USING AGRO-WASTES TO CREATE SUSTAINABLE TEXTILE FIBERS

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ABSTRACT

The global textile industry is adopting sustainable practices delving into eco-friendly wet processing, "green" packaging and innovative fibers and fiber sources. This study evaluates the potential of agricultural residues, such as banana pseudo-stems, stalks, pineapple leaves, and coconut husks, as raw materials for eco-friendly yarn production. The approach of repurposing agro waste offers dual benefits of mitigating agricultural waste and greenhouse gas emissions while providing a sustainable alternative to cotton. The paper highlights the material properties of various agro-waste fibers, details advanced techniques for fiber extraction, and evaluates their diverse applications in textiles and industrial products. Additionally, the environmental advantages, such as biodegradability and waste reduction, are analysed. The economic feasibility, viz. cost-effectiveness and market expansion opportunities are also assessed. The study addresses challenges of scalability and infrastructure limitations by proposing innovative strategies and policy interventions. This work underscores the transformative potential of agro-waste fiber to revolutionize the textile sector, fostering sustainability and a circular economy.

Keywords: *Agro Waste; Pineapple Leaf; Pseudo-stem; Stalks; Sustainable Fibres.*

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1. INTRODUCTION

The increasing demand for sustainability in the textile industry has paved the way for innovations that prioritize environmentally friendly practices. Agro waste, which includes agricultural residues like banana stems, coconut husks, and pineapple leaves, has gained attention as a potential raw material for textile production (Sinha, 1982; Phiri, 2023; Khan, 2022). Historically, these by-products were considered waste and disposed of through burning or landfilling, contributing to environmental degradation. However, advances in technology and an emphasis on circular economy have revealed that agro-waste can be converted into high-value products (Afolalu, 2021; Bala, 2023). This approach aligns with global goals for reducing industrial dependence on synthetic fibers and fostering a greener planet.

1.1 Objectives and Scope

The primary aim of this study is to explore the feasibility of developing yarn from various types of agro-waste and evaluating its applications across the textile sector. The research focuses on identifying the agro-waste types most suitable for yarn production, detailing the methods used for their conversion, and highlighting the potential environmental and economic benefits (Khan, 2022; Tengsuthiwat, 2024(. Additionally, the scope includes analysing challenges faced in scaling such hurdles and addressing gaps in market adoption. By presenting scientific insights, this study seeks to provide a roadmap for stakeholders to integrate agro-waste-based yarn into mainstream textile practices.

2. AGRO WASTES AND THEIR PROPERTIES

The use of agro waste for yarn production relies on the identification of suitable waste materials with desirable properties for textile processing. Different agricultural by-products have unique characteristics that determine their usability in yarn production, such as fiber length, strength, moisture content, and chemical composition. The following subsections detail some prominent types of agro waste utilized in yarn production.

1. *Banana Fiber*
   Banana plants produce copious quantities of peduncles and pseudo-stems after the fruit is harvested, which are often discarded. These stems are rich in natural cellulose and can yield fibers that are strong, biodegradable, and have a silky texture. Banana fiber exhibits properties like high tensile strength and lightweight, making it suitable for apparel and home textiles (Balda, 2022; Khan, 2022).

2. *Pineapple Leaf Fiber (PALF)*
   Pineapple leaves, a significant by-product of pineapple cultivation, contain high-quality cellulose fibers. PALF is known for its stiffness, fine texture, and excellent mechanical properties, making it ideal for blending with other fibers. The use of PALF helps reduce the environmental burden caused by the disposal of pineapple leaves (Doraiswami, 1993; Todkar, 2019; Pandit, 2020).

3. *Coconut Coir*
   Coconut husks yield coir, a robust fiber with excellent durability and moisture resistance. Although commonly used in mats and ropes, finer varieties of coir can be processed into yarn for industrial and nonwoven applications (Batra, 1985; Mathai, 2005; Martins. 2019).

4. *Rice Husks*
   A by-product of paddy cultivation, rice husks are primarily used for their cellulose content. Rice husk fibers are coarse but can be chemically treated to create finer yarns suitable for industrial textiles (Bisht, 2020; Johar, 2012).

5. *Corn and Okra Stalks*
   Corn stalks, often left as residue in agricultural fields, can be processed into natural fibers. They exhibit decent strength and biodegradability, making them suitable for eco-friendly yarn production (Jarabo, 2013; Liu, 2019).

2.1 Significance of Fiber Properties in Yarn Production

The usability of agro-waste fibers depends on their physical and chemical attributes (Hearle, 2008):

- Cellulose content- High cellulose levels enable better spinning and strength in yarns.
- Moisture absorption- Fibers with good moisture retention, like banana and coir, are suitable for textiles requiring breathability.
- Tensile strength- Stronger fibers ensure the durability of the end product.
- Fiber length- longer fibers typically produce smoother, more robust yarns, as seen in PALF and banana fibers.

Typical properties are presented in **Table 1** below. These properties help determine the optimal applications of each fiber type, from clothing to industrial uses. Selecting agro waste with appropriate characteristics not only ensures performance but also aligns with sustainability objectives in yarn production.

Table 1: Physical and Chemical Properties of Agro Wastes

Fiber Source	Fiber Length (mm)	Tensile Strength (MPa)	Moisture Absorption	Primary Composition
Banana Fiber	50–60	500–800	High	Cellulose, Lignin
Pineapple Leaf Fiber	70–90	400–600	Moderate	Cellulose, Hemicellulose
Coconut Coir	100–200	220–250	High	Lignin, Cellulose
Rice Husk	5–10	180–200	Low	Cellulose, Silica
Corn Stalk	20–30	150–300	Moderate	Cellulose, Hemicellulose

2.2 Techniques for Fiber Extraction

The extraction of fiber from agro waste involves various methods tailored to the properties of the waste material. These techniques ensure efficient separation, cleaning, and processing of fibers for spinning into yarn. The steps below outline the key techniques for fiber extraction (Sinha, 1982; Banik, 2011).

Mechanical Extraction

This method involves mechanical force to separate fibers from the agro waste. It is cost-effective and suitable for large-scale operations.

Steps:

Agro-Waste → Shredding → Fiber Separation → Drying → Processed Fiber

Chemical Treatment

Chemical methods involve the use of alkalis, acids, or other chemicals to soften the material and dissolve impurities such as lignin and hemi-cellulose, enhancing the quality of fibers.
Steps:

Agro-Waste → Pre-cleaning → Chemical Treatment → Rinsing → Neutralization → Fiber Separation → Drying → Processed Fiber

Bio-Enzymatic Process

This eco-friendly method uses enzymes to break down non-cellulose components. It is highly effective for high-quality fiber extraction (Akin, 2001).

Steps:

Agro-Waste → Pre-cleaning → Enzymatic Treatment → Soaking → Fiber Separation → Rinsing → Drying → Processed Fiber

2.3 Comparison of Techniques

Comparison of different techniques used for fiber extraction is presented in **Table 2** below.

Table 2: Comparison of Fiber-extraction Techniques

Technique	Advantages	Disadvantages	Application Areas
Mechanical	Low cost, simple setup	Produces coarser fibers	Coir, banana fiber
Chemical	Produces finer fibers	Environmentally hazardous	Rice husk, corn stalk fibers
Bio-Enzymatic	Eco-friendly, high-quality fibers	Costly enzymes, slow process	Pineapple leaf fiber, fine yarns

3 APPLICATIONS OF AGRO WASTE YARN

Agro waste yarn is a versatile and eco-friendly material finding increasing applications in various sectors. Its adoption signifies a shift towards sustainability in two broad industries namely textiles and industrial applications.

3.1 Textile Applications

Apparel

Agro-waste yarn is increasingly being utilized in producing eco-friendly garments. Banana fiber and pineapple leaf fiber yarns are gaining acceptance for their lightweight, breathable, and moisture-absorbent properties. These fibers possess natural lustre and strength, making them suitable for casual and formal wear. Furthermore, such yarn contributes to creating sustainable alternatives to synthetic fabrics, addressing the growing demand for green clothing (Balakrishnan, 2019; Jose, 2016).

Home Textiles

Home textiles, such as curtains, upholstery, and rugs, benefit significantly from the strength and aesthetic appeal of agro-waste yarn. Fibers from coconut coir and banana are especially effective in producing durable and visually appealing home décor items. The biodegradable nature of these materials adds value, making them attractive to environmentally conscious consumers (Jose, 2016).

Accessories and Handicrafts

The unique textures and natural origins of agro-waste yarn make it popular in crafting accessories like bags, belts, and hats. Its durability and customizable qualities appeal to artisans, promoting sustainable craft practices in local and global markets.

3.2 Industrial Applications

Geotextiles

Geotextiles are usd for soil stabilization, erosion control, and land reinforcement. They are constructed from synthetic material such as polypropylene and polyester. Coconut coir is employed as a sustainable alternative due to its high durability and resistance to rotting in moist conditions (Sumi, 2018; Rao, 2005).

Packaging Materials

Eco-friendly packaging solutions derived from agro waste provide an eco-friendly alternative to plastic packaging. Banana fiber and corn stalk-based materials are used to create biodegradable and sturdy sacks, ropes, and twines for agricultural and industrial packaging purposes (Bangar, 2024; Varghese, 2023).

Nonwoven Textiles

Nonwovens from agro waste find applications in filters, insulation materials, and automotive interiors. Pineapple leaf fiber, due to its stiffness and lightweight nature, is converted into nonwoven sheets for industrial usage (Ortega, 2016; Debnath, 2015).

3.3 Emerging Applications

Medical Textiles

Advancements in agro-waste processing are opening avenues in medical textiles. Biocompatible nature makes it suitable for wound dressings and surgical sutures, as they are safe, sustainable, and effective in maintaining sterility (Bala, 2023).

Fashion Innovations

Innovative fashion designers are incorporating agro-waste yarn into haute couture and luxury collections. The eco-friendly appeal and unique textures of banana and pineapple fibers allow the creation of distinctive fashion statements while advocating for sustainability.

Agro-waste applications demonstrate its potential to bridge the gap between sustainability and functional performance. The versatile use of these fibers in textiles and industry not only reduces agricultural waste but also provides a greener alternative for future generations.

4. ENVIRONMENTAL AND ECONOMIC IMPACT

The utilization of agro waste presents significant advantages, both environmentally and economically. These impacts are critical in understanding the broader implications of adopting sustainable practices in the textile industry. Key areas of environmental and economic impact are detailed below (Senthilkumar, 2020; Yafetto, 2023).

4.1 Environmental Impact

Waste Reduction and Resource Optimization

The conversion of agro waste into yarn minimizes the volume of agricultural residues that are either burned or used as landfill, significantly reducing environmental pollution. Transforming by-products such as banana stems, coconut husks, and pineapple leaves into valuable resources promotes a circular economy. This process not only prevents the waste from being discarded but also optimizes the use of existing resources in agriculture and textiles.

Reduction in Carbon Footprint

Traditional yarn production, particularly from synthetic fibers like polyester, relies heavily on fossil fuels and emits substantial amounts of greenhouse gases. In contrast, agro-waste yarn production uses renewable resources, consumes less energy, and produces fewer emissions. Additionally, using bio-based fibers can aid in carbon sequestration during the agricultural phase, making the overall process more environmentally friendly. Further, these fibres can significantly decrease the global dependency on harmful synthetic materials.

Preservation of Biodiversity

Agro-waste yarn production promotes sustainable farming practices by utilizing agricultural residues without the need for additional deforestation or monoculture planting for fiber crops. This approach helps maintain biodiversity in farming ecosystems by ensuring land is not exploited for textile production.

4.2 Economic Impacts

Cost-Effectiveness and Value Addition

Agro waste, traditionally regarded as waste with negligible economic value, can be converted into a valuable product. Farmers and agro-industries can earn additional income by selling waste to textile manufacturers. The low cost of raw materials makes agro-waste yarn a cost-effective alternative to traditional fibers, especially in developing regions.

Employment Opportunities

The agro-waste yarn industry can generate employment in multiple sectors, from raw material collection and processing to spinning and manufacturing. Developing infrastructure for agro-waste yarn production can create job opportunities for rural populations and skilled workers in sustainable industries.

Boosting Local and Export Markets

Countries with abundant agricultural residues, such as India, the Philippines, and Thailand, can position themselves as leaders in agro-waste yarn production. Exporting eco-friendly yarn and finished products can enhance revenue streams and boost the global competitiveness of these nations.

Consumer Demand and Market Growth

As consumers increasingly prioritize sustainability, there is growing demand for eco-friendly products. Agro-waste yarn enables textile manufacturers to cater to this demand, opening up lucrative markets for green textiles. This shift not only supports economic growth but also encourages innovation within the textile industry.

5 CHALLENGES AND OPPORTUNITIES

5.1 Scalability Issues

While agro-waste yarn production is cost-effective, scaling operations to meet industrial demands can be challenging due to limited technology and infrastructure. However, investments in research and development and government incentives can overcome these barriers.

5.2 Policy and Incentive Role

Government policies promoting the use of sustainable materials, coupled with financial incentives, can accelerate the adoption of agro-waste yarn. Subsidies for setting up processing units and tax exemptions for green manufacturing practices are vital economic drivers.

Agro-waste yarn exemplifies how sustainability and profitability can align, offering substantial environmental benefits while fostering economic opportunities. Its adoption supports long-term goals of reducing global waste and building sustainable textile value chains, making it a key player in the future of eco-conscious industries.

6 CONCLUSION

The utilization of agro waste for yarn production represents a significant step towards achieving sustainability in the textile industry. This study highlights the diverse types of agro-waste suitable for yarn production, each offering unique properties that cater to various textile and industrial applications. Techniques such as mechanical, chemical, and bio-enzymatic processes provide efficient ways to extract high-quality fibers while minimizing environmental impact. Agro-waste yarn not only addresses the global challenge of agricultural waste management but also reduces dependency on non-biodegradable synthetic fibers. Its environmental advantages include lower carbon footprints, enhanced biodegradability, and preservation of biodiversity, while economic benefits range from cost savings and added farmer income to new employment opportunities and market expansion.

Despite challenges like scalability and the need for advanced processing technologies, agro-waste yarn offers immense potential for innovation and adoption in global textile value chains. By aligning with sustainability goals, this approach supports eco-conscious consumer demands while contributing to a greener planet. With strategic investments, R&D, and supportive government policies, agro-waste yarn can play a pivotal role in redefining the future of sustainable textiles.

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