WEAVING SUSTAINABILITY

A PLANETARY PERSPECTIVE ON FIBERS IN FASHION

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Abstract

Fibers are integral to the fashion industry, functioning as essential materials and cultural symbols within a global network of production and consumption. This paper adopts a planetary perspective, exploring fibers as dynamic material flows across human, non-human, living, and technological realms. Using Cannabis sativa L. stems as a case study, we examine their transformation from waste to resource, highlighting their potential role in a circular economy. This includes governance and ethical considerations, cultural histories, and the relationship between fibers and geographical locations where all these elements synergize. Understanding fibers holistically is crucial for fostering a sustainable future in fashion and embracing the inherent nobility of fiber.

Keywords: *Cannabis sativa; Biodiversity; Biodesign; Colombia; Waste.*

INTRODUCTION

Fibers are pivotal in textile production and deeply interconnected with industrial, ecological, financial, and societal systems. Traditionally, fibers are viewed through a functional lens. However, adopting a planetary perspective reveals their complex interactions across agriculture, supply chains, consumer behaviors, and eventual disposal in multiple geographies and topographies. This complexity necessitates a broader understanding of where fibers are materials and key ecological and technological actors (Smelik, 2023). Relevant literature offers valuable insights into the role of wool in promoting regional economies, ethical production practices, and environmentally conscious systems such as Local, Slow, and Sustainable Fashion: Wool as a Fabric for Change (Klepp & Tobiasson, 2022). This work highlights wool as an exemplary material within slow and local fashion paradigms, supporting community resources and ethical practices addressing globalized fashion's ecological and socio-economic challenges. Although some farms and regions, such as Australia, adhere to high standards of animal welfare (Singer, 2023), wool production has been associated with ethical and environmental issues, including negligence toward animal welfare and the environmental impact of its unsustainable practices (Plannthin, 2016). Woocoa—a biobased biodegradable alternative to wool—pushes industries to explore non-traditional sources such as marijuana (*Cannabis sativa L.*) (Bonime, 2018). Woocoa represents an advancement in ethical materials, using plant-based fibers and a biotechnological

treatment offering an environmentally friendly possibility. The development of Woocoa demonstrates the potential of biofabricated materials to contribute to innovation in the textile industry.

Recent consumer research indicates a growing interest in innovative materials that are environmentally friendly and ethically produced. This trend has been driven by heightened sustainability awareness and a preference for biodegradable alternatives, as highlighted in the Global Fashion Agenda (2023) report (Syrett & Lammas, 2023). *Cannabis sativa L.* stems, typically discarded during medical marijuana processing, illustrate how waste can transition into valuable resources for textiles, packaging, and construction (Obregón et al., 2023). Incorporating these perspectives offers a comparative lens through which fibers like wool and *Cannabis sativa L.* can be understood as tools for fostering resilience and innovation within sustainable fashion systems.

Even though agricultural practices produce more than 12 billion tons of agricultural refuse globally each year (Klepp & Tobiasson, 2022), examples of how these have been successfully exploited in the textile industry are scarce. Agricultural waste from coconut, pineapple, sugarcane, banana, and corn has demonstrated the potential to be used as a textile fiber (Pilco et al., 2023). Two commercially available examples include Piñatex® (Dela Cruz, 2016) and Bananatex® (QWSTION, n.d.), which use agricultural waste from pineapple (Ananas comosus) and banana (Musa textilis), respectively, providing an eco-friendly alternative to conventional textile fibers. Sustainable options are increasingly in demand within the fashion industry. A shift in consumer mindset towards valuing quality, repairing garments, and making deliberate purchasing decisions is highly needed. This shift exemplifies fibers' potential to influence and be influenced by interconnected human, non-human, and ecological systems. Here we present a case study that encapsulates the evolving narrative of fibers within the sustainability framework.

CIRCULAR REGENERATIVE FIBERS

The Biodesign Challenge (BDC) (Biodesign Challenge, n.d.) is a student competition from high school up to postgraduate where designers, artists, and scientists gather once a year in New York City to share their innovative biotechnological projects. In 2018, BDC introduced the PETA Prize for Animal-Free Wool (Bonime, 2018). This prize, a collaboration between PETA, Stray Dog Capital, and Stella McCartney Ltd., aimed to inspire students to create sustainable, cruelty-free wool alternatives. The prize's inclusion at the Biodesign Challenge Summit at New York's Museum of Modern Art marked a significant step towards integrating ethical considerations into material design. The winning project, Woocoa (Sullivan, 2018), developed by students from Universidad de los Andes (Bogotá, Colombia), created a circular regenerative model using medicinal marijuana stems and coconut fibers discarded after harvest. The sample prototype was conceived as a 100% biodegradable alternative to wool (Mellick et al., 2021) that used coconut fibers discarded from the food industry and marijuana fibers from the northern Cauca region in Colombia, where the local economy was adversely affected by the collapse of the illegal marijuana industry. The fiber blend exhibited enhanced hygroscopic and thermal properties due to the coconut fiber. At the same time, its natural antibacterial qualities and long-lasting durability were attributed to the coconut's coarseness and the hemp's stiffness. However, these two fibers needed a wool look and feel. Therefore, the team applied the Laccase enzyme found in the oyster mushroom *Pleurotus ostreatus* to treat the fiber and obtain smoothness like wool. This vegan wool offers an alternative to animal products and minimizes environmental impact, reflecting a trend towards sustainable, ethical fiber alternatives. Additionally, this approach opens a pathway into a crop that has been cultivated over decades, impacting Colombia's history as a marijuana-producing country. Not only can it create a profitable new market, but it also impacts the country's social and economic systems by creating a new supply chain based on agricultural waste and existing marijuana crops.

The Global Fashion Agenda (2023) (Syrett & Lammas, 2023) states that the industry is pushing towards responsible fiber sourcing. This stems from the continuous and detrimental impacts caused by 149 million tons of fiber processing foreseen for 2030. The report shares that there is a higher demand for recycled fibers, eliminating the use of virgin materials. Also, it refers to opening the scope for sourcing locations, in which brands typically acquire materials from the same sourcing markets. Within the cellulose and bast fiber market, cotton,

Fig. 01

hemp, and linen account for 28% of the global textile market. Cotton farming accounts for many jobs in the Global North and South, such as in the US, India, China, Brazil, and Pakistan. One of the goals of the Global Fashion Agenda (2023) (Syrett & Lammas, 2023) is to support and develop natural fibers such as Woocoa to promote human and ecosystem health. *Cannabis sativa L.* is a crop that regenerates the soil due to its deep root system, which enhances soil aeration and structure. Its phytoremediation properties, including high biomass production and the ability to tolerate and accumulate heavy metals from contaminated soils (Kumar et al., 2017), further contribute to environmental benefits. Additionally, repurposing discarded stems helps mitigate the harmful burning practices typically associated with their production. Agricultural waste accounts for millions of tons globally annually, representing a significant underutilized resource in various industries. Among these, discarded marijuana stalks serve as a byproduct with promising potential for textile fiber manufacturing. To qualify the viability of the discarded hemp stems for textile performance, their physical, chemical, morphological, and mechanical properties were analyzed, and their hemicellulose, pectin, lignin, and cellulose content were determined (Obregón et al., 2023). The successful fiber extraction from discarded marijuana stems was developed under a circular economy framework, thus encouraging the establishment of innovative methods to process marijuana stems into fibers. One such method is water-retting, an ancient but still relevant technique for separating the fibrous material from the plant. With modern biotechnological advances such as enzyme treatments, water-retting enhances the material's durability and versatility. This process exemplifies how traditional techniques, updated with current technologies, can contribute to circular practices, minimizing environmental impact and economic cost. The fibers could be quickly processed via

knitting, and their mechanical properties are comparable to those of similar natural fibers such as wool, coir, sisal, and jute (Obregón et al., 2023). Considering that an agricultural by-product is used as a raw material, the methodology allows maximum utilization of all resources. Reusing agricultural waste promotes a circular economic model for the textile industry. After the water-retting process, a high-quality wool-like raw fiber is placed in an enzymatic cocktail bath. Various enzymatic potencies were positioned to obtain a better wool-like quality (Hernández & Ortiz, 2023). In this case, Woocoa opens the possibility towards a circular, regenerative fiber, bringing a systemic approach to a new economy where sustainability and ethical practices converge into a new era for a country mired by a negative perception of its natural resources, such as marijuana crops.
The fashion ecosystem is responsible for 26% of greenhouse gases and is projected to cause a 2.0°C increase in global temperatures by 2030 (McKinsey & Company, 2020). How can we quantify figures that are intangible in the present but will materialize in the future? What are those innovative, sustainable, and systemic tools applied to the fashion industry? After several iterations, from Cradle-to-Cradle design to the blue economy, we have arrived at the Circular Economy. The model is based on the principle that every product has intrinsic value and should not become waste at the end of its life; it mitigates carbon emissions while staling biodiversity. The circular economy is recognized as a tool to reduce carbon emissions and waste and halt biodiversity depletion (Glazunova, 2024). Under the European Union's Ecodesign for Sustainable Products Regulation (ESPR), textiles, garments, and footwear companies align with circular economy principles. The regulation prioritizes textiles and footwear as key sectors, establishing durability, repairability, recyclability, and waste reduction as mandatory requirements. In the textile sector, these measures emphasize extending product longevity through meaningful design improvements and enhancing recycling processes by minimizing the use of hazardous substances while creating more efficient material recovery systems (European Commission, n.d.). Implementing Digital Product Passports is a focus of the ESPR. It ensures rigorous transparency by detailing a product's composition, environmental impacts (including its carbon footprint), and lifecycle management from resource extraction to post-consumer behavior (European Commission, n.d.). By adopting the ESPR framework, businesses can advance sustainable production systems, reduce resource dependency, and foster a more responsible and circular textile economy (European Commission, n.d.). These initiatives are essential for reducing the environmental footprint of textile production and addressing the increasing demand for sustainable fibers, such as Woocoa.
Ceschin & Gaziulusoy (2016) framework outlines the evolution of design responses to sustainability challenges. This framework positions *Cannabis sativa L.* fibers within a multi-level approach: at the product level, as a biodegradable and renewable alternative to synthetic fibers; at the product-service system design level, where it holds potential for circular models by integrating artisanal knowledge within co-design processes; and at the spatial-social innovation level, contributing to localized economic resilience and ethical production.
These perspectives enhance the understanding of *Cannabis* sp. fibers as both a material innovation and a driver of socio-technical integration, facilitating the transition toward an integrated fashion system. This approach aligns with systems thinking principles, conceptualizing the production process from raw material extraction to post-consumer behavior as an integral part of the fiber's development and sustainability impact. There is continuity in the cycles without causing environmental impacts by avoiding waste creation. In this context, a circular economy not only bridges a resourceful fiber into eliminating waste, such as using discarded *Cannabis sativa L.* stems, but also finding a use for a market that previously was only seen as for making rope or coffee sacks through the continual use of resources, shifting away from the linear model of "take, make, dispose". Circularity emphasizes recycling and redesigning the entire lifecycle of fibers, including cultivation, production, consumption, and disposal.

In a linear production system, fibers like polyester significantly contribute to environmental degradation due to their fossil fuel origins and inability to biodegrade. Recycling initiatives, though aimed at mitigating waste, fail to address the release of microplastics throughout the lifecycle of polyester products—synthetic from production to consumer use and eventual disposal. These microscopic plastic particles contaminate waterways, oceans, and even the human food chain, posing severe ecological risks to marine life and

potentially human health. Furthermore, polyester fibers can take hundreds of years to degrade, exacerbating long-term pollution concerns. In contrast, natural fibers, such as hemp or wool, offer the advantage of biodegradability, decomposing naturally and enriching the soil. Using fibers derived from *Cannabis sativa L.* reduces reliance on synthetic fibers by providing a biodegradable and renewable alternative. However, scaling these processes to a global level requires more than just biotechnical innovation. Circularity demands systemic change in how fashion materials are sourced, produced, and disposed of. Governance structures will need to shift to support the production of sustainable fibers and the implementation of circular economic principles at every stage of fashion's supply chain. Scaling up the production of innovative materials like Woocoa involves cost, manufacturing, and supply chain logistics challenges. The PETA Prize encouraged students to consider the entire lifecycle of materials, including production, disposal, and recycling, ensuring they provide immediate and long-term benefits. Introducing animal-free and sustainable materials signifies a pivotal shift in the fashion industry, challenging traditional practices and offering viable, ethical alternatives. Designers and manufacturers increasingly recognize the value of sustainable practices, setting a precedent for future developments. The Woocoa project was chosen as an example for its alignment with circular economy principles and biotechnological innovation. As a winner of the PETA Prize for Animal-Free Wool at the Biodesign Challenge, Woocoa represented a model of sustainable fiber production, utilizing agricultural waste (*Cannabis sativa L.* stems and coconut fibers) to create a high-performance, biodegradable alternative to animal-derived textiles. Detailed technical data and methodologies from project collaborators are available upon request, including data collection and analysis of technical documentation, such as laboratory protocols for fiber extraction and enzymatic treatment (Hernández & Ortiz, 2023).

THE CASE OF CANNABIS SATIVA L. STEMS

Cannabis sativa, an herbaceous plant originating in eastern Asia (Small, 2017), has since spread globally. Historical records indicate that *Cannabis* sp. plants have been used for textile production since 9000 to 100,000 BC (Ingrouille & Eddie, 2006).

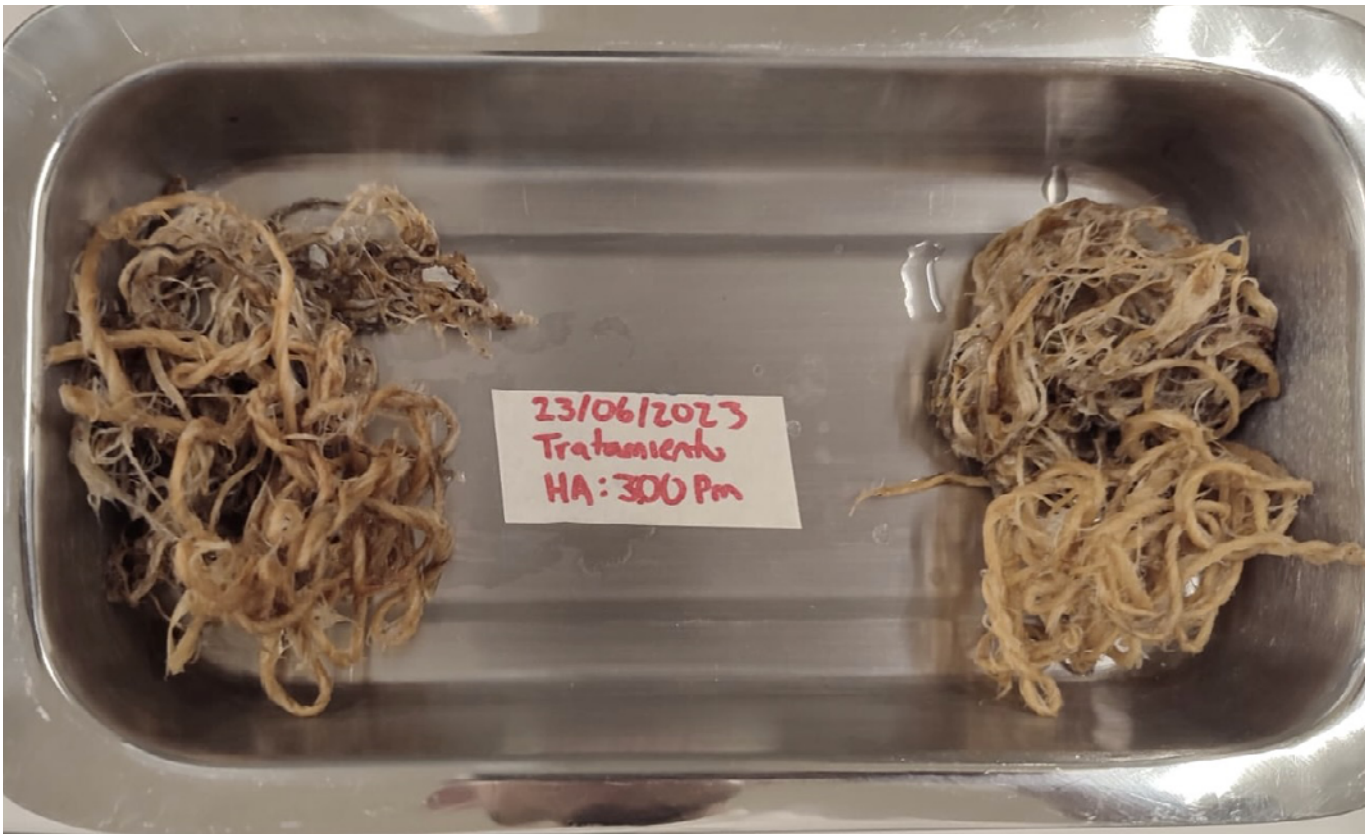

Fig. 02

This species contains cannabinoids such as tetrahydrocannabinol (THC), which affects the human psyche, and cannabidiol (CBD), which moderates THC's psychoactive effects. The variety known as "hemp" or "industrial hemp" has low THC and high CBD content, making it valuable in the textile industry for its antimicrobial, durable, and breathable qualities. In contrast, the plant varieties referred to as "marijuana" are cultivated for medicinal and recreational use due to their psychoactive properties (Small, 2017). Marijuana stems, usually 1–2 meters long (Small, 2017), are not commonly used for fiber extraction compared to hemp, which can reach lengths of 3.5 to 4 meters (Jonaitienė et al., 2016). Marijuana stems are often discarded or incinerated because they lack significant THC content. Repurposing these stems transforms agricultural by-products into valuable textile materials, addressing environmental challenges and demonstrating fibers' role in various systems. A circular economy emphasizes continuous resource use, minimizing waste, and maximizing value. Using fibers from renewable sources like marijuana exemplifies circular practices by repurposing discarded stems and reducing reliance on synthetic fibers. Marijuana fibers, processed through methods like water-retting, extend the lifecycle of materials and align with sustainable practices. This approach reduces waste and environmental impact, supporting circular economy principles by promoting resource efficiency and reducing reliance on petrochemical-derived synthetic fibers. The fashion industry has outlined in the Global Fashion Agenda (2023) report (Syrett & Lammas, 2023) the many impacts of materials and fibers obtained from livestock. It is strongly advised to support fibers associated with transparent, regenerative soil. Environmental consequences have driven increased uptake of certified fibers and strong interest in fibers obtained from a revitalized sustainable farming system (Syrett & Lammas, 2023). Bamboo viscose, while marketed as sustainable, often undergoes chemical-intensive processes that diminish its eco-friendliness (Plannthin, 2016). While marketed as sustainable, bamboo fibers often undergo chemical-intensive processes that diminish their eco-friendliness (Plannthin, 2016). Within this scope, PLA or synthetic biopolymers are biodegradable but rely on an intensive production process that also shares limited mechanical properties compared to Woocoa's fiber blend (Smelik, 2023).

Hemp shares similarities with *Cannabis sativa L.* in its regenerative agricultural benefits and fiber properties but lacks the enzymatic treatment applied to Woocoa, and it also comes from virgin crops and not from discarded stems.

GOVERNANCE AND ETHICS OF FIBER

Effective fiber governance involves regulating production, use, and disposal. As fibers transition from waste to resources, establishing ethical frameworks and addressing fair labor practices, environmental impact, and resource management are crucial. *Cannabis sativa L.* fiber promotes ethical production, minimizes environmental impact, ensures fair labor practices, and allows sustainable resource use to happen organically. The shift from waste to resource presents challenges and opportunities for increasing fair wages and equitable and holistic financial development between the farming of the fiber and the brand where it is ultimately conceived as a garment. To have a holistic view, the design process must understand the fiber, material, design complexity, production, transportation, sales, post-consumption, and end-of-life products. The supply chain needs to decipher and understand where fibers, fabrics, textiles, production, and manufacturing directly impact the current wages of fabrics and

Fig. 03

Fig. 04

clothing manufacturers. Although extensive support and work have been done to apply fair compensation and living wages to workers across the globe, brands' commitments are still lacking in sharing accurate data and transparency across their supply chain. The communities that are most affected are migrant workers and women who are impacted by low wages, appropriating their compensation, and hazardous, unsanitary living conditions (Syrett & Lammas, 2023). This is reflected in not many brands sharing data on agreements between the garment manufacturers and the clothing brand itself. Establishing a roadmap and living wage data across the multiple geographies where textiles and garments are manufactured would support a holistic view in understanding and establishing a fair wage metric. As the Global Agenda (Syrett & Lammas, 2023) demonstrates, a multistakeholder agreement is needed to commonly agree on how to bring auditing within the various stakeholders who participate from tier 1 to tier 4.

CULTURAL HISTORIES OF FIBER TECHNOLOGIES

Understanding historical contexts provides insights into the cultural significance and technological advancements related to fiber production. The evolution of fiber technologies reflects material science advancements and shifts in societal needs influenced by cultural, environmental, and technological factors. Fibers often hold cultural significance beyond their functional roles, and *Cannabis sativa L.*'s historical use highlights its importance across cultures. Local resources and environmental conditions influence fiber production, emphasizing the need for localized knowledge of sustainable practices. In Colombia, the intersection of biodesign and fashion presents an opportunity to transform issues into opportunities for innovation because of the many socioeconomic challenges associated with a country that went through 50-plus years of war. The fashion industry looks to scale artisanal practices and production to meet the worldwide demand for more handmade processes and materials associated with uniqueness, longevity, and regenerative practices. Colombia, the second most biodiverse country in the world, offers an untapped market that can be supported under rigorous biodesign scientific and design thinking methodologies, which will result in a reduction in reliance on animal-derived materials and land-intensive crops. The cultivation of Cannabis sativa L. supports

the reduction of agricultural waste by utilizing discarded stems, aligning with circular economy principles. Repurposing these discarded fibers minimizes reliance on virgin materials, and high-value fibers are created, directly supporting circularity by closing the resource loop and promoting the efficient use of agricultural by-products. This innovation is particularly significant in Colombia, where the textile industry has traditionally relied on importing hemp textiles from China due to the lack of local production. Using *Cannabis sativa L.* fibers thus presents an opportunity to redefine Colombia's material possibilities while fostering sustainable and localized production practices.

By focusing on small-scale, local production, South American countries have the potential to address ethical and environmental benefits from the get-go by combining artisanal practices with biotechnologies stemming from biodesign. Moreover, addressing whether land should be used for growing plants for textiles or repurposed for more biobased, regenerative methods—which should be applied to existing materials—becomes an essential issue when bringing circularity and supporting a cradle-to-cradle approach. Colombia's biodesign efforts could highlight and support a nascent industry that would bring a more sustainable and ethical fashion practice, allowing more circular practices. Comparatively, *Cannabis sativa L.* aligns with slow fashion principles, supporting regional economies and environmentally conscious practices, as highlighted by Smith et al. (2022) exploration of slow and local fashion. Their framework resonates with Colombia's historically artisanal community practices, particularly in regions like Ráquira, Boyacá, where wool has traditionally been a cornerstone of craftsmanship and cultural heritage.

PROVOCATIONS ON FIBER'S AGENCY AND MATERIALITY: THE ROLE IN FASHION SYSTEMS

Fibers act as agents in fashion systems, influencing usability, sustainability, and impact. Recognizing fibers' agency, as seen with marijuana fibers, involves understanding their potential to drive change in fashion practices and contribute to broader environmental and social goals. Material agency refers to fibers' ability to influence and be influenced by various systems and innovations. *Cannabis sativa L.* fibers demonstrate how material agency can drive sustainable practices and shape the future of fashion. Fibers actively create agency within fashion systems and are increasingly recognized for their impact from an emotional, visceral influence when understanding them from an artisanal viewpoint. The history behind *Cannabis sativa L.* (marijuana fibers) goes beyond its functionality and ecological output. This involves viewing their potential to bring change within fashion, advancing aesthetic and viable goals, and broader environmental and social objectives. Fibers inherently possess material agency, meaning they can influence and be influenced by the systems they interact with, including technological and ecological innovations, as well as the stakeholders involved in influencing communities at a cultural and social level. *Cannabis sativa L.* fibers exemplify how biobased materials can pave the way for planetary practices, offering an alternative to resource-intensive, fossil fuel textiles such as synthetics or water and energy-intensive crops such as cotton. Similarly, scaling artisanal production to meet growing global demand invites a crucial reconsideration of the materials we choose to elevate. There is inherent value in supporting local production methods, especially on more minor scales, as this respects biodiversity and can reduce the environmental impact of large-scale industrial processes. For instance, animal-related topics, such as the ethical concerns around animal-derived fibers, prompt us to explore plant-based or alternative materials like *Cannabis sativa L.* fibers. Moreover, as we evaluate the land use for textile industries, a key question emerges: should land be allocated for growing more raw materials when a wealth of existing, underutilized fibers already exists? This discussion becomes even more pressing regarding sustainability goals, emphasizing the need for a circular approach in the fashion industry. By repurposing what is available and embracing locally sourced, sustainable fibers, we can create an innovative fashion future deeply aligned with ecological and societal needs.

The shift toward conscious behaviors reflects an evolving mindset among consumers who increasingly prioritize sustainability and ethical considerations in their purchasing decisions. This transformation is driven by a better understanding and awareness of the environmental and social impacts of the fashion industry, as highlighted in the Global Fashion Agenda (2023) report (Syrett & Lammas, 2023). The report identifies a growing

demand for transparency and accountability from brands, with consumers showing a preference for ethically sourced and sustainably produced products. For instance, it emphasizes that 75% of consumers surveyed prefer clothing from brands that disclose their practices, including supply chain transparency and responsible fiber sourcing, where brands are complying with additional features as clothing passports. The report further identifies those narratives around sustainability, such as the use of recycled fibers, regenerative materials, and circular economy practices, are pivotal in shaping consumer preferences. For example, the Global Fashion Agenda notes the success of brands incorporating recycled materials into their collections. It highlights how ethical considerations, such as fair labor practices, resonate strongly with consumers who demand living wages and safe working conditions for garment workers.

This shift in consumer behavior represents an opportunity for innovative materials like *Cannabis sativa L.* fibers, which align with sustainability narratives by reducing agricultural waste, promoting circularity, and minimizing environmental footprints. As consumers increasingly seek products that align with their values, integrating such fibers into fashion supply chains meets these demands and establishes a competitive advantage for brands that embrace sustainable and ethical innovation.

CONCLUSION AND FUTURE DIRECTION

A planetary perspective reveals fibers' dynamic role in global material flows and forces. The case of *Cannabis sativa L.* fibers demonstrates how traditionally wasted materials can support sustainable practices. By exploring fibers' role in a circular economy, governance, cultural histories, and their interactions with geography, innovative and sustainable approaches to fashion can be developed while respecting its context, people, communities, and biodiversity.

Woocoa aligns with global regulatory efforts, particularly in the European Union, which has introduced initiatives such as the EU Circular Economy Act and the Ecodesign for Sustainable Products Regulation (ESPR) (European Commission, n.d.). These regulatory measures provide a robust framework that reinforces the relevance of fibers like Woocoa, emphasizing their potential to thrive in an increasingly sustainability-driven market. Such initiatives underscore the importance of collaboration, innovation, and governance in advancing a circular and sustainable textile economy, setting new benchmarks in environmental stewardship and resource efficiency. *Cannabis sativa L.* stem waste further exemplifies the potential of agricultural by-products to drive sustainability in textiles. This shift not only minimizes resource extraction but also redefines waste, transforming it from a discarded by-product into a valuable resource for sustainable innovation. Future research should continue to explore new materials and technologies that align with the United Nations 17 Sustainability Development Goals. The case of *Cannabis sativa L.* fibers illustrates the potential of emerging technologies by addressing environmental challenges and promoting circular economy principles. For *Cannabis sativa L.* stems, this principle is particularly relevant as their traditional categorization as agricultural waste transforms into a viable raw material for textiles. While it alone may be insufficient to create systemic change, incorporating additional agricultural waste—many already recognized as valuable and viable sources of fiber—into textile production systems could reduce reliance on virgin materials. The fashion ecosystem can no longer remain detached from a continuous linear production system without considering the entire system and expecting different results. Having a direct responsibility for how the planet is impacted in each production phase is a strong commitment. It starts with design thinking and progresses through biodesign, combining in a systemic evaluation to understand all points of contact and impact. This sustainable tool quantifies the economic value for companies that implement circularity. Biodesign offers a valuable tool for implementing circularity, requiring investment in time, human resources, and materials to achieve long-term sustainability, as demonstrated in the case of Woocoa.

CAPTIONS

[Fig. 01]. Manuel Ortiz: Woocoa *Cannabis sativa L.* dried for two days on a clothesline using the natural air current in Envigado, Antioquia, Colombia

[Fig. 02]. Manuel Ortiz: Woocoa *Cannabis sativa L.* and coconut spun fibers in a Lacasse enzymatic cocktail at Universidad de los Andes, Bogotá D.C., Colombia

[Fig. 03]. Manuel Ortiz: Woocoa Artisanal weaving in Ramiriquí, Boyacá, Colombia

[Fig. 04]. Manuel Ortiz: Woocoa *Cannabis sativa L.* and coconut spun fibers in Bogotá, Colombia

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