 patients. In the maternity hospitals strains of *S. pyogenes* is seen in contaminated bras due to the insufficient drying. Employees of the laundering department of the hospitals are infected by *Salmonella.* due to the contaminated sheets. Barrie, D. et. al. (1994) mentioned the occurrence of *Bacillus cereus.* that leads to post operative meningitis that occur due to contamination in laundry. Gonzaga, A.J. et. al. (1994) mentioned that newborns in hospitals are infected by *S.Aureas.* when they are handled by the laundry staff.

The risk of contamination is very high in hospitals during bed making. Perry, C. et al. (2001) mentioned that the strains of *S.Aureas.* can transfer to patient's bed to nurse coats that are highly pathogenic. VRE - *Clostridium difficile*. and vancomycin resistant enterococci are found majorly in white coats in hospitals. Hospital curtains are majorly contaminated by MRSA (*Methicillin-resistant S. aureus*.). Filling of pillows are contaminated by *Acinetobacter.* Oie, S. et.al. (2002) conducted a study on door handles of hospitals. It was observed that contamination is through MSSA (*Methicillin-susceptible S. aureus*) strains. and MRSA (Methicillin-resistant S. aureus strains).

Microbes in clothing and skin

Barzantny, H. et.al (2011) reported that textiles and skin micro biome is majorly dominated by *Staphylococcus aureas.* and *Micrococcus spp.* It is reported that *Corynebacterium spp.* is an odor causing bacteria. The length of the time the particular clothing is worn also leads to bacterial growth. Fischbach, MA., &Scharschmid, TC. (2013) reported that there was a growth of *Corynebacterium spp* that was worn for a longer period of time that may be due to the release of apocrine glands to clothing that provide the environment for the growth of *Corynebacterium spp* bacteria. Cotton textiles are majorly affected by *Acinetobacter* that may be originated during fabric processing and manufacturing.

Textiles and skin

Skin is the habitat and largest organ on the human body. The outer layer of the skin that is stratum corneum is the horny outer layer that interacts with the environment. The acidity of the surface pH 4.5-5 helps in building the favourable climate for the growth conditions of many pathogenic microorganisms. The acidic pH leads to the growth of commensal bacteria such as *Staphyloccusaureas.* and *Corynebacterium.* The primary interaction between clothing and skin is mechanical. In this case ,two major parameters plays an important role – a). Friction & b). Pressure. Friction leads to many skin ailments Keratosis follicularis and Atopic dermatitis. Prolonged pressure leads to superficial abrasions and deformation of tissue. These conditions also leads to favorable environment for microbial growth. Properties like moisture management, air permeability and heat transfer regulation of the specific textile materials are strongly depend on type of fibre and impact on skin microclimate. Skin microbes depends on the microbial composition that varies from person to person depending upon the age, diet , genetic background and many other factors. Textiles material can alter skin and its microclimate , but it also form a microclimate in itself. Fibers leads to formation of microhabitat Freney, J., & Renaud, F. (2012).

Microbial adhesion in Textiles

For the growth of bacteria, adhesion is a precursor for the colonization on the surface of textiles. Different species of bacteria has a different ability to adhere to various types of textile materials. *Staphylococcus aureus.* majorly adhere on Cotton, Polyester and there blends as compare to *E.Coli.* The contact condition between bacteria and fabric also have a larger impact on bacterial adhesion. Factors like agitation, water absorbency and saturated wetting leads to increase in interaction between the bacterial cells and fiber. Factors like hydrophobicity and hydrophilicity also play a major role in adhesion.

Measuring the hydrophobicity of different cell surfaces is important or gaining insight into adhesion on different surfaces. Hydrophilic substrates have a negative zeta potential indicating limited bacterial binding due to the less hydrophobic interaction between the bacteria and textile material. Using these strategy interface can be designed that prevents the adhesion of the bacteria simultaneously solving the problem related to antibiotic administration.

Bacterial adhesion depends on several factors: Varseney, S. et,al. (2021)

1. Physico-chemical characteristics of the bacteria – Bacteria species, surface energy, zeta potential and presence of biofilm.
2. Surface of material - chemical composition, surface roughness, morphological configuration, zeta potential and surface energy.
3. Suspension medium - type of medium, temperature, exposing time, bacteria concentration, surface tension and flow shear stress.

Textile material also consists of specific texture and topography that has a relation with microbes. Bacterias leads to adhere more in rough surfaces as compare to smooth. The reason behind this is rough surfaces has more depressions and consist of larger surface area which increase colonization of bacteria. The SEM study conducted by Bajpai, V. et. al. (2011) demonstrated that bacterial growth is observed more in rough surfaces of the fibers. Microscopic technologies play a major role in studying all the subjects involved in adhesion mechanism between bacteria and textiles.

Bacteria and hygiene

According Malheiro, J.N.M., & Salvado, L.R.S. (2009) textile materials are considered as a pointer of vaginal infections. Underwear and feminine panties are in close contact with the areas of vagina that is perineum area, vulvar skin and genital mucosa. The physiology of vaginal skin is very specific in terms of temperature (34ºC), pH (less than 4.7) and moisture. Vagina consist of microflora that leads to protection against the pathogenic bacteria meanwhile balancing the healthy conditions. Proper washing of undergarments also play a key role in bacterial growth. Generally, underwears are washed at 40ºC because of energy consumption, delicate ness of the fabric and environmental issues but ultimately bacterias are not eliminated and it there are chances of re-infection. Washing at 60ºC leads to elimination of bacteria. In vaginal ecosystem two species of bacteria are frequently found that is *Staphylococcus Aureus.* (bacteria coccus shaped, have capsule and produce slime to attach on surfaces) and *E. coli.* (bacteria bacilli shaped and have nano-fimbriae to attach on surfaces).

In case of hygiene, textile material should balance the skin flora. For the prevention of bacterial development, textile material should offer a bacteriostatic activity instead of bactericidal activity which kills the bacteria. Textile material should not lead to destruction of skin flora. The non-specific immune defenses should not decreased by the textile material.

2.1.13. Studies on Lotus Fibers (Peoples associated)

The process of extracting fibers manually from Lotus petioles is practiced in the few places of the world – Myanmar, Cambodia, China, Vietnam and Manipur.

1. **Bijiyashanti Tongbram**

She is the botany honors resides at Thanga Tongbram village near Loktak lake under Bishnupur district in Manipur. She lives close to the Lotus filled Loktak lake. In July, 2018 Bijyashanti began to collect different varieties of Lotus to establish agrotourism. She learned about the medicinal properties of Lotus during her graduation. But due to lack of machineries she could not able to put her ideas into reality. Bijyashanti joined entrepreneurships training and programmes on aromatic and medicinal plants organized by Micro Small and Medium Enterprises (MSME). She also began her own research work by reading journals and the internet. One of her family friend informed her that there is a possibility of extracting fibers from Lotus stems. In May 2019, she started extracting fibers from Lotus stems and developed clothes from it. She started her own venture – "Sanajing Sana Thambhal".

(Source: https://www.ifp.co.in/2969/how-bijiyashanti-tongbram-from-manipur-weaves-new-fabrics-of-life-from-lotus-stem)

She has mentioned in her different articles that: -

1. Extraction of Lotus fiber is very tedious and labour-intensive process.
2. She is looking for the engineers who can make machine to ease the task of extraction
3. She has been unable to export at present because she still could not produce more products due to lack of manpower.
4. As the Lotus thread is delicate, using machines may not be feasible.

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2. Phan Thi Thuan

Phan Thi Thuan, 65-year-old women from Vietnam has 40 years of experience in practicing indigenous method for preparing silk from silkworms and weaving it into blankets, scarves and dresses. She born in the family making and selling traditional silk to the French during the colonial time. In 2017, she started to extract fibers from Lotus stems. The idea was suggested by Tran Thi Quoc Khanh**,** a member of the National Assembly of Hanoi. Today she has a group of 20 ladies who snap off the stems from the paddies. She extracts fibers by manual spinning process. Thuan also said making Lotus silk is a painstaking job. The craftsmen need to be skillful and attend to the smallest details in the whole process**.**

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3. Samatao Lotus textiles in Siem Riep Cambodia

Samatao Lotus textiles is a Cambodian social enterprise. It is an innovative and socially responsible producer of Eco-fabrics – than supports the livelihood of the vulnerable women of Cambodia. The enterprise started in 2003. The founder of the company is Mr. Awen Dheval. They develop eco fabrics made from Banana, Kapok, Silk, Organic cotton and Lotus. Extraction of the Lotus fiber is done by the hand. It is mentioned that 1 spinner can produce only 250 m of thread. Major risks are: - low production capacity, long production time that discourage many customers and complexity in the entire process.

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2.2. Research Reviews

2.2.1. Researches related to machine mechanism for extracting various minor fibers.

Ahmed, F.E. et.al. (2019) researchers fabricated plant stem fiber extraction machine with less manufacturing cost and high production in Ethiopia. Ethiopia has a leading agricultural economy, there was a high amount of plant stem which have a fiber dumped as a waste farmers often face the problems for the disposal of stems. There are two methods of fiber extraction: Manual Stripping method which is tedious, time consuming and cannot be recommended for industrial applications. Decorticator is a semi-automatic machine which is expensive and available in Ethiopia. Based on the fiber arrangement in the stem, authors fabricated drum unit. The length of the drum was 75 cm and 65 cm circumference. The drum has two surfaces half of the length of drum has a grooved surface having length of 35 cm and grooved gap of 0.25 inches, each groove has a depth of 0.35 inch whereas another half surface have a length of 35 cm in which nails are welded in the gap of 1.2 cm. Groove surface was used to extract the fibers from the plant stem which has a circular shape like papyrus whereas the nail welded surface is used to extract fiber which have a flat surface like banana and sisal plant. 2 HP machine motor with 900 rpm was used connected with the main shaft by two V- Belts. 0.75 mm thick sheet was used to protect machine from danger. The drum consist of shaft for holding the extraction drum at the two edges of the shaft there are two bearing. Motor under the drum has two pulleys: shaft pulley and motor pulley connected to V- belt. When motor starts rotation, the belt will drive the shaft and start extracting fibers from plant stem. It was concluded the cost of the machine fabricated was found cheap compared to automatic electrical fiber extraction machine and cost of the machine was 650 $ as compared to 3500 $ in case of Automatic electrical in the market.

A small-scale portable manually operated sisal decorticator was developed by Tharun, A. et.al, (2020). The main aim of the project was to design sisal fiber extraction machine which can be operated manually with no electricity using Catia V5 R21 modelling software and later stresses and deformations for the different parts of the machine was analyzed by using ANSYS software. The machine consists of blade which squeezes out the pulp out of the leaf and fiber will be left out. The blade consists of blunt edges and rotates at a certain rpm. Sisal leaf are fed to the blunt edges which scrapes out the pulp from the leaves exposing the fibers. Pedal is connected to the machine which is operated by human. To and Fro motion of the pedal converted to rotary motion by the connecting rod which rotates the driver wheel. Driven wheel is attached to the belt followed by the shaft and then to the blade. Results revealed that quality of the fibers extracted was not similar using electrically motor-powered machine and productivity was also found less but the main advantage was the machine is completely manually operated without using any form of fuel or electricity. So the technology was found cost-efficient for farmers and small scale industries.

Prashant, Y., Gopinath, C., & Ravichandran, V. (2014) developed the extraction machine for coconut fibers. The aim of the project was to design and develop a coconut fiber extraction machine for farmers and small-scale coir industries in India to provide an effective solution to the difficulties in existing process, reduce time and labour cost and to develop a compact fiber extraction machine which could be made available to the coir industry directly. The project began with the collection of information and data on user lifestyle and current process by which they perform their job. Interviews were held with the users. Along with this ergonomic simulation was made to understand user difficulty. Five concepts were generated with different functions and operating processes for coconut fiber extraction machine. Five concept was selected by considering the users operating environment and maintenance which could be used in small scale coir industries and farm sector. The machine works with the gear mechanism, in which two barrels rotates in opposite direction to extract fiber from coconut. Cutting pins are inserted in indexed holes to separate fiber and to give linear motion to coconut shell. Validation was carried out with the user’s group and feedback was positive. There was a potential market for this product.

Sinon., F.G. (2015) designed and fabricated machine for making Abaca yarn (Manila Hemp). From the literature, it was found that in the Bicol areas of Philippines woven products like bags, hats, rugs etc. were made from manually twisted multi - stranded Abaca yarn. Twisted multi –stranded yarns were of lower quality because it produces more protruding fibers in the end products. The another process of producing untwisted multi-stranded yarn was also practiced manually. The manual process of making untwisted multi-stranded Abaca yarn was very slow and it also discouraged the youths to continue this yarn making work only the older members practiced this yarn making process. Hence there was need to work on mechanization of the untwisted Abaca yarn making process to increase the production. The objectives of the study were: **a).** to design, construct and evaluate the fabricated machine for the production of Abaca yarn **b).** To find overall cost and return analysis of the constructed machine. Machine was fabricated using locally available materials. The dimension of the machine was 63.5 Cm (Length), 63.5 Cm (Breadth) and 76.2 Cm (Height). The weight of the machine was 60 Kg. The machine was powered by ¼ single Hp electric motor. The machine consists of belt, pulley and gear system. The machine had four major sections: **1).** Power transmission mechanism **2).** Wrapping and Feeding Funnel **3).** Reel for spooling **4).** Mechanism for timing. For operating the machine, raw Abaca fiber were feed into the wrapping funnel and rotating feeding funnel was further attached to bobbin that consist of fine polyester fiber that wraps around the Abaca fiber. It was found that fabricated machine can produce multi stranded Abaca yarn in the length of 1.2 Km which is automatically wrapped in the spool. The timing device releases the locking rod when the length of yarn reaches till 1.2 Km. It was observed that unskilled operator can develop multistranded yarn using fabricated machine at the rate of 380-430 m/h with the production efficiency of 80-95 %. It was analyzed that fabricated machine can have a payback period of less than one year and a Return on Investment (ROI) of 167 % whereas the yarn developed using traditional method has a negative net income due to slow knot tying technique.

The developed yarn was experimented for weaving on loom. Suggestions were taken from weavers regarding the quality of developed multi stranded Abaca yarn. Following were the observations: - **a).** Yarns has low resistance and breakage during weaving **b).** Fabric developed has a smooth surface. **c).** The fabric developed has a neat and clean appearance. It was further recommended by the researcher that pilot testing of the machine should also be done in other Abaca producing communities in the country to promote the fabricated machine and determine the people acceptance for the technology. Further testing for binding (plying) should also be experimented with other natural fibers.

2.2.2. Researchers related to extraction process of minor fibers

Uttarakhand is well known for its biodiversity and people living in the Himalayan region majorly depend on forest resources like fuels, fibers, fodder and medicines etc for their survival. In today's era of sustainability and environmental consciousness, the natural fiber products has shown an outstanding achievements and they have an excellent demand in national and international markets. Murasing, K.K. et.al. (2021**)** conducted the experimental research on effect on altitudes on the mechanical strength of Grewia Optiva a bast fiber in Garhwal Himalaya, India. It was found that villagers of Garhwal region extract these fibers by retting process which were coarser and further used for domestic purposes like mats, ropes and net etc. The fibers were coarser in its natural form so further research was required to develop a fine quality thread suitable for textile products. The research was carried out with that whether the fiber obtained from different altitudes has different physical properties and which particular altitude had the best quality. For selecting study area and sample preparation, completely randomized design (CRD) had been used for villages. Tree branches were collected from the different villages of Tehri Garhwal region of Uttarakhand. Tree branches were collected from three different altitudes: (a) <1000 masl, (b) between 1000 and 1500 masl and (c) > 1500 masl . Fibers extracted from the tree barks of these three altitudes were further named as : T1, T2, and T3. After collecting the raw material from these regions. The branches were water retted for 3-4 weeks and then fibers were separated by dissolving it in gummy and cementing materials. Then the fibers were washed thoroughly and threshold over the stone for the removal of outer cover. After the removal of outer cover, fibers were dried in full sunny days or in hot air oven at 70ºC for 24 hours. Dried fibers were further washed with double distilled water and air dried for the removal of waxes and other water soluble impurities. Extracted fibers were subjected for physical testing at NITRA (Northern Indian Textile Research Association) at Ghaziabhad, Uttar Pradesh. Testing was done as per ASTM D 1577–07 and ASTM D 3822–07. Testing results showed that T3 (51.24)fiber has a higher denier followed by T1(44.62) and T2 (48.76). Fiber which was low in denier has a soft and silky hand. Breaking strength of T3 (189.6) fiber was found higher followed by T1(178.14) and T2(153.27) which indicates that fiber obtained from the higher altitudes has a higher strength as compare to lower altitudes. T2 fibers has a higher values of tenacity followed by T3 and T1. Elongation at break percentage was higher in T3 (2.48) fibers followed by T2(2.32) and T1(2.13). On the basis of experimental results and analysis the following conclusions was drawn – distribution of Grewia Optiva tree was found upto higher altitude ranges of Himalayas and extraction of fibers from the tree branches of higher altitudes has a better results for the use in textiles. It was further suggested that promotion, conservation and cultivation of higher altitude Grewia Optiva tree should be done.

Facho, C., & Sharma, A. (2018) did the study on Helicteres Isora fiber also called Indian Screw Tree which is obtained from outer bark of Helicteres Isora plant. The plant which grow naturally on the embarkments of the grooves of coconut trees as weeds grows very rapidly once cut. There were two objectives of the descriptive study :-a). To document the harvesting, retting and drying process of Helicteres isora fiber and b). To document the traditional usage of fibers. It was found that good quality Isora fiber can be obtained when the plant is 1-1.5 years old. Coarse and brittle fibers can be obtained when the plant is older than 2 years. Plants shoots are harvested during July- September. The harvesting of 50-100 matured trees can be done in a day using sickle. The outer bark of the plant was peeled off after slicing vertically from center and used for extraction of the fiber by retting process. After well retting (15 days) and stream retting (19 days) the fibers were dried in sunlight for 1-2 days. The entire manufacturing of Isora fiber was done by the Velip community of Goa who were engaged in extraction of Isora Fiber. Different types of ropes are produced from the Isora Fiber. Experienced male members of the community was only involved in the entire process. Ropes prepared were sold in the market in large quantities. But in recent years the traditional farming was slowly declining by the due to modern farming and need of these ropes decreased. There were very few family members practicing this indigenous fiber making process for their household and agricultural usages.

An Experimental study on Evaluation of Brassica Fibre for Textile and Spinning was conducted by Khan, R.I. (2016). The common name of Canola is *Brassica.napus L.* It is the largest source of edible oil at Canada. After harvesting, the remaining stems are left as a waste. For the study, 20 different cultivars (varieties) of *B.napus* plants were grown in the Crop Technology Centre (CTC) at University of Manitoba in Winnipeg, Canada. As the bast fibers are highly susceptible to moisture, all the plant stems were conditioned at 21 ± 1 ˚C and 65 ± 5 % relative humidity for 48 hours before retting process as per ASTM D1776. It was observed that retting time of 19 different cultivators of *B.Napus* ranged between 9 to 12 days. The fiber yield % of all cultivars ranged between 6.82 and 13.82. To impart the spinning properties the retted fibers were subjected to three different treatments 1). Treated with alkali followed by acid treatment and final softening treatment with Tubingal 4748. 2). Enzyme treated with pectinase enzyme 3). For the enhanced enzyme treatment, firstly fibers were treated with AATCC 1993 standard detergent and 0.01% Tx-100 (4-octylphenol polyethoxylate) followed by treatment with pectinase enzyme from *Aspergillus aculeatus.* The treated fibers were evaluated for textile and spinning properties. It was found that feel of enzyme treated fibers of all most of the cultivars were supple and soft. Hence it was concluded that enzyme treated Brassica fibers can be used to develop yarn by cotton spinning system. The thermal decomposition temperature of fibers extracted from all cultivars ranged between 225 ºC and 260 ºC. Mechanical properties of fibers was assessed. Tenacity of all the fibers ranged between 0.012 N/tex and 0.085 N/tex. The control retted fibers had a better tenacity as compared to enzyme treated fiber.

2.2.3. Researches related to spinning process of minor fibers

Nettle is a fiber producing plant which is being grown in the Himalayan region. Radhakrishnan, S., & Preeti, A. (2015) developed the fabrics from nettle fibers which is present in outer sheath of the stem and studied its physical mechanical properties. For the study the nettle fibers were collected from the Van Panchayat area of Uttarakhand region and extracted by the bio-retting technique using enzyme Viscozyme L. To determine the enzyme dosage for the extraction of fibers from the sheath on the basis of the parameters like –strength and flexural rigidity, Box and benkhen statistical design Minitab 19 software was used. Results showed good performance at 0.3 % (owm) on the weight of material used. Bioretted fibers were further bioscoured using Scourzyme L obtained by submerged fermentation of genetically modified Bacillus. The unique property of Scourzyme L helped in breaking pectin in the primary cell wall without any cellulose degradation and had no effect on the tensile strength of fibers. Yarns were developed by blending with organic cotton and bamboo fibers using open end systems. The spinning was done in trytex rotor spinning machine at KCT-TIFAC CORE research center. The best optimized blend ratio obtained was 50:50 nettle fiber: organic cotton and 50:50 nettle fiber: bamboo. 8-10 count blended yarns were achieved. For comparison similar count in 100 % organic cotton and 100 % bamboo yarns were used. Four different samples were prepared using by handloom weaving. Control fabric were 100 % organic cotton and 100 % bamboo fabrics which were used in both warp and weft and one set of the experimental fabric was 100 % organic cotton in warp and 50:50 nettle fiber: organic cotton. Another set was 100 % bamboo fabrics and 50:50 nettle fiber: bamboo fiber. Developed yarns were also subjected for testing. Increase in the strength was observed in Nettle:Organic cotton and Nettle:Bamboo blended yarns as compare to the control yarns this may be due to the higher strength of the nettle fibers. Less elongation was observed in the blended yarns due to higher flexural rigidity of the nettle fibers. The experimental fabrics had less drape co-efficient as compare to the control samples due to the coarser yarn count. The values of abrasion resistance, strength and elongation were higher in the experimental fabrics as compare to control fabrics. It was concluded that since count of the yarn developed is very low it can be used for functional articles like file covers and bags and other household textiles.

Consumers today have a high preference for the fabrics made from natural fibers due to the comfort factor and environment consciousness. The major factors like health, waste management and environment awareness is reflecting the renewed interests in the search of newer plant fibers.

Manyam, A., & Alapati, P. (2018) developed the eco-friendly sisal union fabric. Raw Sisal fibers is harsh in feel. Researchers treated the sisal fibers with three varieties of enzymes: Microsil, Sibosof and New smooth in three different concentration of 0.5 %, 1.5 % and 2 % . The recommended pH- 5 was maintained during the enzymatic treatments. The MLR ratio of 1:30 was maintained during the treatment. The fibers were treated with the enzymatic solution in the continuous rotation of 30 minutes. The spinning of the enzymatic treated fibers was done at Southern Group Handloom Unit , Malikipuram. Continuous yarns were produced by the weavers twisting process and further winded in the bobbin and fabrics were developed in handloom. Results revealed that enzymatic treatment improved the texture and lustre of the fabric. The fabric was found smoother and lustrous as compare to 100 % sisal fabric. It was concluded that sisal fibers can be used in apparels both in industry and cottage level.

Hibiscus cannabinus also called as Kenaf cultivated widely in Andhra Pradesh. It requires very less care and water requirement during its cultivation as compare to Jute. Kenaf fiber has excellent properties: it is antimicrobial, resistance to fire and high absorbency. Fiber is unaffected by humidity and has a sound and thermal insulation property. Fiber has a unique carbon sequestration property. Poongadi,B, et.al. (2021) developed the sustainable fabrics from Kenaf/Cotton blended yarns. Kenaf fibers were cut in the length of 1 inch and blended with 30 mm cotton fibers in the ratio of 50:50. Yarns were prepared by rotor spinning system. 12s count Kenaf/Cotton blended yarns were achieved and further subjected for testing. Testing results of the Kenaf/Cotton blended yarns were compared with rotor spun cotton yarns developed as per the standard SITRA norms. The strength and elongation of the Kenaf/Cotton blended yarns was good. The U % evenness of the yarns was 23 % which was found satisfactory for developing fabrics with various weaves. The fabric was developed from these blended yarns in the pitloom. It was observed that strength and drapability of the fabric developed from Kenaf/Cotton blended yarns was less as compare to standard cotton fabric. But the flammability and elongation was high. Hence due to the superior fire resistance quality of the Kenaf/Cotton blended fabrics it can be used in home textiles such as curtains, aprons, sofa covers and kitchen wear.

A study on "Tensile behaviour of Ramie blended yarns" was undertaken by Sett., S. et.al. (2016). In the study, researchers tried to develop the yarn by blending Ramie with Viscose and Pineapple fibers. For blending , all the three fibers were cut in the staple length of 39 mm. Ramie: Viscose and Ramie: Pineapple blended yarns was developed in the proportion of 100:00, 75:25, 50:50, 25:75 and 00:100. Yarns were developed in the cotton spinning machines. Nine different types of yarns was developed: **a).** 100 % Ramie **b).** 100 % Viscose **c).** 100 % Pineapple **d).**75 % Ramie: 25 % Viscose **e).** 50 % Ramie: 50 % Viscose **f).**25 % Ramie: 75 % Viscose **g).** 75% Ramie: 25 % Pineapple **h).** 50 % Ramie: 50 % Pineapple and**i).** 25 % Ramie:75 % Pineapple. All the yarns were tested for different parameters of tensile strength: tenacity, modulus and specific work of rupture. Results revealed that tenacity of 100 %Viscose yarn was higher than 100 % Ramie yarn. As the amount of Viscose yarn increased in the blend proportion the tenacity increased. The value of modulus decreased as the amount of Ramie fiber in the blend proportion reduced but the modulus remains almost same in 50:50 Ramie: Viscose blended yarn. Specific work of rupture increased continuously with the reduction of the amount of Ramie in the blend proportion. Specific work of rupture was higher in 100 % Viscose yarn followed by 25 % Ramie: 75 % Viscose, 25 % Ramie: 75 % Viscose and 75 % Ramie: 25 % Viscose. In the Ramie: Pineapple blended category, the tenacity and breaking extension of 100 % Pineapple yarn was lower as compared to blended Pineapple yarns and 100 % Ramie yarn.

Dhanlaxmi, R.D., & Pujari, K. (2014) explored the possibility of spinning Mesta yarns blended with Organic Cotton in different proportions. Mesta species *Hibiscus sabdariffa* of variety AS73, CP 560 was grown in the Institute of Organic Farming, University of Agricultural Sciences, Dharwad , Karnataka was selected for fiber extraction and spinning. For blending Organic Cotton DHH-11 (Dharwad Hirsutum Hybrid -11) variety was procured. To make the Mesta Fiber pliable and missible with Cotton fibers, it was treated with Jute Batching Oil (JBO). Blending of fiber was done by stack method. Two different blend proportion was prepared that is 60:40 and 80:20 Cotton and Mesta. For comparison 100 % organic Cotton yarn was also prepared. Spinning was done by ring spinning system. Yarn properties yarn count (Ne), Lea Strength (lb), Count Strength Product (CSP), Single Yarn Strength (kgf/tex), Yarn elongation (%), Yarn hairiness (number of hairs/Km) were tested. Results revealed that 60:40 Cotton: Mesta blended yarn was finer (13.52 Ne) as compare to 100 % Organic cotton yarn (8.9 Ne). Lea strength of 80: 20 Cotton: Mesta yarn was found higher than 100 % Organic Cotton yarn but the elongation was found lower. It was analyzed that cost of producing 1 kg of 100 % Organic Cotton was Rs.148.52 followed by 80:20 Cotton: Mesta was Rs.134.08 and 60:40 Cotton: Mesta blended yarn was Rs.128.20. It was concluded from the study that blending Mesta Fibers imparted strength to the Cotton yarn suitable for knits, curtains and draperies. Hence value addition to these underutilized minor fibers encourages the farmers for cultivating these crops for the better income and it also helps in conservation and utilization of these natural resources.

Devi, M., & Das, M.J. (2022) developed the yarn from Pine Needle fiber extracted from the dry leaves of Pine trees. For the study, the dry leaves were collected from the hilly areas of Himachal Pradesh. Extraction of the fibers was done mechanically followed by chemical process. The major obstacle of Pine Needle fiber is its outer layer which consists of silica and resin which was removed by alkali treatment. After extraction of fibers, two blend proportions were tried that is a). 30 % Pine: 70 % Cotton b). 50 % Pine and 50 % Cotton.
For spinning, initially both the fibers were mixed by hand in the two different proportions and then subjected for carding in the mini carding machine. The carded lap was placed in the prototype draw frame for preparing sliver. After getting the sliver it was plied into 4 plies and again fed into the draw frame for doubling. After doubling the sliver was put in the ring frame for converting into the yarn.

Yarn samples developed were subjected for various tests: twist, evenness, imperfections, CSP and lea strength. For the comparison 100 % Cotton yarn of similar count was also tested. It was found that TPI of Pine: Cotton blended yarn was 10.12 slightly lower than TPI of 100 % Cotton yarn that was 11.02. It was observed that Lea strength, CSP, breaking force, elongation and tenacity of 30:70 Pine-Cotton blended yarn was higher than 50:50Pine-Cotton blended. Higher unevenness was observed in Pine-Cotton blended yarns as compare to 100 % Cotton yarns. Woven fabric sample was developed in CCI Evergreen Rapier machine. In warp direction 100 % Cotton yarn of 2/20 Ne was used 30:70 Pine-Cotton blended yarn of 8 Ne was used in weft direction. The developed fabrics was subject for wet processing operations that is desizing, scouring and bleaching. The fabric produced had a Khadi like appearance. It was concluded from the study that Pine:Cotton blended yarns can be used to prepare heavy weight fabrics . It was further recommended by the researchers that 100 % Pine yarns can be produced by the surface modification of fibers.

Himalayan region of India has an enormous wealth of natural fibers which can be explored. Basu, A., et.al (2019) developed the value-added products from Flax and Pine Needle fiber. The most negative point with Pine needle fiber is the Pine Needle fall on the ground every year in huge quantity which later catches fire and become combustible when dried which causes forest fire that leads to huge losses to the people residing in that particular area. For the study Pine needles was procured from the ground of Almora from Uttarakhand for extraction of fibers at NITRA. After the number of trial and error the time, temperature and concentration of the treatment was optimized. After treatment which was fibers were extracted mechanically by rubbing. Testing of Pine needle and Flax fibers was done. It was observed that Pine Needle fibers has low tenacity, good moisture regain value of 12 %. From the SEM analysis, it was found that the fiber structure was not fully cylindrical and it had a rough surface. From the cross sectional view, it was observed that fiber has a hollow structure which leads to high thermal resistance value and water absorbency. Indian Flax fibers physical properties were compared with the European Flax. Almost all the physical properties were similar to the Imported European Flax but the bundle strength (63.49g/tex) of the Indian flax was found higher than that is 40.82 g/tex. Spinning trials was done by blending Pine needle fiber with Cotton in different proportions. Spinning was found difficult with increase of Pine Needle in blend proportion. Preferential loss of Pine Needle Fiber was observed during carding. The yarns with 70:30 Cotton: Pine Needle Fiber was successfully spun into yarns. For weaving these 70:30 Cotton: Pine Needle yarns were initially sized and fabrics were developed. The fabric developed has a unique appearance which can be used to prepare jackets, apparels and home textiles. Flax fabric was produced in the small scale as compare to imported Flax fabrics. It was concluded from the study that value added textile products can be developed from Pine Needle fiber which is available in massive amount in Himalayan region. Utilization of this plant waste in textiles will improve the economy of Indian Himalayan region and also it helps us in reduction of forest fires which leads to huge loss to human and animal lives. The usage of imported Flax fiber can replaced by Indian Flax fiber and it will generate income to the people residing in that region.

Vanishree, S., et.al. (2018) analyzed the properties of Okra/Cotton blended yarn. Okra (*Abelmoschus esculentu.)* is the major vegetable cash crop cultivated throughout the tropical and warm temperate regions of the world. After harvesting, stalks are considered as an agricultural waste which is used as a compost or fuel. Due to harsh and coarser hand of Okra fiber it cannot be 100 % spun into yarns. An attempt has been made by blending the Okra with Cotton for improving its physical properties. MAHY-18 Okra variety was used in the study. Fibers were collected from the stalks by rank retting. BT Cotton was used for the blending purpose. For blending, Okra fibers were cut approximately to 1 inch of length by hand stapling method. Two different blend proportion was tried that is Okra/Cotton – 30/70 and Okra/Cotton – 50/50. Spinning was done by Cotton spinning system at DKTE's Textile and Engineering Institute, Ichalkaranji Maharashtra. Both the blends that is Okra/Cotton – 30/70 and Okra/Cotton – 50/50 was not successfully spun into yarns due to lots of yarn breakages during spinning. Hence the blend ratio of 25/75 Okra/Cotton was produced. From the test , it was observed that TPI (Twist per inch) of Okra/Cotton blended was less that 100 % pure Cotton yarn. Single yarn strength and lea strength of Okra/Cotton blended yarn was found higher than 100 % pure Cotton yarn. Count strength product (CSP) of 100 % pure Cotton yarn showed higher that Okra/Cotton blended yarn. Different types of yarn defects causes difficulty in fabric weaving. Yarn hairiness, thick and thin places, neps was found higher in Okra/Cotton blended yarn as compare to 100 % pure Cotton yarn.

Islam, R.M., Mia, R., & Uddin, A.J. (2022) conducted a study on investigation of performance of Okra fiber in woven fabric. Researchers blended the Okra fiber with Polyester to obtain the Polyester/Okra blended yarn for woven fabric preparation. For the study, naturally available Okra fiber was extracted from Ladies finger farm Dinajpur, Bangladesh. Extraction of Okra fiber was done by water retting process. Treatment was done in the open bath system using 5 g/L NaOH, 3 g/L $Na_2\ CO_3$, 5 g/L H_2O_2, 1g/L sequestering agent and 1g/L wetting agent. The M:L ratio was kept 1:30 as per the weight of the materials. For blending, the treated Okra fiber was cut into length of 38-40 mm and polyester fiber was cut in the consistent length of 40 mm. Three different (Polyester/Okra) blended yarn was prepared – 90/10, 85/15 and 80/20. For the comparison of quality (Polyester/Flax) blended yarn was prepared - 90/10, 85/15 and 80/20. The count of all the yarns were 30 Tex and spinning was done by ring spinning system. Woven fabric in plain weave was produced by these blended yarns. Testing was done in all three stages that is: Fiber, yarn and Fabric stage as per ASTM test standards. It was observed that linear density of Okra fiber was higher than Polyester and Linen. Elongation of the Okra fiber was found lower than Flax and Polyester. GSM and Thickness of the Polyester Okra blended fabric was found higher than Polyester Linen blended fabrics. From the analysis of fabric abrasion test, it was observed that shade change grade 4 was achieved for Polyester Okra blended fabric and

Polyester Linen fabrics. Weight loss was observed in Polyester Okra blended fabric due to the loss of Okra fiber during rubbing. Air permeability of the Polyester Okra blended fabric was found lower than Polyester Linen blended fabrics. The tensile and tearing strength of Polyester Okra blended fabric was found higher than Polyester Linen blended fabrics in the weft direction. It was concluded from the study that as per economical aspect and wide availability of Okra fiber it can meet actual demand of blended fabrics in textile industry.

Ruznan., W.S. et.al. (2020) focused on production of union fabrics from Banana pseudostem fibers. For the study, *'pisang tanduk'* or plaintain species were used. Initially the layers of pseudostem were retted using two different methods: a). Water retting b) Retting with commercial softener. The cotton yarn used for warp direction was also soaked in water and commercial softener individually. After treatment, fibers were extracted from pseudostem by scrapping the layers by hand using steel scraper. Spinning of 100 % Banana yarn was done using electronic hand spinning machine. 100 % Banana yarn were subjected for the testing of yarn linear density and twist. From the testing results, it was found that 100 % Cotton yarns treated in commercial softener has a higher fineness value 239 Tex as compare to 100 % Cotton yarns soaked in water 245 Tex. Yarns made from commercial softener retted pseudostem layers were higher in fineness and TPM (twist per meter). Two different types of union fabrics were developed: a).100 % Cotton yarn in warp (treated with commercial softener) and 100 % Banana yarn made from water retted pseudostem b). 100 % Cotton yarn (treated with commercial softener) in warp and 100 % Banana yarn made from commercial softener retted pseudostem. Union fabrics were subjected for various testing: areal density, thickness, stiffness and flexural rigidity. The areal density and thickness of water retted samples were higher as compared to samples retted with commercial softener. Bending length and flexural rigidity was found higher in weft fabric samples retted with commercial softener as compare to water retted fabric samples. It was concluded from the study that retting banana pseudostem with softening agent has an impact on yarn linear density, area density, fabric stiffness and flexural rigidity.

Tamta, M., & Kalita, B.B. (2020) conducted study on Roselle yarn and its blends. For the study, Roselle plants were collected from farmer's field of Potya Gaon Jorhat , Assam. Fibers were extracted from the bark of the plant by water retting technique. Water retted fibers were degummed at four different concentration: 0.5, 1, 2 and 3 % at different time period from 1 to 2.5 hour. After degumming, fibers were hydro extracted and dried. From the chemical composition analysis, it was observed that alpha cellulose, wax, pectinous matter decreased in degummed and bleached fibers whereas the percentage of cellulose increased. Lignin was completely removed in degummed and bleached fiber.

Yarns in different percentage of Roselle: Ramie were developed in 40's count on Silk spinning system. 50:50 and Roselle/Ramie exhibited highest TPI. 100 % Ramie yarn showed higher tenacity of 20.87 g/tex and 75:25 Roselle/Ramie showed low tenacity. Elongation was high in 100 % Roselle yarn and 75:25 Roselle/Ramie blended yarn. Plain weave fabrics were made from the developed yarns and apparels and household products were developed. It was concluded from the study that blending of Roselle with Ramie opens up the opportunity for producing variety of textile materials for different applications.

Kalita, B. et.al (2017) extracted the textile grade fiber *H. sabdariffa* by decortication method followed by alkaline degumming. For the study, matured plants of *H. sabdariffa* 120 days older was procured from the experimental farm of North Eastern Institute of Science and Technology, Jorhat India. Bundles of decorticated fibers were prepared and degummed with Sodium Carbonate in a M:L ratio of 1: 10 at different concentrations 2.5 %, 5 %, 7.5 % & 10 % at boiling temperature for time durations: 60, 90, 120 and 150 minutes. Degummed fibers were bleached with alkaline Hydrogen Peroxide. Bleached fibers were subjected for softening treatment with V.I Dispersol. From the chemical composition, it was determined that cellulose content in the bleached fiber was found maximum that is 58 % whereas lignin, pectosan and hemicellulose was reduced after chemical processing when compared to raw fibers. Roselle fiber in its raw stage is light golden in color and its length was 100-130 mm which was very suitable for preparing quality yarn. Reduction in diameter and bundle strength whereas fineness increased. The surface of the degummed and bleached was smoother. XRD analysis showed that after degumming and bleaching, the crystallinity slightly increased from 60 to 64 %. FTIR results showed that sharp peaks at 1513 Cm^{-1} and 1320 Cm^{-1} indicates the C = C aromatic ring which show stretching of lignin.

For yarn preparation, five Kg of softened Roselle fiber were sprayed with castor oil in water emulsion to maintain 35 % of moisture and passed through Jute softener machine. Yarn count of degummed and bleached yarn ranged from 37 to 40 tex. Elongation at break and bulk density increased after chemical processing. Hence it was concluded from the study that both degummed and bleached yarn are suitable for apparel and home furnishing.

Tamta, M., & Mahajan, S. (2022) developed apparel from Eri and Ramie blended and union fabrics. Three fabrics were developed in the study: Blended fabric was made from 50:50 Eri/Ramie blended yarns, Union fabric – I made from Eri yarn in warp and Ramie in weft and Union fabric – II was made from Ramie in warp direction and Eri in weft direction. These fabrics were assessed for different end use applications by the panel of judges from the industrial experts from Ludhiana and faculty members of Department of Apparel and Textile Science, Punjab Agricultural University. As per the opinion of judges, three different apparels were constructed: Men's Jacket was made from 50:50 Eri/Ramie blended yarns, ladies top was made from Union fabric – I and men's Jacket was made from Union fabric – II. For the consumer acceptance, products were shown to randomly selected 30 consumers who visited the local apparel shops in posh markets of Ludhiana city for the aesthetic evaluation using 5-point scale ranging from "excellent" to "poor". The parameters of the evaluation was – suitability of fabric, color combination, design, utility and overall impact. Price suitability of the developed products was also analyzed by taking the preferences from consumers to assess the commercial viability of the developed products. Statistical analysis was done by weighted mean Score (WMS) and percentage. It was concluded from the study that developed products were highly accepted by consumers due to the aesthetic and price suitability.

Sannapapamma, A., Vastrad, J.V., &Kulloli, S.D. (2016) conducted the study on Novel Sisal Handicrafts: A sustainable enterprise for rural artisans. The study majorly focused on extraction, spinning, development of value added products from Sisal fibers and building a sustainable enterprise for rural artisans of Dharwad. In the study Sisal fiber (BAS -1) were procured from the Regional Agricultural Research Station Vijaypura, Karnataka. Extraction of the sisal fibers was done by two methods: traditional pond retting and raspador extraction machine. The extracted fibers were subjected for testing of fibre properties: fineness, length and tensile strength using standard method. Fiber extracted by pond retting method showed better results with respect to fineness, length and elongation whereas Tenacity was high in fibers extracted by raspador extraction machine. Extracted fibers were spun using three spinning methods: traditional hand spinning, *medleri charkha* and coco coir spinning machines. Yarn obtained from *medleri charkha* was found good with respect to quality and production efficiency. Yarn prepared by coco coir spinning machine was more uniform and finer as compare to other two spinning system. It was observed that Twist per meter (TPI) of sisal yarns spun on coco coir spinning was more followed by spinning on *medlari Charkha* and traditional hand spinning. Yarn spun on traditional spinning system has obtained the higher tensile strength. Yarn spun on coco coir spinning has obtained lower tensile strength. The developed yarns were further used for the development of handicraft products. Twelve different house utility articles were developed: small bowl, bharini, rope bowl, cowl bowl, flower basket, felt fruit bowl, pen stand, petal bowl, table mats, wall hangings, small hand bags and coil bag. Preferences of the developed products was taken and statistically evaluated by Weighted Average ranking (WAR). It was observed that small bowl and rope bowl were most preferred by the respondents and least preference was given to wall hangings and small hand bags. The making cost of fashion accessories like hand bag and coil bag was found higher as compare to all other products. Hence Sisal cultivation and their activities like fibre extraction, processing and developing value added products opens the employment opportunities for rural peoples.

2.2.4. Researchers related to dyeing of minor fibers with natural and reactive dyes

Nakpathom, M., et.al. (2012) carried out an experimental study on natural dyeing of Hemp yarns with natural dyes. In the study three different types of Hemp yarns were explored. Two yarns were of industrial category of 720 and 1908 denier and another one was hilly tribe hemp yarns of 2295 denier. All the three yarns was dyed with four different types of natural dyes: Lac (*Lacciferlacca Kerr.),* Marigold flower *(Tagetes erecta L.),* Garcinia bark (*Garcinia Dulcis (Roxb.)* and Annatto seed *(Bixa orellana L.).* For the dyeing, Hemp yarns were initially scoured in a solution of 10 g/L Lavenol PA soap and 1.5 g/L Sodium Carbonate and boiled for 1 hour. Extraction of all four natural dyes was done by boiling in water. The weight ratio of yarn to liquor was 1:3 only in case of marigold dye the ratio was kept as 1: 0.5. For Lac and Annatto seeds dye extraction small amount of tamarind paste and sodium carbonate was added. In Lac and Garcinia bark dyeing, Alum was used as a meta mordant in 5 % owf. In case of Marigold flower dyeing, pre-mordanting was done with Alum. Dyeing was done in the open bath keeping Material to liquor ratio MLR of 1:30. Hemp yarns were placed in the dye bath at room temperature and later the temperature was increased. Dyed yarns were rinsed with water and air dried. All the dyed yarns were subjected for several testing for quality evaluation: color strength test in terms of K/S values, reflectance was measured by datacolor 650 spectrophotometer and color fastness test for light and washing. Results revealed that highest K/S values were obtained for marigold flower dye . It was observed that K/S values increased with the increase in yarn size. Hill tribe hemp yarns of 2295 denier have highest K/S values as compared to industrial hemp yarns. Light fastness and wash fastness rating of all the dyed yarns were in the range of poor to fair category. Hemp yarns dyed with Mustard flower, Lac and Garcinia bark has low color staining on cotton and silk fabrics with the grey scale rating of 4-5 and in case of annatto seeds the rating was only 1-2. Based on research results on site training of natural dyeing of Hemp yarns was conducted. Hilly tribal peoples were trained in the project. It was recommended by the researcher further study can be done for improvement of light and wash fastness of Hemp yarns dyed with natural sources.

Gahlot, M., Pargai, D & Bhatt, P. (2019) did the study on natural dyeing of Himalayan Nettle fibers using *Kattha* industry waste. Total three mordants were used in the study. One was natural mordant that is Myrobalan and two synthetic mordants that is Alum and Ferrous Sulphate were used in the study. Three types of mordanting methods that is pre-mordanting, post –mordanting and simultaneous mordanting was applied. Results revealed that Nettle fiber was dyed successfully in material to liquor ratio (MLR) of 1:40 with 6 % dye concentration for 60 minutes at 90ºC. For synthetic mordanted dyed sample, the pre-mordanting method was best suitable whereas for natural mordanted dyed sample, simultaneous mordanting method has a good results. Fastness values of all the dyed samples were satisfactory. K/S value of dyed samples mordanted with Myrobalan was found higher that was 86.366 as compare to un mordanted control sample that is 51.624. Ferrous Sulphate mordanted samples has a higher K/S value of 115.506 as compare Alum mordanted sample that is 112.404. The study will help to increase the market value of Himalayan Nettle fibers.

Amin, A.N.M., et.al. (2021) experimented dyeing of Pineapple leaf fiber using different dyeing techniques and also evaluated its washing fastness. For dyeing, Material to liquor ratio was 1:20. Two different types of dyeing process were explored in the study: a). Exhaustion dyeing b). Infrared dyeing technique. Pineapple Fibers were dyed with two reactive dyes – a). MX Basic Red 310N b).11b Procion MX reactive dyes in red color. Concentration of the dyes were kept 1.0 %. For both the dyeing process, temperature was kept 90ºC for 60 minutes. It was concluded from the study, that fibers dyed with both the techniques has showed a moderate resistance to color change in washing and good to excellent resistance to staining on both cotton and silk fabric. Hence the infrared red technique leads to reduction in cost, water and electricity consumption.

2.2.5. Researchers related to development of knitted fabrics from minor fibers

Asanovic, K.A., et.al. (2022) studied the effect of pilling on Flax knitted fabrics developed with different structural parameters. For the investigation, four different knitted fabrics were prepared from Flax spun yarn of 27×2 tex on flat bed knitting machine CMS 330.6. After knitting, the fabrics were relaxed on flat surface under standard atmospheric conditions. The formation of pilling in all the four samples was evaluated in different number of rubs (125, 500, 1000, 2000, 5000 and 7000). It was observed that for all four fabric samples after 125 rubs, the grade of pilling vary from 4 to 5 (that is very slight pilling). After 7000 rubs the grade vary from 3 or 3-4 (Moderate pilling). It was investigated that variation in structural characteristics did not have a significant effect on formation of pilling. Developed knitted fabrics were also analyzed for compression properties, thickness loss, air permeability, bursting strength and water retention before and after pilling. Overall it was analyzed that knitted fabric sample developed in low stitch density, less thickness, less weight and open structure has obtained **1).** High thickness loss **2).** High Compressibility **3).** Low Compressive resilience/ability to recover **4).** Higher air permeability **5).** Lower water retention **6).** Lower bursting strength after pilling.

Knitted fabric sample developed in high stitch density, high thickness value, heavy weight and compact structure has obtained **1).** Less thickness loss **2).** High compressibility **3)**. Lower compressive resilience/ ability to recover **4).** Less air permeability **5).** High water retention **6).** High bursting strength after pilling. Assessment of overall quality of knitted fabrics was presented through radar diagrams. It was found that sample knitted in moderate compactness has a best overall quality which was further recommended for production of summer clothing. It was concluded that this kind of study will be helpful to the designers to choose proper combination of knitted structure to achieve the excellent quality with aesthetics.

Uzumcu., B.M. et.al. (2011) developed the knitted fabrics from Kapok blended yarns and tested its properties. Six different types of blended yarns were developed: **a).** 80:20 (Cotton/Kapok) **b).** 80:20(Tencel/Kapok) **C).** 80:20 (PET/Kapok) **d).** 70:30 (Cotton/Kapok) **e).** 70:30 (Tencel/Kapok) **f).** 70:30 (PET/Kapok). **G).** 100 % Cotton **H).** 100 % Kapok yarns were developed in RIETER R - 20 open end machine.

Fabrics were developed in single jersey knitted structure in Mesdan lab knitter machine and subjected for various tests: friction co-efficient, air permeability, water permeability, thermal and moisture management (MMT) properties. Evaluation of the handle properties of the knitted fabrics was investigated by 20 respondents. Classification of the handle properties were divided into five grades from 1 to 5. 1 means stiffest and five means softest were statistically calculated by Arithmetic Mean. From the analysis it was observed that with the increase of Kapok fibers in the blend proportion the softness of fabric increased. Amongst all fabrics, 70:30 (Tencel/Kapok) knitted fabric was rated as softest fabric.

Friction resistance is one of the major factor for assessing the roughness and smoothness of fabric. Friction resistance is higher for the rough fabric surface as compared to smooth fabric. Increase of Kapok fibers in the Cotton: Kapok blended yarns lead to the rougher surface and higher friction coefficient whereas increase of Kapok in Tencel and PET blended yarns leads to the smoother fabric surface and lower friction co-efficient. Water permeability is very important factor for thermal comfort properties. Water permeability decreased with the increase of Kapok fiber ratio in Cotton and PET blended yarns. With the increase of the Kapok Fibers in the blended yarns the air permeability values decreased. Moisture Management properties of textiles has the influence on the thermal comfort of human body. The overall moisture management capacity (OMMC) of 70:30 (Tencel/Kapok) was rated as very good amongst all the fabrics. It was concluded from the study that addition of Kapok fiber in the blend lead to softer fabric, increase in friction co-efficient and it also affects the thermal comfort properties. It was also observed that as the Kapok fibers are very short and thin they tend to leave the yarn structure and fabric body so researchers recommended that further research should be conducted to evaluate the change in fiber proportion after washing. Spinning of the Kapok fiber is very difficult due to the smooth surface and short fiber length. Further experiment should be done on higher proportion of Kapok fibers in the blend ratio for spinning of yarns.

Velumani, A., Kandhavadivu, P., & Parthiban, M. (2021) investigated the effect of blend proportion on the mechanical properties of banana/cotton blended knit fabric. Mechanically extracted banana fibers were used for the study. Raw banana fibers were initially treated with NaOH and further softened with 1.5 % of silicon softener. Banana/cotton blended yarns in proportion of 10:90, 20:80 and 30:70 were developed in the Mini TRYTEX spinning frame. The blended yarns were subjected for testing and results were compared with 100 % cotton yarn of the similar counts.

From the analysis, it was determined that with the increase of banana fiber ratio during blending lead to the reduction of breaking strength and uniformity. Four different types of single jersey knitted fabrics were prepared with the above yarns and tested for bursting strength, abrasion resistance, pilling and shrinkage. It was found that 30/70 Banana/Cotton knitted fabric has highest abrasion resistance and lowest bursting strength as compare to all other fabric samples. The knitted fabric from 20:80 Banana/Cotton and 30/70 Banana/Cotton has obtained the pilling grade – 4 (slight pilling) as compare to 10:90 Banana/Cotton and 100 % cotton has obtained pilling grade 3 (moderate pilling) . The good pilling results was obtained with the increase of banana fiber this may be due to the longer fiber length, more bulkiness, rougher surface and hydrophilic nature. Length wise and width wise shrinkage of all four fabrics were tested it was observed that with the increase of banana fiber shrinkage reduces due to the good dimensional stability of banana fiber.

Sanad, S.H. (2011) studied the comfort characteristics of the knitted fabrics made from Flax/Cotton blended yarns. Blended yarns were developed by ring spinning system using different proportion of flax and long staple Egyptian cotton (G80). The main objective of the research was to study the effect of blend proportion and count on the developed knitted fabrics. Three different counts of yarns were developed that is 20's, 30's and 40's. In each count category, four different types of blend proportion was tried that is:- 70 % Flax/30 % cotton, 50 % Flax/ 50% Cotton, 30 % Flax/ 30% Cotton and 100 % Cotton. The similar blend proportions were followed for 30's count and 40's count yarn. All the developed yarns were waxed and knitted in commercial knitted machine. Diameter of the machine cylinder was 8.89 cm (3.5 inch), gauge length was kept 12. Knitted fabrics were prepared at Cairo secondary school of spinning and weaving, Egypt. From the testing results it was analyzed that 100 % cotton knitted fabric has a higher bursting strength. With the increase of the percentage of flax in blending the bursting strength reduces. As the count increased the bursting strength decreases. The results showed that flax blended fabrics has a higher values of air permeability as compare to the cotton knitted fabrics. K/S values of knitted fabrics made from 20 Ne obtained higher K/S values as compare to 30 Ne and 40 Ne. The K/S values of flax knitted fabrics was found higher as compare to cotton knitted fabrics. Ultraviolet protection factor (UPF) values of flax blended fabrics were higher as compare to cotton fabrics. As the count of the yarn increases the UPF factor decreases. Moisture regain values of the flax blended fabrics was found superior as compare to cotton knitted fabrics which may be due to the larger diameter of the flax fibers. Flax blended fabrics made from 20 Ne yarn has a higher moisture regain values as compare to 30 Ne and 40 Ne. Hence the Flax/Cotton blended fabrics found more suitable for dress material especially for summer season.

Knitting technology is the second most widely used technique for fabric making after weaving. Chowdhuary, N., et.al. (2020) developed knitted fabrics from Jute Cotton blended yarn and studied its properties. Knitted fabrics were prepared in flat bed knitted machine. Two different fabrics were developed: - a). Plain single jersey made from 18's count Jute & 20 denier Lycra b). Rib 1/1 structure made from 18's count jute & 40 denier Lycra. Knitted fabrics were subjected for the treatment.

The developed fabrics were passed through the curing chamber at 180-185ºC for 30 seconds to 1 minute in a stenter machine for heat setting. Bleaching of knitted fabrics was done in the jigger machine in the solution containing 2 % anti-creasing agent, 2 % detergent/wetting agent and 1 % sequestering agent. Then natural impurities were removed by treating the fabric with 3 % Caustic Soda and 10 % Hydrogen Peroxide and 1 % Peroxide stabilizer at 95ºC for 1 hour. The fabric were washed with 1 % Peroxide killer at 50º C and neutralized with 1 % Acetic acid at 40ºC for five minutes. The bleached knitted fabrics were dyed in the jigger machine with the combination of dyes – Remazol Red RR ,Novacron Blue and Indofix Black. Dyed fabrics were later softened. In order to improve the feel and to stabilize the fabric it was compacted by steaming at 100-110ºC for 15-20 seconds. Treated knitted fabrics were subjected for various tests to evaluate the quality characteristics. From the testing results, it was observed that weight of the knitted fabrics majorly depend on the loop length and loop density. Spirality, shrinkage, abrasion resistance, pilling of the developed knitted fabrics was found better as per the ISO norms for knitted fabrics. The washing fastness of the samples was found good. The bursting strength and abrasion resistance of rib 1/1 structure was found higher as compare to plain single jersey structure. Hence these Jute cotton blended knitted fabrics can be successfully used as a replacement of synthetic fibers.

Urge of sustainable fibers is the need of an hour. One of the prominent cellulosic seed fiber is obtained from the Milkweed plant. The fiber has many good properties- it has low density and hollow structure which assist for better thermal insulation property. The major drawback of the Milkweed fiber is difficulty in spinning due to smooth surface, low elongation and strength. Karthik, T., Senthilkumar, P., & Murugan, R. (2018) developed Polyester/Milkweed plated knitted fabrics for the application in active wear. In the study, yarns were developed in 20 tex in proportion of 80/20, 60/40,40/60 of Polyester/Milkweed by rotor spinning system in Trytex machine.

It was found that yarn tenacity decreased with the increase of Milkweed fiber. Yarn unevenness, imperfections and hairiness was found high in the blended yarn because the Milkweed fibers were not able to effectively controlled during yarn preparation.

Four single jersey plated knitted fabrics with the unique platted structure were prepared in laboratory knitting machine: 100 % PES, 80 PES/20 M, 60 PES/40 M and 40 PES/60 M. From the fabric characteristics, it was observed that with the increase of Milkweed fiber the fabric thickness increased and GSM decreased. It was determined that with the increased proportion of Milkweed fiber, the air permeability and water vapour permeability decreased as compare to 100 % polyester knitted fabric. The thermal conductivity of the Polyester/Milkweed knitted fabric was found lower as compare to 100 % Polyester knitted fabric which indicate better thermal resistance. Moisture management tester (MMT) is an equipment to analyze the liquid transport properties of textile material. It was observed that knitted fabrics made from polyester/Milkweed blended yarns has high wetting time and absorption rate as compare to 100 % polyester knitted fabric. The parameters in MMT: Maximum wetting radius (MWR) indicates how fastly the liquid is spreading and evaporating over the textile material and spreading speed is defined as rate of surface wetting from the center of the specimen. It was concluded that as Milkweed fiber are hydrophillic in nature when it was used as an applications in bottom layer the MWR and SS showed higher value. One way transport capacity (OWTC) and OMMC (Overall moisture management characteristics) was also tested. 40 % M/PES and PES/40 % M showed higher OMMC and OWTC value. It was concluded from the study that PES/40 % M- means polyester in the top layer and Milkweed as a bottom layer and reversibly 40 % M/Polyester means Milkweed in the top layer and polyester in the bottom layer showed effective moisture management property to be used in next to skin applications, summer wear and active wear.

Hemp is the lightweight, durable, inherently antibacterial, UV protective fiber. The plantation of Hemp consumes less water as compare to Cotton. Its growth rate is also higher that Cotton and Flax. Ramsanthosh, K., & Punitha, V. (2021) developed knitted fabric from Cotton/Hemp blended yarn and studied its properties. Researchers initially did the retting of hemp fibers with maxtray oil and water mixer. For yarn spinning, three different trials were taken.

In the first trail, Cotton/Hemp 60:40 ratio was decided. In blending, MECH cotton fiber variety was used having the staple length of 28 mm and CSP up to 2000. The hemp used for this blend was higher in denier. During spinning, till carding it worked well and then hemp fiber loses the moisture and desired yarn formation was not achieved. In the second trail, researchers reduced the proportion of Hemp fiber in the blend so the ratio kept was 80/20 Cotton/Hemp and the coarser count of 30’s was decided. With this blend ratio spinning process reached till roving operation but difficulties arised in ring frame. Hence the second trial was also failed. In the third trail, researchers analyzed that spinning difficulties may be due to staple length of particular cotton variety and higher denier of hemp fiber. DCH cotton fiber of 3000 CSP and lesser denier hemp fiber was used. Finally the 80:20 Cotton/Hemp yarn of 20’s count was achieved with twist parameter of 3.6. Knitted fabric was developed from 80:20 Cotton/Hemp yarn of 20’s count achieved in third trail of spinning. The fabric was subjected for testing its physical and comfort characteristics. It was evaluated that moisture transmission of 100 %cotton fabrics was 16.524 g/hm^2 whereas Cotton/Hemp blended fabric has a moisture transmission value of 25.234 g/hm^2. The higher moisture transmission value is due to high moisture regain property of the Hemp fiber. Hence Cotton/Hemp blended fabrics can be used in summer wears.

Grewia Optiva (Bhimal) is a perennial multipurpose tree grown widely in the Himalayan regions specifically in Uttarakhand and Kandi belt of Jammu and Kashmir. Each and every part of the tree has numerous applications: a). Fruits are eaten by the peoples b) Leaves are used as an animal feed and fuel 3). Branches are used for making furniture, torches and fiber extraction. Sidhwani., S., Chanana., B., & Bhagat., S. (2020) experimented with Bhimal branches for fiber extraction and spinning. The significance of the research was to obtain standardized extraction method of Bhimal fibers.

Bhimal tree grows in the degraded land which is not suitable for agriculture uses. Hence the researchers explored the possibility of extracting fibers from branches of Bhimal tree and further making it suitable for use in textile. In the study, branch of 5 year old tree was cut in the length of 11-15 inch for retting. Retting was done with alkali ranging from mild to stronger. But satisfactory results were not obtained with alkali. Therefore, retting was tried with different Acids, Sodium Benzoate and Urea. Proper separation and individualization of fibers was found with Urea retting. Hence different concentrations of Urea were optimized based on the yield percentage and bundle strength of extracted fibers. Bleaching of extracted fibers were done using Hydrogen Peroxide at different concentration and time. Optimization of bleaching was done depending on the whiteness index of the treated fibers. Bleached fibers were further softened with Poly Siloxane Softener. After the softening treatment fibers were manually combed with the help of plastic foil cutter.

Blended yarns were developed in three different proportions: **a).**70:30 (Bhimal: Cotton) **b)**. 50:50 (Bhimal: Cotton) and **c)** 50:50 (Bhimal: Viscose). Development of yarn and its testing was done at the pilot plant of NITRA, Ghaziabad. Testing results revealed that 50:50 Bhimal: Viscose yarn has highest fineness (7.64 Ne) whereas 70:30 (Bhimal: Cotton) yarn has lowest fineness (2.98 Ne) with coarser appearance. Strength and elongation of Bhimal: Cotton blended yarns in both proportions (50:50 and 70: 30) was found lower than Bhimal: Viscose blended yarn. Yarn twist of Bhimal: Cotton blended yarns was higher than Bhimal: Viscose blended yarn. More hairy appearance was observed in Bhimal: Cotton blended yarns as compare to Bhimal: Viscose blended yarn. Z twist was imparted in all three types of blended yarns. It was concluded from the study that fine Bhimal fibers can be extracted by Urea retting which is ecofriendly in nature because Urea is non- toxic and mild chemical. Commercialization of Bhimal fibers can be successfully done by the optimized urea retting process followed by bleaching and softening. Yarns developed can be used in craft sector specifically for souvenirs and household products.

2.2.6. Researches related to specific functional properties of minor fibers and its applications

Chopra, S., & Rana, P. (2021) explored the possibilities of extracting fibers from the aerial roots of banyan tree. The species used in the study was *Ficus benghalensis Linn.* commonly considered as a sacred tree in south – east Asian countries specifically India. The extracts of the different parts of the plant is known for its anti-bacterial, anti-oxidant, anti-cancer and anti-diabetic properties. The aerial roots grow and support from the heavy horizontal branches of the tree. These aerial roots become thick and pillar like when they reach towards the soil. Growth of the tree is not affected by the removal of aerial roots because the crown is supported by the prop roots. Pharmaceutical studies revealed that there are many photochemical compounds in the banyan tree - upenyl acetate, α-Amyrenyl acetate, γ-Sitosterol,Palmitic acid, and Lupeol. Considering the waste and medicinal properties of plants, researchers experimented with the aerial roots for extraction of fibers and find its usage in the hygiene products. The objectives of the study was to optimize the conditions of the extraction process of fibers, testing of the extracted fibers for its physical , chemical , antibacterial and anti-fungal properties. Fibers were extracted by different techniques – water retting, treatment with sodium hydroxide, sodium carbonate, urea and enzyme. The extracted fibers were bleached with using hydrogen peroxide techniques. For increasing the pliability extracted fibers were softened using DPT 080.

The extraction by water retting was tried in several durations – 15, 30,45 and 60 days. It was observed that there was no disintegration of epidermal layers till 15 days. Dissolution of epidermis layers was seen only after the 30 days. Cork consist of fibers were visible only after 45 days then the fibers were extracted manually. In 60 days rotting of aerial roots was observed. 45 days duration was best suitable for the extraction of the fibers. During treatment with sodium carbonate the best extraction condition optimized was 5 g/L Na2CO3 at 90ºC for 120 min in the MLR 1:40. While treating it with sodium hydroxide it was observed that the most efficient optimized condition was 5 g/L NaOH at 90°C for 90 min in the MLR 1:40. The best extraction condition while treating it with Urea was found in the concentration of 7.5 g/L with MLR of 1:40 at 90°C for 120 min. Enzyme treatment is considered one effective then chemical treatment because enzymes are substrate specific they remove the gum content of the fibers without attacking the cellulosic portion of the fibers. Aerial roots were treated with 2.5 %, 5 % and 7.5 % Bactosol CBS liquid for 120, 180, 240, 300 minutes respectively at the room temperature of 75ºC at neutral pH -7. The most efficient optimized extraction condition was observed when the fibers were treated at the concentration of 5 g/l at the MLR of 1:40 at 90°C for the duration of 240 minutes. All the treated fibers were bleached with Sodium Hydroxide. In the SEM analysis it was observed pectin and gummy substances was visible. After treating it with Na_2CO_3, gummy substances were all dissolved. High reduction of gummy substances was observed after bleaching. Softened fibers showed high degree of parallelization. Much degradation of fibers was observed in urea treated fibers. The longest length of the fiber that is 6.45 cm was obtained by urea treatment whereas the shortest length of fiber that is 3.47 cm was obtained by water retting because there was incomplete removal of outer layer and lots of breakage of fiber was found during extraction. The finest fiber that is 87.50 denier were obtained by enzyme treatment and coarser fiber that is 124.39 denier was obtained by urea treatment. Maximum elongation of 8.06 % was found in the NaOH treated fiber whereas less elongation of 3.88 % was found in enzyme treated fiber. Extracted fibers has a shown a positive antibacterial and anti-fungal properties which is very rare and unique property in natural cellulosic fibers. Hence it opens the opportunity for the potential usage in hygiene products such as masks, diapers, sanitary napkins nursing pads. It can be used in geotextiles and mi-crobe resistant filling in mattress.

Menstrual hygiene is one of the essential health related aspects in women. Commer-cially available sanitary napkin can fastly absorb the menstrual fluid but it consists of synthetic fibers, regenerated fibers, dioxin and super absorbent polymers which is harmful for the health and environment. Kumar, R.C., et.al. (2020) conducted an ex-perimental study on moisture behaviour properties of Milkweed and Milkweed /Cotton blended sanitary napkin**.** Milkweed is one of the naturally available fibers which has an excellent moisture management property as compare to cotton fibers because of the low density and hollow structure. In the study, the Milkweed fibers was used as absorbent core in sanitary napkins in different blend ratios – 100 % Milkweed , 80/20 Milkweed /cotton, 60/40 Milkweed /cotton, 50/50 Milkweed /cotton, 40/60 Milkweed /cotton and 20/80 Milkweed /cotton with polypropylene spunbond sheet as first layer and polyethylene water resistant sheet as bottom layer. The developed samples were subjected for testing – liquid spreading rate, liquid reten-tion rate, liquid holding capacity under pressure and quantity of the liquid absorbed. Results revealed that sanitary napkins developed from 100 % Milkweed core and its blends showed lower liquid spreading rate and this property assist for vertical wicking as compare to horizontal wicking. This property will assist the lower skin contact with the wet area which will leads to higher comfort to the users. The liquid retention, liquid holding and quantity of the liquid absorbed has shown higher in 100 % Milk-weed core sanitary napkins and its blends as compare to 100 % cotton and its blends due to the unique inherent hollow structure and cellulose content present in the fiber structure.

Mekala, M. (2021) tested the effectiveness of Sansevieria Trifasciata fibers coated with Rosa Damascene extracts for the application in sanitary napkins. Sansevieria Trifasciata is called a snake plant native to Indonesia, Africa and India. Leaves of this plant contain fibrous material. The plant acts as a purifiers, it removes various toxins such as toluene, formaldehyde and xylene from the air. Fibers extracted from Sansevieria Trifasciata leaf are very strong, durable and flexible. The fibers contain 56 % cellulose, 34 % hemicelluloses and 6 % lignin. Due to the functional property, high percentage of cellulose and low percentage of lignin, it finds the potential application in the core layer of sanitary napkin. Antimicrobial activity is the another essential property for the material to be used in the Sanitary napkin. Hence the researcher aimed to test the effectiveness of using Sansevieria Trifasciata fibers using herbal finishing with Rosa Damascene extracts. In the study leaves of the Sansevieria Trifasciata plants was collected from the Vadavalli region of Coimbatore. Herbal finishing was done by immersing the fibers in the microcapsule solution. Scoured and bleached fibers were tested for water absorbency. Herbal finished fibers were tested for qualitative antimicrobial test against four organisms: *Staphylococcus S.P, Pseudomonas sp, E.Coli* and *Candida Albicans.* It was observed that water absorbency increased after scouring and bleaching. Antimicrobial assessment showed higher zone of inhibition in E.Coli followed by *Candida Albicans* and *Pseudomonas sp.* No zone of inhibition was found in *Staphylococcus S.P*. Hence it was concluded from the study that Sansevieria Trifasciata fibers treated with Rosa Damascene extracts can be effectively used in the core layer of sanitary napkin.

The commercially available sanitary napkins are made of synthetic fibers, SAP (super absorbent polymer) and perfumes for fragrance. The disposal of these commercial sanitary napkins causes serious issue in landfill and environment. Tharakeswari. S.,et.al. (2021) developed the ecofriendly herbal finished sanitary napkins using Cotton and Kenaf fibers. For the study, Kenaf fibers was procured from Go Green Products Chennai, Tamilnadu. Sanitary napkins was developed in three different combination where in first layer used was 100 % finished cotton nonwoven and in third layer biodegradable LDPE sheet was used. For absorbent core layers - In type 1 category 100 % Kenaf fibers was used. In type 2 category 100 % Cotton fibers was used and in type 3 category mixture of Cotton and Kenaf fibers was used. For imparting antimicrobial property, the first layer of sanitary napkin that is 100 % Cotton nonwoven web was coated with neem and turmeric extract for 30 minutes by pad- dry-cure method. Citric acid was used as a cross-linking agent between extract and first layer of napkin. All the layers of the sanitary napkin were sealed using thermal sealing machine at temperature of 175ºC. Developed samples of sanitary napkin was subjected for various testing : free swell absorptive capacity, absorbency percentage, retention percentage, liquid strike through time, wet back strike through time, leakage proof test and antimicrobial test was done as per AATCC 147 parallel streak method. Results revealed that 100 % cotton and combination of Cotton:Kenaf absorbent layer has a highest free swell absorptive capacity. Liquid strike through time and wet back strike through time factors was found satisfactory in Cotton: Kenaf absorbent layer due to the combination of the properties of both the fibers. Absorbency percentage was found higher in Cotton: Kenaf absorbent layer. Retention percentage means during any physical activities the sanitary napkin is capable of holding the menstrual fluids. It was observed that Cotton: Kenaf absorbent layer has a highest retention rate of 97.83 %. Leak factor defines the capacity of the sanitary napkin to resist leaking from sides and bottoms. It was found that 100 % cotton absorbent layer has a highest leakage and Cotton: Kenaf absorbent layer has a less leakage problem. Positive antimicrobial activity was found in treated top layer of napkin against gram positive bacteria with a zone of inhibition of 27.5 mm and for gram negative organism the zone of inhibition was 5 mm only. Kenaf fibers were also tested for antimicrobial test it was observed that fibers has a antimicrobial activity against gram positive bacteria but not resistance for gram negative bacteria. It was concluded from the study developed Cotton:Kenaf absorbent layer with herbal finished top layer can be a effective alternative against synthetic fibers which contributes to green environment.

Cost of the sanitary napkin is a very essential factor. It should be affordable for all income group. Mishra, S., Pandey, R., & Singh, M.K. (2016) prepared sanitary napkin using Flax carded waste as an absorbent core material. For the study, Flax fibers were scoured using non-ionic detergent and bleached with Hydrogen Peroxide. Absorbency test of the raw Flax fiber and treated fiber was determined. Flax fibers were treated with Aloevera gel extract in four different concentration: 100 %, 90 %, 80 % and 70 %. Extraction was done by methanolic gel extract using Citric acid as a cross linking agent. To assess the antimicrobial activity several test was conducted – AATCC Test method 147-2004 (Parallel streak method), EN ISO 20645:2004 (Determination of antibacterial activity – agar diffusion plate test), AATCC-30 1993 (Antifungal activity – assessment of textile materials: mildew and rot resistance by humidity jar method) . Prototype of the sanitary napkin was developed as per IS: 5405-1980. The first layer of sanitary napkin was Cotton:Rayon nonwoven fabric. 100 % Flax fibers in scoured and bleached form was used in the core layer. Thrid layer consist of non – absorbent barrier sheet. Results revealed that absorbency of the raw Flax fibers was 14.663 g/g whereas absorbency increased to 20.797 g/g after bleaching and scouring . It was observed that fibers treated in all four concentrations with Aloevera gel extract have a very effective antibacterial activity against *S.aureas.* It was found that fibers treated with aloevera gel extract have a desirable antifungal activity. It was evaluated that average time taken to absorb 20 ml water was 48.4 seconds and there was no leakage observed from sides and back of the sanitary napkin. Disposability of the sanitary napkin was also tested it was found that pad disintegrated in 1 minute and 35 seconds. As per the standard it should disintegration should not be more than 5 minutes. For evaluating the comfort related features : softness and flexibility the wear trail was done. Developed pads were given to group of girls studying in college, working women and housewives. Maximum respondents rated the pads in between 7 to 9 out of 10. It was concluded from the study short fibers of Flax which is the waste after spinning process has a potential to be used successfully in the core layer of the sanitary napkin. It was further recommended that spinning waste of many other natural cellulosic fibers which is available in large quantity can be explored for functional applications.

Corn is the second largest agricultural crop grown globally. Cultivation of corn generates a huge amount of by products such as stalk, leaves and husk. Due to the health risks of synthetic Superabsorbent polymers (SAP) there is a huge demand of bio-sap. Wijesingha, R.A., &Perara, M.A (2017) developed sanitary napkin using natural corn husk waste. From the literature survey, it was mentioned that good quality fibers can be extracted from immature cornhusks rather than dried husks. For fiber extraction, three different natural extraction methods were done that is slow moving water retting, dew retting and stagnant water retting. Chemical extraction method was also tried by heating with different percentages of NaOH solutions, time and temperature. It was observed that good quality Corn husk fibers was obtained by the combination of two retting methods that is initially fibers were dew retted for 2 days and then subjected for stagnant water retting for 10 days followed by washing and again subjected for dew retting for about 4 days. Microscopical view of the raw corn husk fibers was also analyzed. It was observed that cross sectional view of the fibers were heavily porous which may assist for high absorbency and longitudinal view of the fibers were straight. For the development of sanitary napkin, extracted corn fibers were combed. Cotton nonwoven sheet was used as a top layer, core layer consists of corn fibers and polyethylene sheet was used as a water resistant barrier sheet. All layers together were stitched. Developed sanitary napkin was test for – aerobic plate count, pH value and absorbency test as per standard SLS: 111: 2009. Results revealed that average colony count in the developed sanitary napkin was found 92. According to SLS: 111: 2009 standard, aerobic plate count per grams should be less than 1000 for sanitary napkins. Hence the developed sanitary napkin was found suitable in microbial testing. In the absorbency test no leakage was observed in sides and back of sanitary napkin. The pH value of the sanitary napkin was found 6.1. which is considered hygienic without having any adverse effects on skin. It was concluded from the study the Corn fibers can be successfully used in the development of sustainable sanitary napkin fulfilling all the quality parameters: high absorbency, bacterial resistance and pH.

Excessive use of water in the cultivation of Cotton has made the scientists to research extensively on waste bio mass for the source of fiber. Canola is the largest source of oil globally after Palm oil and Soyabean oil. After the harvesting of Canola plant the stems are left as a waste. These stem waste contain fibrous material. Shuvo, I.I. et.al. (2019) developed the textile grade fibers from Canola biomass and investigated its properties. For the research work, four different cultivars of Canola plant were used. Four different varieties: HYHEAR 1, Topas, 5440 and 45H29 were grown in the growth room at Department of Plant sciences, University of Manitoba, Canada. Stalks of four different varieties were water retted at four individual vessels at room temperature. Each vessel contain 5 L of water. Water was further added in the entire retting process to keep the constant water volume of 5 L. A circular lid with the Weight was placed over the stems in the vessel for the complete immersion of the stems in the water. Continuous inspection of the retting was done in every 12 hours to prevent from over retting. During the inspection, stems were regularly flipped in different position to overcome over retting. When the stems were completely retted, a single slit was made along the length of fibers with the fine needle to peel the fiber skin from the entire stem. This manual technique of fiber extraction prevent the fiber loss. The extracted Canola fibers were washed and dried at oven for 8 hours at temperature of

105º C. Due to inherent stiffness of raw canola fibers of all four varieties it was not suitable for evaluation of fiber properties. Hence the experimental model was prepared for the surface modification of water retting canola fibers of all the four varieties. The model consist of three steps : - 1). Scouring with alkali with 5 % NaOH 2). Alkali treated fibers were subjected for acid treatment in 400 ml solution containing 4 % Acetic acid at 60ºC for 30 minutes followed by rinsing and drying. 3). Acid treated fibers were subjected for softening treatment in 400 ml solution containing 10 % Tubingal 4748 at 40 º C for 30 minutes at acidic pH of 4.5 followed by rinsing and drying. The treated fibers of all four varieties were subjected for the evaluation of physical properties:- fiber diameter, fiber density, tensile strength, thermal resistance and moisture regain. Microscopical analysis was done by scanning electron microscopy (SEM). Results revealed that fiber extracted from 5440 species of canola has a longest retting time of 380.3 hours and fiber extracted from Topas species of canola has shortest retting time of 266 hours. Among all the four species, fiber extracted from 45H29 has a highest mean fiber yield of 10.41 % and 5440 species has a lowest mean fiber yield of 9.11 %. Highest moisture regain (7.64 %) was observed in the fiber extracted from the species HYHEAR 1 whereas the lowest moisture regain (6.03 %) was found in the fiber extracted from the species TOPAS. Variation in mean fiber diameter was observed in all four different species. Fiber diameter of species HYHEAR 1 was 86.93± 57.12 mm followed by 81.54± 31.78 mm for TOPAS, 64.38± 26.22 mm for 5440 and 78.37± 47.79 mm for 45H29. Fiber density of all the four species varies from range between 1.34 g/cc and 1.43 g/cc. It was found that density of Canola fibers was lower than Cotton fiber that is 1.54 g/cc. Hence the Canola fiber has a potential for light weight composites suitable for automotive and aerospace applications for the reduction of fuel consumption. The fiber is light weight due to this hollow structure. It can also be used in the manufacturing of light weight geo-textile fabric. Longitudinal microscopical study of the Canola bast fiber was smooth. Hollow structure was observed in the cross sectional microscopical view. Tensile and breaking strength of all the four varieties were ranked as : Topas has a highest tensile and breaking strength value of 1.93, 12.59 gf/tex followed by 45H29 species (12.52 gf/tex), 440 species (1.41, 9.30 gf/tex) and lowest tensile and breaking strength was observed in species HYHEAR 1 that is (1.28, 8.23 gf/tex). Highest thermal resistance of 257.2º C was observed in species TOPAS and lowest thermal resistance value was found in species 45H29 that is 237.6ºC. Hence the conclusions were drawn that textile grade fibers can be achieved by water retting the canola biomass of four different species that is HYHEAR 1, Topas, 5440 and 45H29. Fibers has an excellent moisture regain and light weight properties. These fibers can be used in apparels and technical textiles. It was recommended by the researchers that further studies should be done for developing the standardization of water retting of these Canola fibers and in-depth investigation on fiber properties and structure should be done to develop strategies for getting the desired flexible canola fibers.

One of the important substances in the sanitary napkin is frequently available absorbing material. Sreekumar, S. et.al (2018) designed and constructed a pulverizing unit for obtaining raw banana fibers with maximum absorptivity for the application as absorbent filler in sanitary napkins. The researchers also worked on optimization of the blades of pulverizing unit to get the most absorbent banana fibers. The schematic design of pulverizing unit consists of Circular cutter, Shaft and circular chamber with slot on the upper side. Initially the researchers studied many other pulverizing units which are used to grind similar kind of fibers like Banana. The production efficiency was also recorded by measuring the weight of the raw fibers obtained by the variations in blades of pulverizing unit. It was observed that fiber size decreased with the increase in number of blades in pulverizing unit. Maximum production efficiency of 79.5 % was obtained in 6 number of blades. Production efficiency dropped to 58 % when 7 blades were taken because of entanglement of fiber strands due to closer arrangement of blades. The definition of absorptivity is amount of water absorbed by the fiber under the specified test condition which is expressed in percentage. Absorptivity of the different banana fibers obtained by the variation of blades were tested as per ASTM D 570. The test was done by keeping the fiber sample in water for 10 minutes. The percentage was calculated by the weight difference before and after immersion of fibers in the water. It was found that absorptivity of the fiber increased with the increase in number of blades in pulverizing unit. Absorptivity percentage with seven number of blades (higher number of blades) was 28.7581 % and fiber size obtained was 3.9 mm. It was concluded from the study that raw fibers extracted from this fabricated pulversing unit with optimized number of blades can be used as an absorbent filler in sanitary napkin.

2.2.7. Researches related to development of knitted fabrics

Hemp plantation has many promising advantages to environment: - a). It requires less water b) produces high amount of oxygen c). Its cultivation does not require any pesticides and fertilization d). Due to the roots, plantation of Hemp helps to maintain strong soil structure which further prevents from landslides. Hemp fiber has good physical and functional properties to be used successfully in textiles: 1). Fiber has a hollow structure with large lumen and polygonal cross-section b). It is hydrophilic in nature c). It has good moisture absorbency higher than commercial cotton. d). It has a resistance towards anaerobic bacterias e). Due to the high lignin content, the fiber absorbs 90 % of ultraviolet radiation without treatment. Many researches has been done on yarn, nonwovens and fabric preparation from Hemp fibers. Korhan, S., Aysegul, K., &Goksu., K. (2023) investigated structural and performance properties of knitted fabrics developed from Hemp: Cotton Blended yarns. Three different types of single knitted jersey fabrics was developed in following compositions: a). 90 % Cotton/10 % Hemp b). 80 % Cotton/20 % Hemp c). 70 % Cotton/30 % Hemp. Count of all the blended yarns was 20/1 Ne. For comparison, 100 % Cotton was also developed in same count and fabric structure. All the fabrics were produced in Navy blue color. For assessing the wear and tear properties of knitted fabrics it was subjected for various testing: Washing fastness, rub fastness, perspiration fastness and pilling. Results revealed that all the knitted fabrics has a good fastness property against washing, rubbing and perspiration as per the standards and acceptable values. Pilling properties of all the fabrics was good. Bursting strength of blended knitted fabrics was found lower than 100 % Cotton. It was observed that with the increase of Hemp in the fabric composition the bursting strength reduces. It was suggested in the research paper that further studies should be done on increasing the proportion of Hemp in the knitted fabric composition meanwhile balancing its bursting strength.

Uzumcu., B.M. et.al. (2011) developed the knitted fabrics from Kapok blended yarns and tested its properties. For the preparation of knitted structure, Kapok fibers were blended with three different types of fibers that is Cotton, Tencil and PET in different proportions. Six different types of blended yarns were developed: **a).** 80:20 (Cotton/Kapok) **b).** 80:20(Tencel/Kapok) **C).** 80:20 (PET/Kapok) **d).**70:30 (Cotton/Kapok) **e).** 70:30(Tencel/Kapok) **f).**70:30 (PET/Kapok).

The blending process was done in the MDTA machine. After blending, spinning was done in RIETER R - 20 open end machine. For the comparison 100 % Cotton, Kapok and PET yarns was also spinned. Count of all the yarns was 20 Ne. All the blended and pure yarns were subjected for knitted fabric preparation in Mesdan Lab knitter machine. Fabrics were developed in single jersey knitted structure and subjected for various tests: friction co-efficient, air permeability, water permeability, thermal and moisture management (MMT) properties. Evaluation of the handle properties of the knitted fabrics was investigated by 20 respondents out of which 6 were male and 14 were female respondents. Classification of the handle properties were divided into five grades from 1 to 5. 1 means stiff and five means soft. Results of fabric handle properties were statistically calculated by Arithmetic Mean. From the analysis it was observed that with the increase of Kapok fibers in the blend proportion the softness of fabric increased. Amongst all fabrics, 70:30 (Tencel/Kapok) knitted fabric was rated as very soft fabric.

Friction resistance is one of the major factors for assessing the roughness and smoothness of fabric. Friction resistance is higher for the rough fabric surface as compare to smooth fabric. Increase of Kapok fibers in the Cotton: Kapok blended yarns leads to the rougher surface and higher friction coefficient whereas increase of Kapok in Tencel and PET blended yarns leads to the smoother fabric surface and lower friction coefficient. Water permeability is very important factor for thermal comfort properties. Water permeability decreased with the increase of Kapok fiber ratio in Cotton and PET blended yarns. Air permeability is a test to assess the breathability of the fabric. With the increase of the Kapok Fibers in the blended yarns the air permeability values decreased. Moisture Management properties of textiles has the influence on the thermal comfort of human body. The overall moisture management capacity (OMMC) of 70:30 (Tencel/Kapok) was rated as very good amongst all the fabrics. It was concluded from the study that addition of Kapok fiber in the blend lead to softer fabric, increase in friction co-efficient and it also affects the thermal comfort properties. It was also observed that as the Kapok fibers are very short and thin they tend to leave the yarn structure and fabric body so researchers recommended that further research should be conducted to evaluate the change in fiber proportion after washing. Spinning of the Kapok fiber is very difficult due to the smooth surface and short fiber length. Further experiment should be done on higher proportion of Kapok fibers in the blend ratio for spinning of yarns.

Asanovic, K.A., et.al. (2022) studied the effect of pilling on the quality of Flax knitted fabrics developed with different structural parameters. For the investigation, four different knitted fabrics were prepared from Flax spun yarn of 27X2 tex on flat bed knitting machine CMS 330.6. After knitting, the fabrics were relaxed on flat surface under standard atmospheric conditions. The formation of pilling in all the four samples was evaluated in different number of rubs (125, 500, 1000, 2000, 5000 and 7000).It was observed that for all four fabric samples after 125 rubs, the grade of pilling vary from 4 to 5 (that is very slight pilling). After 7000 rubs the grade vary from 3 or 3-4 (Moderate pilling). It was investigated that variation in structural characteristics did not have a significant affect on formation of pilling. Developed knitted fabrics were also analyzed for compression properties, thickness loss, air permeability, bursting strength and water retention before and after pilling. It was found that as all four fabric samples were developed from same yarn count but the different structural characteristics affect the behaviour of fabrics.

Overall, it was analyzed that knitted fabric sample developed in low stitch density, less thickness, less weight and open structure has obtained following properties after pilling: **1).** High thickness loss **2).** High Compressibility **3).** Low Compressive resilience/ability to recover**4).** Higher air permeability **5).** Lower water retention **6).** Lower bursting strength.

Knitted fabric sample developed in high stitch density, high thickness value, heavy weight and compact structure has obtained following properties after pilling: **1).** Less thickness loss **2).** High compressibility **3)**. Lower compressive resilience/ ability to recover **4).** Less air permeability **5).** High water retention **6).** High bursting strength. Assessment of overall quality of knitted fabrics was presented through radar diagrams. It was found that sample knitted in moderate compactness has a best overall quality which was further recommended for production of summer clothing. It was concluded that this kind of study will be helpful to the designers to choose proper combination of knitted structure to achieve the excellent quality with aesthetics.

Extraction of fibers from agrowaste has gained the momentum for the various applications in textiles. After Rice and Wheat, Corn is the 3rd important cash crop cultivated in India. During processing, corn husk is removed from the cob and burnt. The husk has a potential fiber which can be used for various applications in textiles. The main advantages of this Corn husk waste are its wide availability with no geographical limitation and commercial value. Jain, A., Rastogi, D., & Chanana., B. (2022) conducted the research on Corn husk fibers and developed products for various end uses. In the study husk was collected from fully matured crops of Syngenta Sugar-75 variety procured from Aterna village, Panipat. The extraction of fibers was initiated with alkaline retting. Further retted with xylanase enzyme - Pulzyme HC for improving fineness and softness. It was found that enzyme treatment did not affect much on the strength but there was an improvement in fineness, pliability and flexibility due to the removal of hemicelluloses. The extracted fibers were subjected for bleaching with Sodium Hydroxide to remove the colors. After softening treatment with silicone softnener, fibers were opening easily and its brittleness also decreased. All the treatments were optimized on the basis of time, concentration, temperature, pH, strength and fineness of the extracted fiber . Corn husk fiber has low bundle strength of 1.3 g/d. Moisture regain was 11.3 %. With high water retention property of 199.99%and neutral pH of 6.8. From SEM analysis it was indicated that fiber had a cleaner appearance after treatments and bleaching removed the cementing material between the fiber bundles also the crystallinity index increased after treatment.

Spinning of yarn was done in ring frame and by hand on Amber *Charkha*. Three different types of yarns were developed: **a).** 50:50 (Cornhusk/ Cotton hand spun) **b).** 50:50 (Cornhusk/ Polyester hand spun) **c).** 50:50 (Cornhusk/ Polyester ring spun). The fabric samples were developed from ring spun yarns only as handspun yarn had very less strength with uneven appearance. Fabric was developed in rapier loom using 100 % polyester in warp direction and 50:50 (Cornhusk/ Polyester ring spun) in weft direction. It was not suitable for apparel uses. Corn husk fiber has a similar appearance with Coir fiber so the researchers further make an effort to blend Cornhusk fiber with Coir in the 50:50 blend proportions. It was found that 50:50 (Cornhusk/ Coir) spun yarn was weaker and low elongation as compare to 100 % Coir yarn. But the properties of blended yarn were found similar to soft twisted coir yarn as per the standard. Various home furnishing products like sinnet and corridor mats was developed from Cornhusk/ Coir blended yarns. It was concluded from the study that production of coarser yarn from Corn husk fiber by blending it with Coir can be used in making handicraft products, home furnishings and biodegradable geo textiles. This sustainable approach can further lead to employment generation to rural sector and it also add value to the Corn husk fiber.

Devi., M &Karpagavalli.,V.S. (2022) developed the nonwoven fabric from Bagasse fiber for the application in disposable medical textiles. Nonwoven fabric was developed by blending it Cotton and Viscose in different proportions: **a).** 75:25 (Viscose/Bagasse) **b).**60:40 (Viscose/Bagasse) **c).** 75:25 (Cotton/Bagasse) **d).** 60:40 (Cotton/Bagasse). Nonwoven fabric was prepared by Needle punching method. All the four nonwoven fabrics were subjected for coating using natural herbs: Neem, Turmeric and Lemon. Herbal extracts were coated on the nonwoven fabric depending on heating conditions and further tufting was done with air dry spray method. Coated fabrics were subjected for Antimicrobial evaluation against *E.Coli.* Results revealed that nonwoven fabrics has an antimicrobial property even after three washes. Finally disposable masks and soles were developed from treated nonwoven fabrics.

Aaditha& Jahan., S. (2018) developed needle punched nonwoven material from *Ficus glomerata*. plant fiber which is locally called as "Gular". The plant is majorly found in Uttarakhand. For the extraction of fibers stems of the plant was cut during pruning followed by water retting for 21 days. After retting, separation of fibers from stem was done and further dried in shade. For the complete removal of the extraneous content retted fibers were scoured using 3 % Sodium Hydroxide for 60 minutes. Scoured fibers were subjected for the preparation of needle punch nonwoven fabric. The nonwoven fabric was developed on DILO Machine based on Germany technology. 100 % *Ficus glomerata* nonwoven sheet was developed successfully. Physical properties of the nonwoven fabric: thickness, weight, stiffness, air permeability, tensile and tearing strength was tested as per ASTM and ISI standards. Results revealed that tensile strength, tearing strength and elongation of nonwoven fabric was found more in machine direction as compare to cross direction because fibers were arranged horizontally in the web. The fabric was found more stiff and compact in machine direction as compare to cross direction. The GSM of the fabric was 113.84 $g.m^2$. The nonwoven fabric has low air permeability value of 46.5 $m^3/m^2/m$ due to heavy weight, consolidated structure and punch density. It was concluded from the study that 100 % biodegradable nonwoven fabric can be developed from *Ficus glomerata*. plant fiber. It is an innovative approach towards ecological sustainability and new source of fiber for developing nonwoven products.

Indu., G.K. (2021) studied the characteristics of pure and blended nonwoven material developed from Sisal and Coir fibers. For the study Sisal fiber was procured from Tumkur district, Karnataka and Coir fiber was collected from Central Institute of Coir Technology, Bangalore. Three different types of nonwoven fabrics was developed: **1).** 100 % Sisal **2).** Sisal/Coir – 70:30 % **3).** Sisal/Coir – 30:70 %. For the development of 100 % Sisal nonwoven sheet, initially the fibers was cut into length of 5 inch. and then feeded into the needle punching machine. In the blended nonwoven fabric Sisal and Coir fibers were cut in the length of 5 inch and weighted as per the blend ratio and feeded into the needle punching machine. All the three fabrics were developed in the length of 2 ½ meters and width of 52 inches. Fabrics was tested as per standard test methods for several parameters: - thickness, GSM, air permeability, pore size, absorbency and bursting strength. Results revealed that 100 % Sisal nonwoven sheet has less GSM and thickness values as compare to blended nonwovens. Air permeability factor of the fabric affects the sound absorption property, filtration and thermal properties. Pure Sisal nonwoven sheet has low air permeability values as compare to blended fabrics. Amongst all three nonwoven fabrics, Sisal/Coir – 30:70 % blended material has higher water absorbency of26.8 % and 100 % Sisal nonwoven material has least water absorbency of 15.2 %. 100 % Sisal nonwoven has larger pore size of 1719.53 micron and both the blended samples has a same pore size of 693.83 micron. Higher bursting strength of 22.6 kg/cm2was found in 100 % pure nonwoven fabric followed by 70:30 Sisal/Coir and 30:70 Sisal/Coir blended nonwovens. Developed nonwoven fabrics can have wide range of applications in home textiles, agriculture and geo-textiles.

Gilda., M & Subramanium, V. (2017) conducted the experimental study on preparation of needle punched nonwoven fabrics using three different natural fibers – Coir, Banana and Jute. Initially all the raw fibers were scoured and treated with softener for 12 hours. After softening treatment all the fibers were cut and subjected for the preparation of nonwoven fabric. Seven different types of nonwoven material was prepared :- **a).** 100 % Jute **b).** 100 % Coir **c).** 100 % Banana **d).** Jute: Banana (50:50) **e).** Jute:Coir (50:50) **f).** Banana:Coir (50:50) **g).** Jute: Banana: Coir (33:33:33). All the needle punch nonwoven material was developed in Oskar Dilo machine. For the evaluation of properties all the fabrics were subjected for several tests: visual inspection, fabric thickness and tensile strength.

For the visual inspection of the developed fabrics, opinions were taken from 25 college students of Tamil nadu. It was observed that amongst all the seven nonwoven samples, 100 % Banana has a good appearance and luster whereas 100 % Coir nonwoven was found low in luster and appearance. All the samples has a rough texture due to the inherent harshness of the fibers.

From the physical properties, it was observed that 100 % Coir nonwoven has a highest thickness whereas 100 % Jute nonwoven has obtained low thickness values. It was found the tensile strength was higher in 100 % Jute in machine direction as compare to other nonwovens. Among the blended category, presence of Jute in the blend ratio has lead to improved tensile properties. Modulus was found higher in the Banana nonwoven. Higher elongation percentage was found in machine direction as compare to cross direction in all the samples. Void content and density of 100 % Jute was found higher as compare to all other samples.

Opinions regarding nonwoven samples were taken from several company owners of Tamilnadu. Company owners liked the nonwoven samples developed from eco-friendly fibers than synthetic and regenerated fibers. The study stated that company owners used these nonwoven fabrics for the construction of country boat due to excellent durability and floating capacity.

2.2.8. Researchers related to Lotus fibers

Chen Y., Wu Q., et. al., (2015**)** experimented with Lotus leaf stalk (LLS) produced as an abundantly available agro-waste. Nano fibrillated cellulose (NFC) was isolated by using chemical pretreatment combined with the high – intensity ultra sonification. For the study, Lotus leaf stalks were collected from the constructed wetland located in Fuzhou, China. Lotus leaf stalks were washed with the de-ionized water and cleaned biomass was dried at 100 ºC for 24 h. After drying, the stalks were cut into pieces and grounded to obtain a powdered sample. The isolated nanocellulose obtained was tested for its chemical and morpho-logical characteristics. Results revealed that brown color of the original Lotus leaf stalk powders was completely changed to snow-white appearance after bleaching indicating highly effective removal of non-cellulose components such as hemicellulose, lignin, wax and other extractives. Bleached Lotus leaf stalk sample found enriched with the cellulose content of 91.86 % found highly suitable for the isolation of nanocelluloses. Length and width distribution diagrams of BLLS (bleached Lotus leaf stalk) fibers was calculated by Morfi analysis and results indicated that distribution of fiber length was less scattered in comparison of their diameters. Transmission electron microscopical analysis (TEM)of obtained NFC (Nano-fibrillated cellulose) revealed slender wire-like cellulose fibrils with nano-sized widths of20 ±5 nm favorable for the anti-strophic reinforcing effect and for the network formation at low threshold during nano-composite . FTIR spectra of LLS (Lotus leaf stalk), BLLS (Bleached Lotus Leaf Stalk) and NFC (Nano-Fibrillated Cellulose) samples was carried out. In the increased intensity of 3420 cm-1 the absorption peaks of bleached Lotus stalk (BLLS) and Nano-fibrillated cellulose) suggests more free hydroxyl groups in comparison to raw LLS (Lotus leafstalk). Hemicellulose content was found dominant with the absorption band at 1740 cm-1 representing the stretching of C= O groups these peaks was almost disappeared in Bleached Lotus Leaf Stalk (BLLS). X- ray diffraction indicates NFC (Nano – Fibrillated Cellulose) has a higher crystallinity index of 70 % compared to the value of 61.25 % for the NFC (Nano-Fibrillated Cellulose) isolated from bamboo fibers. Thermal gravimetric analysis revealed that thermal stability of BLLS (bleached Lotus leaf stalk) and NFC (Nano-Fibrillated Cellulose) was found better in comparison to raw Lotus fibers. Derivative thermo-gravimetry analysis (DTG) indicated lower initial decomposing temperature (Ti) of NFC (Nano-fibrillated Cellulose) at 217º C. Finally, it was concluded that nano-fibrils obtained from Lotus Leaf stalk have a great potential as a reinforcement agents in composites.

Win, S. (2020) conducted the study on Lotus fiber production in Sunn Ye Inn, Sintgaing Township, Mandalay region of Myanmar using the descriptive study design. The main objective of the study was to provide more information about the Lotus fiber production in terms of species, morphological characteristics of Lotus plant , harvesting, extraction method of Sunn Ye Inn village of Myanmar because it is the upcoming fiber in the world of textiles and fashion. The study population was 10 respondents from Sunn Ye Inn village especially the women who used to extract the fibers. Qualitative methods were used for data collection. Key informant interview, direct observation, indirect observation and focus group discussion were used. Peoples extracting the Lotus fiber in the surrounding area of Sunn Ye Inn were interviewed. Results revealed that Lotus plant Nelumbo Nucifera Gaertn. (Padonma Kya) in three different colors: white, red, pink were found abundantly at Sunn Ye Innvillage. Petioles were long and rough with distinct prickles. Villagers harvest most of the suitable stems by boat four times a day. The fiber extraction was carried out mostly by women. In the extraction process the stems were wrapped in the water soaked cloth for the whole day to prevent it from drying. Fourty five pieces of stems were put together on a small table and cut with the small knife to extract fiber which reveals 20-30 fine filaments. Later the fibers were hung to dry. One Lotus extractor produces 250 m of thread daily earning 10000kyaats. One pack weight 8-10 grams per day which was continuously transported to Taunggyi and Innlay in Shan state. It was concluded that Lotus plant provides the job opportunities and better income for the villagers of Sunn Ye Inn area of Myanmar.

Hlaing, C.S. (2016) did the anthropological study on Lotus Robe in Kyaing Inlay lake , Shan state (South). The study was conducted with qualitative research method including key informant interview (KII), direct observation (DO), indirect observation (IO), individual in-depth inter-view (IO), focus group discussion (FGD) and participant observation (PO). The aim of the study was to explore the social values on robe made from Lotus fiber. The study conducted in 2013-2014 with 35 respondents from Kyaing Khan village especially the employers associated with Lotus fiber preparation. Results revealed that according to buddhist doctrine when the world came into existence five buds appeared in Lotus plant an each contained a complete set of Thingan Pareikaya (Prescribed items used for buddhist monks). History revealed that a 50 year old women first observed this Lotus fiber. It was considered sacred. There are two varieties of Lotus a plant found: large Kyar Padommar and small Kyar Padommar. Before drawing the fibers women must firstly clean herself and women cannot pull fiber during the menstrual cycle. Drawing fibers from Lotus needs great patience and probably it was not suitable for young women. It takes a long time for drawing Lotus fibers. It was believed that by offering the Lotus fiber robe, it wouldbring prosperity and good health. The robe is only used for the religious item. It was found that Innthar nationals at kyaing khan village adapt their environmentforliv-ingandtryingtohandoverthetraditionalcustomstonextgeneration.

The experimental study on Dyeing of unconventional banana and Lotus fibres with babul bark was conducted by Singhee, D., Makdan,Y., &Dhanania, Y. (2021).For the study, babul barks powder was used to obtained dye by aqueous extraction meth-od using M:L ratio of 1:20 at boil for 2 hours. Scoured samples of banana and Lotus fabrics were pre-mordanted with 10 % owf Aluminium sulphate using M:L ratio of 1:20for30 min and wereexhaustdyedwith90%owfaqueous extract of babul bark using M:L ratio of 1:20 for 30 min and temperature was 100 º C. From the color strength analysis, it was concluded that initially the K/S value of banana fabric was 2.2 with-out any use of mordant and later dye –uptake K/S value increases to 4.3 after mor-danting. In case of Lotus fabric the K/S value of unmordanted sample was 1.7and the value increased to 2.7 after mordanting. Both the fabrics exhibited good light fast-ness, rub fastness, fastness to acidic perspiration whereas as washfastness rating and fastness to alkaline perspiration was poor. Hence it was concluded that both uncon-ventional banana and Lotus fibers can be dyed effectively with aqueous extract of babul bark.

Cheong. D.Y., (2021) developed Bioinspired Lotus fiber-based graphene electronic textiles for gas sensing. For the experimental work, graphene oxide (GO) solution procured from Graphene super-market, Inc. (USA) was reduced chemically. Mor-phological study of graphene oxide (GO) flakes was done using FESEM (Field emis-sion transmission electron microscopy and atomic force micros-copy. The height of Graphene Oxide were investigated using Nano scope Analysis Software.The chemi-cal reduction of Graphene oxide was done using hydriodic acid (57 wt % in H2O), Sodium Bicarbonate (>99.7%) and acetic acid solution. Lotus fiber was extracted from the stem of Lotus plant. The extracted Lotus fibers were dried in a fume hood. Reduced graphene oxide coated Lotus fibers(RGOLFs) was prepared using dip-coating method. The Lotus fibers were soaked in 3g/L Graphene Oxide (GO)solution for 2 hours later it was subjected for chemical reduction using reduced Graphene ox-ide (RGO) flakes under 40 º C for 2 hours. Morphology of the coated Lotus fibers were studied using Scanning Electron Microscopy (SEM). Chemical composition of the fibers before and after treatment analyzed using Raman spectroscopy and X-Ray photoelectron spectroscopy using 563nm excitation laser. Electrical Conductivity of fibers were characterized using the commercial current voltage meter. The developed RGOLF (Reduced graphene oxide coated Lotus fibers) was tested against the exposure of gas molecules. For the test, RGOLF (Reduced graphene oxide coated Lotus fibers) was exposedto various gases in different concentration including nitrogen(>99%N_2), Ethanol(10ppmCO), Acetone (100 ppm C_3H_6O), Ammonia (100 ppm, NH_3) and Nitrogen Oxide (10 ppm NO_2). Bending test of the RGOLF wasconducted using Computer controlled actuating system. Electric current of RGOLF was analysed after 50 cycles of bending. Results of FTIR, XPS and chemical analysis indicates that graphene oxide was very well transformed on the surface of Lotus fiber. Electrical conductivity was investigated using RGOLF consisting of the various diameters of Lotus fibers ranging from 150-300µm. It was observed that higher electrical conductivity was achieved as the diameter of the fiber increases It was concluded that the Bioinspired RGOLF has a potential to be used in various wearable applications which is ecofriendly, cheap and disposable.

The reduction of fossil fuels and rising competition for electricity has influenced the eco-friendly composites made from natural fibers. Thermal Energy storage (TES) has become one of the attracting strategies. Balaji, A. et.al (2021) developed the bio-composite from Lotus stem as a natural fiber reinforcement. Mixer of epoxy resin, hardener and wood flour was developed in the ratio of10:1:0.25 on weight basis. Weight percentage of Lotus fiber used in the composite was 30 percentage. The Lotus fibers were oriented manually in the mould. The developed composite was post cured under the atmospheric condition for 3hours. In order to develop a cuboid block, 6 number of bio-composite plates were fabricated. It was observed from the TGA curve that the thermal stability of the Lotus stem-based bio-composite was deteriorated at high temperature compared to other natural fiber bio composites. It was analyzed from DTA curve that Lotus fiber-based composite has higher thermal stability with effective degradation temperature. The FT-IR plot indicates the most responsive vibration in the O-H group which leads to changes in the hydrogen bonds.

Strong spectrum was observed at peak 2900 Cm^{-1} revealed the changes of O-H stretching which indicates the presence of intermolecular hydrogen bond between the epoxy resin and cellulose present in the Lotus fiber. This intermolecular bond showed the strength of laminates. Presence of CH_2 stretching was observed at high peak of 820 Cm^{-1}. Stretching of C=O was observed at medium band of 1700 Cm^{-1} which indicates the presence of cellulose acidic functional group present in Lotus fiber. CC stretching was observed at both epoxy resin and Lotus fiber in the region of 1500 and 1450 Cm^{-1}. C-O stretching vibration in resin and fiber at peak 2900 $Cm^{-1.}$ Two weak bands were observed at 2100 and 2000 Cm^{-1} which indicates the bending vibration of C-H. The presence of aromatic ring in epoxy resin was observed at peak 1300 Cm^{-1}. Heat storage capacity of the developed bio composite was tested. The heat reduction was observed gradually with the reduction of mass of ice and water from 2.5 kg to 2.3 Kg, 2 Kg, 1 Kg and 0.75 Kg. It was concluded from the study that development of Lotus fiber-based composite can be efficiently used for thermal packaging.

Increasing awareness towards environment is seeking consumers more towards the usage of ecofriendly materials made from natural fibers. Natural fibers has many advantages like biodegradability, causing minimal health risk and low density but they have low mechanical properties and high moisture sensitivity as compare to the synthetic fibers. But the technology of hybridization or blending the natural material with man-made leads to the better cost-effective product. Abhijit, A.V., Thayyil, A.D., & Babu, T.N. (2021) developed the epoxy reinforced composites from Lotus and E-glass fiber and studied its tensile behavior. In the study, Lotus fibers were treated with alkali. About 250 gms of Lotus fibers were soaked in 1 L of 0.5 % of NaOH solution for 30 minutes and fibers were allowed to dry for 3 days at 65 % humidity and at normal room temperature. It was expected that after alkalization the mechanical properties of the fibers will improve as the non-cellulosic components will remove. Two different types of composites were developed: Lotus fiber with epoxy resin (without e- glass fiber) and Lotus fiber with epoxy resin (with e- glass fiber).

Lotus fiber composite (without e-glass fibers) was prepared by layering technique which consists of three layers of Lotus fibers and four layers of epoxy – hardener in the cavity. Fiber to epoxy volume ratio used in the composite was 60:40. Lotus fiber composite (with e-glass fiber) was prepared in the following composition – 2, 5, 2 layers of Lotus fiber, epoxy hardener and e-glass fiber. The fiber to epoxy volume ratio was 45:45. In both the composite, the arrangement of the fibers was done in three different ways: - uniaxially, biaxially and criss-cross manner. Orientation of the fibers in the composites were the prime factor for the achieving the better tensile strength. Tensile strength test of composites were done as per ASTM D638. Results revealed that uniaxially arranged composite (with e-glass fiber) has obtained highest tensile strength of 18.91 MPa whereas criss-cross and biaxial composites showed lower tensile strength of 18.38 MPa and 11.92 MPa. Lotus fiber epoxy composites arranged uniaxially, biaxially and criss –cross directions obtained the tensile strength of 17.15, 13.73 and 9.14 MPa. It was concluded that with the addition of glass fibers the tensile strength of the specimens arranged in uniaxially, biaxially and in criss-cross manner were increased by 10.24 %, 33.82 % and 30.43 %. These composites open up the huge scopes in the medical and textile applications and due to higher tensile strength it can be used for soft carry bags.

Dhama, A., & Singh, S. (2022) conducted the exploratory research on Lotus silk fabric – A luxurious fabric for high Fashion (Indian Silk 30-33). The attempt has been made to study the Lotus fiber with following objectives – Foundation, history and manufacturing process of Lotus fabric, reason of being a luxurious fabric, sustainability of Lotus Silk fabric and its life cycle assessment. To fulfill the objectives researchers did the secondary research. History depicts that Lotus fiber was originally originated from Myanmar and now this fabric making process is practiced by the small cottage industry of Japan, China, Vietnam and India. It is generally practiced by the women due to the expertise and patience. Due to the scare availability and labor-intensive process the fabric has remain exclusive. Manufacturing of Lotus fiber practiced till now is the exhaustive and labor-intensive process. The process starts early morning with the collection of stems from the pond when the flowers are full bloomed to get a good quality fiber. Life cycle assessment revealed that Lotus fibers has many superior properties and advantages as compare to other conventional textile materials but the only disadvantage is high price due to exhaustive and labour intensive extraction process. It was further suggested in the research paper that there should be a comparative study done on Lotus Silk fiber with other natural fibers.

Zhao L., Chen Sheng D., et.al. (2015) did analysis of length and fineness of Lotus fibers extracted by physical method to provide a theoretical basis for the development and application of Lotus fibers. Physical methods were used in this study to extract fibers. 5-6 stalks were taken in bundle cut off at an interval of 3-5 cm then fibers were pulled slowly from incisions. For determining the fiber length, 1500 fibers were measured which were obtained as 500 for tips, 500 for middles and 500 for bottoms of the stem. And it was concluded that most of the fibers length was between 31-50 mm similar to the sea- island cotton which is 33-43mm. Lotus fiber exists in a vascular bundle in the spiral way. The diameter of Lotus fibers from tip part is smaller, bottom part is larger and middle is average. Diameter of the single Lotus fibers is less than 5 micrometer which is similar to the microfiber. Advantage of Lotus fiber will be that it is natural and easily obtainable without the use of technology which can be used in microfiber textiles with soft hand feeling, large surface area and excellent moisture absorption and adsorption capacity.

For the study on “Bioinspired Green Composite Fiber” the researchers Wu M., et.al., (2014) have taken inspiration from the composite structure of cocoon silk and fabricated fully green composite fiber (GCF) using Lotus fiber (LF) and a biodegradable polymer Poly Vinyl alcohol. The PVA solution was simultaneously spread out from the nozzle into a tiny droplet and deposited on the Lotus fiber bundle. Five kinds of twisted Lotus fiber (LF) bundle were prepared which includes single, double, triple, quadruple and the whole LF bundle from the stem. The tensile strength of single, Double, triple and quadruple Lotus fiber (LF) bundle was measured which was 427.7 ± 17.5 Mpa, 381.5 ±50.3 Mpa, 211.1± 29.3 Mpa and 174.6 ± 21.2 Mpa respectively. The Lotus fiber (LF) bundle were twisted in three different twist angles: 10, 15 and 20. The tensile strength of the twisted Lotus fiber (LF) with angle 20 was higher than 10 and 15. So, the twist angle of 20 was selected for Green Composite fiber (GCF). The PVA solution with different concentration (1, 3 and 5 wt.)% was used. GCF with 3 % concentration of PVA had an appropriate thickness of holding the Lotus fiber bundle (LF) together and had the best mechanical strength. For that two different approaches were carried out. One method included the introduction of highly efficient glutaraldehyde (GA) and the other one was heat treatment to PVA matrix. The result showed that when the heat treatment is combined with method of GA cross linking it improved the mechanical properties of Green composite fiber. Hence the Lotus fibers can be used for reinforcement material.

Liu, D. et al., (2009) researchers studied on morphologic structure of Nn (*Nelumbo Nucifera* fiber) at the different growth stages. According to them the leaf of *Nelumbo Nucifera* acts as an organ for gas exchanging and producing nutrition by photosynthesis. In this paper leaf stalk of four different growth stages were investigated such as Cataphyll (distance of leaf and water is less than 50 cm, the leaf wraps tightly and there are hardly any spines on leaf stalk), Primary Expanding (leaf expanding to brink wrapping with few spines), Expanding (Thin leaf and spines on the leafstalk are not acuate and straight) and Metaphase (completely expanded, leaf becomes thicker with waxy layer, dark color and spines of the leafstalk are hard and straight. Four different fiber samples were taken: tracheary element (extracted from the leafstalks which were dipped into the water with airtight container for 30 days at room temperature), Nn fiber (extracted from the leafstalks of all 4 different growing stages by hand with the help of knife), Lotus root fibers (extracted from Lotus root) and petioles which were leafstalks that dried naturally. XRD results of Nn fiber, tracheary elements and petioles showed that the crystal structure was well maintained during preparation of fiber. FTIR spectra of four samples: Nn fiber at first stage, Nn fiber at fourth stage, tracheary element and petioles not change largely except the relative absorption bands. SEM study of Nn fiber in all four growth period showed that in all the stages there was change in the outward appearance of the fiber. In cataphyll stage there was no link between the fibers, due to the drip wax, the links appear gradually with small quantity at primary expanding stage and the quantity of links between the fibers increases in expanding and function metaphase stage. The diameter of the fiber changes in the different growth period of the leaf. When the leaf gets matured the diameter uniformity improved gradually. The cross section observation of Nn fiber showed that it was slightly elliptical or oval with no central lumen like all other natural fibres and its diameter was only 3-5µm. Good absorbent quality and warmth retention property of the Nn fiber is due to the aperture and hole inside the fiber. It was observed from TEM, that the arrangements of micro fibrils of Nn fiber is well organized and the length of the fiber was also longer as compared to Lotus root fiber. Advantage of this Nn fiber will be it can used in the industries.

Cheng, C. et.al., (2017) executed an experimental study on effect of treatment time with hydrogen peroxide under microwave radiation on components, surface morphology, whiteness, moisture regain, removal rate of impurities, fineness, tensile strength and breaking elongation of Lotus fibers. Fresh Lotus stem were washed, dried and cut into 5 cm lengths and 2g fibres were placed in 100 ml of NaOH solution and treated under microwave radiation. Stems were then washed in deionized water to neutral pH. After that fibres were extracted and dried at 50 C. While analyzing the components, the content of waxes and water-soluble substances of Lotus fibres treated with hydrogen peroxide for 25 min increased to 0.03 to 3.48%. The pectin content before treatment was 8.51% and after treatment was 3.49% only. Hemicellulose in Lotus fibers decreased from 19.29 to 9.12% with the increase in treatment time from 0 to 25 min. Lignin decreased from 32 to 25% with the increase in treatment time from 0 to 25 min. The cellulose content in Lotus fiber increased from 33.01 to 60.92% due to removal of non-cellulosic impurities. Removal rate of impurities increased rapidly from 53 to 73% when the treatment time increased from 0 to 10 min and then it reached 77% for 25 min. From the SEM study, it was observed that the surface of raw Lotus fibers was smooth with many longitudinal grooves and diameter ranges from 75 to 80 micrometer whereas the fibers after treatment with hydrogen peroxide for 5 to 15 min was rough with numerous protuberances and diameter changed from 45 to 55 micrometer. The cross- section shape of fibers was irregular and full of wrinkles. The crystallinity and CI of Lotus fibres after treatment increased from 40.94 to 62.60 % and 46.40 to 60.64%. Hence this study opens up the opportunity for the use of microwaves in preparation of Lotus fibres.

Fengyan L., and Hongjun F., (2015) studied the NaOH degumming on Lotus fibers at different growth period. Environmental scanning electron microscopy (ESEM), X-ray diffraction (XRD) and FTIR were used to characterize the surface morphology and microscopic structure of Lotus fibers before and after degumming. The effect of alkaline degumming on tensile properties of Lotus fibers was also investigated. First the Lotus roots were collected from Jinzhou city of Hubei in China. Three samples were taken as per three growth period 1, 2 and 3 which was grown about 3, 4 and 5 months respectively. Lotus fibers were pulled from Lotus root at 3 different growth stages by hand. Fibers were easily pulled by hand with high water content from the fresh Lotus of period 1 but the fineness was limited while in period 2, fibers pulled were plentiful and fineness increased and in case of period 3 there was no difference in comparison to period 2. For degumming fibers were immersed in NaOH solution with 10 g/L, 20g/L and 30g/L and boiled in autoclave with power of 2 kW at 110° C for 1h,2h and 3h then the degummed fibers were neutralized with Hydrogen peroxide of 10 g/L and rinsed with water. XRD analysis indicated that there was obvious increase in peak intensity occurred in spectrum of the degummed samples which indicates transition possibility from cellulose I to cellulose II. FTIR spectra indicated that most of non-cellulose materials were removed after degumming and hydrogen bonds ruptured because during degumming process the penetration of NaOH into the fiber amorphous regions interrupted the inter-intra molecular hydrogen bond. ESEM morphology of Lotus fibers showed that before degumming the Lotus fiber surface was coarse and connected by binding agents like pectin to fiber bundles and after degumming there was no corrosive dents observed in the surface of the fibers which means that binding agents was apparently removed from fiber surface. In case of fiber tensile properties, breaking force before treatment the fibers were stronger but alkaline treatment significantly reduced the strength in any concentration and time because NaOH gradually penetrates the amorphous areas lead to fiber swelling and fibres becomes soft.

Wang, H., & Cao, G. (2011) did the comparative study on structure and thermal properties of sisal fiber and Lotus petiole fiber. The petioles were degummed with 15g/L sodium hydroxide and 6 g/L soap flakes in 100°C for two hours and then the fibers were extracted from the petiole, dipped in 1g/L H_2SO_4 solution and finally washed in deionized water. The surface morphology, thermal characteristics and reactivity of the fibers was studied using field emission scanning electron microscope (FESEM), Thermo gravimetric analysis (TGA) was carried on TG 209F1 instrument and Fourier transform infrared spectroscopy (FTIR) respectively. FESEM showed that Lotus petiole fiber prepared with degumming method was very long in length, there was little gelatin between the fibers that bundled the fiber together, channels and pits was observed on the surface of the Lotus petiole fiber whereas the surface of the sisal fibers was thick, rough and channels observed on the surface was equal in width. The TGA curve showed that : weight loss of Lotus petiole fiber was 8.7 % in the temperature range of 15-103°C due to the loss of absorbed water in the fiber whereas the weight loss of sisal fiber was 1.7 % in 103°C which indicates that the moisture regain of Lotus petiole fiber is more than sisal fibers. The degradation temperature of both the fibres was almost same at 103°C. Weight losses in the range of 230-368°C for Lotus petiole fiber and sisal fiber was 57.16 and 6.2.98 respectively. FTIR showed that: spectrum of both the fibres was same with the absorption peaks at 3361 cm^{-1} and 2900cm^{-1} which was considered as O-H bond stretching vibrations. Hence it was concluded that sisal fibers was thicker then Lotus petiole fiber. Lotus petiole fiber was smooth than sisal fiber. TGA and FTIR results indicated the composition of both the fibers was same with similar law of degradation temperature and absorption peaks

2.2.9. Researchers related to training the community for fiber extraction and spinning.

Banana is an important cash crop of the world. Apart from fruits, banana crops also produce large amounts of biomass in the form of pseudo stems, leaves and suckers. Shahi, V., et.al (2018) did the study on Social and economic empowerment of farm women in banana fibre based entrepreneurship for sustainable income. The paper has listed numerous use of waste pseudo stem like it can be used in making – organic fertilizer, sap-based products, enriched sap, liquid fertilizer, nutrient spray solution (NSS). With the initiative of Krishi Vigyan Kendra, Vaishali district of Bihar which has a large production of banana has started giving training rural farm women on fibre based technology on the wasteful harvested pseudo stem. In the initial training period the fiber extraction was done by hand but the output was very less nearly 250 gm per day. To solve this problem they started the training for fiber extraction by machine in which 6-8 trainees can extract the fibers simultaneously which cut down the cost and one person can extract 2.5 kg of banana fiber per day. Women were also trained for making value added handicraft products. After engaging in the fiber extraction and handicraft making products from banana fiber there living condition improved in all the ways like: financially, self believe, social participation, there physiological status also increased.

Vijayakumar, M., & Manikandan, C. (2020) executed the study on “Role of women employees in Coir making industry”. Coir is the unique natural fibers extracted from the coconut husk and spin into coir yarn. Tamil Nadu is the second largest producer of coir fiber in India. Only one shift was running to due to shortage of labour. To overcome the problem of labour shortage, workers from economically backward North eastern states like Manipur, Assam and Orissa was hired. The objectives of the study were to ascertain the views and perception of the women employees working in the coir industry and to study the present scenario of women employees in coir industry. The study was carried out in Pollachi taluk in Coimbatore district because it has a wide commercial area for agricultural products specially coconuts. For the study 20 respondents were selected as per the convenience and data was collected using questionnaire for basic details. Simple statistical analysis like chi-square, percentage method and ANOVA was used to analyze the data. Results revealed that 100 % of the respondents were working 8 hours per day. It was concluded that most of the women employees have taken the job as a primary and alternative source to meet the domestic expenditure. So it was suggested in the study that role of empowerment of women is more required to lead and upgrade their good health, family and nation.

Pandey, A., et.al. (2020) demonstrated the techniques of low cost fiber extraction and yarn making from nettle plant implemented by G.B Pant National institute of Himalayan Environment (NIHE) in collaboration with its partner organizations in Lingdem and Lingthem Gram Panchayat Units (GPUs)of Dzongu under Khangchendzonga Landscape Conservation and Development Initiative (KLCDI)-India programme. In the study, skill development training programme was organized on nettle fibre based product making and its value addition. Ms. Ongkit Lepcha, local expert was identified to train selected 15 self motivated members of women and self help groups (SHGs) from Lingdem, Laven, Raklu and Kayem villages of Dzongu pilot site. A training programme was organized in two phases. In the first phase, training was organized during December 2018 focusing on extraction of the outer bark, drying, storage methods of raw material and selection and cutting of stem of wild nettle plants. In second phase of training was organized during the month of March 2019. Selected members were trained for yarn making, weaving and various marketable products.