

ABSTRACT

In the region of northeast India, pineapple (*Ananas comosus*) cultivation thrives, particularly in states like Manipur, where the pineapple plant, known as Kihom, stands as an important crop. Despite its agricultural significance, pineapple harvesting in Manipur yields a surplus of waste, particularly in the form of discarded leaves, as only the fruits are typically consumed. However, this overlooked byproduct holds immense promise for the region's economy and environmental sustainability. With Manipur ranking 6th in pineapple production nationwide, generating 134.82MT of fruits in 2021-2022 alone, the opportunity to transform pineapple waste into eco-friendly textile materials presents itself as a pivotal solution. By harnessing pineapple leaf fiber, not only can we mitigate waste, but also cultivate a sustainable textile industry, preserving traditional weaving practices and providing livelihood opportunities for local farmers, workers, and artisans. This introduction sets the stage for exploring the potential of pineapple leaf fiber as a sustainable textile resource, rooted in the rich agricultural heritage of northeast India. The study aims to utilize pineapple leaf fiber (PALF) for weaving traditional textiles of Manipur, preserving local weaving skills and offering a sustainable alternative to silk. With Manipur's thriving pineapple cultivation, integrating PALF into weaving aligns with the state's handloom industry distinction. The research addresses the need for scientific exploration to validate the feasibility and benefits of PALF in Manipur's weaving traditions.

The study was designed as an experimental and exploratory on pineapple leaf fiber. The main aim of the study was to explore the pineapple leaf fiber in hand woven traditional textiles of Manipur. The current study's objectives were divided into three phases. Initially, pineapple leaf procurement, fiber extraction, testing, and experiment were conducted to prepare yarn from both treated and untreated fibers. The second phase involved creating various handspun yarns and weaving samples on handlooms. Traditional design motifs and color selection were integrated, followed by weaving, dyeing with natural and reactive dyes, cost assessment, and gathering consumer feedback.

In results of availability of the pineapple leaf fiber in India, Several organizations across India were initially approached for pineapple leaf fiber samples, but many were unable to provide them due to various constraints such as labor-intensive processes, time limitations, and difficulties in accessing farms. Some organizations had discontinued their work on pineapple leaf fiber after

completing specific projects. Only two organizations provided samples, which were of poor quality and unsuitable for yarn preparation. Consequently, the researcher had to extract the fiber independently. Interviews were conducted with individuals familiar with fiber extraction, including former staff from the Design Department and the District Industrial Center in Manipur who worked on pineapple leaf fiber in the 1970s.

The researcher explored two extraction methods: mechanical extraction at CSIR-NEIST Laboratory in Manipur and manual extraction at her residence using hand scraping and a hammering technique devised by the researcher to remove the hard covering substance from the leaves before water retting. Light hammering was applied to minimize fiber damage and increase yield, resulting in long and smooth fibers. However, manual extraction was labor-intensive and time-consuming, suggesting machine extraction for larger-scale production.

In pilot experiments, scoured pineapple leaf fibers were found to be suitable for traditional weaving in Manipur without additional softening treatments, eliminating the need for enzyme and chemical treatments in further processing. This approach not only reduced chemical usage but also lowered costs associated with enzyme softening. Additionally, the researcher examined the longitudinal structure of raw, scoured, enzyme-treated, and bleached fibers under FESEM to determine spinning parameters for yarn preparation.

The pineapple leaf fiber possessed qualities of a long staple fiber, with an average length ranging from 65 to 92 cm and a diameter of 0.7-1.2 μm , resulting in a denier of 47.57. It was categorized as both long staple and very fine, and exhibited hydrophilic properties, with a moisture content of 10% and a moisture regain of 11.1%, superior to cotton but lower than flax. Regarding strength, it demonstrated good tensile strength at 4.278 gf/den and a bundle strength of 27 g/tex. Its chemical composition included 3.1% fats and waxes, 1.2% pectin, 2% hemicellulose, 1.3% lignin, and 77.7% cellulose, with a water-soluble component of 14.7%. FESEM analysis depicted alterations in surface morphology under various treatments, with scouring resulting in a smoother surface, bleaching causing structural deterioration, and enzyme treatment leading to an even smoother fibrous surface.

A modified motorized spinning wheel, reminiscent of the Phoenix charkha, was tailored for producing yarn from pineapple leaf fiber. The charkha, set at approximately 200 RPM from its 500 RPM capacity, crafted fine 100% pineapple leaf fiber yarn with a 30s count and an 80-85 TPI

Z-twist for phee, and a thicker 8's count Z-twist yarn for phanek, both suitable for traditional Manipuri textiles. Additionally, five two-ply yarns blending pineapple fiber with rayon and polyester were crafted using Amber and Peti charkhas, evaluated for surface ornamentation on sewing machines. Efforts to create a medium twist ply yarn of pineapple/polyester with the Amber charkha were thwarted by snarls from high twist, resulting in five-ply yarns instead. The phee yarn had a denier of 177D, a 30's count, and an 80-85 TPI Z twist, while the phanek yarn featured a denier of 730D, an 8s count, and a 16 TPI Z twist, both showing minimal variation. Various pineapple fiber combinations with rayon and polyester were spun into yarns using different charkhas, varying in TPI, twist direction, and count. For instance, pineapple/rayon yarns with low twist (PRL) were crafted on the Amber charkha with a TPI of 6-8 and a 15's count, while pineapple/polyester yarns with low twist (PPL) shared similar specifications but with a 14's count. For surface ornamentation tests, these yarns were combined as lower threads with polyester or rayon as upper threads, comprising PRL, PRM (Pineapple/Rayon medium twist), PRP (Pineapple/Rayon- peti charkha), PPL, and PPP (Pineapple/Polyester-peti charkha) yarns, each paired with either polyester or rayon.

The testing of different yarns derived from pineapple leaf fiber provided insights into their strength and elongation characteristics, crucial for assessing their suitability for various applications. The 100% pineapple yarn exhibited notable tensile strength, with the 30's yarn enduring a maximum load of 128 grams and the 8's yarn withstanding a remarkable load of 2176.42 grams. Plies of pineapple yarn blended with rayon and polyester also demonstrated substantial strength, with variations in tenacity and elongation depending on twist density and fiber composition. For instance, Pineapple Rayon (PR) yarns showed varying maximum loads and tenacities, indicating the influence of twist density on yarn strength. Additionally, different twist per inch (TPI) settings were explored for various applications, with very fine yarns suitable for delicate weaves and higher TPI yarns providing increased strength and stability for heavier textiles. The combination of pineapple fiber with rayon or polyester offered a range of yarn options catering to diverse textile needs, from lightweight fabrics to durable applications, each providing the unique properties of natural and synthetic fibers.

The construction of traditional textiles on handloom using pineapple leaf yarn with various warp yarns- silk, cotton, rayon, and polyester served to preserve cultural heritage among the Meitei

community in Manipur. The fabrics- Rani phee, Khurkhul muga Phee, Lengyan Phee, and Muga Phanek demonstrated significant cultural significance and are commonly worn during special occasions. The utilization of pineapple fiber imparts stiffness to the fabrics, resembling traditional textiles, and starch finishing techniques further enhance this characteristic. Fabric properties such as warp and weft yarn counts, GSM, thickness, and tensile strength were evaluated, indicating their suitability for different applications. Tensile strength tests revealed the fabrics' ability to withstand external forces, essential for assessing their durability. Analysis of fabric stiffness and drape coefficient provided insights into their dimensional characteristics and drapability, highlighting their potential for traditional textile production within the Meitei community.

The Kawabata Evaluation System (KES) had been employed to assess the mechanical properties of the Cotton/pineapple Fabric, determining its suitability for women's thin dresses. With moderate stiffness, a smooth surface texture, and high fullness & softness, the fabric had achieved a favorable Total Hand Value (THV) of 3.05 out of 5. Compression tests had revealed uniform compression behavior, softness, and high compressional resilience, ensuring durability. Thickness and weight analyses had highlighted the fabric's adaptability and density, enhancing its drape and shape retention. Tensile testing had shown distinct mechanical characteristics in both warp and weft directions, with varying deformation behaviors. Shear testing had indicated directional dependence in shear stiffness and hysteresis, while surface testing had revealed differences in surface smoothness and roughness. Bending testing had demonstrated directional variations in flexibility and energy transmission. Overall, these analyses had provided comprehensive insights into the fabric's mechanical behavior, affirming its suitability for garment applications.

The dyeing process for 100% pineapple spun yarn (30's) incorporated both reactive and natural dyes to achieve traditional Meitei colors while preserving environmental sustainability. Reactive dyes, known for their vibrancy and colorfastness, provided a diverse range of hues, while natural dyes sourced from local plant species contributed unique tones and eco-friendly alternatives. Color strength analysis revealed distinct characteristics of synthetic and natural dyes, with consistent trends in hue and saturation observed across both types. K/S values were utilized to gauge color intensity and depth, ensuring reliable analysis. Color difference metrics highlighted variations in color between dyed and undyed samples, offering insights into the effectiveness of

the dyeing process. Wash and light fastness tests demonstrated that most reactive dyes exhibited very good to excellent performance, with both reactive and plant dyes proving suitable for dyeing pineapple leaf fiber yarn.

Bromelain enzyme extraction involved varying Material Liquor Ratios (MLR) and mediums. Alkali water (ground water) at a 1:30 MLR and distilled water at a 1:20 MLR were used at 100°C for extraction. Centrifugation parameters were optimized, testing durations of 2, 5, 10, and 15 minutes, with 10 minutes determined as optimal for solid-liquid separation. The centrifuge machine operated at the 2nd stage speed. Filtration and refrigeration followed, storing the samples for further use.

The cost breakdown of the fabricated fabrics involved the utilization of waste pineapple leaves for yarn production, with a total cost of Rs 8000 per kilogram. Analysis of the cost for each fabric—Rani Phee, Lengyan Phee, Muga Innaphee, and Muga Phanek—revealed their unique characteristics and associated expenses. Rani Phee, blending silk and pineapple yarn, was priced at Rs 3010 per meter, boasting delicate designs and intricate weaving. Lengyan Phee, combining cotton and pineapple yarn, featured wider dimensions and graceful patterns at Rs 2193 per meter. Muga Innaphee, crafted from a luxurious Rayon and Pineapple blend, showcased detailed designs at Rs 2318 per meter. Muga Phanek, woven with polyester and pineapple yarn, offered durability and affordability at Rs 759 per meter, incorporating temple stoop motifs. Each fabric highlighted the qualities of pineapple fiber while accommodating diverse preferences and budget considerations.

Feedback was collected on the physical appearance of pineapple leaf fiber, yarns, and textiles through interviews with 74 consumers, including weavers from the Meitei community aged between 18 and 60 years. The questionnaire, consisting of 24 questions, gathered background information, preliminary insights, sample examination, and market feasibility. Both open-ended and closed-ended questions in English and Manipuri were used to ensure comprehensive feedback. The data revealed the potential of pineapple leaf fiber fabrics in the market, driven by consumer interest, perceived value, and alignment with cultural and environmental values. Feasibility feedback indicated a high interest in trying fashion garments made from pineapple fabrics, with 97.3% of respondents expressing interest. Additionally, the Kawabata analysis suggested suitability for women's thin dress fabric. Encouraged by this feedback, the researcher conducted

an experiment to visually assess the effect of creating high-fashion garments using the developed pineapple fabrics.

The hypothesis testing aimed to evaluate consumer acceptance of traditional textiles made from pineapple leaf fiber, with a null hypothesis (H₀) suggesting non-acceptance and an alternate hypothesis (H₁) suggesting acceptance. Chi-square and ANOVA tests were conducted for analysis. The chi-square test on categorical consumer feedback data revealed a significant discrepancy, with more than 50% of consumers accepting the pineapple leaf fiber textiles, leading to the rejection of the null hypothesis. Similarly, ANOVA analysis comparing drape coefficients of developed pineapple fabrics with traditional textiles showed no significant differences, indicating consumer acceptance without altering fabric properties, further rejecting the null hypothesis.

Awareness about pineapple leaf fiber as a textile material was raised through various channels, including TV programs, newspaper articles, product displays, and training programs for handloom weavers. These efforts aimed to inform people about the properties and uses of pineapple leaf fiber, increasing its visibility and recognition. A SWOC analysis highlighted the strengths, weaknesses, opportunities, and challenges associated with utilizing pineapple leaf fibers in traditional textile production in Manipur. Strengths included sustainability and economic benefits, while weaknesses included time-consuming extraction and quality consistency issues. Opportunities lay in the growing demand for sustainable products, while challenges included technical and market-related barriers. Integration and strategy formulation involved developing cost-effective extraction methods, collaborating with local communities, investing in research, and implementing targeted marketing campaigns. Utilizing pineapple leaf fiber aligned with Sustainable Development Goals (SDGs) such as Decent Work and Economic Growth, Sustainable Cities and Communities, and Responsible Consumption and Production, contributing to local economic development and environmental sustainability.