EXPLORATION OF PINEAPPLE LEAF FIBER FOR ENHANCING HANDWOVEN TRADITIONAL TEXTILES OF MANIPUR

Synopsis of Proposed Ph.D. Thesis

By

Ph.D. Research Scholar

Thangjam Roshini

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Guided by

Prof. (Dr.) Madhu Sharan

Department of Clothing and Textiles
Faculty of Family and Community Sciences
The Maharaja Sayajirao University of Baroda
Vadodara, Gujarat

Endorsement from the supervisor

Ms. Thangjam has conducted her Ph.D. research on the topic "EXPLORATION OF PINEAPPLE LEAF FIBRE FOR ENHANCING HANDWOVEN TRADITIONAL TEXTILES OF MANIPUR" under my guidance with the registration number FOF/216, dated 21st January, 2021. She has got the certificate for course work completion. She has done an extensive research on the topic which validates the originality. She has presented her work in all the six month progressive seminar attended by the Department Research Committee, teachers and students of the Department. She has presented a total of eight papers in both International and national level conferences-

1. Presented a paper (oral) entitled **" Waste to wealth: Source of income from pineapple waste"** at the 3rd international conference Global Initiatives in Agricultural, Forestry and Applied Sciences (GIAFAS-2021) at **Shri Guru Ram Rai University, Dehradun, Uttarakhand, India on october17-18, 2021.** ISBN 978-93-5419-016-2
2. Presented a paper entitled **"Creating innovative apparels by designing on looms"** at the virtual international conference: Tracing 75 years of Indian Fashion Post Independence organized by NIFT Gandhinagar on **20th January 2022.**
3. Presented an oral presentation on the topic '**prospects of utilizing bio-waste pineapple leaf fiber for textile products'** at North-east Research concave (NERC) Towards-sustainable Science & Technology, organized by IIT Guwahati, May 20-22, 2022.
4. Presented an oral presentation on the topic '**Pineapple plant as a fiber crop: A natural resource for utilizing in sustainable textile'** at the 4th international conference Global efforts on Agriculture, Forestry, Environment and Food Security,17-19 Sept 2022 at Institute of Forestry, Tribhuvan University, Pokhara campus, Nepal.
5. Oral presentation on the topic **'The journey of pineapple to handloom for making sustainable fashion textiles'** during the international e-conference on Textiles for Advanced Technologies, Textiletech 2022, November 11-13, 2022
6. Oral presentation entitled **'Introducing pineapple leaf fiber as an indigenous yarn for making traditional textiles of Manipur'** during the 34th biennial conference of Home Science Association of India, at St. Teresa's College, Kerala, 15-17 December 2022.
7. Oral presentation entitled **'Experimentation of local natural dyes on 100% Pineapple yarn to produce aesthetic value- added textiles'** during the 1st Indo Japan Textile Research conference, held at IIT Delhi from 27-28th November 2023.
8. Oral presentation entitled '**Pineapple leaf fibre towards the weaving of traditional Manipuri Textiles'** during International conference on innovative advances with indigenous knowledge in Family and Community Sciences, Virtual Mode, 29th November 2023.

She has received Springer Best Paper Award- Oral Presentation on the topic "Prospects of utilizing bio-waste pineapple leaf fiber for textile products", North East Research Conclave organized by IIT Guwahati, 2022. She has attended many FDPs/courses organized by Universities, colleges, and research organization. She has done a training on extraction of fiber from pineapple leaf at CSIR-NEIST, Branch Laboratory of Imphal, Manipur from 01-06-2022 to 29-07-2022.

Her research paper has been published entitled **"Empowering the farmers and the weavers: The economic and social role of pineapple leaf fibre"**, *International Journal of Agriculture Extension and Social Development, Vol.7 (1), 2024, 342-345.*

Other two research papers have been submitted for publishing in journals**- "Experimentation of local natural dyes on 100% Pineapple yarn to produce aesthetic value- added textiles"** during the 1^{st} Indo Japan Textile Research conference, held at IIT Delhi from 27-28^{th} November 2023.

"Textiles from Pineapple Leaves: A Green Approach from Farm to Loom" WRET-2024, International conference on Waste Recycling and Environmental Technology, 8-9^{th} February, 2024 organized by Babasaheb Bhimrao Ambedkar University Vidya Vihar, Lucknow, India.

Synopsis is approved by

Prof. (Dr.) Madhu Sharan	Prof. (Dr.) Uma Iyer
Guide	I/C Head & Dean

Department of Clothing and Textiles
Faculty of Family and Community Sciences
The Maharaja Sayajiaro University of Baroda

Chapter-1

1.1 Introduction-

Northeast India is a region surrounded by beautiful nature. Northeast states of India have a rich source of natural resources. Northeast India is well known for its different cultures and traditions. Like other northeast states, Manipur plays an important role in the handloom industry. Weaving plays a major role in the socio-economic status of Manipur. Weaving on handloom is undeniable in making traditional textiles. The use of local raw material mulberry silk plays a key role in the handloom industry of this state. However, due to the increase in exploration, people are ready to experience new things. Likewise in handloom, they are ready to explore new raw materials which are natural resources for weaving to a greater extent.

Pineapple grows abundantly in that receive high rainfall like West Bengal, Assam, Manipur, and other northeast states, the Western Ghats, and coastal areas like Goa, Kerala, and Karnataka. The 'Philippines' and 'Thailand' have the right climate for pineapple.

Pineapple is one of the main products of this region in India. The fruits are being exported to other parts of the country. The pineapple plant, Ananas comosus belonging to the Bromiliaceae family is widely cultivated for the fruits. This is the most important commercial crop of the state. The state stood 2nd in area and 5th in production wise of pineapple fruit in India according to the National Horticulture Board, 2017-18. Its fruits are extremely used for canning, manufacturing juices and squashes and also for fresh consumption. Not only its fruits but textile fibre can be extracted from its leaves after harvesting.

Pineapple leaf fiber (PALF) is a natural cellulosic minor fiber extracted from pineapple leaves. The pineapple leaf is currently being wasted in the state after harvesting fruits. The fiber derived from the leaves are long, with one of the best fineness and lustrous like silk which make them suitable for many textile applications. Manipur has a fame in the industry of handloom and textiles, the main materials used in weaving traditional textiles of Manipur are cotton and silk. Silk is expensive to buy and requires rearing practices for producing fiber. The cocoons and silkworms are not easy to deal with in the rearing even a smell from incense sticks can kill them. Since silk is expensive, the textiles produced from this fiber can only be worn on special occasions by people who can afford it. The research wants to introduce alternate fiber in the traditional weaving of Manipur which gives a similar appearance to silk at less expense and also utilises the natural resources available locally without much skill training.

Statement of problem-

Large amount of agricultural waste are generated from our agrarian country, India. This amount of waste will be definitely increase since the country becomes the most populated country in the world, there will be rising demand of agricultural products also. Agricultural wastes are the residues of plants left in the farm after harvesting the food. These waste can be utilized in many aspects and utilization of these agro-wastes in making textile fibre is one of them. Different types of fibres can be extracted from different parts of the fibrous crop plants like bast, leaf, seeds, pseudo stem fibre. The extracted agro fibres can be alternative to harmful synthetic fibre in textiles. Lots of agro-wastes are available in north-eastern region of India since the regions' main occupation is agriculture. Pineapple plantation is one of the major agricultural crops in the north-eastern states and Manipur has large contribution in the production of this fruit crop. Therefore, abundance of pineapple leaves are available after harvesting in the state as the only purpose for cultivating this plant is its fruits. Extraction and utilization of pineapple leaf fibre in making Manipuri textile products can be done leading towards vocal for local.

Rationale of the study-

Lots of agro-waste Pineapple Leaf are available local in Manipur. After consumption of Pineapple fruits leaves being wasted. Utilizing this waste will help in economic growth as well as contribute in eco-friendly materials for textiles product. Its production, processing and export will be major source of the livelihoods of small-scale farmers and daily-wage workers. So, the researcher wants to experiment with PALF to utilize the raw material for these textiles by retaining the skills of the weavers. Also it will be an alternate to the conventional fiber silk .The fiber will be sustainable and even cost-effective in course of time. As pineapple is abundantly grown in Manipur, Researcher desires to work on the utilization of this plant into weaving industry of the state which is one of the rulers of handloom in India. People of Manipur want to try new materials without compromising on the traditional textiles. Even they are trying to incorporate new raw material for weaving but without scientifically.

Objectives-

1. To study the present status of availability of pineapple leaf fiber in India.

2. To test the properties of extracted pineapple fiber.

3. To modify the fibre for producing pineapple yarns for the traditional textiles and surface ornamentation.

4. To develop union fabric samples on handloom using the produced yarns as weft with silk/rayon/cotton yarns as warp.

5. To study the properties of the samples produced.

6. To produce colour palettes with reactive & locally available natural dyes used in making the traditional textiles.

7. To develop the traditional textiles of Manipur using Pineapple leaf fibre yarns and study the acceptance.

8. To create awareness about the use of pineapple waste in the area of textiles.

Hypothesis-

1. Null Hypothesis- 100% pineapple leaf fiber without modification is suitable as textile fiber

Alternate hypothesis- 100% Pineapple leaf fiber without modification is not suitable as textile fiber

2. Null hypothesis- Traditional textiles using pineapple leaf fiber will not be accepted by the consumer

Alternate hypothesis- Traditional textiles using pineapple leaf fiber will be accepted by the consumer

Delimitation-

The study is delimited to hand woven traditional textiles of Meitei community of Manipur

Scope of the study-

- The study will provide help to the local pineapple growers in Manipur with respect to utilization of agro-waste leaves after harvesting fruits.
- Generate skill and income to local weavers of Manipur with the fiber extracted from the leaves.
- Fibre extraction can be done with manual extraction or machine extraction. For bulk production, one can extract the PALF fibre with the help of machine. Decorticator (extractor) are available in research institute and extractor machine producer.
- From the extracted fibre spinning process can be carried by the local weavers for preparing different yarns according to the requirements in making the traditional textiles of Manipur.
- One can achieved yarns similar to silk by joining the ends of strands and spinning.
- Motorized machine can be utilized for spinning as an alternative to conventional charkha.
- Using pineapple leaf in making traditional textiles will not only get sustainable textiles but also sustain the traditional practices of weaving.
- Innovative traditional textiles will be achieved by exploring pineapple fiber as an alternative to the existing raw materials for making traditional textiles.
- Help local people to utilize their available resources and produce them into valuable products.
- The locally produced traditional textiles from pineapple leaf fibre can be marketed through handloom industry of the state government which will be benefitted for the state to promote its own local products to other states as well as industries.
- Application of value addition in stage of yarn preparation and weaving can be provided to get more attention from the consumer such as providing different plant dyes and surface ornamentation.
- Apart from traditional textiles, fashion garments can be constructed using the pineapple fabric for global market.

Chapter-2

Review of Literature

Extensive literature was reviewed related to this study. The researcher has gone through various books, articles, research papers, thesis, and dissertations available in the libraries of Hansa Mehta library of The Maharaja Sayajirao university of Baroda, Department of Clothing and Textiles library, Faculty of Technology and Engineering of The Maharaja Sayajirao university of Baroda and from websites of Indian Council of Agricultural Research, Krishi Vigyan Kendra, Govt. of India, INFLIBNET-Shodhganga, Council of Scientific and Industrial Research- Northeast Institute of Science and Technology, branch laboratory- Lamphelpat, Manipur.

The reviewed literature has been presented under following headings

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2.1.1.3 Pineapple cultivation in Manipur

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2.2.1 Natural minor fiber

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2.2.4.1 Threads used in surface ornamentation

2.2.4.2 Sewing threads

2.1 Theoretical review

2.1.1 Production of pineapple

2.1.1.1 Production of pineapple across the globe

According to the National horticulture board's Pineapple report (2002), the estimated annual production of pineapple (Ananas comosus) is 14.6 mollion tones fruits. India became the 5^{th} largest pineapple producer with a yearly production of about 1.2 million tones. Thailand, Philippines, Brazil, China, Nigeria, Mexico, Indonesia, Colombia, and USA were the main producers of pineapple. The area of pineapple cultivation increased by 35% during the year 1991-92 to 2001-02 whereas the rate of production increased by 54%. The main exporters of this fruits are Philippines, Mexico, Brazil, Taiwan, Malaysia, and South Africa. While leading in imports are France, Japan, USA, Italy, Germany, Spain, UK and Canada. The export of India has been increased from 138tones to 837tones during the span of 1991-92 to 2001-02 year. Majority of the world production is used in canning industry since the trade for fresh consumption is limited.

2.1.1.2 Pineapple production in India

As per the report of Krishi Vigyan Kendra on Pineapple, the pineapple cultivation is suitable to high rainfall and humid coastal areas and North Eastern states of India. Commercial producers of pineapple are Assam, Meghalaya, Tripura, Mizoram, West Bangle, Kerala, Karnataka and Goa. The fruit juice is being exported to countries like Nepal, UK, Spain and UAE. The pineapples provide many health benefits like immune and digestive systems, bromelain enzyme from the fruit is good for aid digestion, help in the treatment like Dyspepsia, bronchitis, high blood pressure and arthritis. The ideal temperature this plant cultivation is 20^{o}C to 36^{o}C with humid climate and soil pH should be acidic in nature (5.5 to 6). Sandy loam soil are best and heavy clay soil should be avoided. The most common variety cultivated in India are Kew, Giant Kew, Queen, Jaldhup, Mauritius and Lakhat. Giant kew and Queen are mostly found in Northeastern of India. Pineapple usually flowers after 10-12months old after flowering another duration of 3-6months is required for harvesting. Full ripe fruit is usually harvested for the fresh consumption but for canning, when bottom half of the fruit turns yellow is suitable. Mealy bug and hear rot are main pest and disease respectively however, no serious pest or disease is found in the country.

Fig.1: Variety of pineapple grown in India

2.1.1.3 Pineapple cultivation in Manipur

On 21st July 2008 at Andro in Imphal East district of Manipur, India celebrated its first ever Pineapple Festival.More than one lakh of the spiky however juicy fruit had been reportedly produced. With the effort of a committee- Andro Kendra Development Committee, the 'FirstManipur Pineapple Fair cum Youth Festival' was held at Thambalnu Market of Andro. Imphal east district becomes the largest producer of this fruit among all the districts of Manipur. For the last six decades, the Ngarian community, Andro and its surrounding of Manipur have been cultivating pineapple as their major source of income.A local resident Khamzathang, Second World War soldier and the chief of Bunglon village says, "The pineapple cultivation was first started in Manipur by Pu Songpu Gangte at Khousabung area in the district-Churachandpur, in the year India won her independence. (Pineapple festivals - www.pineappleindia.com)

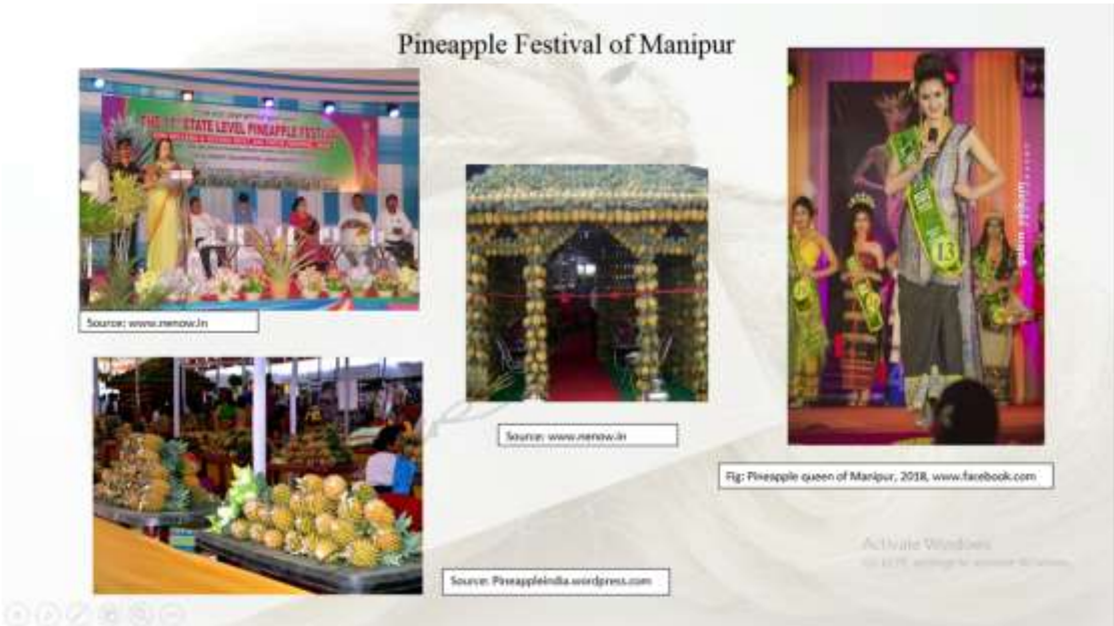


Fig.2: Pineapple Festival in Manipur

2.1.2 Pineapple leaf fiber

2.1.2.1 Pineapple leaf fiber extraction

Pineapple leaf fibre is extracted from the leaves of the plant after harvesting. It has very short length stem which produces a leaves rosette at first and elongates its spirally arranged fibrous leaves said by (Doraiswami, I., Chellamani P., & Gunasekaran, R. (1993)). The length of the leaves varies from 3 feet to longer, width is 2-3 inch, sword in shape, fleshy and dark green. From these leaves, strong, white, lustrous and shiny fibres are produced. Yield percentage is generally from 2% to 3% of the leaves weight. The chief producers of the fibre are Philippines and Taiwan. Brazil, Hawai, Indonesia, India and West Indies are also the producer of the fibre. It is estimated that India covers 87200 hectares of land for the cultivation of pineapple. Fibre yield could be approximately 6 lakh toones per year if proper extraction method is adopted. Pineapple leaf fibre could be extracted from the leaves by means of mechanical or retting process. After one year old, leaves can be used for the extraction. By using a decorticator, machine extraction can be done. The machine extraction involves scrapping of the hard outer layer. Machine used for this work is known as Raspador machine. SITRA has developed a semi-automatic Raspador. The yield capacity of this machine is 5kg of fibre per 8 hr. The machine has been already licensed for the commercial production. Degumming of the fibre is done to soften and make finer by using acids, alkali or enzyme. The linear density of the degummed fibre was range from 16 to 20 denier.

2.1.2.2 Pineapple leaf fiber properties

Pineapple leaf fibre is white in colour, smooth, and glossy appearance like silk, the length is medium and the tensile strength is high. The fibre has soft surface, good absorbency, maintain a good colour when compare to the other natural fibre. It is hydrophilic in nature because of the high content of cellulose. PALF conatins many chemicals composition. The multicellular of the the fibre has polysaccharides, fat, wax, pectin, lignin, uronic acid, anhydride, pentosan, colour, pigment, inorganic constituents. The cells of fibre are joined by pectin. The arrangement of fibre is same as cotton fibre and the cellulose content is 70-82%. The tensile strength of the fibre is greater than jute fibre when the yarn is prepared. Considering the properties of the fibre, it can be utilized in making the reinforced composite material. PALF works well with synthetic fibres because of its economical and biodegradable. The superiority of the fibre mechanical properties is associated with the high value of alpha-cellulose content with low microfibrillar angle (14∘). (Asim, M., Adam, K., & Jawaid, M., & et. al. (2015))

2.1.2.3 Pineapple leaf fiber in textile application

The determination for cultivating the pineapple is the fruit consumption. After harvesting the fruits, use of leaves for manufacturing fibre is also a good commercial sense. Now eco-lover designers are making an effort to move away from synthetic fibre. By tradition, pineapple silk from the leaves of the plant are considered as the 'queen' of Philippine fabrics and the pina fabric is choice of the Philippine elite. Generally, the fiber from the Red Spanish fiber is used to hand weave the fabrics which is worn as the traditional embroidered Philippine formal shirt *Barong Tagalog.* The other varieties Formosa and Cayenne are also used for obtaining the fiber. Pineapple textiles were popular in the world, but later it came along with cheap cotton competitor and consequently stopping pina textile manufacture. Pina has only been rejuvenated in the last two decades or so due to consumer demand for alternative natural fibers. (www.sustainable-fashion-collective.com, 2019)

2.1.3 Woven Traditional Textiles of India

"Textiles serves as a non-verbal form of communication and when decorated as defensive talismans, motifs, colours, and composition impart ones identity and occupation, and very frequently social status." (Askari, N., & Crill, R. 1997)

Expression of Indian in textiles has always been influenced of countryside's topography, climate and natural resource like water, salt and minerals. The origin of the Indian textiles can be found from 2500-1500 BC along the holy Indus valley. People of the Indus valley had the advanced knowledge of colour fixing, dyeing and manufacturing procedure of textiles. Furthermore, there is evidence that Mohenjo Daro People knew about the art of cotton cultivation and transforming the cotton balls into woven fabrics for protecting their bodies. (Karolia, A. (2019)

2.1.4 Handloom of Manipur

Manipur is one of the Northeastern states of India, with the capital city of Imphal. It is bounded by Nagaland to the northern side, in the south by Mizoram, and Assam to the west, Myanmar found in its east. Manipur is the land of numerous groups of people speaking various dialects and languages having various cultures and traditions.

2.1.4.1 Raw materials of Manipuri handloom

In the report of Bahadur, M. by E pao- Tribal people in Manipur grew cotton for weaving their essential textiles. The use of cotton by the tribals has been reported long back. As an annual tribute to the king Khagemba (1597-1652 AD), his people paid cotton. However, during 1950s the staple fibre yarn was imported from outside Manipur. The tribal people shifted their raw material to acrylic wool in the period of 1960s to 1970s. They used one or two ply in their weaving. Around 1980s, acrylic wool of one and two plied yarn turned out to be the most suitable yarn for weaving of tribal. This is because acrylic wool gives warmth, cheap price, and easily available with different colour and hence no need to dye with vegetables which was hard and had little scientific methods. Nettle fibre are used for making thread by Mao, Poumai and Maram tribes. Tarao tribe also used fibre from Sougri mesta in earlier timesfor their cloth Bulapun.

2.1.4.2 Weaving of traditional Textiles

The textiles of Manipur carry their own unique features and characteristics. Traditional Manipuri textiles for women includes a chadder called innaphi, and phanek a warp around skirt. A Manipuri man’s traditional textiles includes- dhoti, jacket and white pagri or turban.

The Meiteis, the indigenous habitants of Manipur, have traditional motifs and designs in their embroidery whose origin is traced back to intriguing nobility. The most popularly known is the work done on the border of phanek mayek naibi- a sarong. A very basic pattern, tindongbi motif is done in satin stitch. An intricate design akoibi mayek is circular one- a series of joining circles, with each circle broken into patterns. (Kamaladevi Chattopadhyay, 1973).

2.1.5 Use of agro waste in textile

The largest sector -agriculture in India plays a significant role in Indian economy. It provides a livelihoods to farmers and consumer. Majority of the Indian population are still into agricultural sector. Cultivation of crops is the major source of income for rural sectors. Being the top sector of the country economy, waste from the agricultural land is a predominant factor in environment. In order to overcome the issues of agricultural waste, many research institutes, Government organizations, industries are working on the utilization of waste from the agricultural output. Extraction of textile fibre from the waste plants after harvesting is one of the ongoing effort of many individuals and organizations. Plants like banana, coconut, palm, flax, pineapple, corn, kenaf etc. after harvesting the crops can be utilized in making sustainable textiles products.

2.1.5.1 Extraction of plant fibre agro waste

Cellulose fibre extracted from the leaf, stalk or pseudo stem have large economic significance and play a vital role in lives and food security of many farmers and processors. Newly developed extractor can ensure the supply of extracted plant fibre throughout the year moving towards the value addition of textiles and its product diversification. Extraction of Plant fibres will also help in improvement of poor rural people and employment generation rural and semi-urban sectors as well. Extraction of banana, pineapple and flax fibre and other plant fibre are done in the ICAR-NINIFET, Kolkata by using the newly developed extractor machines. For the extraction of banana fibre- peeling of truck is the first step. The extraction of fibre from the white and green part of the waste stalk of banana plant is done by means of two methods- hands scrapping and machine stripping. The stripping process is known as tuxing and the stripped stem are called tuxies. Mechanized machine is developed to reduce the labour and time consuming. Extraction of flax fibre is done after retting process, the retted dried stalk is forwarded for scutching process where the the fibres are separated from the outer composites of the stalk. An improved extractor has been developed with the use of an additional two scutching roller. This will help in breaking down of stalk at smaller intervals. Pineapple fibre are extracted from the waste leaves by crushing the hard outer layer of the leaves. Scrapping and combing in the extractor of pineapple leaf fibre has been facilitated. (L, K, Nayak. (2021))

2.1.5.2 Spinning of agro waste fiber

The basic principles applied for spinning of fibres are not same for all different fibres. Even the spinning principles and steps of same fibre may vary according to their properties. To mention that process of spinning cotton is different from spinning of wool again it is also quite different from Jute. Carding basic principles involve in case of cotton and jute spinning may be similar but the separation of individual fibres of jute is done during the carding process itself while cotton fibre individual entity is already existing before the carding process. (Bhowmick, M., & Basak, S., (2021)). Appropriate application of Plant minor fibres are still needed due to its availability and hence belong to unorganized sector. These fibres are usually used in making local handicrafts. If we launch these fibers in larger area, then extraction and spinning systems like jute and cotton can be established for these allied fibres, it can play a dynamic role in textile segment. Blended pineapple leaf fibre yarns spun on cotton and jute spinning system is found to be suitable for the Construction of curtains, bed sheets, carpets, furnishing cloths, towels etc. (Nayak, L, K. (2021).

2.1.5.3 Agro waste fiber in making textile products

Fibre from agro waste like straw are used in making hats. Straw a dried form of grass is also utilized in stuff like mattress. Flax and pineapple are used in manufacturing clothes usually blended with cotton. Coir fibre is being used in production of twine, mats like floor mats, door mats, mattresses, floor tiles even sacking. Roselle fibre can be utilized as a substitute for jute fibre in making burlap. Kenaf fibre obtained from Hibiscus cannabinus plant is specially used in making rope, twine, coarser cloth which similar to cloth made from jute. Increasing uses of kenaf fibre are making wood insulator and clothing grade fabrics, boards, oil absorbent, bedding for animal, packaging material, organic filler to blend with plastics, mats and containers. Banana fibre are cultivated in Japan way back in 13^{th} century for clothing and households textiles. Coarser fibre from the outermost layer of the stem is used in making table cloth and the finer quality is used for making kimono and Kamishimo. Banana fibre is used in making high end rugs with texture similar to silk in Nepal. (Rastogi, M. 2018)

2.1.6 Natural dyes

From the early excavations of Harappa and Mohenjodaro civilization and cave paintings, it is clearly seen that people of prehistoric era knew how to colour their bodies, clothing, and items including the surroundings. Colours were extracted from different sources such as plants, animals and minerals.

2.1.6.1 Sources & extraction of natural dyes

Different sources of natural dyes obtained from plant such as flowers, fruits, barks, leaves, roots, weeds, vines, grasses, and lichens were used in the ancient period. Woad, indigo, madder, log wood, fustic, safflower, and fustic dyes are still used in many places of the country. Woad was the first used natural dye. Woad dye was replaced by indigo because of its deeper and fastness value of blue colour. Red colour of Madder was used to get other colours by using various mordants. However, fast black dye was not known.

Indigo was originally extracted from *Indigofera tentoria* by using fermentation. At present, synthetic supplements are used with this dye. Madder found in Turkey, Belgium and france gave alizarin. The dye is made from its long dried slender roots by grinding and extracting. Annato is extracted from the fermented fruit- Bixa Orellana, pomegranate rind is from Punica granatum, Myrobalan dye got from Terminalia chebula, and species of Acacia, Areca, Mimosa, and Terra japonica provide cutch dye from their wood and pods. Balsam is grown in India and has 500 species. Harshingar, Juglone, Kamala, onions, Persianc berries, Quercitron, tissue are other dyes yielding plants. (Vatsala, R. 2003)

2.1.6.2 Phytochemicals of natural dyes

The chemical groups of plant dyes provided by Ratnapandian, S. (2020) is given below:

Dye plant	Shade	Chemical group
Indigofera tinctoria	Blue	Indigo
Bougainvillea glabra	Yellow	Flavonoid
Caesalpinia sappan	Red	Anthocyanin

Urtica dioica	Green	Chlorophyll
Haematoxylum campechianum	Black	Tannins
Bixa Orellana	orange	Tannins
Acacia catechu	Brown	carotenoids

Indigofera, polygonum species and isatis are primarily produced indigo dyes. The chemical involves in flavonoid is luteolin with shades of yellow. The largest chemical group of dye is flavonoid. Anthocyanins contain red and blue dyes of fruits and flowers. Carotenoids are initially extracted from carrots. These are direct dyes which produce yellow to orangey red colour. Anthracenes have two main groups- anthraquinones and napthoquinones. Anthraquinones produce red, yellow and pink shades and napthoquinones produce pink, purple or brown shades. Chlorophyll, the green pigment of plants are available as dyes in two class chlorophyll a and chlorophyll b. chlorophyll dye is unpopular because of its poor light fastness. Seguin introduced the term tannin in 1790 which is used mainly for converting animal skin to leather. Tannins are identified as polyphenols.

2.2 Research Related Review

2.2.1 Natural minor fiber

Thilagavathi, G., Pradeep, E., Kannaian, T., et al. (2010) studied on development of bamboo, banana, and jute non-woven for application as car interiors for noise control. The three types of non-woven were developed with needle punch technique by blending bamboo/polypropylene, banana/polypropylene, & jute/polypropylene at 50:50 ratio each. By using impedance tube method, sound absorption coefficient was tested. Comparison of physical properties for all the developed samples was done. From the results, the bamboo/polypropylene (PP) non-woven had compact structure which gave lesser CV% of mass per unit area and higher tensile strength than banana/PP & Jute/PP by 510% and 97.3% respectively. The flexural rigidity was too 16.2 % higher than banana/PP and 48.1% higher than jute/PP, the elongation of bamboo/PP was the lowest which had 4.4% lower than banana/PP and 43% lower than the jute/PP. The bamboo fibre was finer than polypropylene hence had a good cohesiveness and gave a compact structure. However, banana/polypropylene blend had lowest thermal conductivity which could be used as thermal insulator. Because of the less cohesiveness between the fibres banana/PP had the lowest air permeability with difference of 702.4% from bamboo/PP and 12.9% from jute/PP. In absorption coefficient, bamboo/PP and jute/PP reached the target level at 800Hz, but 22% lower in case of banana/PP. For higher frequency 1600Hz, increase in thickness of the non-woven could be done to overcome the reduction from the target level. The study concluded that bamboo/PP non-woven could be used in the automotive interior noise control because of its better properties. Banana/PP non-woven with low thermal conduction of 0.0178W/m/k was recommended for thermal insulating applications. Apart from car interior, other applications such as theaters, generator room, auditoriums, and floor mats were suggested for the developed non-woven.

2.2.1.1 Agro waste fiber

Sugarcane bagasse and its potential use for the textile effluent treatment was studied by Orjnela, C, C, J., Anaguano, H, A., & Restrepo, M, A., (2017). The feasibility of using SCB (sugarcane bagasse) as an alternative, potential, and low-cost absorbent for the removal of BR46 was the aim of the study. The parameters- point of zero charge, pH, and size of the particle, absorbent dosage, dye concentration, contact time and ionic strength were determined for the optimization and correlation using a full 2^4 factorial (composite design based on the factors) and a central composite designs of experiment. Absorbent pre-treatment was done with washing using deionized water and 2% (v/v) hydrogen peroxide to remove organic materials followed by oven dry at 100^{o}C for 4hr. The compositional analysis of the fibre was performed and the point zero charge (the pH at which the net charge of the absorbent surface equals to zero) was determined using the Farahani and co-workers' method. For the preparation of dye solution BR46 dye –cationic, an azo compound group was used. To establish the influence of the variables pH and particle size in the dye removal onto SCB, some preliminary experiments were conducted. The optimum pH of the fibre was 6.0 and particle size was 30 gL-^{1}. Effect of the ionic strength was carried out with the solution of calcium chloride and sodium in the range of 0.0 to 0.2 mlL-^{1} at room temperature. The 24 full factorial design analysis provided that the most important factor in the dye removal was the dosage of SCB with a positive effect. The central composite design allowed reaching a maximum dye removal of 95 % under 40mg L-^{1} initial concentration (dye), 6.7gL-^{1}dosage (fibre), 6pH and contact time was 2hr. The results suggested that SCB could be a non-conventional absorbent for BR46 dye removal from the solution. The use of SCB in removal of dye effluent would be a focus on the improvement of environmental aspects.

2.2.1.2 Pineapple leaf fiber

Zhuang, Z., Zhang, J., Li, M., & at al. (2016) conducted a study on optimizing the extraction of antibacterial compound from pineapple leaf fibre with the aim of separation and purification of the active substances from the fibre by providing a theoretical basis and basic data. Self-developed semi-automatic extractor was used for the extraction of fibre. For the test of antibacterial from extracted fibre, Escherichia coli ATCC25922 was used. Dry fibres were powdered and added to single solvent of 400ml each containing chloroform, ethyl acetate, acetone, petroleum ether, or distilled water and water bathed for 2hr and cooled to 25^{o}C. Filtration and evaporation were followed and stored in a refrigerator at 4^{o}C. This process was adopted for the preparation of polar crude extracts. Agar diffusion was done to study the bacteriostatic activity. Qualitative analysis was done on the 5 extracts samples using special colour developing agents. Determination of optimal parameter was done by adopting orthogonal experiment. The antibacterial activity was observed only in the extracts of ethyl acetate (10.20mm), acetone, and distilled water (12.32mm) with acetone having the greatest inhibition zone i.e. 14.76mm. The qualitative analysis of 5 extracts using the special colour developing agent provided flavonoid and phenols from all the extracts except the petroleum ether extract. The obtained flavonoid and phenols could be from Cannabis saliva and Apocynum venetum. Therefore, pineapple leaf fibre likely contained the two said compound. Acetone extract was used to check the optimal parameters since it had the greatest antibacterial activity. With the consideration of extraction rates and antibacterial activity, optimum temperature, time and solid-liquid ratio were was 45^{o}c, 8hr, 1:40 (g/ml) respectively. The optimal process condition obtained from orthogonal experiment was found suitable for the extraction of antibacterial substance from the fibre.

2.2.2 Natural minor fiber application in traditional textiles

To examine the potential use of pineapple leaf fiber in the batik textile restoration was carried out by Kamarudin Z., Yusof Mohd F N. (2016). The study was carried out in two stages with following steps, first- preparation of material to make fiber thread from pineapple leaves, 1. Selection of leaves, 2. Cleaning of selected leaves, and 3. Extraction of fiber from the leaves second stage was- fundamental experimentation on the fiber chemical and physical properties to determine its 1. Acidity 2. Moisture content 3. Density ratio, shape identification, tensile strength and extensibility. Colour red, blue and yellow were used for dyeing and examination of dye absorbency of the fiber.

The result showed pH level between 5.63 i.e. 5 to 6 (weak acid). Hence, it was safe to be used for the restoration. The moisture content value was found to be good i.e. 6-15 and the density of the fiber was about 1.301(g/cm^3) which the value was within the range of natural fiber density. The average tensile strength values of both pure and PALF with CMC were 0.237 KGF and 0.422 KGF respectively. Results on the dyed fiber showed the fiber had the ability to absorb the batik colour and based on the restoration experiment, it could be used for the conservation of batik textile since it had fine thread and was not easily seen. Therefore, the pineapple leaf fiber had potentiality in making eco- friendly thread for the restoration of the textile. The use of pineapple leaf fiber in replacement of man -made fiber was highly recommended. Extensive research was recommended for the chemical properties, biotechnological and engineering aspects to improve the quality and application.

2.2.3 Dyes on natural fiber

Investigation on morphological, mechanical, and color strength properties of IR (infrared) dyed pineapple leaf fibers in comparison with the conventional EX (exhaustion) dyeing technique was conducted by Amin Mohd N A., Ruznan S W., Suhaini A S., et al. (2023). Water retting of leaves for 75hrs was involved prior to the manual extraction method. After extraction, combing and hot air oven dry on the fibers at 70^o C for 30 min were carried out. The surface morphology of the dyed fiber was examined by using SEM and tensile strength of the raw fiber and the dyed fiber was tested. In both dyeing method, four samples approximately 5g each were selected and dyed with the concentration 0.25%, 1%, 2% and 4% each of three primary colours reactive red 11, reactive blue 5, and reactive yellow 86 using liquor ratio 1:20, soda ash at 20g/L and sodium chloride at 60g/L with 70^oC for 60mins and soaping with 5g/L standard soap for 20min at 100^oC and oven dry were performed. From the SEM analysis, no significant difference between samples was found. The highest breaking strength of raw pineapple leaf fiber occurred at 82.60N/mm^2. The highest breaking strength- 69.60 N/mm^2 of the dyed fiber was gain in red reactive dye samples at 1% dye conc. of IR dyeing. The lowest value was 51.90 N/mm2 at 0.25% dye conc. of reactive red EX dyeing technique. In comparison, more force was required to break the fiber dyed with IR dyeing. However, the fiber dyed with 2% conc. in EX dyeing had higher breaking strength value than the IR dyeing. Standard deviations for each dyes were calculated. The result of wash fastness of all the samples was found to be good (4) to very good (4/5). Similar perspiration result- moderate (3/4) to very good (4) in both dyeing technique was observed. IR dyeing provided excellent light fastness similar to conventional EX dyeing. At each dye conc. higher K/S values in IR dyeing was obtained Therefore, the investigation was concluded that IR dyeing was found to be optimum process for dyeing the fiber by providing brilliant colour shades and higher colour strength value. The use of IR dyeing technique on pineapple leaf fiber was indicated as eco-friendly dyeing process. Further studies on IR dyeing on other natural fibers with different dyes were recommended.

2.2.4 Threads

2.2.4.1 Threads used in surface ornamentation

To develop a stretchable embroidery thread by using elastane filament, polyvinyl alcohol (PVA) and dyed polyester and viscose fibers on DREF-3 spinning machine was the aim of "Development of specialty embroidery thread for application in stretchable knitted fabrics for body fit garments" conducted by Agrawal, N., Parmar, M, S., & Agarwal, V. (2019). For making thread, 40deneir eslastane filament is used as primary core, PVA fibre as inner sheath, and polyester & viscose as outer sheath. Hand and machine embroidery was done on the knitted fabric using the developed embroidery thread and the normal thread. The fabric embroidered the developed thread was treated with hot water; the inner sheath- PVA was soluble in water and dissolved. Hence, created the stretch ability between the core sheath and outer sheath. The stretch ability was checked at the embroidery area of the fabric. Comparison between the developed embroidery thread count (11.91Ne) and the normal embroidery thread count (2/23.8Ne) was done. It was observed that the quality of the developed thread had slightly poorer quality than the normal embroidery thread in terms of strength, evenness an imperfection because of the friction spinning technology. Before and after washing stretch ability test were conduct on both the threads and embroidered knitted fabrics. More stretch ability was observed in the developed thread and the stretch ability at the embroidery area of knitted fabrics was tested in wale wise and course wise direction where the stretch ability was gained 15% in the hand embroidered fabric with developed thread when compared with the normal thread embroidered fabric. The stretch ability gained in the machine embroidery of the developed thread on the knitted fabric was 13-16% while comparing with the normal thread embroidered fabric. The developed embroidery thread was given silicon oil treatment to decrease the breakage rate while operating on the embroidery machine. Hand embroidery was found to be satisfactory and it was almost equal to the performance of the normal embroidery thread. Therefore, the multi component thread for embroidery might be a benefit to use in the knitted garments which has stress and strain.

2.2.4.2 Sewing threads

Rajput, B., Kakde, M., Guljhane, S., & et al. (2018) had done an analysis of seam quality on the three types of weft knitted cotton fabrics to study the effect of sewing parameters on seam strength and efficiency. The three types of weft knitted fabric were plain single jersey, 1x1 double rib jersey, and interlock double jersey. The fabrics were sewn by using three different polyester/cotton sewing threads- 1. 40tex linear density with tenacity 43.89 (cN/tex) at 25.07% break elongation. 2. 60tex with tenacity 54.09 (cN/tex) at 27.00% elongation at break and 3. 80tex having tenacity 60.97 (cN/tex) at 28.67% elongation at break. The twist direction was maintained same for all the types of threads as Z/S. The constant stitch density was taken at 14 stitches per inch. Juki lock stitch, flat stitch, and over-lock stitch sewing machine were used for the stitching at a speed of 4500 stitches per minute and produced super imposed seam. With the use of L9 orthogonal design, the effect of types of fabric, thread, and stitch class were investigated at three levels. To check the components effect on the seam quality of lock stitch chain stitch and over edge stitch, ANOVA technique was carried out. The results of the study revealed that the highest strength was observed in interlock double jersey. The stitch length and the stitch density has negative influence on the seam strength. It was observed that the length of the stitch was indirectly proportional to the seam strength. The 80tex thread had shown highest strength in all types of fabrics. This might be due the higher tenacity of the thread. The over edge stitch had better strength than the other stitches because of the influence of low needle thread tension. Considerable effect of linear density on seam efficiency was seen. The increase of seam efficiency with increase in linear density was due to the more incorporation in fibres in the coarser thread. The statistical analysis showed the effect of the fabrics type, thread type and stitch class on the strength and efficiency of seam at significant level. Therefore, the work concluded that it will be beneficial to study the sewing performance of thread on any type of fabric for different applications.

From the extensive reviews, the utilization of agro waste, particularly pineapple leaf fibre, presents a promising opportunity for sustainable textile production. From the extraction of fibre to their application in textiles, various studies highlight the economic, environmental, and cultural benefits of incorporating these natural fibres. As research continues to explore innovative methods and applications, the integration of agro waste in the textiles industry holds significant potential for fostering a more sustainable and diverse approach to fabric production. However, very few research on minor fibre were explored in the area of traditional textiles. Pineapple leaf fibre was explored mainly in the technical textile application.

Chapter-3

Experimental Procedure

The study is designed as an experimental and exploratory on pineapple leaf fiber. The main aim of the study is to explore the pineapple leaf fiber in hand woven traditional textiles of Manipur. The spun yarns will be used for weaving pineapple union fabrics. Present study will also involve softening treatments on pilot basis. Furthermore, modified charkha will be used in terms of ease of spinning and fineness of the yarn. Finally the fabrics will be constructed and incorporation of traditional motifs and colours will be involved and the best samples will be evaluated.

The present chapter deals with material and methods followed for fulfilling the objective of the study.

3.1 Research Design

3.2. Availability of Pineapple leaf fibre in Manipur

3.3. Collection of the raw material

3.4. Extraction of fiber

3.5. Pilot experiment on modification of produced Pineapple leaf fibre

3.6. Testing of properties

3.6.1Physical properties

3.6.2 Testing of chemical properties

3.7. SEM- Identification of chemical bonds using Scanning Electron Microscope.

3.8. Preparation of yarn for weaving and surface ornamentation

3.9. Testing of prepared yarn

3.9.1 Determination of yarn fineness

3.9.2 Determination of yarn evenness

3.9.3 Determination of yarn strength and elongation

3.9.4 Determination of yarn twists (TPI)

3.10. Dyeing of 100% pineapple yarn

- ❖ With reactive dyes
- ❖ With natural dyes

3.11. Testing of dyed yarn samples

- ❖ Colour strength test
- ❖ Wash fastness test
- ❖ Light fastness

3.12. Extraction of bromelain enzyme

3.13. Construction of traditional textiles on handloom

The fabrics will be woven on handloom by the local weavers in Manipur. And testing of fabric samples will be performed. Incorporation of traditional motifs and colours used in their traditional textiles will be involved. Weaving of samples for the traditional textiles on two shaft throw shuttle loom-

- ❖ Union of Silk/Pineapple fabric
- ❖ Union of Cotton/Pineapple Fabric
- ❖ Union of Rayon/Pineapple fabric
- ❖ Union of Polyester/ Pineapple fabric

Testing of the woven fabric samples include-

- ❖ Fabric Thickness
- ❖ Fabric count
- ❖ Cover factor
- ❖ GSM
- ❖ Stiffness/bending length
- ❖ Drape co-efficient
- ❖ Tensile strength
- ❖ Kawabata of selective fabric

3.14. Cost Calculations of the constructed fabric

3.15. Feedback from the consumer

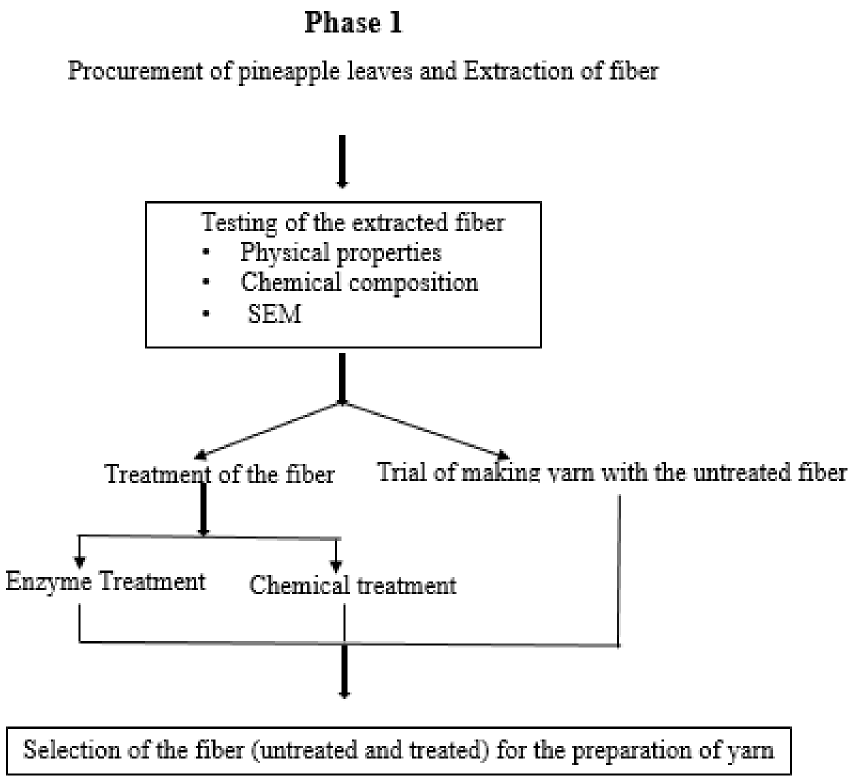
- ❖ Identification of Consumer
- ❖ Interview with questionnaire
- ❖ Analysis

3.16. Awareness of pineapple leaf fibre for textiles

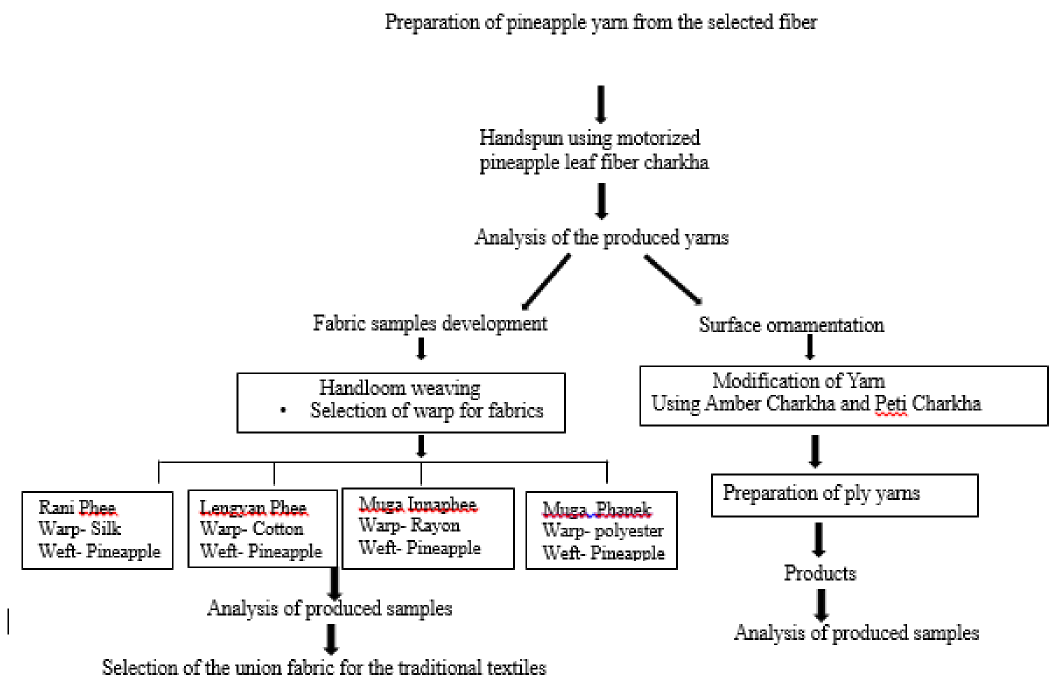
- ❖ Media Coverage
- ❖ Publication of article on newspaper
- ❖ Awareness program

3.1 Research Design

In the view of the objectives, the present study is divided into three three phases. In first phase, procurement of pineapple leaves and extraction of the fibre, testing and treatment of the fibre and selection of the fibre from untreated and treated for preparing yarn. In phase two, preparation of different handspun yarns was done and weaving of samples on handloom was adopted. Selection of motifs and colours used in traditional textiles was done followed by dyeing with natural and reactive dyes, weaving the traditional, cost calculation and taking feedback from consumer was conducted. The research design is shown in illustration 1.



Phase 2



Phase 3

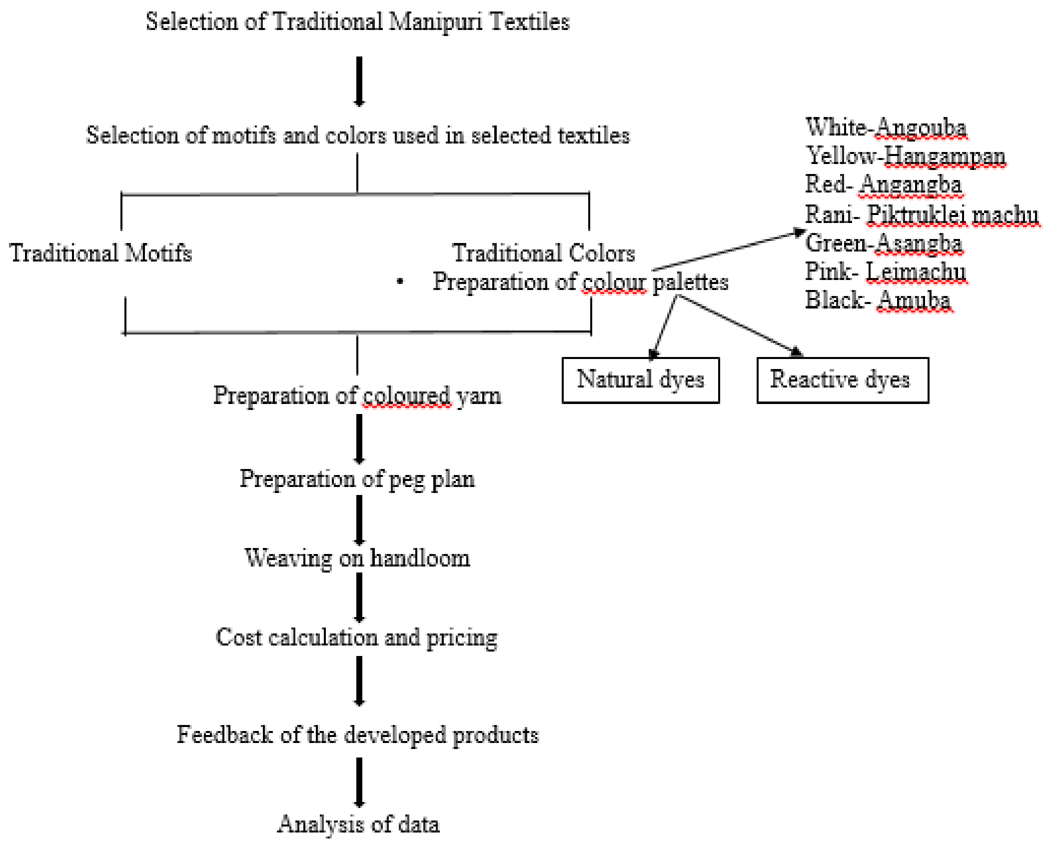


Illustration1: Research design

3.2. Availability of Pineapple leaf fibre in Manipur

Based on the reviews of articles and data provided by the traders on websites, numbers of fibre supplier were contacted through phone calls, email and WhatsApp to check the availability of pineapple leaf fibre across the country.

3.3. Collection of the raw material

The raw material for the extraction of pineapple leaf fibre were collected from the local pineapple farms in Kangchup of Manipur. Kew and Queen Variety were used.

3.4. Extraction of fiber

The fiber were extracted from the procured raw material from the local growers of pineapple plants by means of hand scrapping and machine extraction followed by water retting process (5-7 days). Machine extraction was done at at the CSIR-NEIST branch laboratory at Lamphel, Manipur. After the extraction washing and scouring were done to remove residue from the fibre and then dried.

3.5. Pilot experiment on modification of produced Pineapple leaf fibre

Different treatment of fibre for spining was done by using enzyme treatment & chemical on pilot based experiment. The cellulose enzyme was used for the treatment which was procured from the Rossari Biotech Limited, Dadra & Nagar Haveli. In chemical treatment, hydrogen peroxide and sodium hydroxide were used and the experiment was carried out in the Department of the Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

3.6.1. Testing of physical properties

Testing of the fibre was done to determine its length, fibre fineness, moisture content and moisture regain, tensile strength, and chemical composition of the fibre.

Length of the fibre- Using a steel ruler the length of the fibre is measured. An average of 20 readings were taken.

Fibre diameter-It was determined by measuring the diameter of the fibre under the digital microscope with a micrometre, 20 readings were taken.

Fibre colour and texture- Whiteness index of the fibre was check using spectrophotometer A5100. Texture of the fibre was check under ZEISS Microscope.

Fibre fineness- denier (direct system)- using an average weight of 20 readings of 100 cm length of the fibre.

Moisture content and moisture regain- To determine the moisture content and moisture regain, fibres of 10gm were kept in the oven for 4 hours. After 4 hours, the samples were taken out from the oven and weighed.

Tensile strength- The Universal tensile tester machine (UTM) was used for checking the tensile strength of the fibre. The sample length was 10 cm and an average of 20 readings were taken.

Bundle strength- The bundle strength test of the fibre was carried out by using Llyod Instron Tensile Test.

Whiteness index- Whiteness index of the raw fibre, scoured fibre, and enzyme treated, and bleached fibre was check by using the spectrometer SS5100A was done. D65 illumination with 65000k color temperature equivalent to average day light, at 10^{o} angle of visual were used for obtaining the values.

3.6.2 Chemical composition of the fiber-Chemical composition of grey fibres was determined as per the tests proposed by Turner and Doree. The test was conducted at the Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sajayajirao University of Baroda, Vadadora, Gujarat.

3.7 SEM- Fibre structures of enzyme treated, chemical treated and controlled were observed using Scanning Electron Microscope, CARL ZEISS (USA), Model: Sigma with Gemini Column, resolution 1.5nm- In lens Detector, SE2 Detector, BSD Detector at the PSG Tech, CDE Indutech, Coimbatore, Tamil Nadu.

3.8. Preparation of yarn for weaving and surface ornamentation

For preparing yarn, spinning on different spinning tool/charkha- drop spindle, traditional charkha, phoenix charkha were explored. However, spinning of scoured 100% pineapple leaf fibre hand-spun yarns without any treatment is achieved by using local motorized pineapple leaf charkha made by the researcher. Joining of fibre strand ends to ends can be done to get a continuous length before spinning with the motorized charkha. Plying of pineapple yarn with rayon and polyester yarn by using amber charkha and peti charkha on was conducted for the surface ornamentation. Five types of plied yarns were produced to check the feasibility in making surface ornamentation using the Juki HZL 27Z (Fashion maker).

3.9. Testing of prepared yarn

The properties of the prepared yarn i.e. denier (direct system using ASTM D7025)- using an average weight of 20 readings of 100 cm length of the yarn, yarn count was calculated using the conversion of count system- denier to cotton count, yarn evenness-using the average weight difference of 10 readings of 100cm yarn length, twist per inch(TPI) using ASTM D885, Alfred suter twist tester were calculated on twist tester for single yarn and tensile strength were tested at Aditya Birla's Century Rayon.

3.10. Dyeing of 100% pineapple yarn

The dyeing was carried out on the natural colour of the 100% pineapple spun yarn (30s) without any treatment like bleaching. Using nine reactive dyes, 12 natural dyes (eight were extracted local plant dyes) with conventional exhaust dyeing technique dyeing was done.

- ❖ With reactive dyes

RP- Reactofix dark pink, RO-Procion brilliant orange M-2R, RBY-Procion brilliant yellow M-4G, RY- Procion yellow M-3R, RR-Procion brilliant Red M-5B, RB-Procion black, RG-Procion green, RBP-Procion pink and RBR- Procion brown .

Dyeing on 100% pineapple yarn was carried out with 2% dye, soda ash 20g/l, sodium chloride 30g/l, maintaining 1:30MLR for 45mins at 60 degree Celsius with self pH. Washing with 2% soap solution wash done.

- ❖ With natural dyes

Lac (crystal form), manjistha (powdered), marigold and pomegranate are the common Indian natural dyes used in the dyeing. Among the collected plant dyes, Indian Trumpet tree-*Oroxylum indicum*, Red cedar-*Cedrela toona*, Mulberry-*Morus nigra, and* Roselle-*Hibiscus sabdariffa* were explored to the existing traditional dyes in Manipur.

Selection of traditional colours and source of dyes to be used in dyeing was done based on the traditional colours used in making the Meitei traditional textiles. The colours used are White-Angouba, Yellow-Hangampan, Red- Angangba, Bright pink- Piktruklei macho, Green-Asangba, Pink- Leimachu, Black- Amuba, Orange- komla Machu.

Table 3.1: Details of the local plant dyes

1. Indian Trumpet tree-*Oroxylum indicum* Local name- Shamba The bark of this plant yields flavonoids, anthraquinone- Orange colour	6. Koda tree-*Ehratia acuminate* Local name- Lamuk The bark of the three gives blackish colour.
2. Red cedar-*Toona Ciliata* Local name- Tairen This plants (bark) yields brown colour.	7. Malabar melastome-*Melastoma malabathricum* Local name- Yachubi The dye extracted from the leaves gives yellowish colour.
3. Mulberry- *Morus nigra* Local name- Kabrang The fruits yields greyish colour.	8. Kamala or Kumkum tree-*Mallotus philippensis* Local name- Ureirom laba The bark contains tannins which give reddish brown colour.
4. Roselle-*Hibiscus sabdariffa* Local name- Silok sougri Pink colour is obtained from the fruits.	9. Pomegranate- *Punica granatum* Local name- Kaphoi Peel of the fruits were used for the dye extraction to get brown colour.
5. Hill glory bower- *Clerodendrum infortunatum* Local name- Kuthap The fresh leaves gives pale green dye.	10. Marigold-*Tagetes erecta* Local name- Sanarei Fresh flower were used for the extraction of yellow dye.

Fig: Pictures of the local plants dyes

Dye Extraction process- In the boiling distilled water at 1:40 MLR for 30mins dye extraction was carried out followed by filtration and settling. Prior to dyeing, pre-mordanting of yarn was doneusing 10% of the material weight Alum for 30 minutes.(P, Sukriti 2018).

Dyeing on 100% pineapple yarn with natural dyes was carried out on pre-mordanted yarn using 10% alum by using with 4% dye, 1:30MLR for 45mins at 60 degree Celsius, self pH. Washing with running water was done to remove excess dye.

3.11. Testing of dyed yarn samples

Analysis of the colour strength- CIE L* a* b* c* h*, Colur difference, and K/S values (given wavelength 360-700nm) using spectrophotometer SS5100A was done. D65 illumination with 65000k color temperature equivalent to average day light, at 10^{o} angle of visual were used for obtaining the values. The analysis was done at the Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

Wash fastness and light fastness test were conducted by following ISO standard test no. II (IS: 764: 1979) and AATC test method 16-B-1977 respectively at The Department of Textile chemistry, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat. For the wash fastness test, the undyed yarn without bleaching (controlled sample) and the dyed sample was braided. The braided sample was put in a jar containing a solution of 5gl soap, 2gpl soda ash with MLR 1:50. The jar was closed and proceed into the Launder-O-meter which was run for 30 minutes at 60^{o}C ±2 and the sample was removed and washing with water was done followed by air dried. Scale of 1-5 rating was used for the assessment. In case of light fastness, the assessment was done by exposing the dyed samples to sunlight for the period of 8 hours to check the effect of fading of colour. For this, the dyed pineapple yarns was evenly wrapped on the black sheets. The exposed portion of the sample was then compared with the unexposed portion. The grading was done based on the 1-8 rating scale.

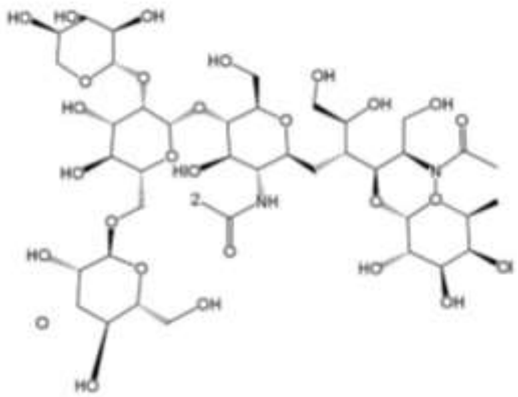
3.12. Extraction of bromelain enzyme

Bromelain is an enzyme complex found in pineapple (Ananas comosus). It is particularly abundant on the stem and fruit of pineapples. Bromelain is used for a variety of purposes, including its potential anti-inflammatory and digestive properties. The Enzyme is mainly used in medicinal purposes such as digestive aids, anti-inflammatory, wound healing, supplement form, and immune system support.

To extend the application of pineapple plant in the textile application, the researcher extracted the juice by grinding and boiling pineapple peels which contains bromelain enzyme. From the biomass of pineapple peel, extraction of bromelain enzyme is done by means of grinding, boiling and centrifugation and filtration. To separate the solid substance from the liquid, centrifugation was done at the Laboratory Department of Community Health Center in Awang Sekmai, Imphal West District, Manipur. The bromlain enzyme is used in treatment of wool, agro-waste fibre, softening of fibre, printing of latex and leather processing etc.

For the experiment, a recipe (Kaur, A., & Chakraborty J, N.2015) for the treatment of the fibre can be adopted. Bromelain was taken at 1% owf with salt 0.5% owf at 66ºC for 45 min at pH 6-7 by maintaining 1:40 MLR. Optimization can be done by varying the percentage of compounds.

Fig: Pineapple peel



Source- Created using Kingdraw

Fig: Centrifuge machine

Fig: Centrifugation at CHC, Laboratory Sekmai

Fig: Extracted Bromelain juice

3.13. Construction of traditional textiles on handloom

The produced yarns was used as a weft for making samples of textiles. Selection of warp yarns according to the existing used in making the traditional textiles was done. Based on the selection of the sample which are compatible for making the specific traditional textile, Union fabrics of silk/pineapple, Rayon/pineapple, cotton/pineapple, Polyester/pineapple were developed for making resemblance of Rani phee, muga Innaphee, lengyan phee and muga phanek traditional textiles. The yarn count of silk-50s, Rayon- 22s, cotton- 25s and polyester-18s were used for the fabrics. All the produced samples were evaluated to check the suitability for each given specific traditional textile.

The physical properties of the developed fabrics were tested. The tensile strength and elongation of the fabrics were tested using ASTM Test method D5035 based on the constant rate of extension, GSM- ASTM Test method D377696, fabric count- using ASTM D 3775-98, fabric thickness- ASTM Test method- D1777-96 using compress meter thickness tester, stiffness-ASTM D 1388-18 using Shirley's stiffness tester and drape co-efficient using drapemeter. Selection of one fabric among the developed samples was done for the Kawabata test.

Fabric thickness- Determination of fabric thickness of the constructed fabrics was done by obtaining the distance between the upper and lower surface of the fabric measured under certain pressure and expressed in mm. The samples chosen for the test were free from folds, crushing or distortion and wrinkles. Universal thickness tester was used for the test.

Fabric count- To determine the fabric count, the number of ends and picks per unit area was calculated. At randomly selected surface of the fabric, the number of warp and weft yarns in one inch dimension of square is counted using the pick glass and five readings were taken. The surface of the which are near the selvedge should be avoided.

Cover factor- To get the cover factor of the fabric, a numerical value was obtained which indicates the area of the fabric covered by the component of yarn. The Formula for calculating the cover factor of fabric is given below:

$$\text{Cover factor } (K_c) = K_1 + \frac{K_2 - K_1 K_2}{28}$$

Where K1 is number of warp per inch

K2 is number weft per inch

Fabric weight (GSM)- weight of the fabric is expressed as mass/unit area in g/m^2. A sample size of 5x5 cm was prepared and weight on an electronic weighing balance to check the weight. GSM was calculated using the formula:

$$GSM = \frac{\text{Weight of sample in gram x 100 x 100}}{5x5}$$

Tensile strength- The tensile strength of the fabric was done by using the Universal tensile tester which has constant rate extension of principle. The raveled sample 15cmx2.5 cm was kept 75 mm± 1mm with speed of 500mm/min. total ten readings were taken to get the average value.

Stiffness/bending length of the fabric- The sample was cut into rectangular size of 15cm x 2.5cm for mounting on Shirley's stiffness tester. The strip of sample was prepared in such a way that it hangs on cantilever and bends downward. A reading was taken when the strip of sample was starting to droop down over the edge of the platform with the movement of the template until the tip the strip appeared in the mirror cuts both the index lines. The bending was observed opposite to the zero line engraved on the platform. This process repeated till 5 readings.

Drape co-efficient- The fabric was prepared according to the size of large disc provided in the drape tester. Under the specimen holder disc, the ammonia sheet was put and mounted the sample between the support discs in the cabinet and closed the door. The light was switched on for 5min before removing the sheet. The small in base of the machine was open and placed an open lid flask containing ammonia solution. Inside this, the ammonia sheet was placed for 15mins and let the visual effect of the drape developed. As per the impression, the sheet was cut for graphical trace and measurement. The formula for calculating the value is given below:

$$\text{Drape co-efficient} = \frac{\text{Area of the draped specimen- Area of the support disc}}{\text{Area of the specimen- Area of the support disc}}$$

Kawabata Evaluation System for Fabric (KES-F):

For the test cotton/pineapple fabric was selected based on the availability, popularity, and comfort of the warp yarn. Following test was included:

- **Fabric Handle Test (Women's thin dress fabric):** This test measures the overall feel or "handle" of a fabric. It considers features such as softness, smoothness, and flexibility. Instruments like the Kawabata test system use various sensors to measure the fabric's mechanical and surface properties.

- **Fabric Shear Test:** This test (KES-FB1) procedures the shearing or slippage resistance of the fabric. It provides understandings into how well the fabric resists deformation under shear forces.
- **Fabric Tensile strength:** This test (KES-FB1A) provides the tensile properties of the fabric using the tensile tester. It gives the tensile resilience and extensibility of the fabric.
- **Fabric Bending Test:** This test assesses the bending properties using pure bending tester (KES-FB2) of a fabric. It helps in understanding the flexibility and drape of the fabric.
- **Fabric Compression Test:** This test evaluates the compressional properties of the fabric using the compression tester (KES-FB3A). It is relevant in applications where fabrics need to endure compressive forces, such as in upholstery or mattress materials.
- **Fabric Thickness Test:** This test measures the thickness of the fabric. It is an essential parameter in applications where fabric thickness is a critical factor.
- **Fabric Surface Friction Test:** This test (KES-FB4) provides the frictional properties of the fabric surface. It is relevant in applications where low friction is desirable, such as in sportswear. Surface properties like roughness, smoothness, and friction are included parameters.

3.14. Cost Calculations of the constructed fabric

By involving the assessment of the expenses associated with the raw material to woven product, cost calculation was done. To calculate the cost of the developed products, costing of raw materials, transportation, scouring, spinning, and weaving were included.

3.15. Feedback from the consumer

To check the use of the developed yarn as an alternative to conventional material in weaving the textiles, a comparison between the traditional textiles produced with pineapple yarns and silk traditional textiles of Manipur was done based on their physical properties and feedback was taken from the Meitei consumer and weavers.

3.16. Awareness of use of pineapple leaf fibre for textiles

The constructed fabric will be analyzed based feedback of consumers and giving awareness about the fabrics developed was done on newspaper, T.V. channel and other social media. For the awareness program about the use of pineapple leaf fibre in textiles, a cluster of weavers was approached based on the production center of local mulberry silk and traditional textiles of Meitei community.

Chapter-4

Results and Discussion

4. 1. Availability of Pineapple leaf fibre in India

4.1.1. South India

1. Vruksha Composites, Guntur, Andra Pradesh
2. Fiber Region, Chennai, Tamil Nadu
3. Shreekruti agropower, Karnataka
4. Akhil from Kerala
5. South Indian Textile Research Institute, Coimbatore, Tamil Nadu

4.1.2. West India

1. Meher, International, Surat, Gujarat

4.1.3. East India

1. ICAR- National Institute of Natural Fiber Engineering and Technology, Kolkata, West Bengal
2. Chandra Prakash & Co., Jaipur/ Kolkata

4.1.4. Northeast India

1. Ramie Research Station, Sarbhog, Assam
2. Sherrard Wallang, Environmentalist, Shillong, Meghalaya
3. M/S Anchal, Teliamura bus stand, Agartala, West Tripura
4. Assam Agricultural University, Jorhat
5. Emitex Export, Noida, Uttar Pradesh- Fibre from Lower Assam and Nagaland-

The above list is the organizations which worked on pineapple leaf fibre. However, due to different reasons these organization couldn't provide the fibre to the researchers. Most them had stopped working on the extraction of this fibre the reasons provided by these different organization were laborious, time consuming, difficult to reach farms, less popular compared to other fibre like banana and most importantly they worked for some projects on pineapple leaf fibre once the projects was completed, they discontinued the work. There were two organizations which provided the researcher the sample of pineapple leaf fibre. Unfortunately, the quality of the fibre they provided was not in the condition of possible to prepare yarn. Very raw form fibre along with the dried leaves as well as expensive (Rs 3000/kg) were sent by one of the organization. The quality of the fibre didn't fulfill the parameters for preparing yarn. The other organization provided a small amount of clean coarse pineapple leaf fibre (23g) however, the strength of the fibre was very less, and it was easily breakable and had a probability of high amount of chemical use. Therefore, considering all the matters, the research had to extract the fibre on her own. The researcher interviewed the personnel- 1. Kh. Shamu Singh, Former-Assistant Director-Design department,Textile Technologist former Assistant director, 2. Athokpam Ibetombi & 3. Ingujam Binoychnadra- Two former demonstrators of the fiber extraction, 3.Soibam Apanbi, a project staff of the Design Department, District industrial centre, Porompat, Manipur who worked on pineapple leaf fibre during the period of 1970s.

4.2. Extraction of fiber

Different extraction methods were explored by the researcher. Mechanical extraction and manual extraction followed by water retting were the methods adopted. CSIR-NEIST, Laboraty in Lamphelpat, Manipur facilitated the mechanical extraction. Manual extraction was done at the resident of the researcher by using hand scrapping method and hammering (explored by the researcher) the leaves to remove the hard covering substance prior to water retting. Since the hand scrapping method sometimes damaged the fibre length and yield of the fibre is less, light hammering on the upper side of the leaves was done before retting. Very long and smooth fibre were obtained from the hammering and retting process. The hammering process saved more quantity of fibre. Although, the manual extraction was laborious and time consuming. Therefore, machine extraction was recommended for larger quantity of fibre production.

4.3. Pilot experiment on modification of produced Pineapple leaf fibre

One of the drawbacks of natural minor fibre is harness and stiffness. Usually, softening of fibre is done on these fibre. Conversely, scoured pineapple leaf fibre without any further treatment was enough for preparing the stiffed yarn of traditional weaving of Manipur. Since the scoured fibre without any treatment was found to be feasible for preparing yarn, the researcher uninvolved the use of the enzyme treated and the chemical treated fibre for further process. Hence, the minimization of chemical used was involved and use of expensive enzymes in softening had been deducted. The structure of the longitudinal view under FESEM of raw fibre, scoured fibre, enzyme treated fiber and bleached was also observed for preparatory of yarn to determine its parameters for spinning.

4.4. Testing the properties of fibre

Length and diameter of the fibre- The average length of the fibre was found from 65-92 cm. The diameter of the fibre was found to be 0.7-1.2µm. The denier of the fibre was obtained as 47.57 denier. This fibre can be considered a long staple fibre as well as a very fine fibre.

Moisture content and regain- Moisture content was 10% and moisture regain was observed as 11.1%. The value of moisture regain is better than cotton which is 9-10% but lesser than flax i.e. 12% as per the standard moisture regain of textile fibers. We can say this fibre is hydrophilic in nature.

Tensile strength and bundle strength: Pineapple leaf fibre had good tensile strength when compared to among other natural fibres. The value of the strength was 4.278gf/den. The bundle strength was 27g/tex.

Table 4.1: Tensile Strength -Speed- 500mm/min, ASTM D 885

Treatments	Max Load (gf)	Tenacity(gf/den)	Stress at break %
Raw fiber	126	4.278	0.9
Enzyme treated	116	4.048	0.6
Chemical treated	115.6	2.38	1.5

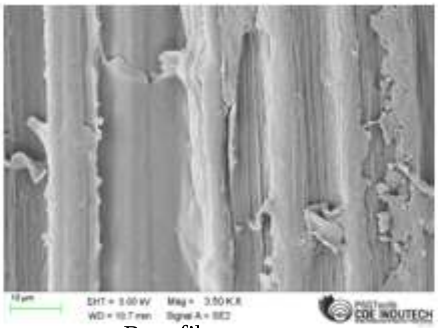
Tensile strength of the raw fiber has the best result in tenacity but with medium elongation among the three tested fiber i.e. raw, enzyme treated, and chemical treated fiber.

Chemical Properties of the fibre -The estimation of water-soluble, Fat and wax, pectin, hemicellulose and lignin content was conducted using soxhlet apparatus in the Department Clothing and Textiles laboratory, The Maharaja Sayajirao University of Baroda, the values obtained are as shown in the table:

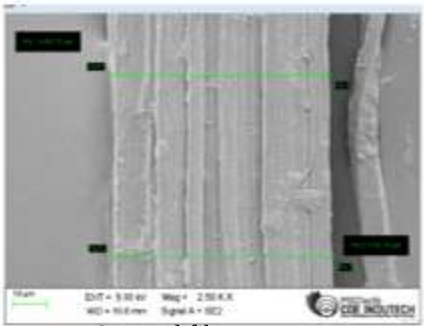
Table 4.2: Chemical composition of the fibre

Properties	Results
Fats and Waxes	3.1%
Pectin	1.2%
Hemicellulose	2%
Lignin	1.3%
Cellulose	77.7%
Water soluble component	14.7%

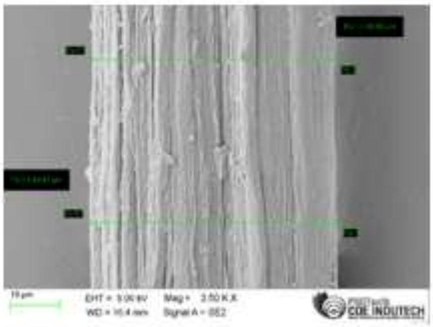
SEM Analysis- FESEM analysis was done to provide exceptionally high-resolution 1.5 nm images, and visualize surface structures and features at the nano scale was done. Observation was to check the physical and chemical changes on the surface of fibre morphology under different conditions, to get the insights into how the fibre respond to the treatment. From the analysis, it was found that the surface structure of the fibre got smoothen after the scouring process, structure of the fibre got deteriorated after beaching and in the enzyme treated fibre, more smooth fibrous surface was observed.



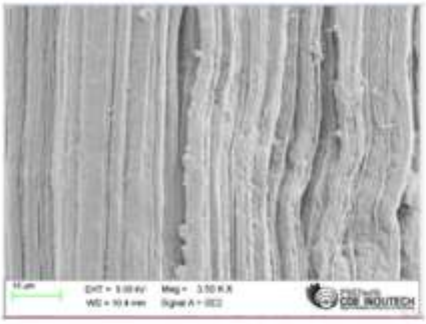
Raw fiber



Scoured fiber



Enzyme treated fiber



Bleached fiber

Fig 1: Scanning Electron Microscope results

4.5. Preparation of yarn for weaving and surface ornamentation

4.5.1 Fabrication of motorized pineapple leaf fibre charkha

A motorized charkha was fabricated based on phoenix charkha for preparing the pineapple leaf fibre yarn. The motor attached in the charkha has the capacity of 500 RPM. The speed of the charkha was maintained at around 200RPM for making the fine 100% pineapple leaf fibre yarn.

Very fine 100% pineapple leaf fibre yarn (30s) with TPI-80-85, Z twist for phee and a higher count yarn (8s) z twist for phanek made with the fiber without any treatment was found to be feasible for the traditional textiles of Manipur. And total five two ply yarns of pineapple with rayon and polyester using amber charkha and peti charkha were used in fashion maker (sewing machine) for checking the feasibility of using as surface oranamentation. The ply yarn of pineapple/polyester made with medium twist -amber charkha was not possible because of the snurl formed from the high twist. Therefore, a total of five ply yarns were made.

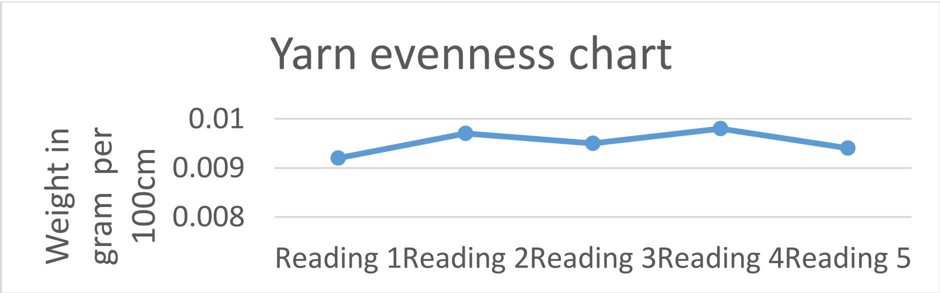
Table 4.3: Properties of the Yarn for phee

Properties	**Results**
Denier of yarn	178D
Yarn Count	30s
Yarn Twist	Z twist 80-85 TPI

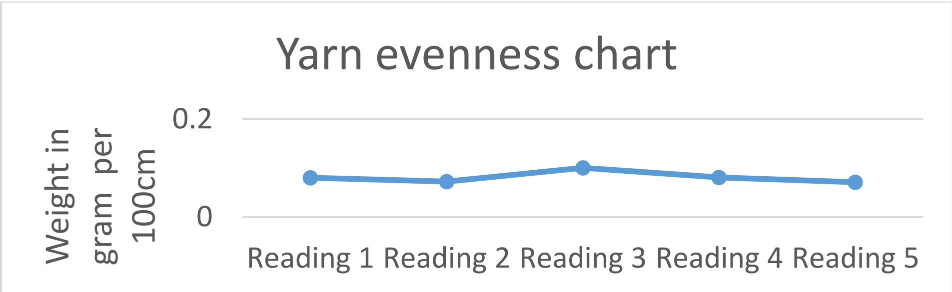
Table 4.4: Properties of the Yarn for phanek

Properties	**Results**
Denier of yarn	730D
Yarn Count	8s
Yarn Twist	Z twist 16 TPI

Since the long strands of the fibre were used for making the yarn, it was found that the evenness result of the yarn was good. (Graph 1) The prepared yarn was found to be even which had the value of mean-0.0095g per 100 cm and the mean deviation was 2.3%.



Graph 1: yarn evenness of 30s



Graph 2: yarn evenness of 8s

The 8s yarn was found to be even which had the value of mean-0.081g per 100 cm and the mean deviation was 9.62%. (Graph 2) Higher the Percentage of MD higher will be the Dispersion or Scatter or Variation. Therefore, we can say that the prepared yarn is even.

Table 4.5: Prepared Ply yarns

Yarn	Charkha	TPI (twist per inch)	Twist Direction	Count
Pineapple/Rayon–low twist(PRL)	Amber	6-8	Z+S Z	15s
Pinapple/Rayon-medium twist(PRM)	Amber	16-17	Z+S Z	13s
Pineapple/Rayon (PRP)	Peti	13-14	Z+S - Z	14s
Pineapple/polyester-low twist(PPL)	Amber	6-8	Z+Z - Z	14s
Pineapple/polyester(PPP)	Peti	14-16	Z+Z - Z	13s

Table 4.6: Combination of yarns for the trial of Surface

Lower thread	Upper thread	Lower thread	Upper thread
Pineapple/Rayon –low twist(PRL)	Polyester	Pineapple/Rayon –low twist(PRL)	Rayon
Pinapple/Rayon -medium twist(PRM)	Polyester	Pinapple/Rayon -medium twist(PRM)	Rayon
Pineapple/Rayon (PRP)	Polyester	Pineapple/Rayon (PRP)	Rayon
Pineapple/polyester- low twist(PPL)	Polyester	Pineapple/polyester- low twist(PPL)	Rayon
Pineapple/polyester(PPP)	Polyester	Pineapple/polyester(PPP)	Rayon

4.6. Testing of prepared yarn

Properties of Yarn- the produced yarns were very fine, lustrous, even and stiff which were very compatible for making the traditional textiles of Manipur. Preparation of the similar fine texture of fabrics used in the textiles of the state was achieved with the help of the finely twisted yarn. Good tensile strength with low elongation was found. In case of threads for surface ornamentation, the ply yarns were not possible to use as upper thread on the machine since there was breakage of the ply yarn because of higher count. Therefore, the total ply yarns were used as lower thread with the combination of two upper thread- polyester and rayon thread. To use the ply yarns on fabric for ornamentation, stitches should be done on the wrong side of the fabric to see the visual effect of the ply yarns on the right side of the fabric. From the result, the ply of pineapple/polyester made with low twist Amber was found to be separated while operating. Hence, the researcher rejected the yarn for using as surface ornamentation threads.

Table 4.7: Tensile strength of the 30s Yarn

Maximum load	128 g
Tenacity	2.13g/den
Strain	1.4%
Elongation	1.4 mm

4.7. Testing of the dyed yarns

The a* value gives reddish/greener where a positive number had red indication and a negative number provides green. A value of b* suggest a dye is yellow or blue where a positive number gives yellow and a negative number means the dye contains blue. c* provides the value of chroma, a distance from the lightness L* axis and h* is used to identify the angle of hue from the centre 0. In case of natural dyes, The analysis of L*a*b*c*h* value was done by maintaining the controlled sample. In case of natural dyes, the value of L* was highest in Kuthap (Hill glory bower) followed by Sanarei (marigold), highest b* value was observed as 66.02 in Shamba (Indian Trumpet tree), the value of chroma was found lowest in *Kabrang* which gained 5.48 and highest in shamba. The angle of hue was highest in *Lamuk* and lowest in *Silok Sougri* this may be due to the pink shade of Silok Sougri which was near the red (0^o) on the color space. (Table 5)

Table 4.8: L*a*b*c*h* values of the dyed samples with natural dyes

Sample	**L***	**a***	**b***	**c***	**h***
Controlled	68.10	2.77	20.74	20.93	82.35
Ureirom (URR)	22.54	29.05	39.77	48.45	53.130
Yachubi (YCB)	46.30	8.83	33.03	34.19	74.99
Lamuk (LMK)	41.33	3.82	34.03	34.24	83.55
Kuthap (KTHP)	56.88	3.90	29.40	29.65	82.39
Silok sougri (SGR)	36.66	25.45	4.79	25.89	10.66
Kabrang (MLB)	38.52	3.12	4.50	5.48	55.25

Tairen (TRN)	36.60	24.61	30.91	39.51	51.45
Shamba (SMB)	43.30	24.86	66.02	70.54	69.33
Sanarei (MRG)	55.53	6.77	40.83	41.38	80.56
Kaphoi (PMG)	49.51	8.28	28.59	29.77	73.80
Lac (LAC)	45.69	18.21	10.91	21.23	30.92
Manjistha (MJT)	42.68	37.20	35.04	51.10	43.272

Table 4.9: L*a*b*c*h* values of the dyed samples with Reactive dyes

(*)Sample	**L***	**a***	**b***	**c***	**h***
Controlled	68.10	2.77	20.74	20.93	82.35
RP	18.87	49.53	12.623	51.11	14.86
RO	32.674	45.071	56.30	74.03	49.49
RBY	57.54	9.75	90.70	91.23	83.83
RY	56.31	14.86	90.38	91.59	80.63
RB	0.000	0.000	0.000	0.000	0.000
RG	15.75	-37.61	25.47	45.42	145.92
RBP	19.13	52.17	-2.40	52.22	357.36
RR	19.10	47.36	32.73	57.57	34.63
RBR	9.65	29.90	16.62	34.21	29.05

(*)reactive colours with the code- RP- Reactofix dark pink, RO-Procion brilliant orange M-2R, RBY-Procion brilliant yellow M-4G, RY- Procion yellow M-3R, RR-Procion brilliant Red M-5B, RB-Procion black, RG-Procion green, RBP-Procion pink and RBR- Procion brown .

Based on the results, RBY had the highest value of L* since it had the lightest shade, followed by RY. The negative value of a* indicates the greener value of the dye. Therefore, the value of RG (37.61) was justified, and RP had a reddish value of a* followed by RR. The yellow value of b* was highest in RBY and RY and lowest in RBP and RP. Since controlled had no shade it had the lowest c* value and RY showed highest value. The hue angle was highest in case of RBP. In the analysis, RB had zero values in the data because black is not in the visible spectrum of colours and cannot exist in any light.

The K/S values were observed from the range of 360nm to 700 nm by using spectrophotometer SS5100A. K is the absorption coefficient and S represents the scattering coefficient of dyes. Among the obtained values, the K/S values of Ureirom were observed starting at the wavelength of 560nm (value of K/S 15.79 with reflectance value 2.81). Different values of K/S were mostly obtained from wavelength starting from 400nm to 700nm for each dye. However, to get reliable value for analysis, selection of K/S values for each dyes was done according to the reflectance value (1-10).

Table 4.10: Natural dyes K/S values

Sr. No.	Natural dye	Local name	K/S at 500nm
1.	Kamala or Kumkum tree- *Mallotus philippensis*	Ureirom Laba	15.79 at 560nm
2.	Malabar melastome-*Melastoma malabathricum*	Yachubi	4.34
3.	Koda tree- *Ehratia acuminate*	Lamuk	5.53
4.	Hill glory bower-*Clerodendrum infortunatum*	Kuthap	1.83
5.	Roselle- *Hibiscus sabdariffa*	Silok Sougri	1.99
6.	Mulberry-*Morus nigra*	Kabrang	2.86
7.	Red cedar- *Toona Ciliata*	Tairen	14.49
8.	Indian Trumpet tree- *Oroxylum indicum*	Shamba	9.87
9.	Marigold-*Tagetes erecta*	Sanarei	2.2
10.	Pomegranate- *Punica granatum*	Kaphoi	3.53
11.	Lac- *Kerria lacca*	----------	3.26
12	Manjista-*Rubia cordifolia*	------------	11.90

Separate K/S value analysis was required for each dye by using the range of wavelength, reflectance and K/S values. The below table provided the K/S value of natural dyes at 500nm. However, analysis of K/S value of every dye (reactive and natural) along with its range of wavelength and different reflectance values was done.

Table 4.11 Wavelength vs Reflectance vs K/S value of dyed yarns (natural dyes)-

Table 4.11.1 Ureirom (URR)

Wavelength (nm)	Reflectance	K/S
540	1.48	32.91
550	2.23	20.95
560	3.29	14.21
570	4.43	10.29
580	5.68	7.84
590	6.94	6.24
600	8.25	5.10
610	9.59	4.26

Table 4.11.2 Yachubi (YCB)

Wavelength (nm)	Reflectance	K/S
410	1.28	38.22
420	2.10	22.80
430	3.00	15.68
440	3.92	11.79
450	4.80	9.43
470	6.67	6.52
480	7.67	5.55
490	8.73	4.77
500	9.42	4.35

Table 4.11.3 Lamuk (LMK)

Wavelength (nm)	Reflectance	K/S
430	1.30	37.49
440	2.22	21.53
450	3.33	14.01
460	4.62	9.84
470	5.90	7.50
480	7.11	6.06
490	8.22	5.12
500	8.87	4.68
510	9.33	4.40

Table 4.11.4 Kuthap (KTP)

Wavelength (nm)	Reflectance	K/S
400	2.01	23.85
410	3.42	13.62
420	4.91	9.21
430	6.64	6.56
440	8.53	4.90
450	10.41	3.85

Tbable 4.11.5 Silok Sougri (SGR)

Wavelength (nm)	Reflectance	K/S
400	2.25	21.23
410	4.14	11.09
420	6.11	7.21
430	7.72	5.51
440	8.71	4.79
450	9.20	4.48
460	9.48	4.32
470	9.60	4.25

Table 4.11.6 Kabrang(LMK)

Wavelength (nm)	Reflectance	K/S
380	1.31	37.23
390	2.36	20.12
400	4.00	11.52
410	5.68	7.83
420	6.87	6.30
430	7.77	5.47
440	8.48	4.94
450	9.05	4.57
460	9.58	4.26
470	10.02	4.03

Table 4.11.7 Shamba (SMB)

Wavelength (nm)	Reflectance	K/S
470	1.14	42.92
480	1.79	26.91
490	2.58	18.32
500	3.12	15.02
510	3.79	12.21
520	5.43	8.24
530	7.30	5.89
540	9.03	4.58

Table 4.11.8 Tairen (TRN)

Wavelength (nm)	Reflectance	K/S
380	1.23	39.76
390	1.95	24.68
400	2.67	17.77
410	3.05	15.36
420	3.08	15.24
430	3.02	15.58
440	2.89	16.33
450	2.72	17.39
460	2.67	17.74
470	2.73	17.36
480	2.88	16.33
490	3.15	14.91
500	3.23	14.49
510	3.45	13.50
520	4.41	10.36
530	5.57	8.01
540	6.60	6.61
550	7.83	5.43
560	9.15	4.51

Table 4.11.11 Marigold (MRG)

Wavelength (nm)	Reflectance	K/S
410	1.75	27.60
420	2.74	17.82
430	3.68	12.60
440	4.75	9.55
450	6.04	7.31
460	7.67	5.56
470	9.58	4.27

Table 4.11.9 Lac (LAC)

Wavelength (nm)	Reflectance	K/S
380	1.51	32.20
390	2.91	16.19
400	4.76	9.53
410	6.63	6.57
420	8.14	5.18
430	9.43	4.35

Table 4.11.10 Manjistha (MJT)

Wavelength (nm)	Reflectance	K/S
390	1.85	25.98
400	3.01	15.64
410	3.66	12.69
420	3.90	11.85
430	3.92	11.77
440	3.73	12.41
450	3.52	13.23
460	3.38	13.79
470	3.32	14.06
480	3.47	13.45
490	3.76	12.31
500	3.88	11,90
510	4.13	11.13
520	5.05	8.92
530	5.98	7.38
540	6.41	6.82
550	7.04	6.13
560	8.69	4.80

Table 4.11.12 Marigold (MRG)

Wavelength (nm)	Reflectance	K/S
390	1.26	38.66
400	2.66	17.80
410	4.06	11.33
420	5.30	8.45
430	6.44	6.80
440	7.44	5.75
450	8.38	5.01
460	9.46	4.33

Table 4.12: Wavelength vs Reflectance vs K/S value of dyed yarns (reactive dyes)

Table 4.12.1 Reactofix Dark Pink (RP

Wavelength (nm)	Reflectance	K/S
410	1.06	46.00
420	1.65	29.22
430	2.17	22.01
440	2.41	19.72
450	2.17	22.09
460	1.51	32.033
590	2.23	21.41
600	6.039	7.31

Table 4.12.3 Procion Brilliant Orange (RC

Wavelength (nm)	Reflectance	K/S
550	2.05	23.42
560	4.13	11.13
570	6.74	6.45
580	10.29	3.91

Table 4.12.2 Procion Bright Yellow (RBY)

Wavelength (nm)	Reflectance	K/S
490	3.00	15.70
500	7.01	6.17
510	12.6	3.17

Table 4.12.4 Procion Yellow (RY)

Wavelength (nm)	Reflectance	K/S
490	2.07	23.18
500	3.70	12.54
510	7.00	6.177
520	13.81	2.69

Table 4.12.5 Procion Black (RB)

Wavelength (nm)	Reflectance	K/S
360 to 700	nil	nil
-	-	-

Table 4.12.6 Procion Red (RR)

Wavelength (nm	Reflectance	K/S
590	2.58	18.40
600	6.07	7.27
610	11.14	3.56

Table 4.12.7 Procion Green (RG)

Wavelength (nm)	Reflectance	K/S
500	1.38	35.21
510	2.73	17.30
520	4.78	9.49
530	5.71	7.78

Table 4.12.8 Procion Green (RG)

Wavelength (nm)	Reflectance	K/S
410	1.04	47.036
420	1.73	27.96
430	2.35	20.31
440	3.47	13.43
450	4.57	9.97
460	4.56	9.99
470	3.23	14.51
480	1.48	32.72
600	2.34	19.55
610	8.07	5.24

Table 4.12.9 Procion Brown (RBR)

Wavelength (nm)	Reflectance	K/S
580	1.37	35.64
590	1.87	28.81
600	2.45	19.40
610	3.20	14.61
620	4.18	10.98
630	5.47	8.16
640	7.29	5.89
650	9.98	4.06

Colour Difference

Color difference refers to the observed difference in color between two samples. It is often quantified using color difference metrics, with the most commonly used being the CIE Value. Colour difference of all the dyes was obtained with difference in colour between the controlled sample and the dyed sample.

Ureirom (URR)

DIFFERENCE		
DL* =	-45.560	Darker
Da* =	26.284	Redder
Db* =	18.028	Yellower
DC* =	27.523	Brighter

Yachubi (YCB)

DIFFERENCE		
DL* =	-21.801	Darker
Da* =	6.061	Redder
Db* =	12.283	Yellower
DC* =	13.259	Brighter

Lamuk(LMK)

DIFFERENCE		
DL* =	-26.770	Darker
Da* =	1.054	Redder
Db* =	13.285	Yellower
DC* =	13.315	Brighter

Silok Sougri (SGR)

DIFFERENCE

DL* =	-31.443	Darker
Da* =	22.673	Redder
Db* =	-15.949	Less Yellow
DC* =	4.965	Brighter

Kuthap(KTP)

DIFFERENCE

DL* =	-11.223	Darker
Da* =	1.136	Redder
Db* =	8.655	Yellower
DC* =	8.729	Brighter

Kabrang(LMB)

DIFFERENCE

DL* =	-29.585	Darker
Da* =	0.351	Redder
Db* =	-16.238	Less Yellow
DC* =	-15.446	Duller

Tairen(TRN)

DIFFERENCE

DL* =	-31.498	Darker
Da* =	21.840	Redder
Db* =	10.165	Yellower
DC* =	18.583	Brighter

Shamba(SMB)

DIFFERENCE

DL* =	-24.798	Darker
Da* =	22.091	Redder
Db* =	45.270	Yellower
DC* =	49.613	Brighter

Lac (LAC)

DIFFERENCE

DL* =	-21.384	Darker
Da* =	15.097	Redder
Db* =	-9.226	Less Yellow
DC* =	0.331	Brighter

Manjistha (MJT)

DIFFERENCE

DL* =	-27.717	Darker
Da* =	37.209	Redder
Db* =	15.641	Yellower
DC* =	33.131	Brighter

Marigold (MRG)

DIFFERENCE

DL* =	-12.570	Darker
Da* =	3.993	Redder
Db* =	20.087	Yellower
DC* =	20.459	Brighter

Pomegranate (PMG)

DIFFERENCE

DL* =	-18.593	Darker
Da* =	5.514	Redder
Db* =	7.849	Yellower
DC* =	8.841	Brighter

Reactofix Dark Pink (RP)

DIFFERENCE

DL* =	-47.857	Darker
Da* =	49.055	Redder
Db* =	-23.354	Less Yellow
DC* =	31.040	Brighter

Procion Brilliant Yellow (RBY)

DIFFERENCE

DL* =	-9.277	Darker
Da* =	7.049	Redder
Db* =	70.972	Yellower
DC* =	71.311	Brighter

Procion Yellow (RY)

DIFFERENCE

DL* =	-10.506	Darker
Da* =	12.156	Redder
Db* =	70.646	Yellower
DC* =	71.675	Brighter

Procion Brilliant Orange (RO)

DIFFERENCE

DL* =	-34.145	Darker
Da* =	45.370	Redder
Db* =	36.572	Yellower
DC* =	54.117	Brighter

Procion Black (RB)

DIFFERENCE

DL* =	-66.810	Darker
Da* =	-2.701	Less Red
Db* =	-19.733	Less Yellow
DC* =	-19.917	Duller

Procion Red (RR)

DIFFERENCE

DL* =	-47.889	Darker
Da* =	44.250	Redder
Db* =	11.777	Yellower
DC* =	36.389	Brighter

Procion Pink (RBP)		
DIFFERENCE		
DL* =	-47.947	Darker
Da* =	46.826	Redder
Db* =	-7.110	Less Yellow
DC* =	31.193	Brighter

Procion Brown (RBR)		
DIFFERENCE		
DL* =	-57.344	Darker
Da* =	26.787	Redder
Db* =	-4.336	Less Yellow
DC* =	13.024	Brighter

Procion Green (RG)		
DIFFERENCE		
DL* =	-51.239	Darker
Da* =	-40.721	Less Red
Db* =	4.513	Yellower
DC* =	24.237	Brighter

Colour fastness

The dyed pineapple yarn colourfastness towards washing and light were observed. A rating scale of 1-5 (1-Very poor, 2- Poor, 3- Good, 4-Very Good, 5- Excellent) was used for grading the performance of the dyed samples towards wash fastness test. All the reactive dyes were observed as very good to excellent results.

From the result, it was observed that the wash fastness of all the dyed samples was found to be 4 grade (very good) except the two dyes- *Silok Sougri* and *Kabrang* which were 2-3 rating (poor-moderate).

Light fastness

The scale 1-8 rating (1-2- Very poor, 2-3 poor, 3-4 Fair,4-5 Good, 5-6 Very Good ,6-7 Excellent, 7-8 outstanding) was used for light fastness test. The light fastness value of Reactive Brilliant yellow (RBY), Reactive Yellow (RY), and Reactive pink (RP) showed the excellent result. Excellent light fastness was gained in *Shamba, Tairen, Yachubi and Sanarei* dyed samples whereas very good to excellent were found in the remaining samples. Therefore, the reactive and plant dyes are suitable for dyeing on pineapple leaf fibre yarn.

4.8. Extraction of bromelain enzyme

Extraction was done using different Material Liquor Ratio and medium- 1. Extraction with alkali water (ground water) at 1:30 MLR 100^{o}C and 2. Extraction using distilled water at 1:20 MLR at 100^{o}C. Optimization of time and speed of regulator were done for centrifugation. Different time interval for centrifugation were observed after 2minutes, 5 minutes and 10 minutes, 15 min. 2 mins and 5 minutes duration were not enough for the separation of solid from the liquid therefore, 10 minutes was found to optimum after 10 mins no further separation was seen. The centrifuge machine had regulator with speed of 5 stages. However, the 2 stage speed was found optimum. The machine as the capacity of 8 tube of 15 ml. Filtration was followed after this process. And kept in the refrigerator.

4.9. Construction of traditional textiles on handloom

Plain weave was used for making the fabric samples silk/pineapple (Rani phee), Cotton/pineapple (Lengyan), Rayon/pineapple (muga Innaphee) and Muga phanek (polyester/pineapple). The traditional Rani phee was a textile of Meitei women named after a weaver Rani from Manipur. The textile was worn as an upper garment during occasion especially wedding. The traditional textile muga innaphee could be seen in many occasion worn by Meitei women. The muga innaphee of Khurkhul was the most popular muga innaphee textile. Lengyan phee could worn by both men and women during occasions. The textile was worn by draping over the shoulder. The textile named muga phanek was made of silk/muga for wearing as the lower garment like sarong. Phanek was the traditional textile of Meitei women and the textile was made mainly with cotton and silk especially mulberry muga of Khurkhul. The stiffness achieved from the fibre showed a very similar structure to the existing traditional textiles which made a highly feasible in making the proposed textiles. Usually, local people & weavers in Manipur apply starch finishing to achieve high stiffness in the textiles. Very thin and lightweight, and good strength in testing were obtained from the developed fabrics.

Table 4.13: Properties of the developed Fabrics

Fabric	**Yarn count**	**Fabric count**	**Cover factor**	**GSM**	**Thickness**
Rani phee (Silk/Pineapple)	Warp-50s weft-30s	Warp-66 weft-44	14.68	56	0.24mm
Khurkhul muga Phee(Rayon/Pineapple)	Warp-21s weft-30s	Warp-16 weft 36	9.24	77.48	0.26mm
Lengyan Phee (Cotton/Pineapple)	Warp-25s weft-30s	Warp-16 weft 44	5.34	75.96	0.30mm
Muga Phanek (polyester/pineapple	Warp -18s Weft-8s	Warp- 39 Weft-32	15.03	184.4	0.57mm

Table 4.13.1: Tensile strength

Fabric	Speed(mm/min)	Maximum load(Kgf)	Percentage strain maximum load
Rani phee (Silk/Pineapple)	Warp- 100	10.209	19.70
	Weft- 100	15.98	5.50
Khurkhul muga Phee(Rayon/Pineapple)	Warp-100	15.91	19.34
	Weft- 100	13.46	6.36
Lengyan Phee (Cotton/Pineapple)	Warp-100 Weft -100	9.90 12.15	22.11 7.50

Table 4.13.2: Average fabric stiffness/bending length

Sample	Warp (cm)		Weft (cm)	
	Face to Face	Back to Back	Face to Face	Back to Back
Rani phee (Silk/Pineapple)	3.12	3.38	9.68	9.32
Khurkhul muga Phee(Rayon/Pineapple)	3.68	3.42	6.41	6.7
Lengyan Phee (Cotton/Pineapple)	3.12	3.1	8.76	8.86
Muga Phanek (polyester/pineapple)	2.98	3.0	7.9	8

Stiffness in draping is one of the main characteristics of the Meitei community's traditional textiles in the state. Without any finishing treatment stiff fabrics were developed by the researchers.

High drape-coefficient were obtained during the test of drapability of the developed fabrics which will be used as drape around the upper body. It was found to be equivalent with drape-coefficient value of the existing starched traditional textiles phee used in Manipur.

Table 4.13.3: Drape coefficient of developed and existing textile

Developed Fabric	Drape coefficient	Fabric (existing textile)	Drape coefficient (Starched)	Drape coefficient (De-starched)
Silk/Pineapple (S/P)	67.57%	Silk/Silk(S/S)	60.61%	18.85%

Rayon/Pineapple(R/P)	57.13%	Rayon/Silk(R/S)	53.65%	15.38%
Cotton/Pineapple(C/P)	64%	Cotton/Silk(C/S)	64.09%	46.66%

The value of drape-coefficient of silk/pineapple, rayon/pineapple, and cotton/pineapple were 67.7%, 57.13% and 64% respectively. From the comparison between the developed and the existing traditional textiles drape co-efficient, the values of developed fabric without any finishing treatment was almost similar to the values of the starched traditional textiles.

Kawabata Analysis-

In the Kawabata evaluation system analysis, the selected fabric cotton/pineapple fabric was suitable for women thin dress fabric. Low stress mechanical properties was obtained to get the compression properties, fabric weight and thickness, tensile properties, shear properties, surface properties, and bending properties. The results for each test are given below:

Table 4.14: Primary and Total Hand value (Women's Thin dress Fabric)

	Koshi (Stiffness)	Numeri (smoothness)	Fukurami (Fullness & softness)	THV KN-302 Winter
Cotton/pineapple	8.17	6.42	9.63	3.05

Table 4.15: Low compression properties (KES-FB3A)

	LC	WC g.cm/cm^2	RC %
Cotton/pineapple	0.303	0.283	37.56

Parameters

LC: Linearity of Compression-thickness curve
WC: Compressional energy
RC: Compressional resilience

Table 4.16: Fabric weight and Thickness

	Fabric Thickness (mm)	Fabric Thickness at max. pressure (mm)	Fabric weight (mg/cm^2)
Cotton/pineapple	0.819	0.448	7.434

Table 4.17: Tensile Properties using tensile tester (KES-FB1A)

	Direction	LT	WT $gf.cm/cm^2$	RT %	EMT %
Cotton/pineapple	Warp	0.552	7.78	52.47	5.64
	Weft	0.753	1.73	73.09	0.92
	Average	0.635	4.67	62.78	3.28

Parameter
LT: Linearity of load- extension curve
WT: Tensile Energy
RT: Tensile resilience
EMT: Extensibilty

Table 4.18: Shear properties using shear tester (KES-FB1)

	Direction	G Gf.cm.deg	2HG gf/cm	2HG5 gf/cm
Cotton/pineapple	Warp	0.552	7.78	52.47
	Weft	0.753	1.73	73.09
	Average	0.635	4.67	62.78

Parameters
G: Shear Stiffness
2HG: Hysteresis of shear force at 0.5 deg shear angle
2HG5: Hysteresis of shear force at 5 deg shear angle

Table 4.19: Surface properties using Surface tester (FES-FB4)

	Direction	MIU	MMD	SMD (µm)
Cotton/pineapple	Warp	0.121	0.0263	7.770
	Weft	0.252	0.0279	12.740
	Average	0.186	0.0271	10.255

Parameters
MIU: Coefficient of friction
MMD: Mean Deviation of MIU
SMD: Geometrical Roughness

Table 4.20: Bending Properties using pure bending tester (KES-FB2)

	Direction	**B** **gf.cm²/cm**	**2HB** **gf.cm²/cm**
Cotton/pineapple	Warp	0.0359	0.0348
	Weft	1.9740	0.9651
	Average	1.0049	0.4999

Parameters
B: Bending Rigidity
2HB: Hysteresis of Bending Moment

4.10. Cost Calculations of the constructed fabric

Cost of the yarn required for making a meter of each fabric (Rani phee, Lengyan phee, Muga innaphee and Muga phanek) was calculated. The details are given in the table 4.21.:

Table 4.21: Raw Material Cost

The yield of the fibre from waste is 4%.	Total cost
1. To produce 1kg of fibre, 40kg of waste leaves are procured @ Rs 10/Kg	Rs 400
2. Transportation charge	Rs 600
3. Cost of Extraction + Scouring	Rs 2000
4. Spinning	Rs 5000
5. Total cost of yarn per Kg	Rs 8000

Table 4.22: Cost calculation of 1 meter of Fabric

Fabric -Silk/pineapple (Rani Phee) width -55cm	Total cost
1.Yarn used in warp: 13.33gm @ Rs 9000 per Kg	Rs 120
2.Yarn used in weft : 17.5gm @ Rs 8000 per Kg	Rs 140
3. Weaving charge with motifs @ Rs 5500 per Rani phee	Rs 2750
Fabric- Cotton/pineapple (Lengyan Phee) width- 82cm	
1. Yarn used in warp: 25.5gm @ Rs 500 per Kg	Rs 13
2. Yarn used in weft: 35gm @ Rs8000 per Kg	Rs 280
3. Weaving charge (with motifs) @ Rs3800 per Lengyan	Rs 1900
Fabric- Rayon/pineapple (Muga Innaphee) width- 97cm	
1. Yarn used in warp: 37gm@ Rs 350 per Kg	Rs 14
2. Yarn used in weft: 38gm @ Rs 8000 per Kg	Rs 304
3. Weaving charge (with motifs)- @ Rs 4000 per Innaphee	Rs 2000
Fabric- Polyester/pineapple (Muga Phanek) width- 63 cm	
1. Yarn used in warp: 30gm@ Rs 300 per Kg	Rs 9
2. Yarn used in weft: 50gm @ Rs 8000 per Kg	Rs 400
3. Weaving charge (with temple stoop motif)- @ Rs 700 per Muga phanek	Rs 350

Therefore, the total cost of the silk/pineapple (Rani phee) per meter= Rs 3,010

The total cost of the cotton/pineapple (Lengyan phee) per meter = Rs 2,193

The Total cost of the rayon/pineapple (Innaphee) per meter = Rs 2,318

The Total cost of the polyester/pineapple (Innaphee) per meter = Rs 759

4.11. Feedback from the consumer

The compatibility of the fibre as an alternative to conventional material in weaving the textiles was found to feasible. Based on their physical appearance of pineapple leaf fibre, yarns, and constructed textiles, the feedback was taken with interview method using open ended and closed ended questionnaires both in English and local language (Manipuri) from the consumer and weavers (total 60 including the weavers) of age group 18-60 years from Meitei community. Different questionnaires were made separately for consumer and weavers. Hundred percent of the responded yes to the pineapple leaf fibre for using as a raw material for making the traditional textiles of Meitei community. People appreciated the work done by the researcher.

4.12. Awareness of constructed traditional textiles

- A Talk in the Khangminashi Program episode 18 by Impact TV on ‘Pineapple leaf fiber’
- 2 newspaper articles on pineapple leaf fibre published in Sanaleibak Daily, Manipur, dated- 13-07-2022 & 05-12-2022.
- Products display during the 9th National handloom day 7th Aug 2023

  Venue- Institute of Fashion Technology

  Faculty of Family and Community Sciences

  The Maharaja Sayajirao University Of Baroda, Vadodara, Gujarat.
- A training program on awareness about the pineapple leaf fibre was conducted for handloom weavers cluster group of Khurkhul, Manipur. The weavers’ group are the people who produce local mulberry silk products (Popularly known as Khurkhul muga).

Chapter-5
Summary and Conclusion

Presently, India is known for agriculture based transforming nation. After harvesting the agricultural foods, utilization of crops residue can be carried out in various sector. Use of agro- waste fibre and other natural minor fibre for making valuable textile products are being done by many organizations, researchers, and institutes. The natural minor fibre extracted from the different parts of the plants can be alternative raw materials to petroleum based synthetic raw materials in textile industry. Use of fibre from crops will lead to not only sustainable raw materials but also reduction of agricultural waste, generation of income to the farmers as well as dual-purpose of the crop. Pineapple leaf fibre is one agro waste fibres which can be used in making textile products. This study focuses on the more sustainability in terms of economy, society and environment. The extracted pineapple leaf fibre is utilized in weaving traditional textiles of Meitei community of Manipur by retaining the traditional practices of weaving in the state. For value addition, dyeing with reactive dyes and natural dyes (mainly the local plant dyes) based on the traditional colour used by the community. A local motorized charkha was fabricated for spinning the pineapple leaf fibre. A total of four traditional textiles were developed. The consequences of the study are-

- ❖ To popularize this non-conventional fibre, briges among the farmers, entrepreneurs, organizations, researchers, institutes, and weavers are highly needed. Proper channel of the fibre beginning from the procuring of raw material- fibre extraction-supplying- product making and marketing is required.
- ❖ Hundred percent pineapple leaf fibre without any treatment was achieved for making yarn with use of local motorized charkha. High tensile strength with low elongation, fine and lustrous yarn were obtained.
- ❖ Dyeing with synthetic dyes and natural dyes was found to be suitable which provided good to excellent results in almost all the dyes.
- ❖ Four type of traditional textiles Rani phee, innaphee and Lengyan phee and one phanek were woven on handloom without any special treatment like starch finishing (stiffness is a mandatory characteristic of traditional textiles of Meitei. High drape-coefficient values were observed in all the developed textile. Consumer showed interest to wear the traditional textiles from the pineapple leaf fibre.

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