Chapter III

EXPERIMENTAL PROCEDURE

The study was structured as an experimental and exploratory investigation into the properties and potential applications of pineapple leaf fiber within the context of traditional hand-woven textiles in Manipur. The main objective was to explore the feasibility and viability of incorporating pineapple leaf fiber into the existing textile practices of the region.

To achieve this objective, the study encompassed a series of methodical steps. Firstly, the process of fiber extraction was explored through both manual and mechanical means. Manual extraction involved traditional hand methods, while mechanical extraction employed modern machinery to streamline the process. This dual approach allowed for a comprehensive understanding of the fiber extraction process and its potential growth.

Furthermore, the study experimented with various softening treatments applied to the extracted fibers on a pilot basis. These treatments aimed to enhance the textile properties of the pineapple leaf fiber, making it more suitable for weaving and subsequent textile production processes. In addition, the research involved the development and utilization of a modified spinning apparatus, known as a charkha, optimized for spinning pineapple leaf fibers. This modified charkha was designed to improve spinning efficiency and enhance the fineness of the spun yarns, thus ensuring the production of high-quality yarn suitable for weaving.

The spun yarns were then utilized in the weaving of pineapple union fabrics. To enhance the aesthetic appeal of these fabrics, conventional dyeing techniques were employed. This included dyeing the yarns using both natural dyes sourced from local plants and reactive dyes, all chosen based on traditional color palettes used in Meitei textiles.

Finally, the fabrics produced incorporated traditional motifs and colors distinctive to Manipuri textiles. These fabrics was put in rigorous evaluation processes to identify the most promising samples to traditional design aesthetics. Through this detailed and systematic approach, the research aimed to scientifically evaluate the potential of pineapple leaf fiber as a valuable resource within Manipur's traditional textile industry, while also preserving and celebrating the region's rich textile heritage.

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

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The fabrics was woven on handloom by the local weavers in Manipur. Testing of fabric samples was performed. Incorporation of traditional motifs and colours used in the traditional textiles was done. Weaving of samples for the traditional textiles on two shaft throw shuttle loom-

3.10.1. Construction Technique

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

3.10.3. Testing of the woven fabric samples include-

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

3.10.4. Kawabata of selective fabric

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3.13. Cost Calculations of the constructed fabric

3.14. Feedback from the consumer

3.15. Awareness of pineapple leaf fibre for textiles

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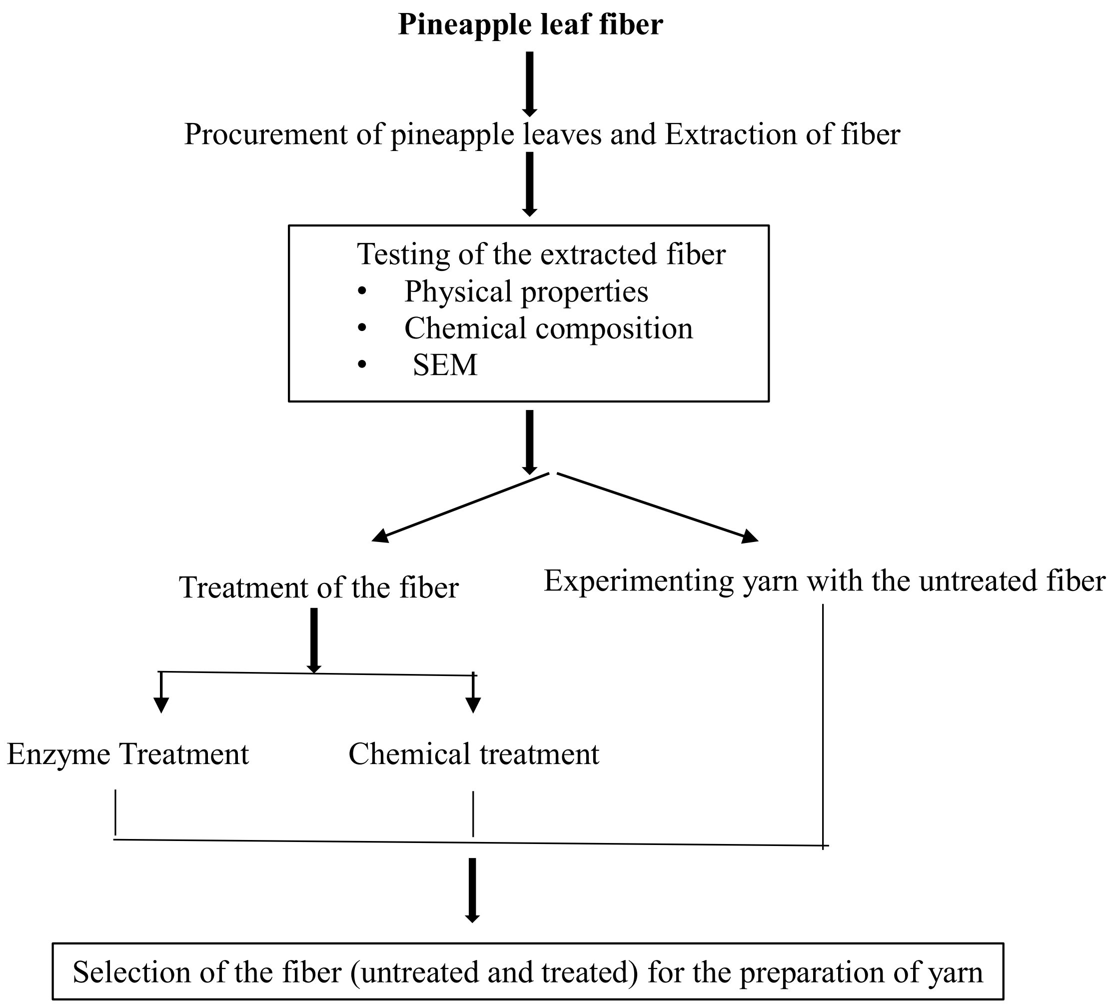
3.1 Research Design

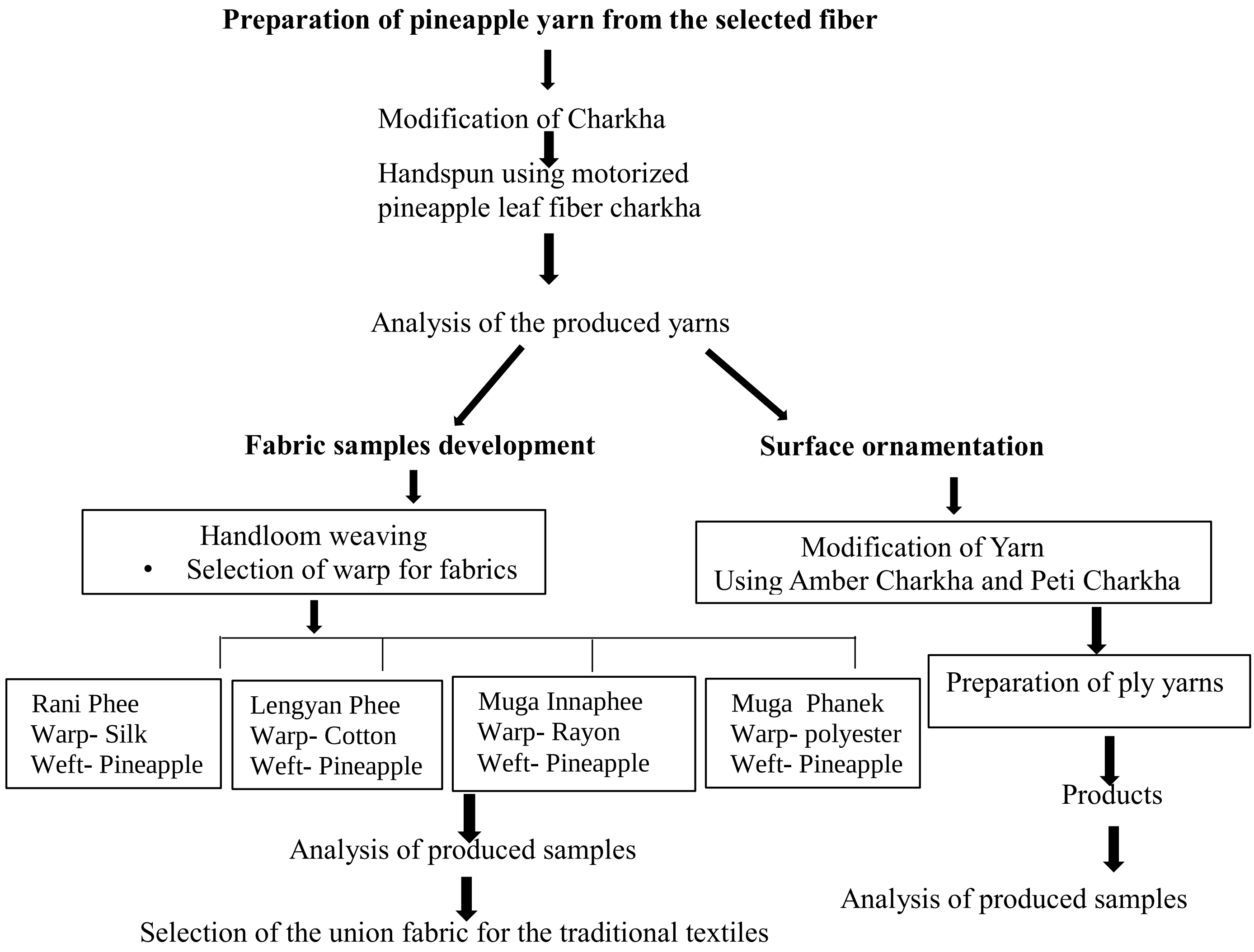
The current study was structured into three phases to address its objectives. Initially, the focus lay on the procurement of pineapple leaves, fiber extraction, testing, and treatment, followed by the selection of fibers for yarn preparation, both treated and untreated. In the second phase, various handspun yarns were prepared, and fabric samples were woven on a handloom, alongside the development of plied yarns for surface ornamentation. This phase also involved selecting traditional textiles, motifs, and colors, dyeing the fabrics using natural and reactive dyes, traditional weaving, cost calculation, and gathering consumer feedback.

The research design followed is depicted in illustration 1

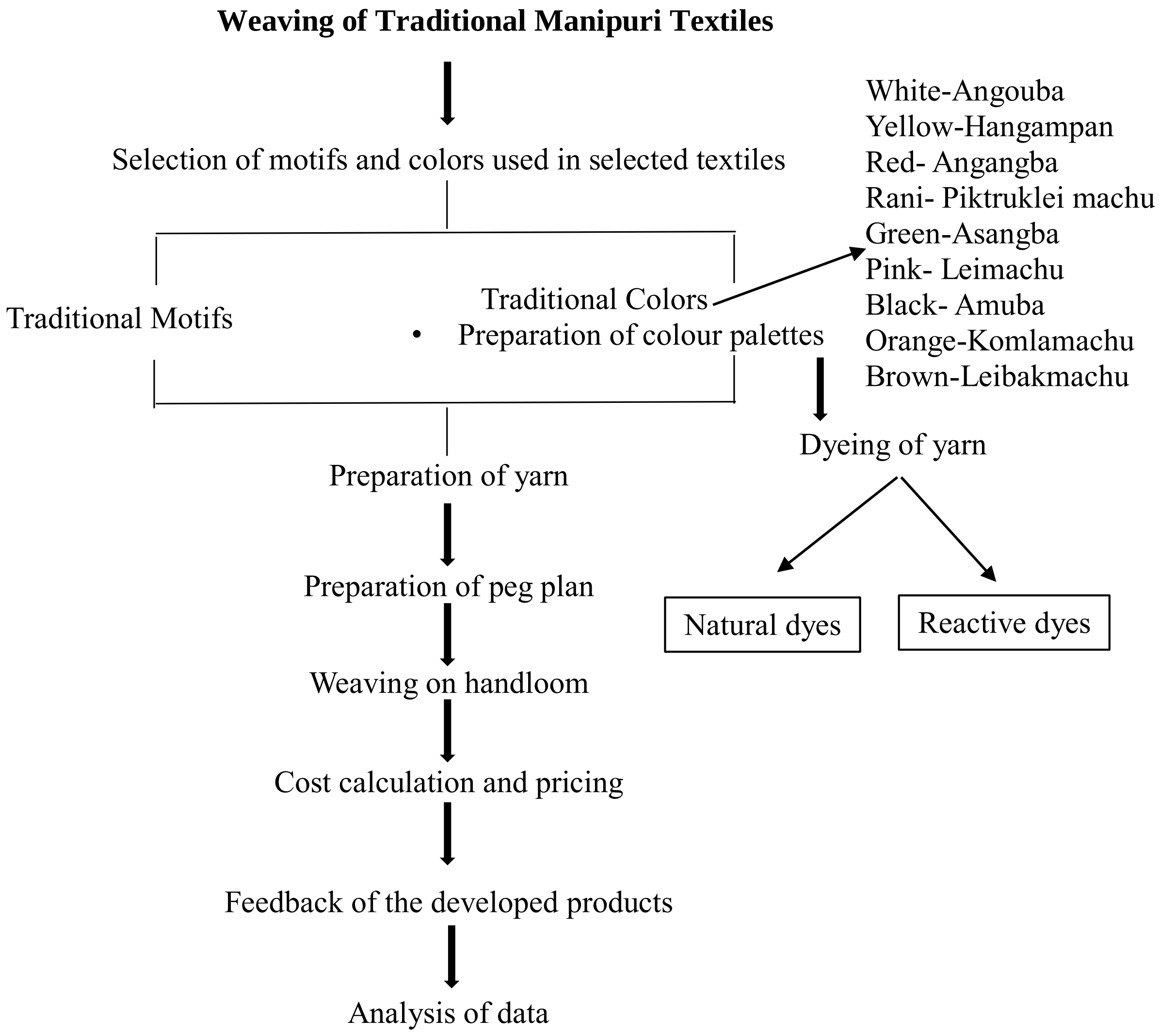
Phase 1



Phase 2


Preparation of pineapple yarn from the selected fiber
Modification of Charkha
Handspun using motorized pineapple leaf fiber charkha
Analysis of the produced yarns
Fabric samples development
Surface ornamentation
Handloom weaving
• Selection of warp for fabrics
Modification of Yarn Using Amber Charkha and Peti Charkha
Rani Phee Warp- Silk Weft- Pineapple
Lengyan Phee Warp- Cotton Weft- Pineapple
Muga Innaphee Warp- Rayon Weft- Pineapple
Muga Phanek Warp- polyester Weft- Pineapple
Preparation of ply yarns
Products
Analysis of produced samples
Analysis of produced samples
Selection of the union fabric for the traditional textiles

Phase 3


Weaving of Traditional Manipuri Textiles
Selection of motifs and colors used in selected textiles
Traditional Motifs
Traditional Colors
• Preparation of colour palettes
White-Angouba
Yellow-Hangampan
Red- Angangba
Rani- Piktruklei machu
Green-Asangba
Pink- Leimachu
Black- Amuba
Orange-Komlamachu
Brown-Leibakmachu
Dyeing of yarn
Natural dyes
Reactive dyes
Preparation of yarn
Preparation of peg plan
Weaving on handloom
Cost calculation and pricing
Feedback of the developed products
Analysis of data

3.2. Availability of Pineapple Leaf Fiber in India

In this section, the focus was on evaluating the availability of pineapple leaf fiber throughout India. This assessment was based on a comprehensive review of articles related to fiber sourcing and data obtained from various traders' websites. To gather detailed insights, a proactive approach was adopted wherein multiple fiber suppliers were engaged through various communication channels including phone calls, email, and WhatsApp.

Through a systematic review of relevant literature and online resources, the researcher aimed to ascertain the availability and distribution of pineapple leaf fiber within the Indian market. Traders' websites provided valuable data regarding the presence of pineapple leaf fiber in different regions of the country, shedding light on potential sources for procurement.

Furthermore, direct engagement with fiber suppliers via phone calls, email inquiries, and messaging platforms such as WhatsApp allowed for a more granular understanding of the current landscape of pineapple leaf fiber accessibility. These interactions facilitated the collection of firsthand information regarding the availability, pricing, and logistical aspects associated with sourcing pineapple leaf fiber across various states in India. By following both secondary research and direct communication with industry stakeholders, the study endeavors to provide a comprehensive overview of the accessibility of pineapple leaf fiber in India.

In the view of availability of Pineapple leaf fibre in Manipur. The researcher conducted interviews with the following individuals in Manipur who worked on pineapple leaf fiber during the 1970s:

1. Kh. Shamu Singh, who previously served as an Assistant Director in the Design Department and has experience as a Textile Technologist.
2. Athokpam Ibetombi and Ingujam Binoychnadra, both former demonstrators involved in fiber extraction processes.
3. Soibam Apanbi, a project staff member from the Design Department at the District Industrial Centre in Porompat, Manipur,

3.3. Collection of the raw material

The raw materials required for pineapple leaf fiber extraction were sourced directly from local pineapple farms situated in Kangchup, Imphal west- District, Manipur.

Specifically, pineapple leaves from both Kew and Queen varieties were utilized for this purpose. This involved gathering the leaves directly from the farms, ensuring they were fresh and suitable for fiber extraction 50-90 cm in length. By obtaining the raw materials from local sources, the study aimed to ensure the authenticity and quality of the pineapple leaf fibers being used in the research process. This particular sourcing process highlights the commitment to using locally available resources and supports the sustainability of the local agricultural economy in Manipur.

Fig. 3.1: A pineapple farm in Manipur

Fig.3.2: Collected pineapple leaves

Fig.3.3: Removing of pineapple leaves spikes

Fig.3.4: Spikes removed pineapple leaves

3.4. Extraction of fiber

The fiber extraction process commenced with the obtained raw materials from local pineapple plant growers, employing both manual hand extraction and mechanical extraction methods. This process was supplemented by a water retting procedure lasting approximately 5-7 days depending on the weather condition. Machine-based extraction was specifically conducted at the CSIR-NEIST branch laboratory located in Lamphel, Manipur, ensuring standardized and controlled extraction conditions. Subsequent to extraction, scouring process used 2g/L of commercial detergent and sodium carbonate with a 1:40 material-to-liquor ratio. The solution was heated to 60°C for 45 minutes, followed by thorough washing. This thorough cleansing process aimed to ensure the purity and cleanliness of the extracted fiber. Finally, the fibers were carefully dried, completing the preparation process for further experimentation and utilization. This detailed sequence of extraction and processing stages features the systematic approach employed to obtain high-quality pineapple leaf fibers.

Fig.3.5: Machine extraction at the CSIR Laboratory, Imphal

Fig.3.6: Machine extracted combed pineapple leaf fibre

Fig.3.7: Washing of the extracted fiber

Fig.3.8: Drying

Fig.3.9: Machine Extracted pineapple leaf fibre

Fig.3.10: Manual Extraction

Fig.3.11: Water retting

Fig3.12: washing of retted fibre

Fig.3.13: Hand Extracted pineapple fibre after washing and drying

3.5. Pilot experiment on modification of produced Pineapple leaf fibre

A pilot experiment was conducted to explore various treatments for enhancing the spinning properties of the produced pineapple leaf fiber. This experimentation involved employing enzyme and chemical treatments on a pilot basis. For the enzyme treatment, cellulase enzyme was utilized, procured from Rossari Biotech Limited located in Dadra & Nagar Haveli. This enzyme treatment aimed to modify the fiber structure and improve its spinning characteristics. In addition to enzyme treatment, chemical treatments were also explored, utilizing hydrogen peroxide and sodium hydroxide. These chemicals were applied to the fiber to induce structural changes and enhance its suitability for spinning. The pilot experiment was carried out at the Department of Clothing and Textiles of the Faculty of Family and Community Sciences at The Maharaja Sayajirao University of Baroda, Vadodara,Gujarat. Through this pilot experiment, various treatment methods were evaluated to determine their effectiveness in modifying the pineapple leaf fiber for improved spinning performance.

3.6. Testing of properties

3.6.1. Physical properties

The examination of the pineapple leaf fiber's physical properties was conducted with meticulous attention to detail, aiming to ascertain its suitability for various textile applications.

Length and diameter of the fiber- Firstly, the length of the fiber was determined using a steel ruler, a common tool in fiber analysis due to its simplicity and accuracy. To ensure precise results, a comprehensive approach was adopted, involving the acquisition of an average of 20 readings. This extensive sampling process aimed to capture any variations in fiber length across the sample population, thereby enhancing the reliability of the measurements. Similarly, the fiber diameter, another essential parameter influencing its mechanical properties, was carefully assessed using a digital microscope equipped with a micrometer. This advanced instrumentation allowed for high-resolution imaging and accurate measurement of fiber diameters. To obtain a comprehensive understanding of the fiber's diameter distribution, 20 readings were meticulously recorded across multiple regions of each fiber sample.

Whiteness index and other Indices of the fiber- The assessment of color and texture involved sophisticated instrumentation. The whiteness index of the fiber was quantified using a spectrophotometer A5100, providing objective measurements of its color purity. Furthermore, the whiteness index of the raw, scoured, enzyme-treated, and bleached fibers was accurately determined using a spectrometer SS5100A. This analysis was conducted under standardized conditions, including D65 illumination with a color temperature equivalent to average daylight and a 10-degree angle of visual observation, ensuring precise measurements across all fiber samples.

Texture of the fiber- The assessment of the texture of the pineapple leaf fiber involved a meticulous examination under a high-powered ZEISS Axio Imager 2 microscope. This sophisticated instrument provided the capability to scrutinize the fiber's surface at a microscopic level, allowing for detailed observation of its structural features and texture. By magnifying the fiber's surface, the microscope facilitated the visualization of

Fig.3.14: ZEISS Axio Imager 2

intricate details such as surface roughness, irregularities, and other morphological characteristics.

*Fibre fineness***-** As per ASTM D 7025, a segment of the fiber measuring 100 centimeters in length was selected for analysis. To ensure accuracy and reliability, this measurement was repeated a total of 20 times, thereby obtaining a comprehensive set of readings. Each measurement involved carefully weighing the 100-centimeter length of fiber using a precise and calibrated weighing instrument. After all 20 measurements were obtained, the recorded weights were compiled and analyzed to calculate the average weight of the fiber segment. This average weight served as the basis for determining the denier of the fiber, as denier is defined as the weight in grams of a 9000-meter length of the fiber.

Moisture content and moisture regain- To assess the moisture content and regain of the fibers, samples of known weight were subjected to an environment with a relative humidity of 65±2% and a temperature of 27±2°C for a period of five days. After exposure, the samples were weighed to determine their initial weight in this conditioned state (W_1). Subsequently, the samples were dried in an oven at 110°C until a constant weight was achieved (W_2).

The moisture content and regain were then calculated based on the difference between these two weights. The formula used for this calculation are (Booth, J.E.1996):

Where, Moisture Content = $100W / W_2$.

Moisture regain = $100W / W_2 + W$.

Weight of water $(W_1 – W_2) = W$

Oven Dried weight = W_2

This equation provides the percentage of moisture that the fibers have absorbed relative to their weight when completely dry and the percentage of water present in the fibre.

Tensile Strength- The evaluation of tensile strength, a crucial measure of fiber durability, was conducted utilizing a Universal Tensile Tester Machine (UTM). This advanced testing apparatus subjected fiber samples, each measuring 15 centimeters in length and 2.5cm in width, to controlled tension until the point of failure. By applying standardized testing protocols, the UTM allowed for precise measurement of the force required to stretch the fiber to its breaking point. To ensure accuracy and reliability, a meticulous approach was adopted, involving the acquisition of 20 individual readings for each fiber sample. This extensive sampling process enabled the establishment of a representative average, effectively capturing variations in tensile strength across the sample population.

Bundle strength- The fiber bundle strength test, following ASTM D 1445 guidelines, was conducted using a Stelometer in the Textile Testing Lab of the Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. The Stelometer is equipped with various components including a pendulum, beam, combs, clamps, jaws, tweezers, and cutters.

Initially, a weighted bundle of combed pineapple fibers was prepared for testing. This bundle was then placed between two jaws, with one jaw mounted on an adjustable holder attached to the beam, and the other jaw positioned at the top end of the pendulum. The loading rate during the test remained constant. The beam of the Stelometer rotates clockwise, and its rotation is controlled by a specialized dashpot-like device. The center of gravity of the beam is situated to the right of its rotation axis. As the pendulum moves, the load on the fiber bundle is directly proportional to the sine of the angle through which the pendulum has rotated.

Fig.3.15: Stelometer

Before starting the test, the fiber specimen was properly adjusted in the jaws, and the pointer was set to zero. The dashpot was then activated. The breaking load, indicating the point at which the fiber bundle broke, was shown by the movement of the pointer on a graduated scale ranging from 2 to 7 kg. After the fiber bundle broke, the broken fibers were collected and weighed. Tenacity, which represented the strength of the fiber bundle, was calculated using the breaking load and the weight of the fiber sample before and after the test. The formula for calculating tenacity was: Tenacity (grams per tex) = Breaking load (kg) × 1.5 × 10 / Sample weight (mg). This calculation provided a measure of the strength of the fiber bundle in relation to its weight.

By systematically evaluating these physical properties through testing procedures, the study aimed to gain a comprehensive understanding of the pineapple leaf fiber's characteristics, thereby facilitating its effective utilization in diverse textile applications.

3.6.2. Chemical composition of the fiber

The chemical composition analysis of the raw pineapple fibers was conducted following the method 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 involving several sequential steps:

a) Water Soluble Components Estimation: A measured sample with known moisture regain was boiled in distilled water for five hours at a liquor ratio of 1:30. The filtered sample was then oven-dried, conditioned, and weighed. The water-soluble components were expressed as a percentage of the original sample's oven-dry weight.

$$\text{Water soluble components (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where, W_1 is the initial weight of the sample

W_2 is the weight after the procedure (removal of water soluble)

b) Fats and Waxes Estimation: After removing water-soluble components, the sample was subjected to extraction in a Soxhlet apparatus using a 2:1 alcohol (methanol): benzene mixture for four hours. The sample was washed with alcohol, dried, and weighed. The result was expressed as

$$\text{Fats and Waxes (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

Where, W_3 is the weight after the procedure (removal of fats and waxes) a percentage of the original sample's oven-dry weight.


Fig.3.16: Soxhlet Apparatus

c) Pectin Content Estimation: The defatted fiber sample underwent boiling for one hour in a 1% ammonium oxalate solution, followed by washing until free from oxalate. The loss in weight due to pectinous material removal was recorded as a percentage of the original sample's oven-dry weight.

$$\text{Pectin content (\%)} = \frac{W_3 - W_4}{W_1} \times 100$$

Where, W_4 is the weight after the procedure (removal of pectin content)

d) Hemicellulose Content Estimation: After pectin removal, the fibers were extracted in a Soxhlet apparatus with a 2% caustic soda solution for one hour, followed by thorough washing.

The loss in weight due to hemicellulose removal was estimated as a percentage of the original sample's oven-dry weight.

$$\text{Hemicellulose content (\%)} = \frac{W_4 - W_5}{W_1} \times 100$$

Where, W_5 is the weight after the procedure (removal of hemicellulose content)

e) Lignin Content Estimation: The treated samples underwent reflux for two hours in a water boiling bath with a 50:1 liquor ratio of 0.7% sodium chlorite solution at pH 4. The pH was adjusted using acetic acid. The filtered samples were washed, dried, and weighed. The lignin content was calculated as a percentage of the original sample's oven-dry weight.

$$\text{Lignin content (\%)} = \frac{W_5 - W_6}{W_1} \times 100$$

Where, W6 is the weight after the procedure (removal of lignin content)

3.7. FESEM- At PSG Tech, CDE Indutech in Coimbatore, Tamil Nadu, Field Emission scanning electron microscope (FESEM) utilized for observing fiber structures was a CARL ZEISS model: Sigma equipped with a Gemini Column. This particular SEM boasts a remarkable resolution of 1.5nm, ensuring detailed imaging of the fiber surfaces. The instrument employed various detectors for image acquisition, including the In-lens Detector, SE2 Detector, and BSD (Backscattered Electron Detector). The In-lens Detector is capable of capturing high-resolution images by collecting electrons that pass through the electromagnetic lenses within the microscope column. It provides detailed surface information with excellent signal-to-noise ratio, making it suitable for observing fine structures and surface morphology of fibers. The SE2 Detector, also known as the secondary electron detector, is sensitive to secondary electrons emitted from the surface of the sample due to electron beam interaction. It produces high-resolution images highlighting surface topography and texture, allowing for the examination of surface features such as pores, cracks, and irregularities. The BSD Detector, or backscattered electron detector, detects electrons that are backscattered from the sample's surface. It provides information about the sample's composition and density variations, making it useful for studying elemental distribution and material contrast within the fibers.

3.8. Preparation of yarn

Yarn preparation was done by exploring different spinning techniques for weaving. However, a specialized motorized charakha for the pineapple leaf fiber was fabricated based on the phoenix charkha since the existing charkhas was not possible for spinning pineapple fiber. Yarn for surface ornamentation was prepared using Amber charkha and Peti charkha.

3.8.1. Motorized Pineapple Leaf Fiber Charkha

The motorized pineapple leaf fiber charkha facilitated the spinning process of pineapple leaf fiber yarns. The charkha was designed and developed by the researcher with the collaboration of a silk expert- Mr. W. Shanta Singh of Samurou Bazar who is expertise in silk spinning in Manipur. Prior to spinning with the motorized charkha, the ends of combed fiber strands were joined together to create a continuous length, ensuring smoother and uninterrupted spinning. A motor with 500 RPM capacity which is also used in sewing machine was utilized to increase the spinning speed. The optimum RPM of the machine was also observed for spinning the yarn. The researcher has filed for a patent of the developed charkha.

Fig.3.17: Motorized pineapple leaf fiber charkha

3.8.2. Yarn for weaving

In the process of preparing yarn for weaving and surface ornamentation, several spinning tools and techniques were explored. These included drop spindle, traditional charkha, and phoenix charkha. However, the researcher achieved spinning of scoured 100% pineapple leaf fiber hand-spun yarns without any treatment using a locally developed motorized pineapple leaf charkha.

Fig.3.18: Hand spinning

Fig.3.19: Hand spinning using earthen pot

Fig.3.20: Drop spindle

Fig.3.21: Phoenix Charkha

Fig.3.22: Traditional Charkha

3.8.3. Yarn for surface ornamentation

Furthermore, for surface ornamentation purposes, the pineapple yarn was plied with rayon and polyester yarn using an amber charkha and peti charkha. Plying involves twisting multiple strands of yarn together to create a stronger and more stable yarn suitable for various applications, including surface ornamentation.

Five types of plied yarns were produced through this process to assess their feasibility for creating surface ornamentation. These plied yarns were then tested using the Juki HZL 27Z (Fashion maker), a sewing machine capable of handling various fabrics and yarns.

Fig.3.23: Amber Charkha

Fig.3.24: Plying with Peti charkha

Fig.3.25: Juki HZL 27Z

Overall, the utilization of different spinning tools and techniques, along with the development of a specialized motorized pineapple leaf charkha, enabled the production of high-quality pineapple leaf fiber yarns for both weaving and surface ornamentation purposes. Additionally, the process of plying with other yarn types expanded the possibilities for creating Value added products appealing surface designs and textures.

3.9. Testing of prepared yarn

The properties of the prepared yarn were assessed using various standard methods and equipment:

3.9.1. Determination of yarn fineness

- Denier, the weight in grams of 9,000 meters of yarn, was determined using ASTM D7025. An average weight of 20 readings of 100 cm length of the yarn was measured.
- The yarn count was then calculated using the conversion from denier to cotton count, which allows for comparison with other yarn types.

3.9.2. Determination of yarn evenness

- Yarn evenness, which refers to the consistency of yarn thickness along its length, was evaluated by measuring the average weight difference of 10 readings of 100 cm yarn length. Higher evenness indicates more consistent yarn thickness.

3.9.3. Determination Tensile Strength and elongation

- Tensile strength, the maximum load a yarn can bear before breaking at the constant speed of 100mm/min, was tested at Aditya Birla's Century Rayon and the coarser yarn and plied yarns were tested at the Department of Textile Engineering, Faculty of Engineering and Technology, The Maharaja Sayajirao University of Baroda.
- The yarn samples were subjected to controlled tension until they broke, and the maximum load at the point of failure was recorded.

3.9.4. Determination of Twist per Inch (TPI)

- Twist per inch (TPI) measures the number of twists applied to the yarn per inch of its length.
- TPI was determined according to ASTM D885 using an Alfred Suter twist tester. This device allows for precise measurement of the twist in the yarn.

Fig.3.26: Twist Tester

These measurements provide essential information about the quality and performance of the prepared yarn. Denier and yarn count offer insights into yarn thickness, while yarn evenness assesses its uniformity. Twist per inch indicates the yarn's twist level, which affects its strength and appearance. Finally, tensile strength is a crucial measure of the yarn's durability and suitability for various applications. Collectively, these properties help in understanding the yarn's overall characteristics and guide its usage in weaving and surface ornamentation processes.

3.10. Construction of traditional textiles on handloom

The produced yarns was used as a weft for making the samples of textiles. Selection of warp yarns according to the existing yarns used in making the traditional textiles was done. Initially, plain weave fabrics using different warps without any motifs were developed to check the suitability for making the specific traditional textiles. Based on the selection of the sample, plain weave union fabrics of silk/pineapple, Rayon/pineapple, cotton/pineapple, Polyester/pineapple **with extra weft traditional motifs and colours** were developed for making resemblance of Rani phee, muga Innaphee, lengyan phee and muga phanek traditional textiles respectively. The yarn count of silk-50s, Rayon- 22s, cotton- 25s and polyester-18s were used for the fabrics. The undyed pineapple yarn along with undyed warp yarns were used in weaving of silk/pineapple, Rayon/pineapple, cotton/pineapple fabrics to keep the natural colour of the the pineapple yarn. All the produced samples were evaluated to check the suitability for each given specific traditional textile.

3.10.1. Construction technique

Fig. 3.27: Two Shaft Frame loom

Throw shuttle loom with two shaft was used for weaving the sample. The throw shuttle loom is a traditional weaving machine in which the shuttle, containing the weft yarn, is manually thrown across the shed (the opening created by the raised and lowered warp yarns) by hand. This method of throwing the shuttle by hand allows for precise placement of the weft yarn, making it suitable for weaving intricate extra weft designs that are not easily achievable with other types of looms, such as fly shuttle looms.

Fig.3.28: Warping beam

One particular design that is uniquely achievable on a throw shuttle loom is **the temple stoop design**. The temple stoop design involves weaving a pattern where the warp threads are stretched or tightened at certain points along the width of the fabric. This design creates a textured or raised effect in the woven fabric, adding depth and visual interest to the textile. The temple stoop design requires careful manipulation of the warp threads during weaving, which is best achieved with a throw shuttle loom. The manual control and precision offered by the throw shuttle loom make it the preferred choice for weaving temple stoop designs and other intricate patterns that require precise handling of the weft and warp threads.

Due to its versatility and ability to handle complex weaving patterns, the throw shuttle loom remains a valuable tool for textile artisans and designers in Manipur who seek to create unique and intricate woven fabrics with decorative motifs and textured effects.

Crucial steps involved in weaving of Meitei community textiles are given below:

1. **Warping the Warp Beam**: The warp yarns are wound onto the warp beam, creating a tightly wound bundle of parallel yarns. This process ensures that the yarns are evenly tensioned and aligned before being threaded through the loom.

2. **Threading through Heddles**: Each individual yarn is then threaded through a heddle in a specific harness. Heddles are devices with an eye or hole through which the warp yarn passes. They are typically arranged in frames called harnesses, and each harness controls a set of warp yarns. Threading through heddles allows for precise control over which warp yarns will be raised or lowered during weaving, thus creating the shed through which the weft yarn will be passed.

3. **Threading through Dents in the Reed**: After threading through the heddles, the warp yarns are passed through dents in the reed. The reed is a comb-like device that sits in the beater and helps to maintain the spacing and alignment of the warp yarns. Threading through the dents further ensures that the yarns remain parallel and evenly spaced.

4. **Attaching to the Cloth Beam**: Once the warp yarns have been threaded through the heddles and reed, they are attached to the cloth beam at the opposite end of the loom. The cloth beam collects the woven fabric as it is produced during the weaving process.

It's essential for the warp yarns to remain completely parallel from the warp beam to the cloth beam throughout this process. Any deviation from parallel alignment can lead to problems during weaving.

The Manipuri terminologies used in handloom weaving:

1. Traditional handloom - Known as "Iyong" in Manipuri.
2. Frame loom - Referred to as "pangyong" in the local language.
3. Fly shuttle loom - Locally termed as "kon" in Manipuri.
4. Loom post - Described as "yongkham makhong mari" in the regional dialect.
5. Side bar - Known as "yongkham makhong phanba nak-yet pheirashing" in the local terminology.
6. Back bar - Referred to as "mayunglang chatnaba pheira" in Manipuri.
7. Front bar - Known as "asaba phee chatnaba pheira" in the regional language.
8. Bottom bar - Termed as "khongnet hapnaba pheira" in Manipuri.

9. Top bar - Described as "nachali amadi phampham pheiru" in the local dialect.

10. Warp beam - Referred to as "mayung lang konnaba" in the regional language.

11. Cloth beam - Known as "Asaba phee konnaba" in the local terminology.

12. Weight - Termed as "hanglak" in Manipuri.

13. Catch - Described as "konsinkhiba asaba pheebu nanthoraktanaba phaba" in the regional dialect.

14. Flange - Known as "mayung langgon phanaba kongoi" in the local terminology.

15. Ratchet wheel - Referred to as "asaba phee konabada happa kongoi" in Manipuri.

16. Pawl - Described as "rachet wheel bu leihanab hapa" in the regional dialect.

17. Sley - Known as "pang" in Manipuri.

18. Sley stick - Referred to as "pang gi pambom" in the local language.

19. Sley race - Described as "pangan dem chenfam" in Manipuri.

20. Crossbar - Known as "pheira" in the regional dialect, specifically used for the sley arm.

21. Reed cap - Termed as "samjet ki makhum" in Manipuri.

22. Shuttle box - Described as "pangandem upoo" in the local terminology.

23. Spindle- chei inside pangandem upoo

24. Picker- hangoi 25. Lever- nachali 26. Wooden shaft- nachei

27. Rod- shingchit 28. Treadle or paddle-khongnetchei

29. Lams –khongnet apheiba 30. Seat- pheesaphan

3.10.2. Types of Fabric

❖ Silk/Pineapple union fabric

The construction of a fabric resembling Rani-Phi by incorporating silk in the warp and pineapple yarn in the weft had been accomplished through the expertise of Kh. Roma Devi, a skilled Rani-Phi weaver from Awang Sekmai, Mayai Leikai, in the Imphal West District of Manipur. This unique fabric creation pays homage to the traditional Rani-Phi while incorporating innovative materials and techniques.

Fig.3.29: Weaving of Silk/Pineapple fabric

To ensure the authenticity and preservation of the original Rani-Phi textile, traditional motifs and colors have been adopted in the construction of this fabric. A collection of traditional motifs and colors are gathered from both primary and secondary sources, to infuse the fabric with the rich cultural heritage of Manipur. These motifs are intricately woven into the fabric using an extra weft technique, showcasing the weaver's skill and attention to detail. The silk yarn used in the warp has a denier of 106D (equivalent to 50's count), providing strength and durability to the fabric, while the developed yarn made from pineapple fiber in the weft has a denier of 177D (equivalent to 30's count), contributing to the fabric's unique texture and aesthetic appeal.

❖ Cotton/Pineapple union fabric

A fabric resembling Lengyan Phi had been created through the skilled craftsmanship of Phuritshabam Shanti Devi, a talented weaver from Khurkhul, Mayai Leikai, in the Imphal West district of Manipur. This fabric reflects the resemblance of the traditional Lengyan Phi while incorporating traditional motifs and colors. Lengyan Phi features simpler motifs, reflecting its purpose as a stole used to cover the wearer's shoulders. Therefore, simpler geometrical motifs were used in Lengyan phi. In the construction of this textile, cotton yarn was chosen

Fig.3.30: Weaving of Cotton/Pineapple fabric

for the warp, while pineapple fiber was used for the weft. The cotton yarn, with a count of 25's (equivalent to 212D), provides a strong and stable foundation for the fabric. The use of cotton yarn in the warp ensures that the fabric maintains its structural integrity and durability. The weft, made from the same prepared pineapple yarn with the denier of 177D was used.

❖ Rayon/Pineapple union fabric

Examining the feasibility of using Rayon/Pineapple union to emulate Khurkhul muga (Mulberry silk) Innaphee, a sample was crafted by skilled weaver Phuritshabam Shanti Devi from Khurkhul, Mayai Leikai, Imphal West district, Manipur. Similar to silk/pineapple and cotton/pineapple fabrics, traditional motifs and colors from the Meitei community of Manipur were incorporated into the fabric design to maintain the cultural authenticity of Khurkhul muga Innaphee. The yarns utilized in the fabric production had deniers of Pineapple-177D and Rayon-242D.

Fig.3.31: Weaving of Rayon/Pineapple fabric

❖ Union of Polyester/ Pineapple fabric

To replicate the traditional muga phanek textile of Manipur, typically woven from local mulberry silk by Khurkhul weavers. To achieve this, polyester yarn (295D) was combined in the warp (the vertical threads) and pineapple yarn (177D) in the weft (the horizontal threads) of the fabric. This combination woven by a weaver Thengujam Anjina, was chosen to resemble the texture of the original textile while making it more accessible and cost-effective. Lower denier pineapple yarn was selected to match the thickness of the original muga phanek. Temple motifs, traditionally found on

Fig.3.32: Weaving of Polyester/Pineapple fabric

muga phanek borders, were incorporated into the fabric design. Furthermore, traditional colors were used to ensure the fabric closely resembled the original textile in appearance and cultural significance.

3.10.3. Testing of the woven fabric samples

The physical properties of the developed fabrics underwent comprehensive testing using ASTM standards. Tensile strength and elongation were evaluated following ASTM Test method D5035, while GSM (grams per square meter) was determined using ASTM Test method D377696. Fabric count was assessed through ASTM D 3775-98, fabric thickness using ASTM Test method D1777-96 with a compress meter thickness tester, stiffness via ASTM D 1388-18 utilizing Shirley's stiffness tester, and drape coefficient measured with a drapemeter. One fabric from the developed samples was selected for further analysis using the Kawabata test method.

Fabric thickness- To determine the fabric thickness of the constructed fabrics, a standardized procedure was followed. This involved measuring the distance between the upper and lower surfaces of the fabric under specific pressure conditions, typically expressed in millimeters (mm).The samples selected for the test were carefully prepared to ensure accuracy and consistency of results. They were free from any folds, creases, crushing, distortion, or wrinkles that could affect the measurement process. This ensured that the fabric's natural thickness was accurately represented during testing.

A universal thickness tester, designed specifically for this purpose, was employed to conduct the measurements. This device applies a controlled pressure to the fabric sample and accurately measures the resulting thickness. By maintaining uniform testing conditions and using specialized equipment, the test results were reliable and consistent across all samples. The fabric thickness measurement provides valuable information about the fabric's bulkiness and density, which are important considerations for various applications such as garment manufacturing, upholstery, and technical textiles.

Fabric count- Fabric count refers to the density of warp and weft yarns in a woven fabric and is expressed as the number of ends and picks per unit area. To determine fabric count, a systematic procedure was followed:

Randomly selected areas of the fabric were chosen for analysis, ensuring that the fabric's overall composition was accurately represented. It's important to avoid areas near the selvedge to minimize distortion in the readings. Using a pick glass, the number of warp (ends) and weft (picks) yarns within a one-inch square area of the fabric's surface were counted. This process involves placing the pick glass over the fabric and visually counting the number of yarns intersecting with the grid lines. To ensure accuracy, multiple readings were taken at different locations across the fabric. Typically, five readings were recorded to account for any variability in yarn density within the fabric. Once the counts for both warp and weft yarns were obtained, they were averaged to determine the fabric count per unit area. This count provides valuable information about the fabric's weave structure and density.

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:

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

Where, $K_1 = \frac{\text{EPI (End per inch)}}{\sqrt{\text{(warp count)}}}$

$K_2 = \frac{\text{PPI (Pick per inch)}}{\sqrt{\text{(Weft count)}}}$

K_1 is the warp cover

K_2 is the weft cover

Number of Warp yarns per Inch (warp count): This refers to the number of warp yarns (lengthwise yarns) present in one inch of the fabric's width. It indicates the density of the warp yarns within the fabric.

Number of Weft Yarns per Inch (weft count): Similarly, this represents the number of weft yarns (widthwise yarns) found in one inch of the fabric's length. It denotes the density of the weft yarns across the fabric.

The cover factor provides valuable information about the fabric's density and how closely the yarns are packed together. Higher cover factor values indicate greater yarn coverage and denser fabric construction, while lower values suggest more open or loosely woven fabric structures.

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- To assess the tensile strength of the fabric, a Universal Tensile Tester was utilized, operating on the principle of constant rate extension. A raveled sample of dimensions 15cm x 2.5cm was carefully prepared from the fabric. This sample size ensures consistency and accuracy in the testing process. The prepared sample was securely mounted onto the Universal Tensile Tester, ensuring that it was positioned correctly within the grips of the testing machine. The gauge length, referring to the distance between the grips of the testing machine, was set to 75mm ± 1mm. This standardized distance ensures uniform testing conditions across all samples. The testing machine was set to apply tension to the fabric sample at a constant speed of 100mm/min. This controlled speed ensures consistent testing conditions and accurate measurement of tensile properties. A total of ten readings were taken during the testing process to capture variability and obtain a representative average value. These readings provide a comprehensive assessment of the fabric's tensile strength under different conditions. The data collected from the tensile testing, including maximum load applied before fabric failure and corresponding elongation, were analyzed to determine the fabric's tensile strength properties. The Test was done at the Department of Technology, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat.

Stiffness/bending length of the fabric- To determine the stiffness or bending length of the fabric, a Shirley's stiffness tester was employed. The procedure involved the following steps:

A rectangular sample of the fabric was cut to dimensions of 15cm x 2.5cm. This standardized size ensures consistency in testing. The prepared fabric strip was mounted onto the Shirley's stiffness tester. The sample was positioned so that it hung over the edge of the platform in a cantilever fashion, with one end fixed and the other end free to bend downward. A template with index lines and a mirror were positioned on the platform. The movement of the fabric strip was observed through the mirror to accurately determine the point at which it started to droop downward. A reading was recorded when the fabric strip began to droop over the edge of the platform. This process was repeated five times to ensure consistency and reliability of the measurements. The bending of the fabric strip was observed in relation to the zero line engraved on the platform. Readings were taken when the tip of the fabric strip intersected both index lines on the template. The collected readings were analyzed to determine the stiffness or bending length of the fabric. This parameter provides valuable information about the fabric's rigidity and ability to maintain its shape under bending forces.

Drape co-efficient- To determine the drape coefficient of the fabric, the following procedure was followed:

1. **Sample Preparation**: The fabric sample was prepared to fit the size of the large disc provided in the drape tester. It was carefully mounted between support discs in the testing cabinet.

2. **Ammonia Sheet Placement**: An ammonia sheet was placed under the specimen holder disc. Additionally, an open-lid flask containing ammonia solution was positioned in the base of the machine. This setup facilitated the development of a visual effect on the fabric sample.

3. **Light Activation**: The light within the testing cabinet was switched on and allowed to remain illuminated for 5 minutes. This step ensured adequate exposure to light before removing the ammonia sheet.

4. **Ammonia Exposure**: After the 5-minute period, the ammonia sheet was placed inside the open-lid flask containing ammonia solution for a duration of 15 minutes. This exposure to ammonia allowed the visual effect of the fabric drape to develop.

5. **Observation and Measurement**: Following the ammonia exposure period, the fabric's drape was observed, and any impressions were noted. The fabric was then cut according to the impressions for graphical trace and measurement.

6. **Graphical Trace and Measurement**: Using the impressions left on the fabric, a graphical trace was created to visually represent the fabric's drape characteristics. Measurements were taken to quantify the extent of the drape, providing numerical data on the fabric's drape coefficient.

The formula for calculating the value is given below:

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

3.10.4. Kawabata Evaluation System for Fabric (KES-F):

The Kawabata test was conducted at the Central Institute for Research on Cotton Technology (CIRCOT) in Mumbai. For the test cotton/pineapple fabric was selected based on the availability, popularity, and comfort of the warp yarn. This test comprises two stages: subjective evaluation and objective evaluation of the fabric.

During the subjective evaluation stage, primary hand values such as Koshi (Stiffness), Numeri (Smoothness), and Fukurami (Fullness and Softness) were assessed. These primary hand values are rated on a ten-point scale, with ten representing the highest value and one representing the lowest. The fabric samples were compared to standard reference samples provided in a handbook produced by the Hand Evaluation and Standardization Committee (HESC) to determine their specific category. The categories include Men's Winter/Autumn Suiting, Men's Summer Suiting for Tropical Climates, Ladies' Thin Dress Fabrics, Men's Dress Shirt Fabrics, and Knitted Fabrics for Undershirts. These comparisons help in determining the Total Hand Value (THV) of the fabric, which represents its overall hand characteristics.

The objective evaluation of the fabric involves utilizing a set of instruments known as the KESF system. Following tests were included:

- **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. This test evaluates the fabric's resistance to repeated shearing forces. Specimens are repeatedly sheared to a set angle under a predetermined pretension load. Dynamic creep, calculated as the ratio of elongation under dynamic conditions to pretension load alone, provides insights into the fabric's behavior under cyclic shearing.

- **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. This test assesses the fabric's response to stretching forces. Specimens, typically 20 cm wide and 5 cm long, are clamped between sets of clamps and subjected to a peak load of 10 kg. The stress/strain curves generated during the test provide valuable insights into the fabric's behavior under tension. Parameters such as percentage tensile elongation, tensile energy, energy recovery, tensile resilience, and linearity are evaluated from the stress-strain curves.

- **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. Bending behavior is evaluated by bending fabric samples to standard curvatures and observing their recovery. Samples are bent in both warp and filling directions, as well as on the face and reverse sides. Bending rigidity and hysteresis width at specific bending curvatures are quantified to assess the fabric's flexibility and recovery characteristics.

- **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. This test measures the fabric's response to compressive forces. A standard fabric area is subjected to a known compressive load, and parameters such as fabric thickness, work done in compression, and compressive resilience are evaluated. Linearity and compressibility of the compression curve provide additional insights into the fabric's behavior under compression.

- **Fabric weight & Thickness Test:** This test measures the weight and thickness of the fabric. The thickness of the fabric was measured in mm while the weight of the fabric was measured in mg/cm^2. It is an essential parameter in applications where fabric weight & 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. Surface characteristics, including roughness and friction coefficients, are assessed using electronic sensors. The fabric's movement under tension is monitored, and surface roughness and friction coefficients are computed over a defined length of fabric. Mean deviation of coefficient of friction and index of surface roughness are key parameters derived from the surface test.

Table 3.1: The parameters measured and evaluated in each of the described tests

Test	Parameters
Tensile Test	Percentage tensile elongation (EMT%), Tensile energy (WT), Energy recovered (WT'), Tensile resilience (RT%), Linearity (LT)
Shear Test	Shear modulus (G), Hysteresis width at shear angle of 0.5 degrees (2HG), Hysteresis width at shear angle of 5 degrees (2HG5)
Bending Test	Bending rigidity (B) lies between the curvature radius 0.5 cm-1 and 1.5 cm-1 (µnm), Hysteresis width at a bending curvature of + 0.5 cm-1(mN) (2HB)
Compression Test	Fabric thickness at very low compressive load (TO), Fabric thickness at maximum compressive load (TM), Work done in compression (WC), Work recovered (WC'), Compressive resilience (RC%), Linearity of the compression curve (LC), Compressibility (EMC%)
Surface Test	Coefficient of surface friction over a three-cm length of fabric (MIU), Mean deviation of coefficient of friction (MMD), Index of surface roughness (SMD)
Shear Fatigue Test	Creep elongation under dynamic conditions, Creep elongation under pre-tension load alone

These parameters provide comprehensive insights into the mechanical behavior, flexibility, resilience, and surface characteristics of fabrics, enabling a thorough assessment of their suitability for various applications in the textile industry.

3.11. Dyeing of pineapple yarn

The dyeing process was performed on the natural color of 100% pineapple spun yarn (30's), without any prior treatment such as bleaching. Both reactive dyes and natural dyes were utilized to achieve a diverse range of colors and effects.

3.11.1. Dyeing with Reactive Dyes

Nine different reactive dyes were employed in the dyeing process. Reactive dyes are commonly used for cellulosic fibers like pineapple yarn as they form covalent bonds with the fiber, resulting in excellent colorfastness and wash resistance. The conventional exhaust dyeing technique was applied, wherein the dyes were dissolved in a suitable dye bath and the yarn was submerged in the dye liquor. The dye bath was heated to the recommended temperature for reactive dyes, typically between 40-60 degrees Celsius, and maintained for a specific duration to ensure proper dye absorption and fixation onto the yarn fibers. The dyes used were- 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 .

1. Dye Preparation:
    - Each Procion dye was prepared in a concentration of 2%.
    - Additionally, soda ash was added at a concentration of 20g/l, and sodium chloride at 30g/l. These chemicals aid in dye absorption and fixation onto the yarn fibers.
2. Dyeing Process:
    - The pineapple yarn was then added to the dyeing vessel containing the prepared dye solution.
    - The dyeing process was conducted at a temperature of 60 degrees Celsius for 45 minutes, maintaining a liquor ratio of 1:30 (material to liquor ratio).
    - The self pH of the dye bath was maintained, ensuring optimal dyeing conditions for the Procion dyes to adhere to the yarn fibers.
3. Washing:
    - Following the dyeing process, the yarn was washing with a 2% soap solution. This step helped in removal of any excess dye or chemicals from the yarn surface, ensuring color fastness and preventing bleeding during subsequent use or washing.

3.11.2. Natural Dyes:

Twelve natural dyes were utilized, with eight of them being extracted from local plant sources. Natural dyes offer a sustainable and eco-friendly alternative to synthetic dyes, often providing unique and earthy color tones. The extraction of natural dyes from plant sources involved various methods such as boiling, maceration, or fermentation, depending on the dyeing properties of the plant material. Similar to reactive dyes, the conventional exhaust dyeing technique was employed for natural dyes. The dye baths were prepared using the extracted natural dyes and the yarn was immersed for dye uptake. The dyeing process for natural dyes typically requires longer durations and may involve the use of mordants or additives to enhance dye fixation and color intensity.

Fig.3.33: Malabar melastome-*Melastoma malabathricum*

Fig.3.34: Indian Trumpet tree-*Oroxylum indicum*

Fig.3.35: Hill glory bower-*Clerodendrum infortunatum*

Fig.3.36: Kamala or Kumkum tree-*Mallotus philippensis*

Fig.3.37: Red cedar-*Toona Ciliata*

Fig.3.38: Koda tree-*Ehratia acuminate*

Fig.3.39: Roselle-*Hibiscus sabdariffa*

Fig.3.40: Mulberry- *Morus nigra*

Fig.3.41: Marigold-*Tagetes erecta*

Fig.3.42: Pomegranate- *Punica granatum*

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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 3.2: Details of the local plant used for dyes

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

1. Dye Extraction process

The process of dye extraction involved boiling the natural dye sources in distilled water at a ratio of 1:40 (material to liquor ratio) for 30 minutes. This allowed the dye compounds present in the materials, such as lac, manjistha, marigold, pomegranate, Indian Trumpet tree, Red cedar, Mulberry, and Roselle, to be released into the water. After boiling, the dye solution was filtered to remove any solid particles and then allowed to settle to ensure clarity and purity of the dye extract.

Before dyeing, the pineapple yarn underwent pre-mordanting using alum. Pre-mordanting helps to improve the uptake and fixation of the dye onto the yarn fibers. A solution containing 10% alum, relative to the weight of the material, was prepared and the yarn was immersed in it for 30 minutes at room temperature.

2. Dyeing on 100% pineapple yarn with natural dyes

Subsequently, the pre-mordanted yarn was dyed using the extracted natural dyes. The dyeing process involved using 10% alum as a mordant in the dye bath, along with a concentration of 4% dye relative to the weight of the material. The dye bath was prepared with a material to liquor ratio of 1:30 and maintained at a temperature of 60 degrees Celsius for 45 minutes. The pH of the dye bath was adjusted to a suitable level for dye absorption, ensuring optimal dyeing conditions.

After dyeing, the yarn was washed with running water to remove any excess dye and mordant residues. This step is crucial to prevent color bleeding and ensure the colorfastness of the dyed yarn. Overall, this elaborate dyeing process using natural dyes and pre-mordanting techniques helps to achieve vibrant and long-lasting colors on the 100% pineapple yarn, while also promoting sustainable and eco-friendly dyeing practices.

3.11. 3.Testing of dyed yarn samples

- ❖ Colour strength test

The analysis of color strength and colorimetric properties, including CIE L*a*b*, color difference, and K/S values, was conducted using a spectrophotometer Premier Colour Scan SS5100A. This spectrophotometer is capable of measuring color across the visible spectrum (wavelength range 360-700nm) with high precision and accuracy. The testing was performed under D65 illumination, simulating average daylight conditions with a color temperature of 6500K. Additionally, a 10-degree angle of visual observation was utilized to ensure accurate color perception.The colorimetric properties were evaluated using the CIE L*a*b*c*h* color space, which defines color in terms of lightness (L*), red-green axis (a*), yellow-blue axis (b*), chroma (c*), h* (hue angle). These values provide quantitative measures of color appearance and allow for precise comparison between samples.

Color difference analysis was conducted to quantify the perceptible difference between the controlled (undyed) sample and the dyed samples. This assessment helps determine the effectiveness of the dyeing process in altering the color of the yarn. K/S values were also determined, representing the ratio of absorption coefficient (K) to scattering coefficient (S) of the dyed samples. This value is indicative of the color intensity and depth of the dyed material.

Furthermore, the transmission curve of both the controlled sample and dyed samples was analyzed. This curve provides insights into the light transmission characteristics of the samples across different wavelengths, allowing for a detailed understanding of color absorption and reflection.

The testing was conducted at the Department of Clothing and Textiles, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat. This facility is equipped with state-of-the-art equipment and expertise to carry out precise color analysis and evaluation of textile materials. Overall, the comprehensive analysis provided valuable insights into the color properties and performance of the dyed pineapple yarns.

❖ Wash fastness test

The evaluation of colorfastness to washing was conducted following ISO standard test no. II (IS: 764: 1979). In this test, dyed pineapple yarn was braided with undyed pineapple yarn to create composite specimens. These composite specimens were then placed in glass jars containing a soap solution of 5 gpl (grams per liter) and a soda ash solution of 2 gpl, with a material to liquor ratio of 1:50. The jars were closed and placed in a Launder-O-Meter, a machine used for simulating washing conditions. The Launder-O-Meter was operated for 30 minutes at a temperature of 60 ± 2°C, mimicking typical washing conditions.

After the washing cycle, the samples were removed from the Launder-O-Meter and washed with water to remove any residual soap and soda ash. They were then squeezed to remove excess water and dried in the air.The assessment of colorfastness to washing was performed using a Grey scale, which allows for the grading of color changes on a scale from

1 to 5. A grade of 1 indicates poor colorfastness, while a grade of 5 indicates excellent colorfastness.

This testing procedure was carried out in the textile chemistry laboratory of the Department of Textile Chemistry, Faculty of Technology and Engineering, at The Maharaja Sayajirao University of Baroda. This laboratory is equipped with the necessary facilities and expertise to conduct standardized testing procedures for evaluating the performance of textile materials.

- Light fastness test

The evaluation of colorfastness to light was conducted following AATCC test method 16-B-1977. In this test, dyed pineapple yarns were evenly wrapped in black sheets to ensure consistent exposure to sunlight. The samples were then exposed to sunlight for a duration of 8 hours to observe the effect of fading of color due to sunlight exposure.

After the exposure period, the samples were assessed for lightfastness by comparing the exposed portion with the unexposed portion of the material. This comparison allowed for the determination of any changes in color intensity or fading caused by sunlight exposure.

The assessment of lightfastness was graded on a scale from 1 to 8, with a grade of 1 indicating poor lightfastness and a grade of 8 indicating excellent lightfastness. The grading scale provided a standardized method for evaluating the performance of the dyed samples under sunlight exposure.

This testing procedure was conducted in the textile chemistry laboratory of the Department of Textile Chemistry, Faculty of Technology and Engineering, at The Maharaja Sayajirao University of Baroda. The laboratory is equipped with the necessary facilities and expertise to perform standardized testing procedures for evaluating the colorfastness and performance of textile materials.

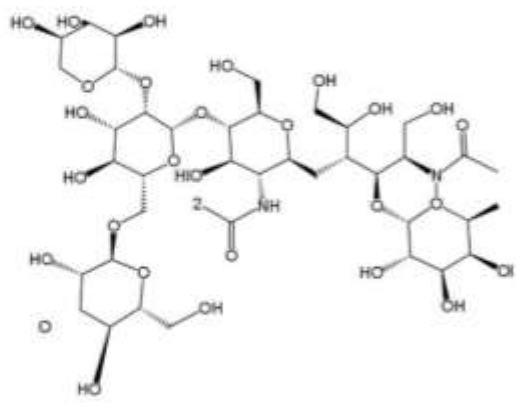
3.12. Extraction of bromelain enzyme

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.

The bromelain enzyme extracted from pineapple peels can be utilized in various textile applications, expanding its utility beyond medicinal uses. Some potential applications of bromelain enzyme in textile treatment include:

1. Treatment of Wool: Bromelain can be used to treat wool fibers, potentially enhancing their softness and texture.
2. Agro-waste Fiber Treatment: Bromelain enzyme can be applied to fibers derived from agricultural waste materials, aiding in their processing and improving their properties for textile applications.
3. Softening of Fibers: Bromelain can be used to soften various types of fibers, making them more pliable and comfortable for use in textiles.
4. Printing of Latex: Bromelain may have applications in the printing industry, particularly in the preparation of latex for printing on textiles.
5. Leather Processing: Bromelain enzyme can also be employed in leather processing, potentially aiding in the removal of impurities and improving the quality of the finished leather products.

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.



Source- Created using Kingdraw
Fig.3.43: Bromelian enzyme

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

Fig.3.44: Pineapple peel

Fig.3.45: Extracted Bromelain juice

Fig.3.46: Centrifugation at CHC, Laboratory Awang Sekmai

Fig.3.47: Centrifuge machine

3.13. 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.

Here's a breakdown of the key components typically included in such calculations:

1. **Raw Material Cost**: This includes the cost of obtaining pineapple leaves for fiber extraction. Factors such as the sourcing method, quantity required, and any associated labor or transportation costs are taken into account.
2. **Transportation Cost**: The cost of transporting pineapple leaves from the plantation to the processing facility needs to be factored in. This can include expenses related to shipping, handling, and any necessary logistics.
3. **Fiber Extraction Cost**: The process of extracting fibers from pineapple leaves involves specialized equipment, labor, and energy consumption. The cost of these resources, along with any required chemicals or treatments, is considered in this stage.
4. **Spinning Cost**: Once the fibers are extracted, they are spun into yarn for weaving. Spinning costs include expenses related to machinery, labor, energy, maintenance, and any additives used to enhance the quality of the yarn.
5. **Weaving Cost**: Weaving PALF yarn into fabric involves machinery, labor, energy, maintenance, and any additional materials required during the weaving process, such as dyes or finishes.

3.14. Feedback from the consumer

An assessment was conducted to evaluate the potential of utilizing the newly developed pineapple yarn as a substitute for conventional materials in textile weaving. This involved comparing traditional textiles made with pineapple yarns against the silk traditional textiles of Manipur, considering their physical attributes. Additionally, feedback was gathered from both Meitei consumers and weavers (Age group- 18-60 years) from Manipur. This feedback encompassed opinions on various aspects such as aesthetics, cultural significance, and practical considerations related to production and usage.

- Meitei Consumer Feedback: Meitei consumers were interviewed to gather their opinions on both types of textiles. A questionnaire was provided which covered aspects such as aesthetic appeal, cultural significance, perceived value, and willingness to purchase or wear.

- Weaver Feedback: Feedback was also sought from traditional weavers in Manipur who have experience working with both pineapple yarns and silk and only silk as well. Their insights on ease of handling, weaving characteristics, production challenges, and overall satisfaction with the end products are valuable for understanding practical considerations.

3.15. Awareness of use of pineapple leaf fibre for textiles

The analysis of the constructed fabric was carried out by incorporating feedback from consumers, which played a crucial role in understanding its reception and potential market viability. To increase awareness about the newly developed fabrics utilizing pineapple leaf fiber, a comprehensive outreach campaign was undertaken across various media platforms, including newspapers, television channels, and social media channels.

Specifically, the awareness program focused on educating the public about the innovative use of pineapple leaf fiber in textiles and its benefits. The campaign aimed to reach a wide audience, including consumers, weavers, and other stakeholders in the textile industry.

To ensure targeted outreach and effective engagement, a cluster of weavers of Khurkhul in Manipur was approached strategically. This cluster was selected based on its proximity to the production center of local mulberry silk and traditional textiles of the Meitei community. By targeting this cluster, the awareness program aimed to influence existing weaving expertise and infrastructure while introducing an alternative material that aligned with local traditions and practices. Additionally, the awareness campaign utilized various media channels to disseminate information about the benefits and applications of pineapple leaf fiber textiles. Newspaper articles, television features, and social media posts were employed to showcase the potential of this sustainable and eco-friendly material.

3.16. SWOC Analysis

A SWOC analysis for utilizing pineapple leaf fiber (PALF) in making the traditional textiles of Manipur was conducted by following the given steps:

1. **Strengths**: Identify PALF's inherent advantages, such as sustainability and cultural significance.

2. **Weaknesses**: Recognize PALF's limitations, such as processing challenges and quality consistency issues.
3. **Opportunities**: Explore external factors that can enhance PALF's market potential, like growing demand for sustainable products.
4. **Challenges (or Constraints)**: Acknowledge external barriers, such as technical limitations and consumer education gaps.
5. **Integration and Strategy Formulation**: Integrate findings to develop strategies that leverage strengths, mitigate weaknesses, capitalize on opportunities, and address challenges.

In conclusion, the investigation examined into the availability of pineapple leaf fiber in India and meticulously proceeded with the collection and extraction processes. Pilot experiments on fiber modification provided valuable insights, followed by comprehensive testing of both physical and chemical properties. FESEM analysis further enhanced understanding by identifying chemical bonds through Field Emission Scanning Electron Microscope. Preparation of yarn was facilitated by the Motorized Pineapple Leaf Fiber Charkha, leading to the creation of yarn suitable for weaving and surface ornamentation. Thorough testing ensured the quality and characteristics of the prepared yarn met desired standards. Utilizing traditional weaving techniques on handloom, fabric construction was achieved with the incorporation of traditional motifs and colors, offering a diverse range of fabric types. The subsequent testing of woven fabric samples provided critical data on various parameters such as thickness, fabric count, and tensile strength.

Dyeing experiments with both reactive and natural dyes expanded the versatility of pineapple yarn, with subsequent testing ensuring colorfastness and durability. Extraction of bromelain enzyme added another dimension to the study's scope. Cost calculations provided insights into the economic viability of the constructed fabrics, while consumer feedback shed light on market acceptance and preferences. The study also contributed to raising awareness regarding the potential of pineapple leaf fiber in textiles.

Lastly, the SWOC analysis offered a comprehensive evaluation of strengths, weaknesses, opportunities, and challenges encountered throughout the study.