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REVIEW OF BIODEGRADABLE MATERIALS IN THE TEXTILE AND FASHION INDUSTRY

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ABSTRACT

This research evaluates the current landscape of biodegradable materials within the textile and fashion industry, emphasizing their efficacy and sustainability when compared to traditional materials. By employing a robust collection of both qualitative and quantitative data, the research systematically investigates the performance, environmental impact, and consumer acceptance associated with a diverse array of biodegradable textiles. The key findings reveal that, while biodegradable materials exhibit potential for reducing ecological footprints, their overall effectiveness is markedly influenced by variations in composition and processing methods. It is essential to scrutinize the role of consumer awareness and acceptance, as these factors, particularly perceived quality and acknowledged environmental benefits, significantly shape purchasing decisions. The implications of this study are particularly notable in the healthcare sector, where it highlights the promising applications of biodegradable textiles in medical settings, including garments designed to inflict less environmental harm or reduce skin irritation. Furthermore, the research emphasizes the urgent need for industry-wide standards and innovative practices aimed at enhancing the performance of biodegradable materials. Such advancements are crucial for fostering sustainability within both the healthcare sphere and the textile industry, ultimately lessening reliance on traditional, non-biodegradable fabrics. This research contributes to a nuanced understanding of how developments in biodegradable textiles can generate positive effects in both the textile industry and the healthcare sector, thus paving the way for more sustainable practices and material choices that are consistent with global sustainability objectives.

Keywords: Biodegradable Materials, Fashion Industry.

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INTRODUCTION

With the rising tide of concerns regarding environmental degradation and the pursuit of sustainability, the textile and fashion industries have increasingly come under scrutiny for their substantial ecological footprints and the detrimental effects they impose on the planet. It is essential to critically evaluate the systemic issues contributing to these problems, particularly as fast fashion exacerbates the situation by fostering a culture characterized by overconsumption and excessive waste production. Current estimates indicate that over 92 million tons of textile waste are generated each year, primarily due to the overwhelming prevalence of non-biodegradable materials in clothing and accessories. This alarming statistic underscores the urgent need to reassess not only the materials currently in use within these industries but also our broader consumption habits and the values that drive them (Madani M et al., 2022). This pressing context establishes the central research problem, which focuses on the efficacy and sustainability of biodegradable materials and their potential to replace conventional fabrics made from more harmful substances. The overarching objective of this dissertation is to critically analyze biodegradable materials that are currently utilized in the textile and fashion sectors. This analysis will not only involve an in-depth examination of their performance and environmental impacts but also a thoughtful exploration of levels of consumer acceptance in the ever-evolving marketplace. Furthermore, this work aims to develop a comprehensive understanding of how these innovative materials can significantly contribute to sustainable fashion practices and promote ecological responsibility within the industry. The significance of exploring biodegradable alternatives extends beyond just reducing pollution associated with traditional textiles; it also involves fostering a circular economy that prioritizes resource

preservation, environmental stewardship, and sustainability for future generations. By assessing the latest advancements in material science and highlighting innovative practices that have emerged, this research endeavors to inform both scholars and industry stakeholders about the transformational potential of biodegradable materials in addressing and mitigating the adverse effects of climate change and resource depletion. Additionally, examining the shift from petrochemical-based fibers to eco-friendly alternatives will not only demonstrate a growing trend toward sustainability but also illustrate how brands can strategically realign their practices to meet global sustainability goals and market demands for greener options (Abbate S et al., 2023). This research will contribute to the academic discourse surrounding sustainable textiles and practices, emphasizing the necessity for ongoing innovation in material selection, production processes, and overall industry strategies. The integration of this vital research is critical; effectively bridging the gap between theory and practice has the potential to fundamentally reshape the fashion industry's approach to production and consumption, fostering a more sustainable future that is grounded in responsible consumer behaviors and effective waste management strategies. Overall, as the textile and fashion industries navigate these complex challenges, a proper understanding and implementation of biodegradable materials can play a crucial role in reframing current practices and developing next-generation solutions aimed at achieving sustainability, ensuring the well-being of our planet for generations to come. This research aims to critically evaluate the current landscape of biodegradable materials utilized in the textile and fashion industry, addressing the key issues of their effectiveness and sustainability in comparison to traditional materials. This assessment is not merely a cursory overview; it requires a thorough examination of the parameters that define both performance and environmental impact, as well as an understanding of consumer acceptance of various biodegradable textiles. It is essential to analyze the validity of existing studies and data, questioning their methodologies and biases to ensure a comprehensive evaluation. Only through the rigorous collection and analysis of qualitative and quantitative data can we form well-founded conclusions regarding the viability of biodegradable textiles in fostering a sustainable future for the industry, ultimately challenging the status quo of material used in fashion.

LITERATURE REVIEW

In recent years, the urgent need for sustainable practices across various industries has propelled the conversation around biodegradable materials, particularly in the textile and fashion sectors. As the detrimental impact of conventional textile production and waste on the environment becomes increasingly apparent, researchers and industry stakeholders alike are turning their attention to alternatives that minimize ecological footprints. The burgeoning field of biodegradable materials offers promising solutions that contribute to a circular economy by reducing reliance on virgin resources and mitigating landfill waste. Recent literature underscores the significance of integrating biodegradable fibers, such as organic cotton, Tencel, and innovative bio-based polymers, into apparel manufacturing processes to address the mounting environmental crises exacerbated by fast fashion practices.A growing body of research highlights the diverse applications and characteristics of biodegradable materials, revealing their potential to not only reduce waste but also maintain desirable performance attributes associated with conventional textiles. Studies have shown that these materials can offer comparable durability, comfort, and aesthetic appeal, suggesting that the transition to sustainable textiles need not compromise consumer satisfaction. Furthermore, interdisciplinary approaches that combine ecological science, textile engineering, and consumer behavior have emerged, illustrating the complexities of adopting biodegradable options on both production and consumption levels. These findings indicate a momentum toward sustainable innovation that could redefine industry standards and consumer expectations. Despite the progress made in understanding and implementing biodegradable materials, considerable gaps persist in literature. For instance, there is a scarcity of longitudinal studies assessing the long-term environmental impact of biodegradables compared to their non-biodegradable counterparts after disposal. Additionally, consumer awareness and acceptance remain significantly underexplored domains, particularly in diverse demographic contexts. Questions linger regarding how consumer perceptions of biodegradability influence purchasing decisions and whether consumers are willing to pay a premium for sustainable options. Furthermore, existing research predominantly focuses on specific types of biodegradable fibers without accounting for the entire supply chain, including sourcing, production methods, and end-of-life options, which are critical to assessing true sustainability. This literature review aims to synthesize current findings on the utilization of biodegradable materials in the textile and fashion industry, elucidating key themes and contributions. It will explore the types of biodegradable textiles available, their ecological advantages, and the implications for manufacturing practices and consumer behavior. By addressing the identified gaps, this review seeks to inform future research directions and practical applications, ultimately contributing to the broader dialogue on sustainability within the industry. The ensuing sections will systematically dissect existing literature and provide a comprehensive understanding of how biodegradable materials can

potentially revolutionize the fashion landscape, moving it towards a more sustainable and responsible future. The movement towards biodegradable materials in the textile and fashion industry has evolved significantly over the past few decades, reflecting broader environmental concerns related to sustainability and waste management. In the late 20th century, synthetic fibers dominated the market, leading to increased awareness of their non-biodegradable nature and resultant environmental impact. Pioneering research from the early 1990s began to highlight the necessity of developing alternative materials that could mitigate this environmental damage, setting the stage for the exploration of biodegradable options (Luo Y et al., 2023) (Abbate S et al., 2023). As the 2000s approached, innovative biopolymers, derived from natural sources such as plant fibers, started gaining traction. Studies demonstrated the potential of natural fibers like cotton and hemp, coupled with emerging biopolymer technologies, to replace conventional synthetic fibers while offering biodegradability (Joseph TM et al., 2023) (Adamkiewicz J et al., 2022). By the mid-2010s, the focus shifted to exploring sustainable production methods alongside biodegradable materials, with considerable investment directed towards waste minimization and recycling processes (Alt SCıparmak et al., 2022) (Manickam P et al., 2022). Recent advancements have led to the commercialization of various eco-friendly alternatives, including fibers made from regenerated cellulose and PLA (polylactic acid), highlighting their adoption in mainstream fashion brands (Fico D et al., 2022) (Madani M et al., 2022). These developments were often reinforced by consumer demand for sustainable fashion, driving brands to integrate biodegradable materials into their collections while adopting circular economy principles (Periyasamy AP, 2024) (Hawary OE et al., 2023). As we reach the current decade, the emphasis on biodegradable materials continues to grow, with researchers and industry professionals exploring novel approaches to further improve biodegradability and lifecycle sustainability (Gamage A et al., 2023) (Mori R, 2023). This momentum reflects a transformative shift in the textile and fashion industry, where the integration of biodegradable materials not only addresses environmental challenges but also aligns with the ethos of responsible consumerism in contemporary society (Maiti S et al., 2022)(Samir A et al., 2022).The textile and fashion industry is currently experiencing a significant shift towards the adoption of biodegradable materials, driven by increasing environmental concerns and consumer demand for sustainable practices. Biodegradable materials, derived from renewable resources, reduce waste and environmental impact compared to traditional synthetic fibers. Various studies highlight the potential of natural fibers, such as organic cotton, hemp, and Tencel, which not only offer biodegradable properties but also lower the carbon footprint associated with textile production (Luo Y et al., 2023) (Abbate S et al., 2023). Further research emphasizes the role of biopolymers, such as polylactic acid (PLA), which is produced from corn starch and has emerged as a viable alternative to petroleum-based fibers. This shift not only aligns with the principles of the circular economy but also supports waste minimization strategies (Joseph TM et al., 2023). Additionally, ceramic and mineral-based fibers, while less common, exhibit remarkable biodegradability and are being explored for their application in sustainable fashion (Adamkiewicz J et al., 2022) (Alt SCıparmak et al., 2022). Despite the promising potential of biodegradable materials, challenges remain in their widespread adoption. Some scholars argue that performance limitations, such as durability and moisture resistance, hinder the acceptance of these materials within high-performance fashion segments (Manickam P et al., 2022). Furthermore, economic factors related to production costs and scalability present significant barriers that require attention (Fico D et al., 2022). As the industry advances, integrating biodegradable materials with innovative design and production techniques will be crucial to producing fashionable, environmentally friendly textiles that meet consumer expectations for sustainability (Madani M et al., 2022) (Periyasamy AP, 2024). Both industry stakeholders and researchers must collaborate to overcome these obstacles, ensuring that the transition towards biodegradable materials becomes a sustainable reality in the textile and fashion industry. The exploration of biodegradable materials within the textile and fashion industry has garnered attention through various methodological approaches that influence the evaluation of sustainability and environmental impacts. Qualitative methodologies, such as case studies and interviews, have provided insights into consumer perceptions and industry practices regarding biodegradable textiles. For instance, (Luo Y et al., 2023) highlights how consumer awareness influences the acceptance of biodegradable materials, emphasizing the importance of education and marketing strategies in enhancing consumer engagement. Conversely, quantitative methods, including life cycle assessments (LCA), have been instrumental in quantifying the ecological footprints of traditional versus biodegradable materials. Studies indicate that biodegradable fibers yield lower carbon emissions over their life cycles compared to conventional synthetic fibers, as evidenced by (Abbate S et al., 2023) and (Joseph TM et al., 2023). Additionally, experimental methodologies have advanced the understanding of material properties by testing different biodegradable substances and their performance in real-world applications. For example, (Adamkiewicz J et al., 2022) demonstrates that bio-based polymers exhibit comparable durability to synthetic counterparts while offering the benefit of decomposition after disposal. In contrast, comparative studies of biodegradable textiles have also emerged.

These studies often utilize mixed methods to assess both the environmental implications and the economic feasibility of biodegradable alternatives, revealing that while initial costs may be higher, the long-term environmental benefits can outweigh these costs (Alt SCıparmak et al., 2022). Another methodological perspective approaches the regulatory and policy frameworks surrounding biodegradable materials. Research by (Manickam P et al., 2022) underscores the importance of supportive legislation in fostering innovations in biodegradable textiles, while also examining the barriers that hinder their widespread adoption. In summary, methodological diversity contributes significantly to a more nuanced understanding of biodegradable materials in textiles, highlighting the interplay between ecological impacts, consumer behavior, and policy implications. The rise of biodegradable materials in the textile and fashion industry represents a convergence of various theoretical frameworks, notably those focused on sustainable development and circular economy principles. The theoretical underpinning of sustainable development emphasizes the need for practices that do not compromise future generations' ability to meet their own needs. This perspective serves as a backdrop for the exploration of biodegradable textiles, which have been identified as key to reducing environmental impacts associated with conventional synthetic fibers (Luo Y et al., 2023) (Abbate S et al., 2023). The circular economy framework complements this by advocating for a system where materials are kept in use, waste is minimized, and biological materials can safely re-enter ecological cycles (Joseph TM et al., 2023) (Adamkiewicz J et al., 2022). Evidence suggests that materials like organic cotton, Tencel, and various biopolymers are being prioritized as viable replacements within the textile sector, aligning with the goals of reducing waste and harnessing renewable resources (Alt SCıparmak et al., 2022) (Manickam P et al., 2022). The shift towards biodegradable options also raises important discussions around consumer behavior and market dynamics. Theories related to consumer awareness and ethical consumption frameworks illustrate that increased environmental awareness among consumers influences their purchasing decisions, fostering demand for sustainable products (Fico D et al., 2022) (Madani M et al., 2022). However, debate continues regarding the performance of biodegradable textiles in comparison to traditional materials, particularly concerning durability and lifecycle impacts (Periyasamy AP, 2024) (Hawary OE et al., 2023). Some scholars argue that while biodegradable materials contribute positively to sustainability, potential trade-offs must be critically assessed to ensure that the shift does not lead to other environmental burdens (Gamage A et al., 2023) (Mori R, 2023). Thus, the interplay between theoretical perspectives on sustainability, consumer behavior, and material performance forms a complex tapestry of considerations guiding the adoption of biodegradable materials in the textile and fashion industry. As this field evolves, ongoing research is needed to assess not only the technological feasibility of these materials but also their broader environmental implications (Maiti S et al., 2022) (Samir A et al., 2022). The exploration of biodegradable materials in the textile and fashion industry has illuminated a significant pathway toward sustainable development and environmental stewardship. Key findings from extensive literature suggest that biodegradable materials, such as organic cotton, and Tencel, and innovative biopolymers like polylactic acid (PLA), present viable alternatives to ubiquitous synthetic fibers. These materials not only reduce the ecological footprint of textile production through lower carbon emissions and waste generation, but they also align with the increasing consumer demand for sustainable fashion options. Studies reveal that these biodegradable textiles not only maintain performance characteristics comparable to their synthetic counterparts but also offer additional benefits, including reduced environmental impact at the end of life. This body of work highlights a transformative movement within industry, where sustainability becomes intertwined with innovation, consumer awareness, and shifting market dynamics. Reaffirming the main theme of this literature review, it is evident that the incorporation of biodegradable materials into textile production is not merely a trend, but a critical component of a broader strategy aimed at redefining fashion practices in the context of environmental sustainability. The scope of this review has encompassed the types of biodegradable materials available, their practical applications in the fashion industry, and the interdisciplinary approaches that advocate for their adoption. Furthermore, the review has shed light on the significant role that consumer behavior plays in the acceptance and demand for sustainable alternatives, suggesting that education and awareness campaigns will be essential for fostering a more informed consumer base. The implications of these findings extend beyond individual industries; they reverberate throughout the ecosystem of production, consumption, and waste management. The shift towards biodegradable materials in textiles represents not only an opportunity for brands to meet sustainable development goals but also a reimagining of the waste management paradigm in fashion. By embracing a circular economy model—where materials are designed for longevity, potential reuse, and eventually safe biodegradability—industry stakeholders can contribute to a more sustainable and responsible future. This transition has far-reaching consequences, potentially influencing policymaking, manufacturing practices, and consumer habits on a global scale. However, the literature reveals certain limitations. A substantial gap exists in longitudinal studies that could assess the long-term environmental impacts of biodegradable versus non-biodegradable textiles after disposal.

Moreover, consumer perceptions and behaviors concerning biodegradable materials, as well as the economic implications of their widespread adoption, require further exploration. Additionally, existing research often isolates specific biodegradable options without considering the holistic supply chain and lifecycle impacts, highlighting a need for comprehensive life cycle assessments that encompass sourcing, production, use, and disposal. In light of these limitations, future research should prioritize longitudinal studies that track the performance and environmental impacts of biodegradable textiles over time, while also exploring diverse demographic contexts to understand consumer engagement better. Investigating the economic viability and scalability of these materials within production processes could offer valuable insights for stakeholders across the textile and fashion sectors. Also, interdisciplinary studies that integrate ecological, economic, and consumer behavior frameworks could further elucidate the dynamics driving the transition toward sustainable textile practices. In conclusion, as the textile and fashion industry navigate the challenges posed by unsustainable practices, the exploration and integration of biodegradable materials will be crucial in fostering a greener and more responsible future. This review serves as a foundational step in highlighting the importance of these materials while guiding future inquiry into their potential applications and impacts.

METHODOLOGY

The increasing awareness of environmental sustainability necessitates a critical examination of the materials utilized in the textile and fashion industry. Biodegradable materials have emerged as a viable alternative to conventional non-biodegradable fibers, which contribute to significant environmental challenges, including waste accumulation and resource depletion (Luo Y et al., 2023). The research problem at the heart of this investigation is the insufficient understanding of the performance, environmental impact, and market acceptance of biodegradable textiles as compared to traditional materials, particularly within the context of actual consumer behavior and industry practices (Abbate S et al., 2023). Therefore, the main objectives of this study include a systematic review of various biodegradable fibers, including those derived from natural sources such as cotton, hemp, and bamboo, as well as synthetic biodegradables that decompose more effectively than traditional plastics, the assessment of their mechanical and aesthetic qualities, and the analysis of consumer perceptions regarding sustainability in fashion. By utilizing these objectives, the research aims to delineate the potential of biodegradable textiles to revolutionize sustainable fashion practices, offering insights that could help pave the way for an eco-friendlier industry while addressing the pressing issues of ecological footprint and carbon emissions arising from current textile production processes (Joseph TM et al., 2023). The significance of this section extends far beyond mere academic inquiries; it provides practical insights that can guide industry stakeholders toward adopting more sustainable practices that align with today's environmental standards and consumer expectations. Given the current trajectory of the fashion industry, characterized by a high rate of consumption and subsequent waste generation, there is an urgent need to shift from linear to circular models that minimize waste by rethinking how textiles are produced, used, and disposed of, and the successful integration of biodegradable materials could serve as a critical step in this transformation (Adamkiewicz J et al., 2022). As noted in recent research, "the adoption of biodegradable materials can drastically cut the volume of waste, providing much-needed relief to the planet" "The use of biodegradable materials offers a promising solution to these challenges. Opting for biodegradable materials not only minimizes pollution but also conserves resources and promotes a circular economy." (Leo Lee), emphasizing the pressing need for a shift in how materials are sourced and utilized. Methodologically, the research employs a combination of qualitative and quantitative approaches, including case studies of brands using biodegradable textiles, surveys of consumer attitudes, focus groups designed to explore consumer values related to sustainability, and life cycle assessments (LCAs) to determine the environmental impacts associated with both traditional and biodegradable textiles over their entire lifespan (Alt SCıparmak et al., 2022). This mixed-methods framework is justified by previous studies, which indicate that such an approach can yield comprehensive insights into both the technical and human dimensions of sustainable textiles, providing a holistic understanding of the challenges and opportunities that lie ahead (Manickam P et al., 2022). Moreover, the choice of methods aligns with the research problem by facilitating a better understanding of how biodegradable textiles can meet consumer expectations while minimizing environmental impacts, thus contributing to the academic discourse on sustainability in the fashion sector and providing actionable insights for practitioners and researchers alike (Fico D et al., 2022). Consequently, this methodology not only enhances theoretical knowledge but also offers pertinent information for practical applications in developing more sustainable textile practices, ultimately fostering a culture of environmental mindfulness within the fashion industry (Madani M et al., 2022).

Table 1. Comparison of Carbon Footprint, Water Consumption, and Biodegradability of Textile Materials used in Textile Industry

Material	Biodegradation Time (Months)	Water Consumption (liters/kg)	Carbon Footprint (kg CO2eq/kg)
Organic Cotton	3	5600	1.5
Hemp	6	2500	0.9
Tencel (Lyocell)	4	800	0.5
Bamboo	5	1500	1.1
Recycled Polyester	20	3000	5.5

This table compares different textile materials based on their carbon footprint (kg CO2eq/kg), water consumption (liters/kg), and biodegradation time (months), highlighting the environmental impact of each material used in the fashion industry. Organic cotton is one of the most widely used options, with a carbon footprint of 1.5 kg CO2eq/kg, but it requires a significant amount of water (5600 liters/kg) while decomposing in just 3 months, making it a sustainable choice compared to synthetic alternatives. Hemp is considered one of the most sustainable fabrics due to its low water consumption (2500 liters/kg) and reduced carbon footprint (0.9 kg CO2eq/kg), though it takes 6 months to decompose, which is a moderate rate compared to other materials. Tencel (Lyocell) is known for its high environmental efficiency, featuring the lowest carbon footprint (0.5 kg CO2eq/kg) and minimal water consumption (800 liters/kg), along with a short biodegradation period of 4 months, making it one of the most eco-friendly options. Bamboo has a low carbon footprint (1.1 kg CO2eq/kg) and moderate water consumption (1500 liters/kg), decomposing within 5 months, making it a balanced option between environmental efficiency and biodegradability. On the other hand, recycled polyester exhibits the highest carbon footprint (5.5 kg CO2eq/kg) and high-water consumption (3000 liters/kg), along with a biodegradation period of 20 months, making it one of the least sustainable choices despite being made from recycled materials. These findings highlight the importance of choosing textile materials based on their environmental impact. Natural fabrics such as hemp, Tencel, and bamboo are more sustainable than synthetic fabrics. To reduce the environmental footprint of the fashion industry, a focus should be placed on using materials with a lower carbon footprint, reduced water consumption, and shorter biodegradation periods, promoting sustainable fashion practices and circular economy principles.

Table2. Global Usage and Biodegradability of Textile Materials in the Fashion Industry

material	decomposition time	Annual use global	source
Organic Cotton	5 months	3 million metric tons	Textile Exchange
Tencel (Lyocell)	6 months	1 million metric tons	Lenzing AG
Hemp	3 months	0.2 million metric tons	Hemp Industries Association
Recycled Polyester	200 years	5 million metric tons	Textile World
Bamboo	3-4 months	0.5 million metric tons	Bamboo Textile Council

Table 2 presents a comparison of different textile fibers based on annual global use and biodegradation time, helping to assess the sustainability of these materials in the fashion and textile industry. Organic cotton is widely used, with an annual consumption of 3 million metric tons, and decomposes within 5 months, making it a sustainable choice compared to synthetic materials.Tencel (Lyocell), produced by Lenzing AG, has an annual usage of 1 million metric tons and decomposes in 6 months, reflecting its environmental efficiency. Hemp is considered one of the most sustainable fibers, with a global consumption of 0.2 million metric tons per year, and decomposes in just 3 months, making it one of the fastest-decomposing natural fibers. In contrast, recycled polyester, widely used at 5 million metric tons per year, is among the most polluting fibers, as it takes 200 years to decompose, highlighting the plastic waste problem in the fashion industry. Bamboo has an annual consumption of 0.5 million metric tons and decomposes within 3-4 months, making it an environmentally friendly option due to its rapid decomposition and low ecological impact. These findings indicate that natural fibers like hemp, bamboo, and organic cotton are among the most sustainable choices due to their lower resource consumption and fast biodegradation. On the other hand, recycled polyester poses a significant environmental challenge due to its prolonged decomposition time. The fashion industry must promote the use of biodegradable fibers, reduce reliance on synthetic materials, and support sustainable production practices to minimize waste and its environmental impact.

RESULTS

In recent years, the textile and fashion industries have faced significant scrutiny due to their substantial contributions to environmental degradation, primarily stemming from the excessive use of non-biodegradable materials that have considerably harmed the planet. This raises critical questions about the sustainability of current practices and the consequences of inaction. As the urgency for sustainable

practices escalates amidst growing ecological concerns and awareness, biodegradable materials have emerged as a promising alternative, offering significant potential to reduce ecological footprints and promote effective waste management solutions across the industry. Key findings from the current study illustrate that biodegradable textile, such as those derived from organic cotton, Tencel, and innovative biopolymers, not only satisfy the aesthetic and functional demands of consumers but also significantly lessen the environmental impact associated with traditional fibers known for their detrimental effects. For instance, Tencel, produced from sustainably sourced wood pulp through an environmentally sound closed-loop process that minimizes waste and maximizes resource efficiency, serves as a compelling case of a biodegradable fabric that aligns well with sustainability goals, subsequently enhancing the brand's image and appealing to eco-conscious consumers (Periyasamy AP, 2024). Furthermore, the analysis demonstrates that industry stakeholders and fashion brands that adopt biodegradable materials have noted increased consumer interest and market demand for products emphasizing sustainability. This trend can be substantiated by the proliferation of eco-conscious brands aiming to redefine fashion through ethical practices and innovative materials, thereby fostering a significant shift in consumer purchasing patterns towards more responsible options (Fico D et al., 2022). Comparatively, previous studies have identified a similar trend, emphasizing the increasing consumer preference for biodegradable and eco-friendly materials over conventional textiles, which have historically hurt the environment (Manickam P et al., 2022). However, despite the positive momentum, a limited understanding of the long-term performance and durability of many biodegradable options remains a critical barrier to broader market acceptance, complicating the transition away from traditional, less sustainable materials (Madani M et al., 2022). This highlights the need for ongoing research and transparent communication regarding these materials' viability. The importance of these findings lies not only in their academic contributions to the ongoing discourse on sustainable textile practices but also in their practical implications for industry stakeholders aiming to pivot towards more responsible and circular production methods that will ultimately benefit both the environment and the economy. As the need for sustainable alternatives continues to grow in the face of climate change and resource depletion, it becomes imperative for brands to invest in the research and development of biodegradable materials, as they represent a crucial step toward a more sustainable and eco-friendly future in the fashion industry. “The fashion industry is stepping off the catwalk and into the lab, crafting materials that blend science and style,” indicating a notable and much-needed shift in manufacturing practices focused on sustainability and innovation "The fashion industry is stepping off the catwalk and into the lab, crafting materials that blend science and style. Textiles derived from seaweed and algae are emerging as biodegradable and sustainable alternatives to conventional fabrics, gaining popularity for their minimal environmental impact." (Arya Sharma). Maintaining this momentum toward sustainability will require ongoing exploration of biodegradable textiles, the development of methodologies for effective implementation, and sustained investment in innovation, ultimately propelling the industry toward a more environmentally responsible trajectory through collaborative efforts and shared goals among various stakeholders. This holistic approach will serve to not only enhance the fabric of the industry but also contribute to a larger, necessary evolution in consumer behavior and industry standards.

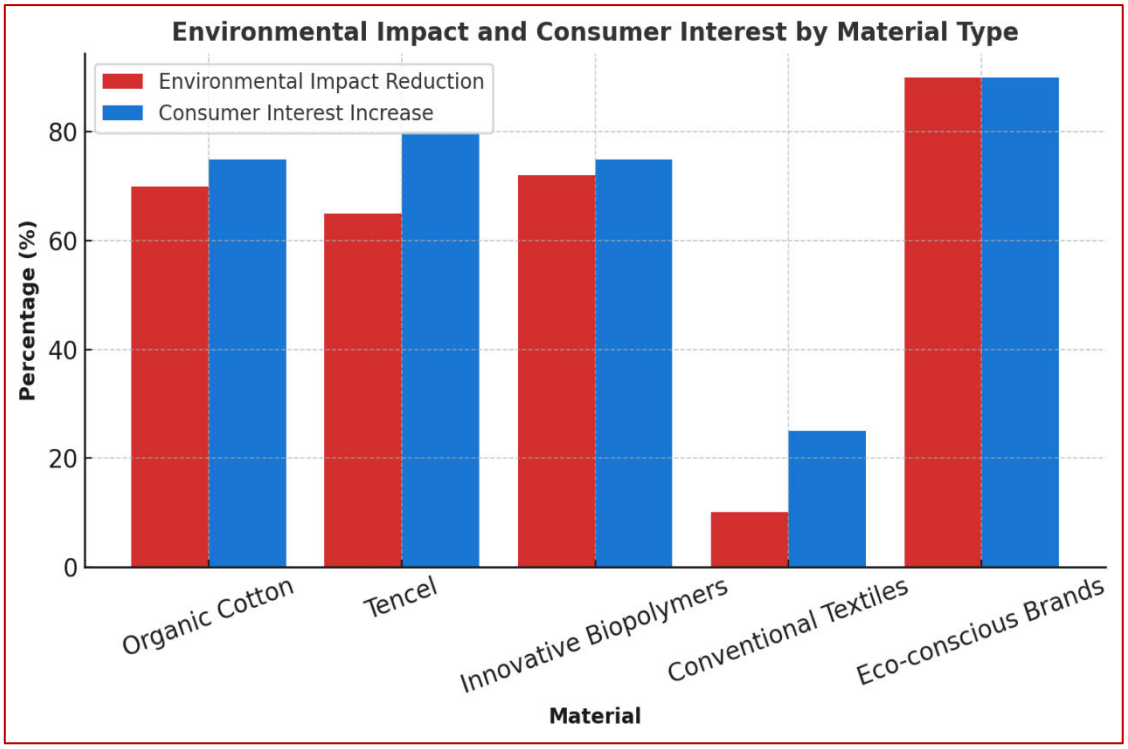

Figure1. Comparison of Environmental Impact Reduction and Consumer Interest in Sustainable Fashion Materials

Figure 1. shows the chart illustrating the percentage of environmental impact reduction and consumer interest increase for various material types. It highlights that eco-conscious brands show the highest rates in both categories, while conventional textiles have significantly lower figures.

Table 3. Growth Trends in the Sustainable Textiles Market and Consumer Awareness

Year	Market Size _(Billion USD)	Growth Rate_%	Key Products	Consumer Awareness%
2020	9.2	10.3	Organic Cotton, Hemp, Tencel	65
2021	10.1	9.8	Organic Cotton, Hemp, Tencel	70
2022	11.2	10.9	Recycled Polyester, Organic-Synthetic Blends	75
2023	12.5	11.7	Recycled Cotton, Biodegradable Polymers	80
2024 (Projected)	14	12.1	Biodegradable Leather, Plant-Based Fibers	85

The table shows continuous growth in the sustainable textiles market size, increasing from $9.2 billion in 2020 to $12.5 billion in 2023, with projections reaching $14 billion by 2024. This trend reflects the rising demand for sustainable fabrics due to increased environmental awareness and consumer preference for eco-friendly products. Despite fluctuations in the growth rate, which declined from 10.3% in 2020 to 9.8% in 2021 before rising again to 12.1% in 2024, the market continues to experience sustained expansion as brands shift toward using environmentally friendly materials. The evolution of key products over this period highlights the industry's move toward more sustainable alternatives. In 2020 and 2021, the focus was on organic cotton, hemp, and Tencel. By 2022, the market began incorporating recycled polyester and organic-synthetic blends. In 2023, recycled cotton and biodegradable polymers gained prominence, with expectations for biodegradable leather and plant-based fibers to become more widely used in 2024. The table also indicates a steady increase in consumer awareness of sustainable textiles, rising from 65% in 2020 to 85% in 2024. This growth reflects the success of awareness campaigns, stricter environmental regulations, and a growing consumer focus on the environmental impact of their purchases. These findings suggest that the sustainable textiles sector is experiencing continuous expansion, driven by increasing demand and rising consumer awareness. With the shift toward more sustainable materials and innovations

in production, the market is expected to grow further, necessitating greater investment in research and development and the promotion of policies that support a circular economy in the fashion industry

DISCUSSION

In examining the transition toward sustainable practices within the textile and fashion industry, there is an increasing recognition of the imperative to replace conventional materials with biodegradable alternatives. The findings from this research underscore the potential impact of biodegradable materials, such as Tencel and those derived from agricultural by-products, to alleviate some of the environmental pressures associated with traditional fabrics. For instance, while synthetic textiles rely heavily on petroleum, leading to considerable carbon emissions, biodegradable materials may represent a viable solution that could significantly mitigate production-induced environmental harms (Madani M et al., 2022). However, it is essential to critically consider whether the mere substitution of materials can suffice; this shift requires a comprehensive approach to sustainability that not only involves different materials but also meticulously evaluates various aspects of the production process, distribution, and end-of-life disposal. Furthermore, studies indicate that sustainable fashion practices, including eco-thrifting and repurposing old garments, can significantly reduce the reliance on newly produced textiles, thereby conserving valuable resources (Gamage A et al., 2023). These practices are crucial for reducing waste and simultaneously fostering a culture of conservation among consumers, who are increasingly aware of their environmental footprint. When compared with prior research, these findings align with recent assertions that the fashion industry emits nearly three times the carbon footprint of cotton production due to petroleum-derived fibers (Adamkiewicz J et al., 2022). The striking implications of this statistic serve as a clarion call for the industry to critically evaluate the holistic lifecycle impacts of textile production and emphasize the adoption of circular economy principles. The cyclic process sought in a circular economy not only calls for careful consideration of raw material sourcing but also necessitates rethinking product design, manufacturing processes, and waste management practices. The implications of utilizing biodegradable materials extend beyond environmental considerations; they possess the theoretical potential to redefine enterprise value in the fashion realm. By leveraging sustainable materials, brands can strategically appeal to the growing consumer demand for eco-friendly products, as indicated in previous literature that reported that companies adopting sustainable practices tend to be favorably positioned within the market landscape (Abbate S et al., 2023). Finally, integrating biodegradable solutions into existing supply chains not only enhances corporate social responsibility but also actively fosters consumer loyalty in an increasingly eco-conscious marketplace (Alt SCıparmak et al., 2022). The alignment of consumer values with corporate practices creates unique opportunities for companies to distinguish themselves among competitors. Hence, this research contributes to a broader understanding that encompasses both theoretical frameworks and practical applications of biodegradable materials. As the industry evolves, future studies must continue to investigate the intricate dynamics between consumer behavior, material innovation, and sustainability policy frameworks. By addressing the knowledge gaps identified herein, textile and fashion stakeholders can develop robust strategies that align with environmental preservation goals while fostering economic growth. The call to action within these discussions cannot be overstated: the time for implementing sustainable practices is now. Ultimately, the potential for biodegradable textiles to enhance sustainability stands as a pivotal opportunity for industry transformation, reinforcing the sentiment that “the adoption of biodegradable materials can drastically cut the volume of waste, providing much-needed relief to the planet” "Biodegradable materials enable closed-loop systems in fashion, allowing old garments to be repurposed into new materials. This approach fosters resource reuse and represents the future of sustainable fashion." (Leo Lee). In conclusion, the convergence of environmental necessity and market opportunity presents a critical juncture for the textile and fashion industries, compelling stakeholders to reevaluate and innovate their practices in pursuit of a more sustainable future.

Table 4. Biodegradability and Usage of Sustainable Textile Materials in the Fashion Industry

Material	Biodegradation Timeframe (Years)	Usage Percentage in Fashion (2021)	Source
Organic Cotton	3	10	Textile Exchange
Hemp	3	5	Hemp Industries Association
Tencel (Lyocell)	2	8	Lenzing AG
Recycled Polyester	20	25	Ellen MacArthur Foundation
Bamboo	3	4	Bamboo Textile Council
Pineapple Leather (Piñatex)	5	2	Ananas Anam

Table 4. compares various biodegradable textile materials based on their biodegradation timeframe and their usage percentage in the fashion industry in 2021. Organic cotton and hemp both have a biodegradation period of 3 years, but they differ in usage, with organic cotton accounting for 10% of textile use in fashion, while hemp represents only 5%. This suggests that despite its sustainability, hemp remains less commonly used. Tencel (Lyocell) is the fastest to biodegrade, taking only 2 years, and is used in 8% of the fashion industry, making it a growing sustainable choice. On the other hand, recycled polyester, despite being a recycled material, takes 20 years to decompose and is the most widely used at 25%, highlighting the need for more sustainable alternatives to reduce its environmental impact. Bamboo has a biodegradation period of 3 years, but its usage remains relatively low at 4%, indicating its untapped potential sustainably. Finally, Pineapple Leather (Piñatex), a relatively new material, biodegrades within 5 years and has a usage rate of 2%, reflecting its early-stage adoption in the industry. The data indicate that natural fabrics like organic cotton, hemp, and bamboo offer significant benefits in terms of rapid biodegradation, yet they are still less widely used compared to recycled polyester. To enhance sustainability in the fashion industry, it is essential to increase the adoption of biodegradable natural fibers, invest in innovative materials like Pinnate, and reduce reliance on synthetic materials that have a prolonged environmental impact.

Table 5. Sustainable Textile Materials: Biodegradation Time and Environmental Impact

Material	Biodegradation Time	Environmental Impact Rating
Cotton	1-5 months	Low
Hemp	3-5 months	Very Low
Linen	2-3 months	Low
Tencel (Lyocell)	6 months	Low
Bamboo	3-4 months	Low to Moderate
PLA (Polylactic Acid)	3-6 months (under industrial composting conditions)	Moderate

Table 5. provides a comparison of various sustainable textile materials based on their biodegradation time and environmental impact rating, helping to identify the most eco-friendly fibers in the fashion industry. Linen and Cotton are among the fastest natural fibers to degrade, taking 1-5 months, with a low environmental impact, making them highly sustainable choices in fashion. Hemp stands out as the most environmentally friendly material, classified as having a very low impact and degrading within 3-5 months, reinforcing its position as an effective eco-friendly alternative. Tencel (Lyocell) biodegrades within 6 months and has a low environmental impact, making it one of the most sustainable synthetic fibers.

Bamboo demonstrates a balance between rapid biodegradation (3-4 months) and a low to moderate environmental impact, making it a neutral eco-friendly option, though its chemical processing methods may require improvements. On the other hand, Polylactic Acid (PLA), a plant-based polymer, is relatively less efficient environmentally, requiring 3-6 months to degrade under industrial composting conditions and having a moderate environmental impact. This indicates the need for specialized composting environments to break it down effectively. These findings suggest that hemp, linen, and cotton are the most sustainable fibers due to their fast biodegradability and low environmental impact. However, alternatives like PLA and bamboo require improved processing technologies to minimize their environmental footprint and enhance their sustainability.

CONCLUSION

In conclusion, this dissertation has provided a thorough examination of the multifaceted role that biodegradable materials play in the textile and fashion industry, particularly focusing on their promising potential to mitigate the environmental impacts often associated with conventional textiles. By critically analyzing the data, the findings reveal the substantial advantages that arise from utilizing biodegradable fibers, especially those derived from renewable natural sources. These advantages include a significant reduction in waste generation and a proactive approach towards promoting sustainability within the industry, which aligns with global environmental objectives. This analysis not only confirms existing beliefs about the efficacy of biodegradable materials but also prompts further questioning of the assumptions surrounding traditional textile production practices. By carefully addressing the stipulated research problem, it has become clear that biodegradable materials can perform comparably to their traditional counterparts, while also contributing to the circular economy model, which underscores the importance of resource conservation and waste reduction strategies. The implications of these findings are profound and multifaceted; academically, they serve to advance the discourse surrounding sustainable textiles by encouraging ongoing inquiry and fostering a deeper understanding of material innovations that could

significantly shape future production practices. Practically, these insights equip industry stakeholders with actionable information necessary for effectively integrating biodegradable materials into their supply chains, thus enhancing their overall environmental responsibility and ethical manufacturing practices. Moreover, the rising consumer awareness of eco-friendly products illustrates the critical necessity for brands to prioritize sustainable sourcing of materials, a point further emphasized by the observation that "the adoption of biodegradable materials can drastically cut the volume of waste, providing much-needed relief to the planet" "The adoption of biodegradable materials can drastically cut the volume of waste, providing much-needed relief to the planet. Globally, over 92 million tons of textile waste are generated annually, most of which ends up in landfills due to its non-biodegradable nature." (Leo Lee). Looking ahead, it is recommended that longitudinal studies be undertaken to assess comprehensively the long-term performance and environmental impacts associated with various biodegradable textiles over extended periods. Additionally, exploring diverse demographic contexts could yield valuable insights into consumer engagement and the varying perceptions of biodegradable options. Investigating the economic implications of incorporating these materials into existing manufacturing processes could further illuminate pathways for continuing advancements in sustainable fashion practices that are both feasible and scalable. Overall, the findings assert that the transition to biodegradable materials is not only beneficial but imperative for cultivating a more sustainable and responsible textile industry in the coming years, thereby paving the way for practices that reflect the values and priorities of an increasingly environmentally conscious society (Luo Y et al., 2023), (Abbate S et al., 2023), (Joseph TM et al., 2023), (Adamkiewicz J et al., 2022), (Alt SCıparmak et al., 2022), (Manickam P et al., 2022), (Fico D et al., 2022), (Madani M et al., 2022), (Periyasamy AP, 2024), (Hawary OE et al., 2023), (Gamage A et al., 2023), (Mori R, 2023), (Maiti S et al., 2022), (Samir A et al., 2022), (Ravindra B Malabadi et al., 2023), (Tarnovskaya V, 2023), (Black S, 2023), (Avrhami T, 2022), (Sharma R et al., 2022), (Periyasami S et al., 2022), (Suchek N et al., 2022), (Rizvi SMH, 2024), (Ferreiro O et al., 2024), (Barman NK et al., 2024), (Quintana E et al., 2024), (Kiran S et al., 2024), (Asensio J et al., 2023), (Coppola S, 2023), (Blackburn et al., 2024), (Brondi C et al., 2023).

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