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FASHION'S FIBRES AS PLANETARY FLOWS

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CONTENTS

EDITORIAL

FASHION'S FIBRES AS PLANETARY FLOWS

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INTRODUCTION

Fibre, the basis of fashion's materiality, is experiencing a rising demand year on year, reflecting the insatiable desire for 'more' that defines the dominant fashion system. With an annual consumption of 124 million tonnes in 2023, a doubling in twenty years (Textile Exchange 2024), humanity's appetite for fibre has never been more voracious. Recent studies on fashion's fibre are diverse: including technical analyses of different fibres' sustainability benefits or challenges (e.g., Subramanian et al 2021), analysis of their value chains (e.g., Mellick et al 2021) and cultural histories (Stanes and Gibson 2017; Smelik 2023). In industry contexts there are calls for fibre to be traceable from all sources – whether from forests, oil fields, farms, or laboratories – and their impacts to be quantified and reduced (e.g., UNECE 2021; Changing Markets 2022).

The fourth issue of Fashion Highlight Journal proposes a planetary perspective on fibre, viewing it as a dynamic interplay of material flows and forces shaped by both human and non-human actors, the living and the technological, and the crowded continuum between them. In this Introduction we will first briefly situate our study of fibres within theoretical perspectives of new materialism and posthumanism. Then we will introduce the thirteen peer-reviewed papers through three thematic threads that we have detected among and across them.

FIBRE AS MATTER

When we chose a focus on fibres for this issue, the idea was born within the framework of both new materialism and posthuman theory. New materialism involves a turn (or return) to matter and materiality: researching fibres means to take matter seriously (Colman and Van der Tuin 2024). This means looking in detail – and wonder! – at the non-human elements that are so prominent in the world of textiles and of fashion. New materialism allows that particular spotlight on the very materiality of fibres. This emphasis on matter and materiality is reinforced by posthuman theory, which advocates for a rigorous non-anthropocentric perspective. By decentring the human subject, posthumanism enables a deeper understanding of fashion as a materially co-produced phenomenon within a complex network of interconnected human and non-human actors (Braidotti 2013, 2016). The term posthuman reflects the idea that humans are inherently entangled with the broader material and technologically mediated world (Braidotti and Hlavajova 2018, 3). Posthumanism challenges binary thinking by recognizing a nature-culture continuum, blurring distinctions between humans and their many non-human counterparts. Similarly, new materialism highlights that things—whether objects, art, fashion, or people—are composed of matter, encompassing organic, mineral, vegetable, and synthetic materials (Fox and Alldred, 2018; Smelik 2018). We – and they/those – are agentic matter on a continuum (Barad 2003). In the case of textiles, the non-human can be made of ancient natural fibres like wool, linen, silk, cotton, or hemp; of semi-synthetics like rayon, viscose and bamboo; and of technologically produced synthetics such as nylon, polyester, acrylic, or mylar—to just name a few. As we will see below, most of the papers in this issue focus on natural fibres rather than synthetic ones.

One of the fundamental insights of new materialism is the entanglement of subject and object. People and clothes are not distinct entities but rather form "hybrid agencies," as Tim Ingold (2016: 69) describes, mutually shaping one another within what he terms the "meshwork of things" (2012: 437). We wear the fibres on our skin: silk gives an either warm or cool sensation in diverse weather circumstances; cotton receives our sweat; wool keeps us warm but can also prickle our skin; and polyester makes us feel sweaty. Ingold observes that in discussions around materiality there is often a lack of attention to actual materials. As he reminds us, "to know materials, we have to follow them" (437); and this is precisely what so many papers in this issue attempt to do. To know the materiality of our clothes—the fabrics of our T-shirt, jeans, or dress that we wear on our bodies—we must follow its trajectory from beginning to end—starting from the very beginning: the fibres.

From a new materialist perspective, matter is not merely passive or inert but should be recognized as an active and meaningful force in the world (Barrett and Bolt 2013, 3, 5; Ingold 2012). Materials and objects possess agency—not in an anthropomorphic sense, but rather, as Ingold (2010) describes, as an emergent flow. For him, things are gatherings of dynamic forces and movements. We are all familiar with the agency of fibres: wool prickles, linen crinkles, silk soothes. This perspective aligns with Jane Bennett's concept of the vitality of things and non-human materials, which she terms "vibrant

materiality" (2010: viii). Matter, she argues, is not brute or inert. Rather, drawing on Bergson, she describes materiality as a dynamic flow (2010: 92). Recognizing the vibrancy and vitality of things, she contends, allows us to fully acknowledge matter and "the force of things" (2010: viii). The central aim of these and other theories of materiality is to reveal the deep entanglement between humans and things (see Brown, 2001, 2015). The papers in this issue contribute to this discourse by highlighting the materiality of fibres within the field of fashion. New materialist and posthuman perspectives on fibre recognize its vitality, or as Ingold (2013) describes it, a "world of active materials". These perspectives also enable a deeper understanding of the politics, power dynamics, exchanges, and agency involved in the creation of fibre as matter—encompassing humans, non-humans, and more-than-humans. In this sense, a posthuman approach provides a framework for analysing the dynamics, ethics, and materiality of fibre on a planetary scale. Here, we may follow Morton (2013) to understand fibres such as polyester as 'hyperobjects': objects so vast, so planet-wrapping in their spatial impact and so long in their temporal lifespan (from ancient fossil fuel origins to eventual photo-degradation), that they resist comprehension.

In using the term 'planetary' rather than 'global' we seek to recognise the Earth as the primary living system of human and non-human entanglements. This notion of the planetary has roots in the Gaia hypothesis, first proposed by atmospheric chemist James Lovelock and extended by microbiologist Lynn Margulis (Margulis and Sagan, 1997). For us, the term 'global' carries a narrower view of human-centred trade and governance, whereas the term 'planetary' can encompass the more-than-human nested within numerous living systems; the planet – the 'blue marble' – as life itself. In recent decades, analysis of planetary boundaries has brought new awareness of the convergent crises facing the Earth system (Rockström et al 2009), demonstrating the ways in which a view of the planetary can aid understanding.

Viewed through a planetary lens, fibres are unruly: no corner of the earth is free of microfibres, as they persist in air, water and soil, and coagulate in oceans. The production of fibre reshapes entire landscapes (UNCCD 2024). Fibre envelops every human body. Fibres can be living technologies, in the case of genetically modified cotton plants, or blended combinations of biological and synthetic matter in stubborn melanges that resist easy separation. Fibres are traded: they are commodities hedged on the futures markets, travelling the planet and criss-crossing national borders. Recognizing fibre's importance and agency, invites a more expansive, ethical, and material-driven understanding of fashion in a planetary context.

FIBRES: THREADS AND THEMES

The issue Fashion's Fibres as Planetary Flows showcases reflections, provocations, and speculations on fashion's future, focusing on the tiny strands of fibre that are aggregated by the tonne, traded as commodities, spun into yarns, branded as products, and wrestled over in the marketplace. While we invited papers on individual fibre stories of all forms, from viscose, cotton, wool, silk, polyester, nylon and beyond, we were struck that synthetic fibres make an appearance only obliquely, and as a predicament – synthetic fibre contaminates, it is artificial, it sheds micro plastics, accrues falsehoods, makes recycling troublesome. It is interesting to see that the authors (and indeed, the wider pool of submissions) chiefly selected to discuss natural materials: wool, silk, cotton, hemp, fungi, nettles and brambles. This obviously has to do with the urgent issue of sustainability; almost all authors take sustainable textiles as a desirable goal, and the development and processing of new – or ancient – fibres as a way of achieving that. Considering the focus on sustainability, several papers focus on the problems and possibilities for recycling fibres. The papers for this issue Fashion's Fibres as Planetary Flows write about the pivotal role of fibre in a circular economy, the governance of fibre, the ethics of fibre, the cultural histories of new and old fibre technologies, fibre and place, and provocations on fibre's agency and materiality. As editors we have organized the papers in different sections, detecting some threads and themes between and across the diverse papers.

RELEARNING AND UNLEARNING

The first of these themes explores a relearning and unlearning in engagements with fibre, place-based knowledge and culture. In these papers we see a return to ancient knowledge and the need to reinscribe the traditions and heritages of place. In 'Prospering Wild Fibres: Twisting Cords of Belonging', Dagmar Venohr provides a reflective account of the embodied experience of working with wild fibres such as nettles and brambles, an invitation for

reconnection and understanding. In 'Weaving Nature: The Flow Of Ainu Elm Bark Fibres Through Hokkaido's Ecosystems', Elisa Palomino describes the Ainu people's approach in Japan as one founded in ritual and respect for the tree as non-human gift giver. She advocates for a shift from resource-intensive, petroleum-based materials to sustainable, nature-based solutions inspired by Indigenous practices. In 'Unstitched Narratives' Megha Chauhan and Pramila Choudhary investigate the cultural and ecological significance of the fibre desi oon, an indigenous wool from India, commonly formed into versatile unstitched garments known as Pattu, a handspun and handwoven textile found in both the Thar Desert in Rajasthan and the Himalayas in Himachal Pradesh.
In 'Cheap Silk: A More-Than-Human History Of Sericulture In Slovenia's Goriška Region', Mateja Fajt investigates the deep place-based cultural histories of fibre, in this case, sericulture and the language and stories that arose around it. This is a story of anthropomorphised worms: silkworms cosseted and pampered, cared for like babies due to the wealth they brought the community. Rather than human-centred fibre extraction, in this story, insect, mulberry tree and human act back and shape one another. The paper asks what is lost or now absent, as this region no longer has these practices embedded in the daily life of its community.

FIBRE, PLACE, AND VALUE/VALUES

The notion of absence also comes through in Joanne Benham Rennick's account of a New England cotton mill's transformation into a museum. In 'Material Culture: the Transformation of a New England Cotton Mill into a Centre for Learning and Cultural Preservation', Rennick explores how a post-industrial nation has romanticised its past in cotton production when a former mill becomes a museum, linked to the national parks. Through museums such as this, the origins of the cotton of today are disguised rather than revealed. Cotton yarn and fabric production become something historical and cultural rather than a present-day industrial reality.
Themes of place and value/values continue in the next two papers, each examining a natural fibre. In 'From Sheep to Shelf: a Case Study on Circularity and Value-Sharing in Australian Wool's Global Value Chain', Tiziana Ferrero-Regis and Zoe Mellick take the case of a single brand's wool supply chain that, while still spanning the planet, connects supply chain actors closely through shared values. The authors propose this as 'value shoring', in which supply chain partners may be far-flung, but are united in ensuring ethical treatment of the animal at the centre. Paige Tomfohrde and Jaleesa Reed's analysis of the 'soil-to-soil' vision of the Fibershed movement acts as a counterpoint to the long supply chains described by Ferrero-Regis and Mellick. In 'Fashioning Fiber Futures: The Fibershed Approach To Revitalizing Regional Fiber Networks', they examine Fibershed's 'strategic localism' with natural fibres which centres knowledge from the margins, prioritising the soil and centring the communities producing the fibre. As they put it, "Fibershed recognizes that more is not needed, but a better approach to what exists is necessary".

CRITICAL REFLECTIONS ON NEW FIBRE STORIES

Increasingly, as sustainability concerns and the opportunity for circular fibres is trumpeted, fibre can be branded as products. Fibres that are 'recycled' or 'organic' and so on, carry an aura of goodness about them that a conventional or virgin fibre may not. As sustainability credentials continue to be fiercely contested, the eco-labels associated with varieties of cotton or wool (whether certified as 'responsible', 'organic', or 'regenerative') now command a premium. What futures do these fibres promise?
In 'Familiarizing With Fungi for the Textile Sector: A First-Person Journey into New Materialist Technologies, from Leather to Yarn', Clizia Moradei explores the future of fungi for new materials. She experiments in style by writing into the first person as 'we fungi' to challenge human-centredness.
Emma Lynas, Juliana Luna Mora, and Rebecca Van Amber's paper 'Fibre Fantasies: A Critical Examination of Wellness Claims in Textile Marketing' uncovers some of the pseudoscientific claims or even mystical claims regarding the properties of fibres such as bamboo. The tension between synthetic fibre and natural is explored by Isabella Alevato, Timo Rissanen, and Stefan Lie's. Their paper 'From Bio-Based to Fossil-Based to Bio-Based: Exploring the Potential of Hemp as a Material for Next-Gen Fur' weighs up the fibres' qualities and puts forward the opportunity that hemp may present as the feedstock for a new faux fur.

circular economy, Giovanna Danies and Carolina Obrégon examine the revalorising of what was deemed waste to create new fibres with regenerative characteristics, made from agricultural residues of the stems of Cannabis sativa L. (grown for medicinal marijuana) and coconut fibres. Beyond a circular economy approach, Daniel and Obregon prompt reflection on the scale and place-based approach in the Colombian context.

The final two papers look further at circularity and fibre. Magdalena Kohler's paper 'Challenges and Solutions for Recovering Mixed Fiber Waste from Knitted Used Textiles' takes a design-led approach to proposing that fibres be considered and reclaimed as part of a conscious approach to reclamation. Kohler usefully steps through the processes around what this reclamation involves and what will be required for it to be realised.

Harkening back to the notion of absence explored earlier, the last fibre story takes a technology – Resortecs dissolvable thread – to discover what a vanishing fibre can mean and do. In 'Stitching Sustainability: Threads as Catalyst of Change in Fashion', Erminia D'Itria and Acerina Trejo Machin explore how the Resortecs dissolvable thread becomes an agent to 'undesign' and disassemble the garments that contained it.

The thirteen contributions to "Fashion's Fibres as Planetary Flows" capture the diversity of fibre stories possible and demonstrate the opportunity for extended understandings of fibre and its place within human and more-than-human worlds. The planetary flow of fashion's fibres foreground the interconnectedness of material, human, and ecological systems, urging a reimagining of fashion's global impact and its role in the complex, shared fabric of the Earth. We hope that this issue stimulates a dialogue about fibre as the fundamental element of fashion, shaping its present and future.

REFERENCES

Barad, K. (2003). Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. Signs: Journal of Women in Culture and Society 28(3), 801–831.

Braidotti, R. (2013). The Posthuman. Polity Press.

Braidotti, R. (2016). Posthuman Critical Theory. In Banerji, D., Paranjape, M. (eds) Critical Posthumanism and Planetary Futures. Springer. https://doi.org/10.1007/978-81-322-3637-5_2

Braidotti, R., and M. Hlavajova, eds. 2018. The Posthuman Glossary. Bloomsbury.

Brown, B. (2001). Thing Theory. Critical Inquiry 28 (1), 1–22.

Brown, B. (2015) Other Things. The University of Chicago Press.

Changing Markets Foundation. (2022). Synthetics Anonymous 2.0: Fashion's persistent plastic problem. https://changingmarkets.org/wp-content/uploads/2022/12/Synthetics-Anonymous-2-online-reports-layout.pdf

Colman, F. and I. van der Tuin (2024). Methods and Genealogies of New Materialisms. Edinburgh University Press.

Ingold, T. (2012). Toward an ecology of materials. Annual Review of Anthropology,
41, 427–4 42. https://doi.org/10.1146/annurev-anthro-081309-145920

Ingold, T. (2015). The Life of Lines. Routledge, 2015.

Ingold, T. (2013). Making: Anthropology, archaeology, art and architecture. Routledge.

Margulis, L. and Sagan, D. (1997). Slanted Truths: Essays on Gaia, Symbiosis and Evolution. Springer.

Mellick, Z., Payne, A., & Buys, L. (2021). From Fibre to Fashion: Understanding the Value of Sustainability in Global Cotton Textile and Apparel Value Chains. Sustainability, 13(22), 12681. https://www.mdpi.com/2071-1050/13/22/12681.

Morton, T. (2013). Hyperobjects: Philosophy and Ecology after the End of the World. University of Minnesota Press.

Payne, A. (2019). Fashion Futuring in the Anthropocene: Sustainable Fashion as "Taming" and "Rewilding". Fashion Theory, 23(1), 5-23. https://doi.org/10.1080/1362704X.2017.1374097

Rockström, J. et al. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2): 32. [online]: http://www.ecologyandsociety.org/vol14/iss2/art32/

Smelik, A. (2018). New Materialism: A Theoretical Framework for Fashion in the Age of Technological Innovation. International Journal of Fashion Studies 5(1), 31-52. https://doi.org/10.1386/infs.5.1.33_1

Smelik, A. (2023). Polyester: A Cultural History. Fashion Practice, 15(2), 279–299. https://doi.org/10.1080/17569370.2023.2196158

Stanes, E., & Gibson, C. (2017). Materials that linger: An embodied geography of polyester clothes. Geoforum, 85, 27-36. https://doi.org/10.1016/j.geoforum.2017.07.006

Subramanian, K., Sarkar, M. K., Wang, H., Qin, Z.-H., Chopra, S. S., Jin, M., Kumar, V., Chen, C., Tsang, C.-W., & Lin, C. S. K. (2022). An overview of cotton and polyester, and their blended waste textile valorisation to value-added products: A circular economy approach – research trends, opportunities and challenges. Critical Reviews in Environmental Science and Technology, 52(21), 3921-3942. https://doi.org/10.1080/10643389.2021.1966254

Exchange, T. (2024). Materials Market Report 2024. https://textileexchange.org/app/uploads/2024/09/Materials-Market-Report-2024.pdf

Tsing, A. L. (2015). The mushroom at the end of the world: On the possibility of life in capitalist ruins. Princeton University Press.

UNECE. (2021). Policy brief – Harnessing the potential of blockchain technology for due diligence and sustainability in cotton value chains. https://unece.org/sites/default/files/2021-04/ECE_TRADE_C_CEFACT_2021_12E-TextilePolicyBrief_0.pdf

UNCCD (2024). Fashion & Land: Unravelling the Environmental Impact of Fibres. United Nations Convention toCombat Desertification (UNCCD), Bonn. https://www.unccd.int/sites/default/files/2024-12/UNCCD-Fashion%26LAND-FINAL%20online%20publication_final_single%20pages.pdf

ESSAYS

WILD FIBRES COMMONING

TWISTING CORDS OF BELONGING

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Abstract

With this text I would like to show how nettles and other wild fibres have changed my self-perception as a cultural scientist over the past three years. My intensive involvement with textile fibres has opened fundamentally different perspectives in research and teaching. I suppose that they have great potential to bridge the conceptual gap between nature and culture that still prevails in people's minds. The conceptual perspective for this field of research is referred to here as *NatureCultureTransfer*. This premise has led to many encounters with other fibre enthusiasts in recent months. Using autoethnographic methods, I have explored my changing relationship to fashion and textiles based on my study of nettles. Workshops and training courses, my impressions of seminars and other autoethnographically recorded explorations of wild fibres and the consequent broadening in textile knowledges are presented here. In addition to the references usually cited, all persons named shared their findings with me and voluntarily gave me permission to publish them, for which I am very grateful.

Keywords: *Nettle; Ethnography; Textile Knowledges; Education of Sustainable Development (ESD)*

WILD FIBRE COMMONS – TEXTILE ACTIVITIES PRODUCE RESISTANCE

For my research, wild fibres are a sign of a common, still loose and at the same time designable textile connection between humans and other than human worlds. How can their transformative power be recognised? – Over the last three years, I have constantly come across wild plants and people who approach them differently. I experience it as an ongoing process of growing community in the sense of actively spreading a mindful and knowledgeable practice in working with wild fibre plants that are easily accessible. I see *commoning* as an activity that enables, creates and maintains vital relationships between me and other worlds. I look critically and angrily at the increasing capitalisation of common goods and am convinced that the value of these commons cannot be understood in terms of so-called goods but rather as ways of acting. With Silvia Federici (2016) I think, "if commoning has any meaning, it must be the production of ourselves as a common subject" (p. 386). Throughout these connecting encounters, activities and exchanges around wild fibre occurrences, extraction and processing, I am slowly getting an idea of what it might mean to practice a subjectification process that is common to all. The performativity (Barad, 2003) of wild fibres functions for me here on the one hand as a vivid symbol for my abstract, rather philosophically conceptualising thinking, and on the other hand

conceptualising thinking, and on the other hand as a concrete action and transformative manner to handle everyday fibre material honorably (Kimmerer, 2013).
In a joint conversation, the textile artist Alice Fox called it *silent activism*. Grateful for this formulation, which I already appreciate in Fiona Hackney's work (2013), I would like to add a certain defiant resistance. Contrary to general expectation, my sensory attention is directed towards the seemingly insignificant, the incidental or the disruptive, the permanent *vibrating material presence* (Bennett, 2010) of wild fibres. Full of joy, I perceive a kind of *cosmological murmur* (Stengers, 2005) and increasingly see fibres and cord in everything that encompasses me. Nettle fibres, for example, can be easily tapped with bare hands and twisted into strong cord. In no time at all wild and prickly bramble vines are transformed into sturdy ropes that can carry us. The immeasurable variety of wild fibres becomes more obvious to me every day: the tattered tree bark on the asphalt, the fine strands of algae collected at the Baltic Sea, the fine threads surrounding my freshly harvested corn, the floating seeds of the thistle, the little hairy clouds left behind by the daily wandering dike sheep, the remains of your pullover on my lint brush, the woolly mice under our bed .I twist threads out of everything that connects me – with places, things, people and more than human beings, my *Mitwelt*, the world as the epitome of the co-living[1].

SITUATING KNOWLEDGES – CONNECTING WITH OTHERS DIFFERENTLY

A few years ago, working as a lecturer in the theory and history of fashion in the context of fashion design training, I initially felt a growing desire for a truly different approach to fashion, dress and textiles. It seemed increasingly pointless to me to accompany young people in their development into critical beings without being able to provide them with effective tools, which really matters for sustainable change in the fashion system.
The global context of Fashion[2] is too complex for the people working in it to feel self-effective, empowered or capable of acting. As in almost all areas of life, the economic principle of competition prevails in the textile industry, regardless of how sustainable an ecological transformation of fashion is intended to be. *Defashioning* (Niessen, 2022), as a concrete activist practice for a growing appreciative perception of the various fashions, is therefore the only effective option for action for me. As I am not a competitive person myself, I prefer to seek out encounters that create common ground. This entails a different understanding of education: as a teacher, I always remain a learner. To facilitate learning with intrinsic motivation, I need a space that can be explored together and that enables the exchange, acquisition and growth of self-empowering education (Haug, 2003) and social comprehension (Ahmed, 2018).
My longing to teach fashion, dress and textiles differently, to nurture 'situated knowledges' (Haraway, 1988) and textile practises to explore quite alternative paths of togetherness, initially led me to nature education. A good three years ago, I took part in a three-day nettle workshop run by Mechthilde Frintrup on processing nettle fibres into textile yarns. In her *Brennnessel-Buch* (Frintrup 2020), which is now in its 4th edition and was awarded the German Garden Book Prize in 2021, you will find detailed instructions on how to process nettle fibres as well as biological, cultural and culinary knowledge based on her many years of practical experience with this plant (Fig. 01). The course was organised by the Swiss nature education cooperative *Feuervogel*. This organisation, which grew out of forest education, has now been offering courses, activities and meetings for twenty-five years to "develop a meaningful, constantly growing and sustainable relationship between people and nature" (Feuervogel, 2024). Training lead Nadja Hillgruber has been organising numerous further education courses and campaigns on the magic of nettles for several years, such as the nettle weeks in Winterthur for the association *Brennpunkt*

1 As Donna Haraway emphasises: "It matters what matters we use to think other matters with; it matters what stories we tell to tell other stories with; it matters what knot knots, what thoughts think thoughts, what descriptions describe descriptions, what ties tie ties. It matters what stories make worlds, what worlds make stories." (Haraway 2016, 34).

2 Fashion written with a capital F stands for the global fashion system driven by so called modern, Eurocentric values; fashions in the plural mean all possible ways of dress from various cultures worldwide (Niessen 2022, 440).

Fig. 01

Brennnessel, an initiative of *Swiss Nettle*, whose aim is "a holistic approach to the utilisation and promotion of nettles" (Abt & Hofer, 2024). Mechthilde and Nadja have recently translated the film Nettle Dress (2024, www.nettledress.org) by Allan Brown, founder of the *Nettle for Textiles Group* (www.nettlesfortextiles.org.uk), to make it more accessible to a German-speaking audience. With her love of textile experimentation and courageous composure, Mechthilde sparked both my nettle addiction and my growing curiosity for the textiles in our immediate surroundings during the workshop. On the way to the hostel together, we each harvested a stalk of nettle (*Urtica dioica*). Equipped with gloves and secateurs, we grasped which growth form is suitable for fibre processing and how to handle and cut the plant: first wipe from bottom to top, so that many of the small, upward-facing stinging hairs on the stem and underside of the leaf break off. They are very fragile, consisting of silica and injure the skin with a light touch. The burning sensation is triggered by the liquid they contain, and the ingredients can even heal rheumatic inflammatory processes.

Equipped with these insights, it is no longer such a great test of courage to brush the underside of a small heart-shaped nettle leaf across one's forehead. This activates the third eye and thus the pineal gland, explained Mechthilde. With my forehead marked, my attention was sharpened when I harvested nettle fibres myself for the first time. After cutting and wiping a plant and then stripping the leaves from top to bottom, I gently bit at the evenly spaced knots between the square, hollow stem and then slowly and forcefully broke it open from the bottom up. This creates a special sound, amplified by the cavity inside. The fibres of the stinging nettle lie next to each other, arranged in parallel in the waxy thin bark. If the lengthwise split wood layer is always broken between the knot-like thickenings of the leaf bases, the bast fibre bundles can be carefully detached at these hinges from above and below. Now, holding the outer layer with the fibres in my hands, which is divided into two to four strips, I am more than enthusiastic, I'm passionate. Even as a child, I loved to peel the bark off willow branches to feel the coolness and fresh scent. The stinging nettle has a special odour

and flavour that quickly become memorable. I'm already beginning to believe that I can even smell and taste a difference between nettles growing in certain regions.

PERSONAL NETTLE STRING REVOLUTION – IN ONE GO

As a dressmaker, fabric has always seemed to me to be the most basic textile material. For as long as I can remember, I have been involved in the production and finishing of textile surfaces, experimented a lot and am always keen to explore other textile practices that are still unknown to me. It's crazy that I've only just realised that thread, yarn, cord or string are actual works of wonder. I seem to have understood these linear structures only as an in-order-to. Sure, I know the groundbreaking book *Women's Work* by Elizabeth Wayland Barber (1994), it's been on my bookshelf for years. But why did I miss out on the *string revolution* for so long? It was only by working with wild fibres that I finally came to this profound realisation: "String seems such a simple, almost inevitable invention, yet its appearance was a momentous step down the road of technology" (Barber, 1994, p. 70).Immediately after I learned about harvesting and extracting the fresh fibre in Mechthilde Frintrup's nettle workshop, she showed us how to make bracelets from twisted cords in no time at all. It is a technique that is as simple as it is ingenious: two strands of fibre are twisted and crossed in constant repetition. I take a strand of the parallel fibres between the thumb and index finger of my left and right hand, two thumbs apart. I twist the strand away from my body with my right hand until it twists over and forms a loop by itself. I take this between the thumb and index finger of my left hand. Now I have two strands, one at the top and one at the bottom. I always twist the upper one away from me and then cross it over the lower one towards me. I hold the formed twist on the left with my thumb and index finger. Now twist the upper one away from the body again, then cross it over the lower one towards the body and hold it in place. Twist, cross, hold, twist, cross, hold, again and again. When I let go of the cord after a few centimetres, it does not untwist. The opposing forces of the crossed twist and the twisted cross hold each other. If the two ends become too short, I lay another fibre strand across the cord as in an inverted V, so that both previous strands, the upper and the lower one, are lengthened. The extension created in this way is included in the next twisting and crossing and disappears. The cord can be continued endlessly in this way, even with different fibres.The most fascinating thing about this basic textile technique is how enthusiastic so many different people are about it. Perhaps it is because of how quickly we can recreate it, without long descriptions and many explanatory words: just by watching and trying it out. The ability to transform the fibres of a supposed weed, of the inconspicuous and ubiquitous stinging nettle, into a tough cord without any additional tools feels like a textile initiation from seemingly nowhere. Therefore, it feels textile spark from nowhere to be able to transform the fibres of a supposed weed, the inconspicuous and ubiquitous stinging nettle, into a tough cord without any additional tools. It seems remarkable to me that Barber speaks of a groundbreaking technological development, and that Mechthilde sees the things made from such cords as 'animated utensils' (Frintrup, 2020, p. 169), without the two being in contradiction. Handmade from wild fibres, these cords contain both perspectives and have given me a deeper, practical understanding of the complex *NatureCultureTransfer* in textiles.

WILD FIBRE BONDS – COMMONLY CREATED CONNECTIONS

The nettle fibre prompted me to start further training in nature-based environmental education at SILVIVA (2024), a Swiss foundation that promotes a holistic approach to the ecological, social, cultural

Fig. 02

Fig. 03

and economic aspects of mankind's relationship with the natural sources of life. I intend to give a fundamentally different perspective to the education of fashions and textiles in terms of their natural and cultural context, both theoretically and practically, which in my opinion cannot be separated. At various training courses, I have had the opportunity to develop activities with textile fibres and to do them with many different people. In addition to stinging nettle fibre, I have studied the use of nutria fur, mushroom leather production and the potential of native trees for textile fibre production from both a cultural and natural science perspective. As part of the training programme, my personal goal is to integrate education for sustainable development (Unesco, 2024) into the teaching of material culture. This is achieved through concrete, practical and theoretical examination of wild fibres, which I translate into we had the task of developing an outdoor game, and to realise our idea we needed a string. action-oriented methods. Cord twisting is the simplest and most impressive. In one of the courses, The others were amazed when I quickly twisted together an extremely robust cord from the delicate blackberry vines that covered the forest floor. They also wanted to learn it and persuaded me to pass this technique on to all the other participants in the course. It was wonderful, the entire course consisting of mixed-age people with different professional backgrounds was enthusiastic. Many immediately had ideas for application in their own educational settings. For example, the idea was born to develop a group dynamic activity with young people, in which the processing steps are divided up among each other in order to carry the heaviest possible stone with the jointly produced rope. Bramble fibres are thicker, more durable and longer than those of nettle, and their processing is also slightly different, as the fibres are located between the thorny outer skin and the soft, slightly woody stem filled with pith[1]. The cord twisting itself was just as fascinating for everyone as it had been for me.

3 A very useful tutorial on processing bramble fibre and many other fibres and further processing is shown by Sally Pointer (https://youtu.be/3SJdWjSEN6g?feature=shared). She is an archaeologist and has been teaching ancient heritage skills for many years..

From then on, many of the participants could be seen with happily twisting hands. This common twisted time filled us with great joy and still connects us today.

ENTHUSIASM EDUCATES – DESIGNING TEXTILE TEACHING

For a few months now, I have been responsible for teaching textile education at the Institute for Material Culture, Carl von Ossietzky University of Oldenburg. Fortunately, this job has allowed me to continue my further education and integrate my research on *NatureCultureTransfer* into my teaching. As a matter of course, I shared my previous fibre experiences with the students in the seminar *mitWelten – NaturKulturTransfer mit NesselKraft*, and they have acquired the techniques for fibre extraction and cord twisting (Fig. 02) "I can't stop," says Elias Isfort, describing his enthusiasm. For him, it was an important realisation that nettle fibres are available everywhere as a textile material, and he now has the valuable ability to harvest and process them from the plant. This has given him a different approach to nature in practice and a different understanding of aesthetic research in the field of textiles. Sophie Bartsch experimented with obtaining the nettle fibres through the natural rotting process, like the retting of the linen plant in the processing of flax fibres. She found it remarkable how much patience, care and precision are required for this delicate process. Appreciation for the stinging nettle, which was previously only perceived as a painful, annoying weed, grew with every fibre that was sourced and twisted (Fig. 03). This became very clear during the presentation of the specially designed *textile thing* at the end of the seminar: even the shortest, twisted piece of cord is valuable.When student Antonia Rieger returned a borrowed book to me, there was a little cordage inside (Fig. 04). For me it was a precious gift, which I now always associate with her and the wonderful work *Brennnesseln. Ein Porträt by Ludwig Fischer* (2017). It provides an excellent scientific insight[1]

Fig. 04

into the biological and cultural-historical significance of the nettle plant and has been published in the *Naturkunden*-series, which brings together strong voices in nature writing. The editor and writer Judith Schalansky sees one reason for the problems of our time in the fact 'that we've left nature to the scientists' (Schalansky, 2021). It is now a matter of finding a different language that can convey nature to people. The seminar showed me: the simple technique of twisting cord is a textile

4 The book *Die Brennnessel: Kleidendes Unkraut* by Václav Michalička (2021), translated from the Czech into German, provides another very comprehensive short cultural history. In English, the publications *From Sting to Spin: A History of Nettle Fibre* by Gilliam Edom (2010) and *Yarn* from Wild Nettles: A Practical Guide by Birte Ford (2017) are very informative. It is also worth noting that these books are self-published or by very small publishers.

wild fibres differently. This *NesselKraft*-seminar took place in cooperation with the Regional Environmental Education Centre Oldenburg (RUZ) to initiate, strengthen and further develop thematic cooperation between nature-based environmental education and teacher qualification in textile studies. The aim is now to jointly develop a course for primary school classes about nettles. I sat in on the RUZ course *Our Second Skin*, which has already been held with many school classes, for research purposes. The participating children in a fourth primary school class were highly motivated. In terms of content, this is about the textile chain, which is taught in learning stations from the fibre to the dress. At one station, the children can try out how cords are made by untangling existing cords and twisting them again. One child was particularly active and when I showed how a woollen thread could easily be made from raw wool, which was presented at another table, there was no stopping them. Everyone else who showed an interest was immediately involved and gave it a try. Many children learnt quickly, some developed an ambition that I unfortunately had to carefully curb as there was not enough unspun wool available. The clearly pre-structured concept of the course emphasised other forms of learning: The children were to cognitively deepen their acquired textile knowledge by solving written tasks.
However, education for sustainable development needs to involve all the senses equally, enable research-based learning and be multi-perspective. Textiles could empower people to take transformative action if they are trusted to acquire valuable knowledges in an open, self-responsible and intrinsically motivated way. During this interaction, I have a lasting memory of the enthusiasm for textile techniques that was quickly kindled: "I can do that with *anything*," said the child, beaming.

WILD FIBRES WANDER – TEXTILE BONDS GROW

The book *Wild Textiles* by Alice Fox (2022) provides a great overview of the other wild plants that can be used to make cordage. There are detailed instructions on harvesting and extracting fibres from plants previously regarded as weeds. She also processes many other materials, gathering in the wild and usually regarded as rubbish or scrap. Her artistic works encourage people to simply treat things otherwise. For a long time, I had been toying with the idea of taking part in one of Alice Fox's 'Wild Fibres' workshops and talking to her. In August this year, I had the opportunity to go on an intensive short textile fibre research trip to South Shropshire in Great Britain: Bobby Britnell (2024) organised a three-day workshop with Alice at her studio in Moor Hall. She is a textile artist and expert in bark cloth, and lives in a beautiful place in the middle of nowhere west of Birmingham. With the programme of textile and art educational workshops and meetings at her studio she is also a focal point of the *Textile Study Group* (2024). For more than fifty years, this network has been active in the encouragement and dissemination of artistic textile techniques throughout Britain. The diversity of textile artwork by its currently twenty-five members is extraordinarily remarkable: "If there is a definitive insight to draw from these varied perspectives on creative practice, it is that ways of making as many and varied as the individuals involved" (Hill & Miller, 2020, p. 14). The evening before the workshop at Moor Hall, I was able to gather impressions relevant to my research: I finally got to meet Bobby, and Alice Fox reviewed her artistic path in a lecture for a wider audience, showing numerous works and answering questions from the many guests. Most of the materials for Alice's current work are sourced from her allotment, a rented patch of land and tool shed, amongst others in an urban setting. This is where she grows, harvests, collects, dries and processes all her wild fibres and many other natural stuffs (Fox, 2022). When Alice asked me at the beginning of the workshop what our conversation would be about, what I wanted to know from her, I couldn't tell her. It was only when I got to grips with the fibres that I was able to formulate my thoughts: How can it be that we pay so little attention to the fibre, the cord, the thread and the value of these inconspicuous textile objects? Neither in their materiality nor in their cultural impact do we notice the omnipresence of fibres as the basis of textiles in our everyday surroundings. How can we change this?
During our conversation and in the moments of sharing it becomes clear: Alice does not claim to have any knowledge or skills that she wants to pass on to others. It's more about listening to her conversation with the wild fibres, witnessing the process and entering a conversation with the material, the plants and the place. Making precious little cords from previously completely underestimated, mostly overlooked, often unloved plants

Fig. 05

is a gentle and quiet change that is very fulfilling. Alice doesn't instruct us how to do things and how not to do them. Here she shares how she creates, shows us what she thinks and recounts about where her inspiration comes from: the material itself. She communicates things through her artisanal and artistic dialogue with the properties of what she meets in her everyday environment. In this way, she forms a connection with the natural spaces and cultural places (de Certeau, 1985), available through her creative practise.

The days in Moor Hall were full of intense conversations between all the participants and just as many quiet moments in which we collectively twisted our previously collected fibres into a variety of cords and strings (Fig. 05). Not only are nettle fibres processed differently from those of bramble, rush, field bindweed, iris or willowherb, even the fibres of a single plant species differ depending on harvest time, growing location and weather conditions. The diversity lies in the difference and therein lies their actual value. Every cord has become different and is now something special for us.

SUMMARISING THOUGHTS – WHAT'S TO COME

Writing this text gave me the opportunity to summarise the numerous experiences of the past three years as well as the most recent ones in a brief

narrative overview. I am very pleased about this, because I often find it difficult not to formulate my research topics in an overly theoretical and conceptual way. What is now pending is a more comprehensive scientific evaluation of the extensive data on *NatureCultureTransfer* by means of autoethnography. I hope I will have enough time and space to continue writing T*extile Circumstances on the Outskirts of Fashion* soon. After all, the nettle course for primary school children also needs to be developed, and another plant fibre love has been kindled in me, willowherb .

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CAPTIONS

[Fig. 01] Young, wild, and vigorous nettle plant in spring. When carefully processed these fibres are very soft and light green. (Image right is held by the author.)

[Fig. 02] A student who has just learnt the technique of twisting cords packs her treasures into a theory paper. (Image right is held by the author.)

[Fig. 03] A round bundle of nettle fibres from rotten stems, divided and stripped wooden, hollow components and an intact stem. A stone was used to divide the fibres, as the wooden parts were already very hard. (Image right is held by the author.)

[Fig. 04] This little cord gift from a student is still in one of the nettle nature books on my bookshelf. (Image right is held by the author.)

[Fig. 05] Full of pride and appreciation, all workshop participants show each other their small woven cord pieces. (Image right is held by Alice Fox.)

REFERENCES

Abt, D. & Hofer, M. (2024, August 26) SwissNettle: Ein ganzheitlicher Ansatz zur Nutzung und Förderung der Brennnesseln. Swiss Nettle. https://swissnettle.ch

Ahmed, S. (2018). Being the Change: Lessons and Strategies to Teach Social Comprehension. Heinemann.

Barad, K. (2003). Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. Signs, 28(3), 803–831. http://www.jstor.org/stable/10.1086/345321

Barber, E. W. (1994). Women's Work: The First 20.000 Years: Women, Cloth, and Society in Early Times. Norton.

Bennett, J. (2010). Vibrant Matter: A Political Ecology of Things. Duke University Press.

de Certeau, M. (1985). Practices of Space. In M. Blonsky (Ed.), On Signs, (pp. 123–145). Johns Hopkins University Press.

Edom, G. (2010). From Sting to Spin: A History of Nettle Fibre. Urtica Books.

Federici, S. (2016). Feminism and the Politics of Commons. In M. Hlavajova & M. S. Sheikh (Eds.), Former West: Art and the Contemporary After 1989, (pp. 379–390). MIT Press.

Feuervogel (2024, August). Leitbild. https://www.feuervogel.ch/ueber-uns/

Fischer, L. (2017). Brennnesseln. Ein Portrait. Matthes & Seitz.

Ford, B. (2017). Yarn from Wild Nettles: A Practical Guide. Birte Ford.

Fox, A. (2022). Wild Textiles: Grown, Foraged, Found. Batsford.

Frintrup, M. (2020). Das Brennnessel-Buch: Die magische Nahrungs-, Heil- und Faserpflanze. AT.

Hackney, F. (2013). Quiet Activism and the New Amateur: The Power of Home and Hobby Crafts. Design and Culture, 5(3), 169–194. DOI: 10.2752/175470813X13638640370733

Haraway, D. (2016). Staying with the Trouble: Making Kin in the Chtulucene. Duke University Press.

Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. Feminist Studies, 14(3), 575–599. https://www.jstor.org/stable/3178066Haug, F. (2003).

Lernverhältnisse: Selbstbewegungen und Selbstblockierungen. Argument.

Hill, J. & Miller M. (2020). Introduction. In Textile Study Group (Ed.), Insights, (pp. 11–14). Textile Study Group.

Kimmerer, R. W. (2013). Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants. Milkweed.

Michalička, V. (2021). Die Brennnessel: Kleidendes Unkraut. Wieser.

Niessen, S. (2022). Defining defashion: A manifesto for degrowth. International Journal of Fashion Studies, 9(2), 439–444. https://doi.org/10.1386/infs_00082_7Pointer, S.

(2019, June 28). Preparing bramble fibres for cordage [Video]. YouTube. https://www.youtube.com/watch?v=3SJdWjSEN6g

Schalansky, J. (2021): Interview by C. Steinberg. https://magazine.tank.tv/issue-87/talks/judith-schalansky

SILVIVA (2024, August). CAS Naturbezogene Umweltbildung. https://www.silviva.ch/weiterbildung/cas-nub/

Stengers, I. (2005). The cosmopolitical proposal. In B. Latour & P. Weibel (Eds.), Making Things Public, (pp. 994–1003). MIT Press.

Unesco (2024, August). Education for sustainable development. Sustainable Development. https://www.unesco.org/en/sustainable-development/education

WEAVING NATURE

THE FLOW OF AINU ELM BARK FIBRES THROUGH HOKKAIDO'S ECOSYSTEMS

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Abstract

Japan's Indigenous Peoples, the Ainu, inhabitants of Hokkaidō island, are renowned for their robes made from 'exchanges' with botanical species, such as elm bark fibres. Their God-spirits (kamui) manifesting in flora, fauna, and natural forces, guided their respectful use of materials, ensuring that nothing was wasted. Their spiritual practices, in reverence for nature, contrast with today's destructive driven fashions.

Textiles are often overlooked in the ecological humanities. This paper, through a framework rooted in decolonial and Indigenous studies, environmental history, cultural anthropology and regenerative design, explores the ecological entanglements of human-nature coexistence, materiality and agency of elm bark fibre garments, weaving together their narratives, practices and environments.

The study highlights the ingenuity and sophisticated technologies that allow the transformation of plant fibres into durable garments essential in northern climates. It explores the Indigenous perceptions of nature and resource extraction, particularly during the pre-colonial and early colonial periods in Hokkaidō.

By exploring Ainu textile traditions, this paper highlights the potential of Indigenous knowledge to inform sustainable fashion practices. However, applying this learning must avoid perpetuating the colonial legacy of exploitation. Instead, efforts should prioritise equitable partnerships that respect and protect Indigenous contributions, while guiding a move away from petroleum-based systems.

Keywords: *Ainu Indigenous Peoples; Traditional Ecological Knowledge; Elm Bark Cloth: Attush; Arctic Fashion; Sustainable Fashion Practices.*

METHODOLOGY

The research methodology used in this paper can be outlined in five main strands.

INDIGENIST APPROACHES TO RESEARCH

As a non-Indigenous Research Associate at the Smithsonian Arctic Studies Center specialising in Arctic Fashion, I employ an Indigenist research methodology rooted in the wisdom, cultures, and experiences of Indigenous communities. This decolonising approach prioritises the voices of Indigenous Elders as primary sources, honouring their cultural protocols and knowledge systems (Wilson, 2007). Open to researchers of all backgrounds, this paradigm emphasizes mutual respect, community benefit, and the integrity of Indigenous traditions (Rix et al., 2019). Indigenist research is rooted in Indigenous Knowledge (IK), or Traditional Ecological Knowledge which has been recognised through the United Nations Declaration on the Rights of Indigenous Peoples, reflecting the philosophies and identity of Indigenous communities (Wilson, 2007). IK is tied to the cultural practices, landscapes, and environments that sustain and transmit it, offering an alternative to Western knowledge systems (Dierksmeier, 2021). This work integrates land and culture recognition practices (Shaginoff, 2021). My research involves collaboration with Indigenous communities such as the Hezhe, Alutiiq, Ainu, and Nanai (Palomino, 2022). These partnerships have enriched my understanding of Indigenous cultures and built meaningful relationships.

Fig. 01

A key focus of my work is facilitating Native artists' reconnection with their artefacts in museum collections, recovering and sharing oral histories and ethnographic accounts (Gordon et al., 2013). I acknowledge the Elders who have guided me on this research, including Yukiko Kaizawa and Reiko Kayano (Ainu) Shigehiro Takano (non-Native Japanese), June Pardue (Alaska Native, Alutiiq and Inupiaq) and Anatoly Donkan (Siberian Native Nanai). Additionally, this work was informed by artists like Masahiro Nomoto (Ainu), and Maki Sekine (Ainu).

DECOLONISING RESEARCH PRACTICES

Since 2017, I have collaborated with the curators of the Nibutani Ainu Culture Museum, Kenji and Maki Sekine co-creating workshops on Ainu culture and promoting the connection between Ainu artists and other Indigenous Arctic Peoples (Palomino et al., 2023). During my annual field trips to Japan, I have documented the many Ainu traditions such as fish skin processing through the work of these exceptional artists (Palomino et al., 2024).

In March 2022, fieldwork was conducted across the National Museums of Hokkaido, bringing Arctic Native experts into direct contact with historical Ainu artefacts. Supported by the Japan Foundation, the fieldwork and accompanying conference advanced knowledge of Arctic Fashion production such as fish skin, elm bark and bast fibres production.

The team included Native Alutiiq and Inupiaq fish skin artist and grass weaver June Pardue, fish skin artist Anatoly Donkan (Nanai, Eastern Siberia), a Japanese translator, a Russian translator and me, an Arctic fashion scholar (fig.1). We examined several Ainu elm fibre robes and woven grass accessories, with June noting similarities to Alutiiq grass woven traditions. A highlight was meeting 91-year-old Ainu weaver Reiko Kayano (fig. 2). Reiko shared her elm bark weaving skills, while visits to the Nibutani Ainu Museum with curators Kenji and Maki Sekine brought insights into Ainu embroidery. Maki, an embroidery artist, discussed the motifs of her Kaparamip robes, which June and her fellow Alaska Native artists recognised from home as similar to Tlingit designs.

For the Alaska and Siberian Native artists, connecting with each other and Ainu knowledge keepers was a long-held dream. Similarly, for Ainu communities, meeting Indigenous Peoples worldwide provided an opportunity to explore their place within the global Indigenous landscape. This exchange enriched Elders, museum curators, and participants alike (Palomino et al., 2023).

ETHNOGRAPHIC RESEARCH

Ethnographic research explores groups or aspects of their lives (Myers, 2008; Hammersley & Atkinson, 1995), involving immersion and participant observation. However, such practices often marginalise Indigenous groups and perpetuate dominant societal interests. Historically, geographical methods have supported colonisation. Decolonising approaches emphasize collaborative knowledge production, fostering egalitarian relationships and co-designed objectives, methods, and outcomes. Extractive practices are replaced with mutual communication, enabling non-academic collaborators to shape research priorities, design, and analysis. Methods like auto-ethnography and storytelling capture overlooked experiences (Radcliffe, 2021). This auto-ethnographic research applied Participatory Action Research (PAR), creating a partnership with Native artists as co-researchers actively shaping all research stages, highlighting their central role in knowledge co-production.

LITERATURE REVIEW

This paper examines the historical use of Ainu elm bark fibre through historical literature from the late 19th and early 20th centuries supplemented by contemporary literature on material sustainability. A critical review informed a framework for understanding traditional elm bark practices, which was refined through further participatory action research fieldwork. The method aimed to gather insights into traditional elm bark cultural theory and practice to document its historical, cultural, and environmental significance.

Fig. 02

ARCHIVAL RESEARCH: ARTEFACT ANALYSIS

Fieldwork conducted at Hokkaido Museums involved archival research, observations and documenting collections. Employing a qualitative methodology, particularly an arts-based inquiry (Denzin & Lincoln, 2008), facilitated the creation of new knowledge through active participation. Primary data collection included semi-structured interviews with museum curators and Native Elders. Visioning elm bark artefacts emphasised a practice-led approach, involving material analysis and hands-on interaction with the artefacts. In-depth analysis deciphered the design elements and styles, weaving, construction and dyeing techniques and spiritual meanings. Triangulation of data was achieved combining the above with a further analysis of literature on elm bark fibre traditions.

ELM BARK FIBRE ARTEFACTS IN INTERNATIONAL MUSEUMS

Historical records at international museums provide valuable information on elm bark fibre artefacts, but the traditional knowledge of the Ainu themselves matters even more. Over two centuries, explorers and scientists collected artefacts documenting Ainu's identities, often storing them far from their origins. This led to the alienation of these communities from their heritage. Museums worldwide have amassed ethnographic collections, often under the wrong assumption that these cultures were disappearing. However, these collections, which include ritual objects, clothing, and tools, contain crucial information about traditional knowledge and material culture. Today, many Indigenous Peoples seek to reconnect with their heritage through these artefacts (Palomino, 2022).

The history of these collections is closely tied to colonialism, with many items acquired through violent means. Museums are now beginning to acknowledge this history and are working with Indigenous communities to ensure that artefacts are displayed and interpreted respectfully. In Hokkaidō, Ainu artefacts have been returned to their communities, building local museums where Ainu artists run workshops sharing their skills, allowing them regain control over their cultural heritage.

Museums with ethnological collections provide key insights into the relationship between humans and nature. Elm bark fibre artefacts illustrate the technological innovation and cultural adaptation of Ainu communities over time. These objects are a testament to the Ainu's resilience and sustainability, reflecting their connection to the environment and their ability to thrive in Hokkaidō.

FIBER AND LAND: THE POWER DYNAMICS OF JAPANESE AINU ASSIMILATION

The Ainu are the direct descendants of the Jomon, one of Japan's earliest cultures dating back over twelve thousand years. Before being integrated into modern nation-states, the Ainu called their homeland Ainu moshir, or "the Land of Men" which originally spanned Japan's Hokkaidō and formerly North-Eastern Honshū, Russia's Sakhalin, the Kuril Islands, Khabarovsk Krai, southern Kamchatka Peninsula and the Amour River estuary region (Godefroy, 2018).

During Japan's military aggression from the fourteenth to seventeenth centuries, Hokkaidō's natural resources were overexploited. Ainu traditional clothing and materials were discouraged, favouring dependence on Japanese textiles, especially cotton. Despite these pressures, the Ainu's use of animal skins and local bast fibres persisted into the late nineteenth century in remote areas where Japanese influence was limited (Dubreuil, 2002).

Women's activities included fishing, gathering edible, medicinal or processable plants for clothing, and crafting intricately designed garments (Fitzhugh and Dubrueil, 1999) using locally available natural resources (Williams, 2017). This respect for nature was jeopardised by the increased invasion of Japanese commercial interests and territory and was threatened by their growing dependency on Japanese goods during the Edo period (Godefroy, 2018). The Hokkaidō Ancient Aborigines Protection Act of 1899 further displaced the Ainu, stripping them of their culture (Dubreuil, 2002). Despite this, Ainu ethnicity persisted, with the Ainu formally recognised by the Japanese government in 2008 for the first time as "Indigenous Peoples with a distinct language, religion and culture" and formally in legislation in 2019. This legislation accompanied the international focus in Japan as host of the Olympic games in 2021 (Godefroy, 2011).

ELM BARK FIBRE TRADE: TRAVELLING ACROSS NATIONAL BORDERS

As the Ainu navigated the pressures and influences of external cultures, particularly from the Japanese, their migration patterns shifted, pushing them northwards. This movement saw some Ainu communities settling on Sakhalin Island, the Kuril Islands, and even the southern tip of Kamchatka by the first millennium AD (Cevoli & Glebova, 2015). The relocation of these communities was not just a physical migration but also a cultural one, as they encountered new environments and neighbouring Peoples. This context of movement and adaptation is crucial to understanding the evolution of Ainu material culture, which was shaped by both the need to thrive in new landscapes and the desire to maintain cultural continuity.

The Ainu were not isolated in their cultural evolution. Various Ainu groups, such as the Tohoku Ainu in Honshu, the Sakhalin Ainu, the Kurile Ainu and the Kamchatka Ainu, interacted with other North Pacific Peoples, creating a shared heritage among these groups. Oral narratives suggest that the Ainu and the Northwest Coast Peoples of southern Alaska, are part of an extended family. The Aleutian Islands were likely a critical trans-Pacific route for contact between the Ainu, Aleut, and Tlingit peoples. Historical records confirm that the Aleut and Ainu were forced by Russians to trap sea otters together in the Kuriles during the 1700s, but earlier contact was likely (Dubreil, 2007).

Trade played a pivotal role in this cultural exchange, especially between China and Japan. By the 17th century, a well-established trade route stretched from northern China across the lower Amour River—home to Indigenous groups such as the Hezhe, Nanai, Ulchi, and Nivkh—to the Ainu of Sakhalin and Hokkaidō. This route facilitated the exchange of various goods, including silk fabric, metal objects, adornments, and lacquer bowls (SRM, 2021). Interestingly, many of the motifs used by Sakhalin Ainu textile artists bear resemblance to those used by the Nivkh people of the lower Amour region of Siberia, highlighting the interconnectedness of Indigenous cultures across this region (Murray et al., 2018).

This phenomenon of cultural and resource borrowing in response to changing climates and ecosystems is a common theme among Indigenous Peoples, as noted by Lewallen (2016). For the Ainu, this borrowing was not passive but rather an active and creative process. Ainu women played a crucial role in this cultural synthesis. They incorporated new materials—sometimes borrowed from neighbouring cultures, such as sealskins and cotton fabrics—into their traditional robes, all the while adhering to Ainu aesthetics and cultural principles.

EXCHANGES AMONGST HUMANS, NON-HUMANS AND MORE-THAN-HUMANS TO CREATE FIBRE AS MATTER

For the Ainu (fig. 1) every element of the physical world—mountains, trees, lakes, and animals—is inhabited by spirits deserving of respect. Their lifestyle and economy were shaped by these natural resources, with a deep reverence for kamui, God-spirits who would visit the Earth in the forms of plants, animals, or natural forces such as wind, rain, and snow (Geoffroy, 2018). This spiritual connection is reflected in the creation of highly spiritual clothing made with the materials resulting from their "exchanges" with various animal and plant species (Krutak, 2012).

The Ainu religion revered these God-spirits, with shamans playing a crucial role as intermediaries (Geoffroy, 2018). These Gods lived in a parallel world, kamuy-mosir, and all natural phenomena were, in fact, Gods in disguise—gifts to be respected. If the Gods had been honoured, they came to them in the shape of trees as temporary gifts (Batchelor, 1971). For the Ainu, elm trees harboured spirits, and the act of harvesting the bark was accompanied by rituals of gratitude. When they peeled bark (the protective clothing of the elm tree God) for producing attush cloth, they thanked the tree for giving up its 'clothes'. Only bark from one side of the tree was taken to ensure the tree's survival, and after the bark was stripped, trees were marked to allow them to recover, and a strip of bark would be wrapped around the tree so that it would not lose any more of its 'clothes' in the wind. Then, offerings of grain and tobacco were made to appease the spirit of the tree (Batchelor, 1971; Dubreuil, 2002). The connection between physical peeling bark for fibre and spiritual practices of gratitude brings together spiritually charged items intertwining tangible and intangible values for their makers and users.

Ainu robes (fig. 3) were originally used in ceremonial acts (fig.1), embodying a respect for kamui. The decorative elements (fig.4) of the attush cloth embroidered by Ainu women were imbued with a protective meaning for their loved ones. Each part of the garment was symbolically linked to different realms: the upper edges represented the Upper World, the hem the underworld or underwater world, and the middle parts the human world. The embroidery, often concentrated on the collar, upper back, hemline, and cuffs, would guard the wearer against harmful spirits, particularly at the openings of the garment where spirits might enter (Murray et al., 2018). These designs, made with chain stitching using blends of the various earthy colours of elm bark, were typically symmetrical (Krutak, 2012) and abstract. The symbols reflected the spirituality of both the maker and the wearer through the emotional connection concentrated in the garment with each stitch of the needle. The communication between the Ainu and these deities was expressed through a sensitive approach to working with natural materials, and the creation of clothing under spiritual aesthetics. Despite the devastating impact of colonialism on Ainu traditions, Hokkaidō textile artists today continue to imbue cloth with spiritual force by introducing a blessing during the process (Lewallen, 2018).

In Ainu cosmogony, when a person died, they were dressed in their best attush attire and placed by the hearth, positioned lengthwise with the feet facing the doorway, ready for the journey to the afterlife. If the deceased was a woman, she was buried with items essential for her journey: needles and thread, Native and Japanese textiles in different colours and styles, a set of weaving tools, and her personal trinkets. These items were deliberately cut, torn, or broken; a symbolic act intended to release their spirits. Once damaged, these belongings were buried with their owner, ensuring the deceased was well-provided for on the passage to the next life (Batchelor, 1971).

In times of distress, such as the current climate crisis, it is crucial to reconnect with nature and humanity's role as a responsible steward. The spiritual significance of elm bark could be integrated into contemporary sustainable fashion practices, reminding us of the Ainu's connection to nature by integrating Indigenous knowledge, into nature-based solutions (NbS) while adopting a regenerative design perspective (Lyle, 1996; CSM, 2024; Korhonen & Niinimäki, 2024; Weichenrieder, 2024).

ELM BARK FIBRE TECHNOLOGY: AGENCY AND MATERIALITY HISTORICAL ELM BARK FIBRE PRACTICES FROM THE FORESTS OF HOKKAIDŌ

In the mountains of Hokkaidō, the Ainu People developed sophisticated textile techniques using natural fibres harvested from the plant life in their surroundings. Although they did not cultivate plants, they extensively used bast fibres, particularly from the inner bark of the Manchurian elm and

1 At is the Ainu word for elm and tush is the Ainu word for bark.

2 NbS is a newly emerging term for actions to harness the power of ecosystems to protect people, optimise ecosystem infrastructure and ensure a stable and biodiverse future.

Fig. 03

Fig. 04

Japanese linden growing on slopes near the humid riversides or valleys. To protect themselves from bears, Ainu men and women would gather in groups and venture into the Hokkaidō mountains in search of a suitable tree. Once they found one with high-quality bark, they begun the process. Their fibre was obtained by stripping the rough outer bark of the tree from living elm trees before the spring growth began, a period when the bark was easier to peel away. Using a slender blade, they cut around the base of the tree, pulling the bark until it slipped off the trunk, peeling all the way up to the very top (Batchelor, 1971).
They peeled the trees' papery bark in long rolls like scrolls. Once sufficient bark was gathered, they would carry it home and soaked it in warm water (fig.5). After a week, the bark would soften, allowing the women to separate the inner layers from the outer ones. These long layers were then hung to air dry and split up by fingers into threads and bundled. The bark was added to boiling water, and just before it boiled again, wood ash was mixed in to soften the threads for easier separation. The pot was then covered and simmered for several hours, ensuring the alkaline mixture evenly penetrated the bark. The boiled, softened bark, now reddish-brown, was thoroughly washed in running water to remove any sliminess that could weaken the fibres. Once the fibre layers separated, they were carefully kneaded and peeled to avoid uneven thickness. The fibres were hung outdoors on a pole or frame to dry for about two weeks in sunlight, which fades the colour, and rain, which evens it out. After drying, the fibres were softened in water

again, peeled into thin layers, shredded into 2 mm wide strips, and dried. The shredded fibres were lightly twisted and spun into long threads, a process that took a month to produce a single ball of thread. Then they were ready for weaving or to be made into sewing thread (Dubreuil, 1999; Kodama, 1999; Kogei Japan, 2024).

Thread-making was a process, achieved by chewing the fibres with their teeth, creating aqueous emulsions with the salivary fluid making the fibres supple. Many evenings, members of the community would gather in dim light, conversing while Ainu women chewed the fibres into thread. The thread or yarn was used in its natural golden colour but could also be coloured using vegetable dyes from Native plants like marigold and madder (fig. 6). Some garments were dyed to achieve a darker colour, accomplished by steeping the fabric in a warm decoction of oak or alder bark, or by soaking it in marshy areas. This process resulted in a dirty reddish hue, leading to these garments being called kunnep, meaning "black things" (Batchelor, 1971). Finally, the warp threads, which must be longer than the fabric, were set outdoors on windless days to prevent tangling. A stake was hammered into the ground to secure the loom's warp threads, with another stake holding the threads on the opposite side. Two people worked together— one feeding the threads while the other setting them on the loom. Afterwards, the threads were bundled at 70 to 90 cm intervals, and the stakes were removed. The Attushi karape (fig.7), an ancient backstrap loom, fixed one end of the warp threads to a pillar and the other to the loom and the weaver's waist. The weaver sat down, pulled the threads while weaving and rolled the woven cloth on the ground as they moved forward (Kogei Japan, 2024). These threads were woven into a dense, warm golden-coloured fabric known as attush. The elm fibres need moisture in the air to weave it, with weaving often taking place during the heavy snowfall season of February and March, making the fibres easier to work with. Weaving was typically done at night, with the weaver sitting in the main room, surrounded by community members who would chat and encourage her.

Fig. 05

Fig. 06

During the summer months, the women prepared bark for cloth-making, twisted thread, and crafted mats (Batchelor, 1971).
The woven cloths were then assembled to create the robe (fig.4). Unlike the uniformly wide sleeves or the varying sleeve lengths of a woman's Japanese kimono that indicates marital status, the sleeves of an Ainu garment are tapered. The robe is secured with a simple, narrow woven belt, rather than the wide Japanese obi, making the Ainu-style gown more practical for work. For ceremonial garments, the designer must carefully choose the size, colour, shape, placement, and types of materials to be appliquéd. When left undecorated, simple attush robes were used as workwear and often traded to the Japanese for similar purposes. When adorned with decorative elements, the garments became ceremonial attire, revered as wearable art (Dubreuil, 2002). The attush cloth was both durable and well-suited for the sub-arctic climate of Hokkaidō. The hollow nature of the fibres provided natural insulation, making the garments effective in retaining heat. For summer wear, the fibres were twisted to close the hollow core, allowing body heat to escape, while in winter garments, the fibres were left untwisted to better insulate the body (Dubreuil, 2002). The attush cloth was coarse and brittle when dry but became very strong when wet. Properties such as water resistance and the ability to repel moths contributed to the longevity of the garments, making them popular as workwear for the herring fishing industry and for sailors on Kitamae ships travelling between Honshu and Ezo-chi (Northerncross, 2015). Over time, the fabric became softer with wear, enhancing its comfort and texture (Dubreuil, 2002; Murray et al., 2018). A finer variety was crafted from nettle bast fibres or hemp. During the summer Ainu wore leggings made from elm bark fibre to protect themselves from insects and wore sandals made from elm bark and vines (Batchelor, 1971).
The Ainu used bone needles and fibres from the elm tree, sometimes dyed black, for sewing and embroidery. Indigo dyed cotton cloth, once a luxurious and highly prized material, was traded from the Japanese and used by the Ainu

Fig. 07

for appliqué decorations around the neck, front opening, sleeves, and hem (fig. 4). This style of attire only emerged during the Meiji era (1868-1912), when cotton fabrics became affordable for many Ainu people. This adaptation marked a significant shift in Ainu textile practices, blending traditional materials with new influences (Dubreuil, 2002).The process of creating an attush robe could take over a year, with the garments being passed down through generations as treasured items. Ainu women were responsible for every phase of the creative process, from harvesting the bark to weaving the fabric and decorating the finished garment. The embroidery motifs (fig.4) were created from memory (Batchelor, 1971) with mothers and grandmothers teaching young girls by drawing patterns in the sand or ashes of the fire pit. Each design was unique, reflecting the wearer's personality and social status (Dubreuil, 2002).

CONTEMPORARY PROCESSING OF ELM BARK FIBRE

Along the Saru River basin in southern Hokkaidō, elm and linden trees have always abounded in the remote village of Nibutani (Kogei Japan, 2024). This craft has been sustained by the people of Biratori, specifically by two remaining elm bark weavers, Yukiko Kaizawa and Reiko Kayano, now in their 80s and 90s. Yukiko Kaizawa (fig.8), began weaving at a young age, selling her work to high-end Japanese department stores.Despite her over 50 years of dedication, the tradition faces a challenge: younger generations are interested but find it difficult to sustain due to the craft's time-consuming nature and lack of economic viability. Maki Sekine, an Ainu embroidery artist and Yukiko Kaizawa's daughter, continues to uphold her family's legacy. Reiko Kayano, the other elm bark weaver in Nibutani, is a 90-year-old Ainu woman and the widow of Shigeru Kayano, a prominent figure in the Ainu cultural movement and the first Ainu member of Japan's parliament. His efforts were instrumental in the enactment of the "New Ainu Law" in 1997.Moreover, Nibutani-attush was the first Hokkaidō item to be designated as "traditional craft" by the Japanese Ministry of Economy, Trade and Industry in 2013 (Northerncross, 2015).

In addition, it is important to note that the creation of elm bark garments has not stopped since its beginnings, even with the arrival of cheaper and easier to use cotton (Dubreuil, 2002).

FUTURE OF ELM BARK FIBRE MATERIAL CULTURE

Elm bark fibre offers an example of how clothing can connect people to the land, past, and present. Its production encapsulates values of collaboration, ecological resilience, and local pride, while addressing the pressing need to replace fossil-fuel-derived materials with sustainable alternatives (Gilbertson, 2024). By reviving elm bark fibre weaving, local skills are developed, creating valuable cultural and economic connections. Historically, Ainu weavers have transformed elm bark into textiles, using processes that harmonise with seasonal rhythms and regional biodiversity. These traditional practices serve as a model for contemporary regenerative systems, which prioritise small-scale, flexible production, blending old technologies, and fostering community-based initiatives. Such systems align with a more equitable and sustainable economy by reducing reliance on extractive industries while promoting community well-being. Elm bark's potential reinforces its value within an ecological fibre system. Revitalizing this craft can help build local fibre economies that respect history, land, and culture while fostering innovation and entrepreneurship. Regenerative practices that support bast fibres, including elm bark fibre, can improve biodiversity, and reduce carbon footprints. Such practices promote harmony with nature and demonstrate a shift toward a fashion industry rooted in climate and social justice (Minney, 2024).

Drawing insights from Ainu traditions offers an opportunity to envision regenerative practices in fibre sourcing and craft production that respect planetary boundaries. However, it is crucial to ensure that such inspiration avoids perpetuating colonial legacies of extraction and recontextualization. By prioritising non-exploitative, collaborative approaches, we can foster resilient systems that support a sustainable and equitable future in fashion and beyond.

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3 The term Nibutani originates from niputai which is an Ainu language word that means "a land where the trees grow thickly"

Fig. 08

CONCLUSIONS

Natural elm bark fibre processing in Hokkaidō, provides valuable lessons for creating a sustainable society. Humanity's material footprint has exceeded the planet's limits, making it essential to look to Indigenous practices for guidance. The Ainu's painstaking process of harvesting, spinning, and weaving elm bark into attush cloth exemplifies a sustainable approach to fashion, rooted in respect for nature and minimal waste.

In the village of Nibutani, the continuation of the elm bark textile tradition by a few committed artists demonstrates the resilience of Ainu craftsmanship. The use of attush has evolved beyond traditional robes, finding new life in modern fashion and interior design. Ainu women play a crucial role in bridging ancestral heritage with contemporary practices, contributing to cultural revitalisation. This research highlights the importance of attush craft in preserving cultural identity. The tradition of elm bark textiles offers insights into sustainable practices that contrast sharply with the environmental destructiveness of modern fashion. By studying historical elm bark artefacts, we gain a deeper understanding of the techniques, tools, and spiritual significance that have sustained Ainu communities for generations.

Integrating Ainu Indigenous knowledge systems which include cultural, spiritual, and ecological practices, into contemporary nature-based solutions (NbS) can enhance climate resilience and promote sustainable practices in the fashion industry. Indigenous Peoples, despite their small global population, manage lands rich in biodiversity, offering critical insights into sustainable land management. The expertise of Ainu seamstresses, who were once artists, designers, biochemists, and climatologists, demonstrates the potential of biobased textiles to inspire more sustainable practices in today's fashion.

This paper calls for a shift from resource-intensive, petroleum-based materials to sustainable, nature-based solutions, inspired by Indigenous practices. While building on Ainu traditions and other indigenous knowledge systems offers possibilities for promoting waste reduction, biodiversity restoration and community empowerment, it is essential to prioritise collaboration and mutual respect, avoiding the risks of continuing colonial legacies of exploitation and reinterpretation. Adopting a regenerative design perspective can guide more sustainable and ethical material practices, while challenging the destructive patterns established by Western colonialism.

CAPTIONS

[Fig. 01] Elisa Palomino, June Pardue, Ainu performer artist, and Masahiro Nomoto, Director of Culture Promotion Department at the Upopoy National Ainu Museum. Shiraoi, Hokkaido

[Fig. 02] Elisa Palomino, June Pardue, Reiko Kayano, Lyna Torayashiki, Anatoly Donkan, Oleg Mitrofanov and Elisa Palomino in Nibutani, Hokkaido.

[Fig. 03] Ainu hunter wearing a ceremonial attush. Ezotō kikan. Hata, Awagimaru, 1764-1808. Japanese Rare Book Collection, Library of Congress. Washington, DC, USA.

[Fig. 04] Ainu ceremonial garment with cotton appliqué and embroidery on elm-bark fibre cloth. Minneapolis Institute of Art, Minneapolis, USA.

[Fig. 05] Elm bark soaked in warm water by Yukiko Kaizawa.

[Fig. 06] Elm bark yarn in its natural golden colour and dyed with vegetable dyes from indigenous plants such as marigold and madder, by Yukiko Kaizawa.

[Fig. 07] Two Ainu women weaving in the Attushi karape loom. Ezo kikō. Tani, Bunkei, 1778-1840.

Japanese Rare Book Collection, Library of Congress. Washington, DC, USA.

[Fig. 08] Ainu weaver Yukiko Kaizawa. Nibutani, Hokkaido, Japan

REFERENCES

Batchelor, J. (1971). Ainu Life and Lore: Echoes of a Departing Race. Tokyo: Kyo Bun Kwan.

Cevoli, D. & Glebova, E. (2015). Esthétiques de l'amour: Sibérie extrême-orientale. Paris: Musée du Quai Branly. Paris. Flammarion.

CSM (2024). MA Regenerative Design. Available at: https://www.arts.ac.uk/subjects/textiles-and-materials/postgraduate/ma-regenerative-design-csm

Denzin, N. K. and Lincoln, Y. S. (2008) Collecting and interpreting qualitative materials. London: Sage.

Dierksmeier, L. (2021) Indigenous Knowledge as a Resource: Transmission, Reception, and Interaction of Knowledge between the Americas and Europe, 1492-1800 (F. Fechner & K. Takeda, Eds.). Tübingen University Press.

Dubreuil, Chisato, O. (1999). Ainu Art: the Beginnings of Tradition." In Ainu: Spirit of a Northern People, W. Fitzhugh and O. Dubreuil Chisato (eds), pp. 287–300. Arctic Studies Center, National Museum of Natural History, Smithsonian Japan Focus.v. 5 n.11.

Fitzhugh, W.W. & Dubreuil, Chisato, O. (1999). Ainu: Spirit of a Northern People. Arctic Studies Center, National Museum of Natural History, Smithsonian Institution and University of Washington Press.

Gilbertson, Z. (2024). Bioregional Resilience through bast fibres. Exploring machinery and methods to support UK fibre production. Institution and University of Washington Press.

Dubreuil, Chisato, O. (2002). Ainu Art on the Backs of Gods: Two Exquisite Examples in the DIA Collection. Bulletin of the Detroit Institute of Arts, v. 76, n. ½, pp. 4-17.

Dubreuil, Chisato, O. (2007). The Ainu and Their Culture: A Critical Twenty-First Century Assessment. The Asia-Pacific Journal:

The Churchill fellowship. Available at: https://media.churchillfellowship.org/documents/Zoe_Gilbertson_Final_Report.pdf

Godefroy, N. (2018). The Ainu assimilation polices during the Meiji Period and the acculturation of Hokkaido's indigenous people. Paris: National Institute of Oriental Language and Culture Studies.

Godefroy, N. (2011). Deconstructing and Reconstructing Ainu identity from assimilation to

recognition 1868-2008. Contemporary Population(s) of Japan panel. 13th International EAJS (European Association for Japanese Studies) Conference.

Gordon L. Pullar, Knecht, R. A. & Haakanson, S. Jr (2013). Archaeology and the Sugpiaq renaissance on Kodiak Island: Three stories from Alaska. Études/Inuit/Studies.V 37, n. 1, 2013, pp. 79–94.

Hammersley, M. & Atkinson, P. (1995). Ethnography: Principles in Practice. London, New York:

Routledge.

Kodama, M. (1999). "Clothing and Ornamentation." In Ainu: Spirit of a Northern People, W. Fitzhugh and O. Dubreuil Chisato (eds), pp. 313–26. Arctic Studies Center, National Museum of Natural History, Smithsonian Institution and University of Washington Press.

Kogei Japan (2024). Nibutani bark cloth. Biratori Ainu Bunka Joho Center. Available at: https://kogeijapan.com/locale/en_US/nibutaniattoushi/

Korhonen, A. & Niinimäki, K. (2024). Framing Regenerative Fashion. In Sustainability and the Fashion Industry, pp. 1-18. Routledge.

Krutak, L. (2012). Tattooing among Japan's Ainu people. Available at: https://www.larskrutak.com/

tattooing-among-japans-ainu-people/

Lyle, J.T. (1996). Regenerative design for sustainable development. John Wiley and Sons.

Lewallen, A. E. (2016). The Fabric of Indigeneity: Ainu Identity, Gender, and Settler Colonialism in Japan. School for Advanced Research Global Indigenous Politics Series. University of New Mexico Press.

Lewallen, A. E. (2018). Ainu textiles: Cloth weighted with affection and prayer. Available at: https://garlandmag.com/article/ainu-textiles/

Minney, S. (2024). Regenerative Fashion and Just Transition Report. Available at: https://safia-minney.com/wp-content/uploads/2024/09/Regenerative-Fashion-and-Just-Transition-Report.pdf

Murray T., Soenksen, V. & Jackson, A. (2018). Textiles of Japan: The Thomas Murray collection

at the Minneapolis institute of art. Munich: Prestel.

Myers, M.D. (2008). Qualitative Research in Business & Management. London: Sage.

Northerncross (2015). Traditional Craft; Nibutani attush. Nibutani Craft Cooperative Association.

Palomino, E. (2022). Indigenous Arctic Fish Skin Heritage: Sustainability, Craft and Material Innovation. PhD thesis. University of the Arts, London.

Palomino, E., Pardue, J. & Donkan, A. (2023). Fish skin Peoples of the Bering Strait: Encounters in Hokkaido, Japan. Smithsonian Institution National Museum of natural History. Arctic Studies Center Newsletter. May 2023. N.30. pp.74-75. Available at: https://repository.si.edu/handle/10088/116560

Palomino, E., Karmon, A., Topaz, O., Solo, A. & Cordoba, A. (2024). 'Digital Tools in the Fashion Industry: fish skin garments and Ainu fish skin traditions'. Technology, Sustainability and the Fashion Industry: Can Fashion Save the World? A. Schramme and N. Verboven (eds.) Routledge.

Radcliffe, S. A. (2021). Decolonizing Geography: An introduction. Polity Press.

Rix, E.F., Wilson, S., Sheehan, N. & Tujague, N. (2019). Indigenist and Decolonizing Research Methodology. In: Liamputtong, P. (eds) Handbook of Research

Handbook of Research Methods in Health Social Sciences. Springer, Singapore.

Shaginoff, M. (2020) You are on Indigenous Land. Available at: https://www.anthc.org/wp-content/uploads/2021/11/You-are-on-Indigenous-Land-Shaginoff.pdf

SRM (2021). Ancient cultures and Indigenous peoples. Sakhalin museum. Available at: http://sakhalinmuseum.ru/en

Weichenrieder, S. (2024). Leveraging Indigenous Knowledge for Effective Nature-Based Solutions in the Arctic. The Arctic Institute Arctic Extractivism Series 2024. Available at: https://www.thearcticinstitute.org/leveraging-indigenous-knowledge-effective-nature-based-solutions-arctic/

Williams, D. (2017). Ainu Ethnobiology. Contributions in Ethnobiology. Society of ethnobiology. Department of Sociology and Anthropology, University of Puget Sound, Tacoma, WA.

Wilson, S. (2019). Research Is Ceremony: Indigenous Research Methods. Halifax: Fernwood Pub.

UNSTITCHED NARRATIVES

CULTURAL AND ECOLOGICAL SIGNIFICANCE OF DESI OON IN RAJASTHAN AND HIMACHAL PRADESH

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Abstract

This paper explores the cultural and ecological significance of *Pattu*, a heritage unstitched textile from Rajasthan and Himachal Pradesh, India, emphasising its potential to contribute to a more sustainable future for the fashion industry. *Pattu*, crafted using *desi oon* and traditional practices, embodies traditional knowledge of sustainable textile production.

We discuss how *Pattu's* production supports biodiversity, soil health, and traditional livelihoods, highlighting the adaptability of pastoralist communities in the face of climate change. We argue that integrating local wool and traditional practices into contemporary fashion can offer valuable lessons in sustainability and resilience. By showcasing *Pattu* as a case study, the paper advocates for a shift towards ethical and eco-conscious practices in the fashion industry, emphasising the importance of cultural conservation and the value of traditional ecological knowledge in shaping a more sustainable future.

Keywords: *Indigenous wool; cultural textiles; unstitched textiles; fashion and culture; heritage*

INTRODUCTION: SHARED TEXTILE HERITAGE

Author 1 and Author 2, PhD researchers based in the UK and Canada, have come together to explore their shared heritage and the environmental importance of unstitched *desi oon* textiles from Rajasthan and Himachal Pradesh, India—specifically *pattu*. After more than a decade in India's craft-based textile industry, we recognised a significant academic gap concerning these textiles, which are deeply rooted in local biodiversity and cultural practices.

For us, these textiles represent more than just garments; they are cultural legacies that bring forth childhood memories, where the texture and feel of wool were intimately tied to their experiences of community, land, and belonging. However, these traditional textiles are being replaced by synthetic, petrochemical-based fabrics that are cheaper, lighter, and more widely accessible. This shift threatens cultural heritage and poses environmental risks through microplastic pollution and the disintegration of community-based, land-centric textile practices. A key driver of this research is the recognition of *desi oon*'s critical role in India's economy and biodiversity. The rise of synthetic textiles has significantly impacted India's indigenous wool industry, reflecting broader political and economic shifts that threaten local ecosystems and pastoral communities (Das & Iyengar, 2021). This paper traces the journey of pattus made of desi oon from its origins in the

Fig. 01

harsh landscapes of the Himalayas and Thar Desert to its transformation into textiles and beyond. *Pattus* stand out for its adaptability and cultural relevance. As unstitched garments, they can be customised for personal expression while preserving their traditional warmth and functionality. Historically, *pattus* have protected communities from the harsh desert heat of Rajasthan and the cold mountain climates of Himachal Pradesh, symbolising the interconnection between humans, animals, and the environment.

We view *desi oon* as an 'active material' (Ingold, 2013) that mediates relationships between humans, animals and the land, shaping cultural, environmental, and economic landscapes. We aim to contribute to a nuanced understanding of fashion's materiality and its entanglement with human and non-human actors. Our research builds on both personal and professional inquiries, as we revisit the textile traditions passed down within our families. These unstitched woollen garments, embedded in our familial and regional heritage, serve as a lens through which we explore the broader themes of materiality and sustainability.

MAPPING THE CHANGE

India's wool industry has a vast population of over 40,000 skilled pastoralists who herd and hand-spin wool (Iyengar, 2021), contributing to a rich heritage supported by a substantial population of 43 registered sheep breeds (Das, 2021; Iyengar, 2021). However, the industry has faced a marked decline in recent years, primarily due to the growing reliance on imported wool. This finer, softer wool with longer fibres has increasingly replaced the coarser desi oon, this is not just an economic setback; it has also disrupted local biodiversity, as pastoralist communities who have long played a key role in managing their ecosystems face increasing challenges in sustaining their ways of life. The sheep in these communities are not just livestock; they play an integral role in agriculture and ecology, fertilising the land, providing food through their milk and meat, and supplying durable materials for local production (Das & Iyengar, 2021). However, a sharp decline in the value of their wool over the past two decades has led to altered grazing practices and weakened ecosystems that these pastoral communities depend on (Das & Iyengar, 2021).

In response, efforts to revitalize *desi oon* are gaining

close partnership with civil society, academia, government agencies and the private sector is spearheading the 'cartographic representation of pastoralist routes across the country' to highlight the significance of these communities. These maps visualise data on changes in vegetation, land use, and the impact of climate change over the last 30 years, offering a comprehensive view of how development and conservation policies have affected pastoralist livelihoods (Centre for Pastoralism, 2021). Additionally, initiatives like the Desi Oon Hub, launched by Khamir and RangSutra in 2019 and now supported by 13 organisations (Aana Jaana, Avani, Cotton Rack, Dakhni Diaries, Earthen Tunes, Khamir, Kullvi Whims, Miyar Mufflers, Peoli, RangSutra, Shepherds of Himalaya, The Color Caravan, and URMUL), are pivotal in rebuilding desi oon value chains in harmony with regional ecosystems, significantly contributing to the wool revival in India (Centre for Pastoralism, 2022). The shift in India's wool industry reflects a broader tension between traditional, localised practices and the pressures of industrialisation. *Desi oon* production, shaped by the rhythms of the land and the needs of rural communities, is increasingly being challenged by crossbreeding programs and government initiatives aimed at imposing the industrial time scale. These initiatives promote a once-yearly shearing schedule suited for 'improved' sheep breeds, which results in unusably long *desi oon*, further marginalising local practices and threatening the sustainability of traditional wool economies (Hoover, 2018). In conclusion, the evolving dynamics within India's wool industry reveal a complex interplay between traditional livelihoods, biodiversity, and modernisation pressures. Revitalising and revaluing the desi oon economy offers a pathway that honours both cultural heritage and environmental resilience. This paper enriches the burgeoning literature on *desi oon* by providing a comprehensive examination of unstitched textiles from Rajasthan and Himachal Pradesh. Through narrative inquiry, this study explores the cultural significance of unstitched textiles and their potential to enhance sustainable practices and promote ecological and cultural sustainability within the global fashion industry.

1. *desi oon* is local/indigenous wool

2. *Pattu* is a handspun, handwoven, unstitched textile found in both the Thar Desert in Rajasthan and the Himalayas in Himachal Pradesh, India.

METHODOLOGY

This research uses narrative interviews and observation, supplemented by a review of secondary sources such as reports from the Centre for Pastoralism. These reports provide a broader context on the indigenous breeds, detailing their presence and decline, ecological impacts, and economic significance within regional and national textile industries, and facilitate comparisons with narrative interview stories.

The narrative interviews were conducted in a semi-structured format to allow open-ended conversations that encourage participants to share personal stories and insights. Participants were selected using purposive and convenience sampling to include individuals with direct experience in *desi oon* production, ensuring a depth of perspective on the cultural and practical aspects of textile crafting. The first author conducted an online narrative interview with her father, who is from Himachal Pradesh and grew up directly involved in the family's desi oon production for domestic use. The insights from this interview offer a personal view into the traditional practices and lived experiences associated with *desi oon*.

The second author returned to her native village in Rajasthan to conduct a narrative interview with her grandmother, an active participant in agricultural activities and the caretaking of various livestock. Her grandmother also engages in hand-spinning during her free afternoons, a skill that is integral to her lifestyle. She shared profound insights on the significance of this craft in their daily lives, including how the spun yarn is passed on to weaving families for further processing.

Additional interviews were conducted with five weaving families, including a retired 79-year-old weaver and a father-and-son duo who actively continue the craft. The son, aged 28, highlighted a resurgence of interest among younger generations, partly spurred by interactions with students from the National Institute of Fashion Technology, who engage with the community for craft documentation and collaborative design projects. The research also involved a visit to the URMUL Trust, a non-profit organization that supports livelihood activities related to wool and *Pattu* weaving in the Thar Desert.

STITCHING UNSTITCHED TEXTILE NARRATIVES

Each pastoralist community in India has their own

set of 'storied textiles' (Das & Iyengar, 2021: 66). Das and Iyengar (2021) use this term to describe the deep cultural, historical, and practical significance of these textiles for the pastoralist communities that produce them. They are not merely functional items but are interwoven with the communities' way of life, identity, and traditions, embodying the legacy of pastoral knowledge and craftsmanship. Thus, the term 'storied' encapsulates both the tangible and intangible heritage embedded within these handcrafted wool products. Building on this, we discuss two such storied textiles - Pattu found in both Rajasthan and Himachal Pradesh, emphasising their connection to the land and cultural significance.

As Indian researchers abroad, our inquiry into unstitched textiles is also a personal exploration of the textiles that have been part of our familial heritage. Pattus from Rajasthan and Himachal Pradesh, found within our family collections, hold significant cultural and emotional value. This rediscovery of our textile legacies has not only informed our research but also allowed us to engage with these materials as living artefacts of identity, connecting us to our ancestral lands.

PATTU (RAJASTHAN)

Drawing on my (Author 2's) auto-ethnographic experience in Kapuria, Rajasthan, India, I have observed the intricate practice of hand spinning in rural communities, where elderly women spin finer-count wool yarn for everyday clothing on the *Charkha* (traditional spinning wheel). Around a century ago, Mahatma Gandhi introduced the *charkha*, empowering India to spin *khadi* (hand-spun, handwoven fabric), a symbol of independence and resistance to colonial rule (Iyengar, 2021). In these rural settings, men typically spin thicker yarn for cords and outdoor uses using drop spindles. These communities, composed of pastoralists, and farmers, rear livestock such as sheep, goats, camels, and cows, which play a central role in daily life. Livestock is crucial to the agro-economic system in arid and semi-arid regions, where animalhusbandry sustains the rural economy. Sheep, in particular, provide essential resources like meat, milk, and wool, supporting a semi-nomadic lifestyle and generating supplementary income at minimal cost.

The practice of hand-spinning wool during quiet afternoon hours not only meets personal and

Fig. 02

ceremonial needs but also represents a sustainable production method. By using locally sourced wool, these communities reduce their environmental impact and support biodiversity. Grazing practices help maintain land health, replenish soil, and foster a balanced ecosystem. My grandmother's use of handspun wool and resourceful repurposing of materials reflects the community's deep connection to nature and sustainable living.

Although wool is often associated with winter, woollen textiles like *Pattu* protect against the desert's extreme temperature fluctuations, from freezing nights to scorching midday heat. Traditionally woven from desi wool, *Pattu* textiles, typically black and white, use fibres sourced from the local environment. Artisans exchange materials at every stage of production, forming a critical part of the local economy and cultural practices. The *Pattu* symbolizes strong ties between tradition and the environment, particularly in Western Rajasthan regions like Barmer, Jodhpur, and Jaisalmer (Parasrampuria, 2020).

Various types of unstitched *Pattu* textiles are produced in these communities. Once enough handspun yarn is collected, local weavers craft the Pattu in exchange for grain, reflecting the interdependence between humans, livestock, and the land. Surplus *Pattu* is sold to generate additional income, enhancing economic resilience. The *Pattu* is a multifunctional cloth used as a shawl, draped skirt, blanket, mat, or rain cover. Its tight weave ensures durability, providing warmth in desert winters while also serving as bedding or a floor covering. The term "*Pattu*" comes from "*patti*," meaning narrow-width fabric, traditionally woven on pit looms in two-foot-wide, nine-foot-long panels (Rustagi, 2021). These panels are skillfully joined by hand fagoting (Nath & Wacziarg, 1987), creating a large textile ideal for wrapping around the body (Bhandari, 2004). In resource-scarce communities, Pattu is versatile, offering protection from dust and cold as a wrap, head covering, or blanket (Jaitly, 1990).

The Meghwal community, known for its expertise in crafting *Pattu*, produces varieties such as *Kashida Pattu*, *Baradi*, *Bhojasari*, and *Hiravali Pattu*. Each type follows a specific sartorial code: *Baradi* (chequered *Pattu*) is worn by women, while young men prefer highly decorative styles, and older men opt for plain ones. Men often wrap themselves in large woollen blankets, folding them over their shoulders as the day warms, while women wear woollen head coverings and skirts made from similar fabrics (Rustagi, 2021).

The use of indigenous wool strengthens the desert's resilient ecosystem due to its adaptability. This ecosystem connects artisans—spinners, weavers, dyers, and embroiderers—with farmers and herders, creating a cohesive value chain in harmony with the local environment. By promoting the local wool value chain, artisans gain control over natural raw materials, making craft production ecologically sound and sustainable. This practice reinforces the longevity of traditional weaving and textile crafts, preserving cultural heritage while supporting ecological sustainability. At the core of this system lies a web of interdependence that binds communities, economies, and nature, fostering both cultural and environmental resilience.

PATTU (HIMACHAL PRADESH)

As seen in the case of Pattu from Rajasthan, wool is a valuable material for understanding the essence of a place, it is a direct manifestation of the environment in which sheep live and offers a tangible connection to the environment. While sheep are typically shorn once a year in most production systems globally, the process occurs more frequently in the Himachal region, every 6 months or even 3 times annually, reflecting the area's distinct growing seasons (Hoover, 2018). months or even 3 times annually, reflecting the area's distinct growing seasons (Hoover, 2018).

The following stories and terminologies are specific to my (Author 1's) father's family, who are from the Chirgaon subdistrict in the Shimla district of Himachal Pradesh. As dialects in Himachal Pradesh change across districts, the terms used here might vary in other regions. My father was a part of the *desi oon* cultural system at a young age, learning to spin and weave wool by observing his father. By the age of eight, he was helping his family with desi oon production for domestic use, taking on responsibilities such as caring for their 50–60 sheep and a few goats. These animals were raised both for wool and as a food source, with wool typically harvested in the summer months. Families living in higher altitudes often kept larger flocks and bartered wool for essential items like salt, rations, ginger, and chillies. Gaddis, also called transhumanist nomads (Axelby, 2007), annually traverse thousands of kilometres across the Himalayan ranges, moving livestock from the lower forests to the higher alpine pastures for summer

grazing encountering challenging conditions in the uninhabited high-altitude pastures. Their transhumant nomadism is based on the seasonal exploitation of different but complementary ecological and climatic zones, a 'vertical' migration that allows shepherds to be in tune with of variations in altitude, climate and geography (ibid). Pastoralism, an integral part of the desi oon ecosystem is built on a deep connection between the Gaddis' way of life and the cyclical patterns of nature, illustrating a sustainable interaction with their environment that supports both their cultural heritage and the regional ecology. The *Gaddi* pastoralists on their descend to the plains with their flocks, were welcomed by farmers who grew wheat. Farmers invited them to rest overnight, exchanging wool or livestock for the organic manure the sheep and goats provided. The pastoralists also carried rations with them for their return journey to the mountains.

Families living at higher altitudes often maintain larger flocks, bartering wool for essential items such as salt, rations, ginger, and chillies. Known as transhumant nomads, the Gaddis annually traverse thousands of kilometres across the Himalayan ranges (Axelby, 2007). They move their livestock from the lower forests to the higher alpine pastures for summer grazing, facing the challenging conditions of uninhabited high-altitude pastures. This seasonal movement, or 'vertical migration,' allows them to exploit different but complementary ecological and climatic zones, aligning their herding practices with variations in altitude, climate, and geography (Axelby, 2007: 38). Pastoralism is a cornerstone of the *desi oon* ecosystem and is deeply embedded in the Gaddis' way of life. It mirrors the cyclical patterns of nature through their rotational grazing land use. Upon descending to the plains, Gaddi pastoralists are traditionally welcomed by farmers, who host them overnight in exchange for wool or livestock, which provide organic manure crucial for agricultural productivity. The pastoralists also carry rations for their return journey to the mountains, ensuring a sustainable cycle of resource exchange and mutual benefit.

My *par-dadaji* (paternal great-grandfather) along with other men in the family, used to spin wool (seen in figure 4), though her son, my *dadaji* (paternal grandfather) learned the craft of weaving

Fig. 03

Fig. 04

more as a hobby from local weavers. These traditional practices gradually waned in the 1980s, as my family increasingly engaged in apple farming, which meant reduced grazing land for the livestock. This shift mirrored a broader trend within the community, where many families moved away from traditional wool crafts toward agricultural work and market-purchased clothing, altering their consumption habits.

Several traditional tools and techniques were used in wool processing. *Tumbna* was the method of separating wool fibres by hand to create long threads, a skill essential for producing strong fibres. Other key tools included the *chitki* (a bow used to beat the wool) and the *takli* (a spindle used to spin wool into yarn). The loom, which could be set up in various areas such as under the veranda, was used to weave *patti* (a narrow strip of woolen fabric). During the winter months, when farming activities slowed, wool processing became a communal activity. Entire families would spin wool, often competing to see who could fill their *takli* the fastest, while working in rhythm with the changing seasons. Once the wool was spun and woven by my *dadaji* (paternal grandfather), the patti underwent a treatment process called mandna. In this process, the woven fabric is soaked in a mixture of *chullu* (apricot) remnants from the oil-making process and water. The wool was then kneaded using feet and the whole body's weight in a physically demanding task, which was carried out by my *dadiji* (paternal grandmother). After kneading, the fabric was stretched and hung to dry with weights at the bottom, resulting in a thick, waterproof, and windproof wool. The woven fabric was sent to tailors for stitching into garments (as seen in Figure 4). *Patti* fabric was narrow, less than half a meter wide, and was used to create dohru (blanket), which consisted of two pieces of patti joined together, measuring 2 by 5 meters. Pattu was another shawl-like garment worn for outdoor activities, with men and women wearing variations of it. Coarser wool from goats was used for *makingbichona/fakule* (carpets), while finer wool from young sheep was reserved for items like children's clothes, mufflers, and shawlsDespite the shift toward commercial farming, wool continues to provide a sustainable source of income in Himachal Pradesh, especially as the state wool federation has increased wool prices over the past years (Himachal Pradesh Wool Federation, 2021). In addition to its economic value, wool holdsspiritual significance in the region. The *Gaddi* pastoralists, for instance, believe their sheep and goats were created from the dirt that Lord Shiva removed from his body and that he gifted them with the clothes to help them endure the harsh winters. This belief, deeply embedded in local traditions, shows the sacred relationship between the pastoralists and their livestock (Centre for Pastoralism, 2016).

RESHAPING THE FUTURE OF UNSTITCHED TEXTILES

Heritage textiles such as *Pattu* offer a vital pathway for contemporary fashion to embrace sustainability and cultural conservation. They transcend their material form, serving as carriers of knowledge embedded in the ecological and cultural systems that have nurtured them for centuries.

As the fashion industry shifts towards slow production, local materials, and ethical practices,

these unstitched textiles represent more than just a craft revival; they embody a crucial link between past, present, and future sustainable textile practices, thus supporting traditional livelihoods. This shift in the fashion industry is gaining momentum with initiatives like the *Desi Oon* collective, where collaborations, both local and international, reveal the potential of *desi oon*. A notable example is the partnership between Kullvi Whims and Zazi Vintage, which has successfully presented desi oon and its artisans to a global audience. Their collaborative products, jumpers, capes, and especially unstitched ponchos, are named after the artisans, bringing their stories and craftsmanship into global fashion dialogues through their feature in Vogue. Throughout their collaboration Zazi Vintage, highlighted the social, ecological, and spiritual significance of desi oon, sharing culturally rich narratives through social media. Similarly, a collaborative social enterprise model involving Rangsutra Foundation, Urmul Setu Sansthan, and the Centre for Pastoralism and artisans as co-founders, supports the value chain of desi oon in Bikaner, Rajasthan. This collaborative effort involves pastoral herders, spinners, and *Pattu* weavers in producing yardages for contemporaryapparel while preserving traditional craftsmanship. Their collection, Dhaani, inspired by pastoral hamlets, features naturally dyed, handwoven, handspun, and hand-embroidered desi oon jackets and overcoats. By using sustainable heritage techniques, this initiative not only supports pastoral and artisan livelihoods but also meets modern design demands, with partnerships like FabIndia, IKEA, and C&A amplifying their impact. Reflecting on the future of India's wool heritage, it becomes clear that appreciating local wool and textiles is more than a nostalgic exercise; it is crucial for fostering a deeper respect for the interconnected systems of life on Earth. The ecological knowledge embedded in these fibres and the cultures that produce them is deeply relational, situated, and intertwined with their environments. These ways of knowing are embodied through ritualised learning practices within communities (Fletcher et al., 2019) and provide essential insights into the natural world that modern, dualistic approaches often overlook. Moreover, local beliefs, histories, and cultural practices reveal how communities interact with and understand nature. (Leitão, 2022) These narratives lay the foundation for designing in and for a world where multiple realities and ways of knowing coexist (ibid). In conclusion, the future of heritage textiles like *Pattu* lies in their potential to teach us to live sustainably and in harmony with the natural world.

CAPTIONS

[Fig. 01] Author 2's Naani (maternal grandmother), Anchi Devi, stands before her 80-year-old handspun on Charkha (spinning wheel) and hand-embroidered Pattu, handwoven by a local weaver. Photo taken in circa 2015, shows her wearing a machine-made acrylic sweater, synthetic skirt, and chemically dyed cotton head scarf. Photo Credit: Choudhary, P.]

[Fig. 02]Two generations of weavers stand with various styles of handspun and handwoven Pattu. The lower image shows an elderly weaver who stopped weaving due to decreased demand and the unavailability of the right type of wool. The next two images show a reed made from local wood,

adjustable for weave density. The final image shows warp on the ground, on the other side at a pit loom. Photo Credit: Choudhary, P.]

[Fig. 03] Author 2's Naani handspinning on her 80-year-old Charkha in the afternoon, sitting outside the gadhal (an open living room in desert areas). This was her daily practice. The next image shows abandoned Charkhas, now repurposed for cooking fuel due to the lack of demand for handspun wool. The final image shows the Marwari sheep breed, where crossbreeding has led to coarser, shorter fibers.Photo Credit: Choudhary, P.]

[Fig. 04] Author 1's par-dadaji (paternal great-grandfather) spinning wool using a takli (spindle) (circa 1980s), which was then made into a Nehru jacket worn by her dadaji (paternal grandfather) (circa 1990s). Photo Credit: Top and bottom: Chauhan, M.; Middle photo: Bara, B. (D'Source)]

REFERENCES

Axelby, R. (2007). 'It takes two hands to clap': How Gaddi shepherds in the Indian Himalayas negotiate access to grazing. Journal of Agrarian Change, 7(1), 35-75. https://doi.org/10.1111/j.1471-0366.2007.00139.x

Bhandari, V. (2004). Costumes, Textiles and Jewellery of India-traditions in Rajasthan. Delhi: Prakash. Centre for Pastoralism. (2022). Desi Oon - Hamara Apna: Assessment of the state of value chains for indigenous raw wool in India. Delhi: Published by Centre for Pastoralism.

Centre for Pastoralism (2022). Centre for Pastoralism Annual Report.

Das, S. (2021). A glimpse into the indigenous wool economies of India. Pastoral Times, April, p.4.

Das, S., & Iyengar, S. (2021). Reviving indigenous wool craft of India. In Saad, Q. (Ed) Futuring Craft, Indian Ocean Triennial Australia IOTA 21 International Conference (pp. 64-90). Retrieved from https://indianoceancrafttriennial.com/wp-content/uploads/2021/12/IOTA21-conference-proceedings-3_compressed.pdf

Fletcher, K., St. Pierre, L., & Tham, M. (Eds.). (2019). Design and nature : a partnership. Routledge.

Himachal Pradesh Wool Federation. (2021). Annual Report. Shimla.

Hoover, J. (2018, September). Shepherds and Shawls: Making Place in the Western Himalayas. Paper presented at The Textile Society of America Symposium Proceedings. Retrieved from https://digitalcommons.unl.edu/tsaconf/1087

Iyengar, S., (2021). Reviving a Heritage in Peril: India's Endangered Traditions of Cotton and Wool! Journal of Heritage Management Volume 6, Issue 1, 25-39.

Ingold, T. (2013). Making: Anthropology, archaeology, art and architecture. Routledge.

Jaitly, J. (1990). The Craft Traditions of India. Delhi: Lustre Press pvt. ltd.

Leitão, R.M., (2022). From Needs to Desire: Pluriversal Design as a Desire-Based Design. Design and Culture, 14(3), pp.255–276. Retrieved from https://doi.org/10.1080/17547075.2022.2103949

Centre for Pastoralism. (2016). Living Lightly: Journeys with Pastoralists – Exhibition Report. Delhi: Sahjeevan and Foundation for Ecological Security (FES).

Nath, A., & Wacziarg, F. (1987). Arts and crafts of Rajasthan. Thames and Hudson.

Parasrampuria, S. (2020). Pattu weaving a Warm Web of Production. [Undergraduate thesis, National Institute of Design] https://files.persona.co/107436/GPDoc_BDes_TD_S1600109_Shreya_v1.pdf

CHEAP SILK

A MORE-THAN-HUMAN HISTORY OF SERICULTURE IN SLOVENIA'S GORIŠKA REGION

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Abstract

This paper examines the historical development of sericulture in Slovenia's Goriška region through Jason Moore's theoretical framework of capitalism as world-ecology. Drawing on historical records from the 16th to early 20th centuries, it analyses how silk production functioned as a complex system of organizing human and extra-human natures for capital accumulation. The study focuses particularly on three interconnected categories of "Cheap Things": the undervalued labour (Cheap Work), the appropriation of silkworms and mulberry trees as non-human workers (Cheap Nature), and the unrecognized care work primarily performed by women (Cheap Care). Silkworms were given the highest care and human characteristics—they were referred to as "cavaliers" due to their gluttony and high maintenance, and were also held close to their chests during hatching. Today, sericulture's legacy lives on as a performative and discursive practice demonstrating how the capital puts nature to work even when the original industry is no longer present. The story of sericulture in Goriška region illuminates broader patterns in fashion production, encompassing everything from dislocated material production to appropriation of human and non-human work.

Keywords: *Sericulture; Non-human Labour; Capitalism; Capitalocene; Textile Production; Textile History*

INTRODUCTION

Sericulture, cultivation of silkworms to produce raw silk, represents a complex interweaving of human and non-human labour, requiring minimal investment yet demanding labour. Historically it relied on the appropriation of human and non-human work (directly silkworms and trees), rather than on exploitation through wage labour. This paper examines the history of silk production as a production network encompassing both human and more-than-human actors, exploring how capital puts nature to work (Moore, 2015). Focusing on Slovenia's Goriška region—a border region in the crosshairs between Italian and Slovenian cultures—I argue that this regional history illuminates broader patterns in fashion production, from dislocated material production to appropriation of human and non-human work. Mulberry trees in Goriška reflect the region's economic structure and social interactions, where the Slovenian peasant population struggled economically. Silkworms were given the highest care and human characteristics—they were referred to as "cavaliers" due to their gluttony and high maintenance, and were also held close to their chests during hatching. Today, sericulture's legacy lives on as a performative, discursive practice in the form of storytelling—a type of simulation, to quote Baudrillard (1999). People's memories, dusty tools and remaining trees perform a curated version of local cultural heritage and landscape. I approach this legacy by researching how the capital still puts

nature to work even when the original industry is no longer present.

With this paper I argue that sericulture is an example of how capitalism organizes nature through both material and discursive practices. I approach this topic with Raj Patel and Jason Moore's theory of capitalism, particularly their concept of Cheap—understood as "a practice that mobilizes all kinds of work–human and animal, botanical and geological–with as little compensation as possible" (Patel & Moore, 2017, p. 19). I examine sericulture through three interconnected categories: Cheap Work (of landless farmers or coloni), Cheap Nature (silkworms and trees), and Cheap Care (predominantly women's labour). The provocative title of the paper "Cheap Silk" emphasises the true value of this material commodity, which carries prestigious connotations in fashion.

THEORETICAL FRAMEWORK

Moore's conception of capitalism as world-ecology, rather than merely an economic or social system, provides the foundational framework for this analysis. World-ecology represents "a method of bounding and bundling the human/extra-human/web of life relation—a manifold and multi-layered relation that encompasses everything from the micro-biome to the biosphere" (Moore, 2015, p. 19). This approach allows us to examine sericulture not just as an economic activity, but as a way of organizing nature that encompasses both material practices (cultivation, breeding) and discursive ones (categorizing trees as "beneficial" or "invasive").

Moore refers to new geological era as Capitalocene ("Age of Capital") rather than Anthropocene ("Age of Man") (2015, p. 57), to emphasise the destructive role of capitalism. This framing emphasizes that environmental transformation stems not from abstract human activity but from specific capitalist practices of organizing nature for profit. In sericulture, this manifests in the deliberate modification of both landscapes (through mulberry cultivation) and organisms (through silkworm domestication).

The concept of Cheap on the other hand provides the analytical tools for understanding how the work of sericulture is organized and justified within capitalism. Patel and Moore underline that cheap should not be understood as low cost: but rather a strategy, a practice, a violence that mobilizes all kinds of work–human and animal, botanical and geological–with little compensation as possible (2017, p. 22). Appropriation is the process where unpaid work, including labour, forestry, and agriculture, is turned cheap, transforming nature into a cheap commodity (Moore, 2015, 107-126). In sericulture the three interconnected categories of "cheap things" are: Cheap Work (labour of coloni in cultivating mulberry trees and silkworms, with minimal payment), Cheap Nature (appropriation of silkworms and trees as non-human workers, meaning not only their immediate labour but also their biological reproduction and genetic modification over time) and Cheap Care (performed mostly by women in the delicate and intimate care of silkworms). All three categories are very much connected and intertwined—life cycle of a silkworm is a involves all three: the agricultural labour of cultivating (Cheap Work), the biological work of the organism itself (Cheap Nature), and the intimate care required for its survival (Cheap Care). For greater transparency, I shall unpack each individually in the next chapters. I support my argument by drawing from historical sources and current discourses.

CHEAP WORK: REGIONAL CONTEXT AND LABOUR RELATIONS

The Goriška region is located in the west of Slovenia, stretching in the north between the Julian Alps, up to the Vipava Valley, sharing a lengthy borderline with Italy, most notably with the bordering towns of Nova Gorica/Gorizia. With its turbulent history, the region was affected by Italian territorial expansion in the twentieth century, subjected to a policy of Italianisation and, in its most violent form, annexed by Fascist Italy and later occupied by Nazi Germany. History of sericulture in Goriška region represents a compelling case study of capitalism as world-ecology, where geopolitical forces and human and non-human labor converged to create a system of resource extraction and labor exploitation. Sericulture spread from the Republic of Venice in the middle of the 16th century and flourished in the 18th century — a so-called "golden century of silk" in Goriška (Panariti, 1993, p. 17). The industry, where, in addition to raw silk and silk semi-products, silk fabrics were also produced (Bellina, 1993, p. 53). Jewish merchants from Gorizia, Gradisca, and Trieste played crucial roles alongside

government incentives, including the establishment of a state office and then a magistrate with a silk manufactory (Žontar, 1957, p. 17, 53[1]). There was a clear class distinction and paradigm of Cheap Work in silk production: "only peasants and poor townspeople cultivated silkworms" (Žontar, 1957, p. 54). At times it was the source of an important supplemental income for the rural population, other times it was their basic annual income (Ipavec, 2008, p. 35). After the First World War, sericulture and the silk industry in Goriška became part of the Italian economy since the Slovenian territory was occupied (Rijavec et al., 2024, p. 167). The mulberry trees that grew in almost every home in Goriška should not be wrapped in romantic notions; rather, they are a reflection of region's economic structure and social interactions, where the Slovenian peasant population was struggling economically. Landowners owned large number of mulberry trees on their lands, while coloni cultivated them and the silkworms. The Goriška region's[2] population gradually abandoned silkworm cultivation due to silkworm disease, scarce practices of sericulture remained until the beginning of the 20th century due to high silk market prices (Ipavec, 2008, p. 15). Nevertheless, the abandonment of Italian silk production led to the decline of this industry in the wider region, as well as a rise in viticulture and the profitable export of cherries, that became more profitable and stable activities that coincided with the sericulture season. (Ipavec, 2008, p. 38). This historical trajectory demonstrates Moore's theory: capitalism does not simply act upon nature but develops through nature. Meaning that the rise and fall of sericulture in Goriška exemplifies how capitalism continually seeks new ways to organize human and extra-human natures to secure itself.

CHEAP NATURE: THE NON-HUMAN LABOUR OF SILK

Silk is framed as a natural material, yet its methods raise conceptual questions alongside ethical concerns. The development of silk is a result of human and non-human activity, including millennia of animal domestication, meticulous tree cultivation, and discipline methods. It is crucial to comprehend not only that humans reshaped what are now known as silkworms, but also how much work animals put into the process of domestication and production of silk, which accelerated capitalistic processes of silk trade. This is achieved by approaching the topic of animal domestication using Moore's theory of capitalism, which asks what nature does for capitalism rather than what capitalism does to nature (2015, p. 18). In a similar manner but from the biological science Sánchez-Villagra explores how domestication is an ongoing process rather than an invention or an event, and it is often conceptualised solely from a human perspective (2022). Furthermore, it ignores the active role of the domesticated — benefiting human proximity and interaction and is a reflection of the West European view of our place in nature that is not universal among humans (Sánchez-Villagra, 2022, p.2). "Traditionally, domestication has been seen as resulting from goal-driven human action, with narratives about selection for traits that differentiated wild and domestic forms. In reality, domestication of different species has involved different kinds of interactions" (Sánchez-Villagra, 2022, p. 4). The dichotomy between "wild" and "domesticated" is more difficult to apply to the subject of insect domestication, especially since worms or moths have connotations of undesirable rather than domesticated. After thousands of years, silkworms function completely in dependence on humans, they have difficulty flying, are visually impaired, and lack the camouflage colouring that would allow them to survive in the wild (Postrel, 2020, p. 27). Domestication and mutation of animals is only part of how Cheap Nature was appropriated for economic interest in sericulture.

1 Anti-Semitic sentiments are also evident in historical works about sericulture in Goriška. The Jewish community in Gorizia was compelled to live in a ghetto and was despised by middle-class and noble merchants due to their entrepreneurship, as the Jews were apparently more successful in exploiting poor silk farmers than they were. In the meantime, Jewish silk traders asserted that they paid more for cocoons than did bourgeois merchants and that they provided loans and levies to assist silk growers during difficult times. (Žbontar 18-19). Silkworms were also referred as Jewish "worms" (Ipavec, 2008, p. 39).

2 It was present also in other parts of present day Slovenia, but due to favourable climate, it was prevalent in Goriška region (Rutar, 1997, p. 97).

Trees[1] used for feeding silkworms are also the result of human modification. Silk farmers created pruning techniques that increased leaf production and crossed two mulberry tree kinds to make the tree leafier (Postrel, 2020, p. 28). While mulberries could be tall trees; people cut them to a lower height so they could easily reach the leaves, since leaf picking was essential for feeding the silkworms stored indoors. Generally viewed as one of the most useful tree species in the world, mulberry tree combines high yields in leaves with soil conservation and amelioration of greenhouse gasses and the leaves have both traditional and modern applications in medicine (Altman &Farrell 2022). Planned planting of white mulberry (*Morus alba*[2]) for the needs of sericulture can be recorded in Tyrol as early as the beginning of the 15th century and west of the Soča river in the 17th century and "in the middle of the 19th century, there were around 2 million mulberry trees in Goririška and Gradisca area, which were used to feed silkworms" (Žontar 1957, p. 15, 87). Mulberries were often positioned at the edge of vineyards and also along houses, yards, and roads. The economic value of mulberries at that time can be seen in the memory of a silk grower from Goriška, recorded by Vesna Mia Ipavec (2008): "The people of Furlan were ready to pay a lot, like for a whole harvest of cherries, for mulberry leaves[3]" (p. 64). The trees were therefore valuable, and farmers even organized night watches to prevent theft. Planting and cultivating the mulberry trees were an essential component of sericulture, and this is evident also in the book of a historian, Josip Žontar who in 1957 published a study on sericulture in Slovene lands from the 16th century onwards. Supported mostly by primary sources in the form of historical documents from Vienna, a large part of the book is devoted to endeavours and many times failed attempts at organising the cultivation of mulberry trees. Numerous dead trees, whether in nurseries or on the land, were a result of the harsh continental climate or inaccurate estimates of the industry's potential profit, which varied in success. Despite meticulous human interventions during the flourishment of sericulture and full abandonment of the mulberry trees, they live on in another context and transcend the time scale of human memory. The attempts to cut down the trees serve as a brief example of this: workers damaged their tools while attempting to cut down old mulberry trees, oblivious to the fact that they were covered in shells in several areas following World War I. The trees overgrown the metal; thus, this was not discovered until later (Ipavec, 2008, p. 111). Mulberry trees are by no means the most prevalent plant of sericulture that shapes the landscape of the Goriška region. Due to a silkworm disease in the 1860s, a new type of moth was introduced that required the leaves of another tree, *Ailanthus altissima*, or the Tree of Heaven (Ipavec, 2008, p. 117). This tree was actively propagated throughout Europe and North America in order to cultivate the *Sami cynthia* silkworm, but the cocoons were eventually shown to be unsuitable for mechanical silk extraction (Petauer, 1993, p. 684). Classified as an invasive non-native plant, it is defined as "a species, subspecies, or taxon of a lower category that is introduced to an area outside its (past or present) range of natural distribution, or an area that could be reached by natural dispersion without direct or indirect human influence" (Kus Veenvliet & Humar, 2011, p. 7). Tree of Heaven, a common non-native tree species in Goriška, has low energy value, making it unsuitable for firewood use, but can be helpful as technical wood under certain circumstances (Arnšek, 2009, p. 9). The concept of alien and invasive species is a social issue[4]; there is no such thing as a uniform terminology of biological invasions. Due to the complexity and interdisciplinary nature of the topic, it is not

3 Besides trees used for feeding the silkworms branches of chestnut trees were often used in the process of cocooning of the worms (Ipavec, 2008, p. 66).

4 White mulberry tree was transported to Europe in the 14th century and grows faster than black mulberry tree (Morus nigra) that was originally used to feed silkworms (Ipavec, 2009, p. 22-23).

5 The witness refers to the period after the First World War, when the local economy had not yet recovered and the inhabitants were no longer engaged in sericulture.

6 "Social scientists, accustomed to deliberations about the cultural connotations of terms like alien or non-native, accuse invasion biologists of being xenophobic (which is a legitimate concern within the narrow boundaries of their specialized debates), though biologists use the term in a very different context and usually without any cultural connotations. It is therefore important to carefully reflect on the different contexts when using terms such as non-native (or alien, exotic, foreign, etc.) in science or policy." (Humair et al., 2014, p. 19).

possible to reach a uniform consensus regarding definitions of invasiveness (Humair et al., 2014, p. 17). What is defined as invasive is determined by the current human economic interest: since the trees are no longer being used for their original purpose (sericulture) and have no other beneficial usage, they are categorised as unwanted and viewed as too numerous in count. Due to its rapid reproduction, it displaces the nature acceptable by capitalism: such as cultivated food plants or "unspoiled natural" areas used for tourism, sport or leisure. Two kinds of trees: Mulberry tree and Tree of Heaven are both still present in the region are perceived differently. The categorization of species as "invasive" versus "heritage" reveals the inherently political nature of environmental classification systems, reflecting what Moore terms capitalism's double internality where nature both constitutes and is constituted by capitalist relations (2015, 24). Tree of Heaven becomes problematic precisely when it ceases to serve capital's productive needs in sericulture. Even more, the shifting categorization illuminates how capitalism continuously reorganizes and redefines nature through both material and discursive practices. Mulberry trees achieve "heritage" status through its historical connection to productive labour, while the Tree of Heaven is relegated to the category of "invasive" due to its resistance to current forms of capitalist appropriation. This process demonstrates how capitalism continues to put nature to work even after the decline of original activities, through the labour of maintaining particular aesthetic and cultural landscapes deemed economically valuable.

CHEAP CARE: ANTHROPOMORPHIC TREATMENT OF SILKWORMS AS INFANTS

Silkworms were treated as very delicate beings: they were kept in an inside space[1], the owners thoroughly cleaned the premises in advance, and if necessary, the people heated the space with stoves (Ipavec, 2008, p. 16). The care practices surrounding silkworm cultivation reveal a complex intersection of animal domestication and gendered labour. Fresh leaves from mulberry trees were the main food of silkworms, initially finely chopped like tobacco leaves, and eventually they consumed whole branches. The work of children in the family played an important role in this. Women, as bearers of care work in society and the family, also performed this type of work with silkworms: hatching, cleaning, and overviewing their growth. At the time when it seemed that the mulberry trees would start to sprout leaves, people warmed the silkworm eggs in their chest until they hatched (Ipavec, 2008, p. 68). Furthermore, women silk farmers were sometimes waking up every two hours at night to feed the worms (Ipavec, 2008, p. 70). Similar records can be found from the time of the Song dynasty (960-1279) from an elderly silk farmer. They tended the silkworms "as if they were new-born infants" (Postrel, 2020, p. 27). The demanding nature of the work, the caring work that often falls to women or older children, the schedule of caring and frequent feeding — all mentioned characteristics resemble domestic childcare work. This embodied practice of almost "mothering" silkworms reflects feminist approach to the concept of care — work that is simultaneously essential to production yet systematically devalued and gendered. The participation of women and children in these care rituals demonstrates how sericulture, like other forms of agricultural production, relied on the appropriation of domestic labour power outside formal wage relations.

Even their name indicates the anthropomorphism of these animals: under the influence of the Italian language and production, the local inhabitants called silkworms "cavaliers" and not with a Slovenian word (*sviloprejka*); they did not know this term, and it only became more known after the Second World War (Ipavec 2008, p. 17). In her research, Ipavec (2008) claims there are several possible explanations for this name: the name is said to come from the image of a silkworm before cocooning, when it begins to bow the front part of its body, which alludes to bowing, but actually the silkworm indicates the intention to cocoon (p.17). The term cavalier is also said to come from the need for worms for special living conditions (Panariti, 1993, p. 30).

CHEAP SILK: THE ABSENT FIBRE AND PERSISTING STORIES

The story of sericulture in Goriška region reflects the wider picture of the fashion industry: alienation from the production process and final product, physical distance from fashion and textile

7 Initially in the living spaces of the owners, at the end of 18 century in a separate small houses for silkworms (Ipavec, 2008, p. 30).

production, and the transition from maker to consumer. Even when sericulture was a part of the mentioned region, silk itself was not present in the lives of the silk farmers. In the clothing culture of the 18th and 19th centuries, silk was present in the clothes of the women in the region - as bodices, but especially as shoulder scarves as well as headscarves, sometimes as silk clothes of inferior quality (Ipavec, 2008, p. 101). In the 20th century, women sometimes dressed in silk on Sundays and holidays. Perhaps the most widely distributed silk came "from the sky": sourced from Allied silk parachutes of white or yellow-green colour (Ipavec, 2008, p. 102)[1]. Silk proves to be an absent fibre: absent as the final material in the times of the production in the Goriška region and absent today from the production as well as consumption. Its presence is often fluid in its presentation, when marketing falsely evokes the opulent texture of silk by using the name "satin".

In this article I seldomly mentioned silk as a fibre, as a textile product, as the final material goal, the product, the commodity that is traded on the market and worn by people. So, where is the fibre? The last organised shift towards the preservation of sericulture occurred after the Second World War, with the beginning of socialist Yugoslavia. In the post-war years, the new government organised post-war reconstruction, encouraging the existence of a textile industry with its own raw materials (Ipavec, 2008, p. 42). There was no far-reaching success in Goriška, and the number of mulberry trees also decreased. The last purchase is said to have taken place in the mid-60s, shortly before nylon shirts began to appear in Italy (Ipavec, 2008, p. 51). New synthetic materials replaced silk; farmers sought jobs in factories; farms cut down mulberry groves and opted instead for vineyards and orchards. This greatly changed the image of the cultural landscape (Ipavec, 2008, p. 51). In Slovenia, sericulture only appears as a boutique asset for tourist or educational purposes in a form of Baudrillard's simulation (1999). Sericulture persists only as a performative, discursive practice in the form of *the story*. The absence of economic objective is being filled with *the story* or more precisely: *the story* of the territory is becoming the economical goal as a discursive practice of contemporary tourism. The story sells, more than the commodity itself. The shift from production to simulation, sericulture's transformation from material practice to tourist narrative demonstrates how capitalism commodifies not just physical resources but cultural memory itself. Even more, the contemporary persistence of sericulture as purely narrative practice reveals how capitalism continues to put nature to work even in the absence of material production.

8 Silk from allied parachutes was used by the partisans who founded a theatre during the war and used this material to sew costumes and set designs.

REFERENCES

Arnšek, T. (2009). Visoki pajesen na Goriškem. http://www.digitalna-knjiznica.bf.uni-lj.si/vs_arnsek_tadej.pdf.

Altman, G., & Farrell, B. (2022). Sericulture as a sustainable agroindustry. Cleaner and Circular Bioeconomy, 2. https://doi.org/10.1016/j.clcb.2022.100011.Baudrillard, J. (1999). Simulaker in simulacija; Popoln zločin. Ljubljana: Študentska založba.

Bellina, M. (1993). Il tessuto di seta a Gorizia tra sette e ottocento; In: Maria Masau Dan and Lucia Pillon, ur. Il filo lucente: La produzione della seta e il mercato della moda a Gorizia 1725-1915, 53-81. Gorizia: Edizioni della Laguna.

Buchli, V. (2000). An Archaeology of Socialism. Oxfod: Berg.

Hann, R. (2019). Beyond Scenography. London: Routledge.

Humair, F., Edwards, P. J., Siegrist, M., & Kueffer, C. (2014). Understanding misunderstandings in invasion science: why experts don't agree on common concepts and risk assessments. NeoBiota, 20, 1-30.

Ipavec, V. M. (2008). Murve in »kavalirji«, Svilogojstvo na Goriškem. Nova Gorica, Ljubljana: Založba ZRC SAZU.

Kus Veenvliet, J., & Humar, M. (2011). Tujerodne vrste na zavarovanih območjih. Poročilo o aktivnosti za krepitev zmogljivosti v sklopu projekta WWF Zavarovana območja v dinarski regiji. Access: https://www.gov.si/assets/ministrstva/MNVP/Dokumenti/Narava/Invazivne-vrste/tujerodne_vrste_zavarovana_obmocja_kus_veenvliet.pdf.

Moore, J. W. (2015). Capitalism in the Web of Life: Ecology and the Accumulation of Capital. London: Verso Books.

Panariti, L. (1993). Innovazione e ritardo tecnologico: L'industria della seta nel Goriziano del settecento; In: Maria Masau Dan and Lucia Pillon, ur. Il filo lucente: La produzione della seta e il mercato della moda a Gorizia 1725-1915, 17-44. Gorizia: Edizioni della Laguna.

Petauer, T. (1993). Ailanthus altissima. Leksikon rastlinskih bogastev ([1 ed.], p. 684). Ljubljana: Tehniška založba Slovenije.

Postrel, V. (2020). The Fabric of Civilization. New York: Basic Books.

Patel, R. & Moore, J. W. (2017). A History of the World in Seven Cheap Things: A Guide to Capitalism, Nature, and the Future of the Planet. Berkeley: University of California Press.

Rijavec, T., Šalej Lah, A., & Berčič, R. L. (2024). Revival of sericulture in Slovenia. 166–172. https://www.ttf.unizg.hr/en/tzg-2024/1094

Rutar, S. (1997). Poknežena grofija Goriška in Gradiščanska. Nova Gorica: Branko, Ljubljana: Jutro.

Sánchez-Villagra, M. (2022). The Process of Animal

Domestication. Princeton: Princeton University Press.
Žontar, J. (1957). Svilogojstvo in svilarstvo na Slovenskem od 16. do 20. stoletja = Die Seidenzucht und das Seidengewerbe im slowenischen Volksgebiet vom 16. bis zum 20. Jahrhundert (Let. 11, str. 159). Slovenska akademija znanosti in umetnosti. http://www.dlib.si/details/URN:NBN:SI:DOC-R3ZENCGP.

MATERIAL CULTURE

THE TRANSFORMATION OF A NEW ENGLAND COTTON MILL INTO A CENTRE FOR LEARNING AND CULTURAL PRESERVATION

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Abstract

This paper examines the Boott Cotton Mill in Lowell, Massachusetts, tracing its evolution from a major textile manufacturing hub in the 19th century to its current status as a Museum and educational centre within the Lowell National Historic Park. Initially a pivotal player in the global cotton industry, the mill was integral to New England's economic growth, contributing significantly to American industrialization. However, globalization and technological changes led to its economic decline and eventual closure, reflecting broader deindustrialization trends.
Its subsequent transformation into a National Historic Park represents a shift from industrial production to cultural preservation and urban restoration. The park now offers exhibits, guided tours, and educational programs that highlight the history of textile manufacturing, fashion and design and the various ways in which the efforts to produce fabric also wove the culture and shaped the identity of a community. This preliminary study situates the mill, its labourers and its products both historically and today in the form of a National Historic Park, as a shaper and perpetuator of fashion, culture, education and community while pointing to opportunities for further research to understand the relationship between fibre production and culture.

Keywords: *Cotton; Mills; History; Culture; New England*

THE COTTON MILLS OF LOWELL MA: WEAVING THE FABRIC OF COMMUNITY

The Boott Cotton Mills Museum at Lowell National Historical Park sits in Lowell, Massachusetts, 30 miles from Boston on the Merrimack river near Pawtucket Falls. It was developed in the 1830s as a new mill town amongst a consortium of textile manufacturing operations established and operated by the Boston Manufacturing Company. Operations faltered in response to 20th century challenges until finally ceasing in 1955. Soon afterwards, in the early 1960s, a group of Lowell citizens, most of them descendants of the mill workers, came together with a plan to "revitalize the community, transform the educational system, and stimulate the local economy" (National Park Service, 1992, p. 90). They proposed to celebrate the region's fibre- and weaving history by turning the mill architecture and the diverse community the mill workers had established all around it into an "historical park that would present the city as a living museum" (ibid.).
Through primary and secondary source analysis of materials from the National Park Service, and site visits to the Lowell National Historic Park site during May through August 2024, this paper considers the lasting impact that textile production at the Boott Cotton Mill has had on the identity of the region. Other researchers have noted the historical and industrial importance of New England mill towns in the region, and examined

the opportunities and challenges of the National Park Service's "culture-based approach to revitalization" and the city's partial "renaissance" (Stanton, 2006, p.3) through heritage tourism. This paper contributes to the literature by considering the ways in which fibre, fabric, and textile manufacturing are both resources for and perpetuators of culture. It offers perspective on how the repurposing of industrial heritage sites such as textile mills, can preserve the historical legacy of a region while generating innovative collaborations that enhance socio-economic prospects, civic pride, and community-engaged learning.

FROM NEW ENGLAND FARM GIRLS TO ETHNIC ENCLAVES

The Boott Cotton Mill is one in a series of New England textile manufacturing sites developed under the auspices of the Boston Manufacturing Company established in 1813 by Henry Cabot Lowell and a group of business associates (Mullin & Kotval, 2021). These textile mills and the urban communities that sprung up around them played a critical role in the rise of the American Industrial Revolution by harnessing natural resources (river power and raw materials), technological innovations, and human labour. The Boott Mill of Lowell, Massachussettes was among the most successful of these (Gross, 2000).

It was designed and overseen by former British army engineer Kirk Boott. Boott's grand vision for the project went well beyond the factory itself and included city planning, architecture and construction of streets and buildings as well as "mills, canals, locks, machine shop and worker housing" (National Park Service, 1992, p. 32). Throughout the 19th century, the Boott Mill transformed the region from an agrarian settlement to a booming industrial zone employing thousands of workers. Initially, labourers were drawn from surrounding farm communities: primarily young women who could be spared from farm work to take paid employment in town. These young, unchaperoned workers, typically ranging in age from 15 to 25, were obliged to live with relatives or in mill-owned boarding houses managed by older women also employed by the mill (Dublin, 1994). These "mill girls" formed the backbone of labour from the early 1830s to the mid-1850s until waves of Irish immigrants fleeing the Great Famine arrived in droves, eager for work.

Various global crises ensured the continuing influx of other immigrants whose cheap labour benefited the mill while simultaneously undermining efforts to improve labour conditions and causing inter-group tensions. From its origins as a proud "Yankee mill town" in the 1830s, by the 20th century, Lowell had become home to more than 40 different ethnic groups including, "Irish, French Canadians, Greeks, Poles, Italians, Swedes, Portuguese, Armenians, Lithuanians, Jews, [and] Syrians" (Kenngott, 1912; National Park Service, 1999, p. 68) and sustains a host of ethnic enclaves. Like the fabrics being designed and woven in the mill, these groups learned to live and work together and their cultural, linguistic and traditional influences are now woven into the cultural tapestry of the region and continue to influence it today (Forrant, 2022).

GLOBALISATION AND UNRAVELLING

With access to cheap human labour, and raw materials in the form of cotton planted and picked by African slaves, rapid technological improvements, and a steady demand for textiles at home and abroad, the New England mills boomed profitably for more than a century (Yafa, 2006, 112-113).

Alongside this profitability came social organisation that, among other things, led to unionisation, demands for fair pay and worker protections, government regulations for land and water use, and higher taxation. As technologies improved, outdated machinery required costly updates to maintain productivity. At the same time, post-Civil War opportunities appeared in the Southern States where civic and business advocates offered cheaper and abundant land, labor, and resources without the constraints of high taxes or worker protections. Instead of reinvesting in the older New England mills, capitalists sent their money south and the mills went into steep decline (Gross, 2000).

As great swaths of humanity flooded into America from war- and famine-ravaged regions around the world, a steady state of decline had descended on the mill operations of Lowell. World War I brought a short uptick of productivity but was soon followed by closures in the 1920s. The American stock market crash of 1929 and the decade-long Great Depression exacerbated the situation further. Another blip of productivity occurred as mill operations shifted to support the demand for fabric and munitions during World War II but again fell

off severely until the Boott Mill finally closed its doors in 1955 (ibid.).
As with other communities where industry falters, the mill monopoly seemed to be a death sentence for Lowell and many families left the area in search of economic opportunities elsewhere (Blewett, 1982; 1990). The mills and associated buildings were closed and fell into disrepair or were knocked down to make way for modern projects (ibid.).

THE NATIONAL PARK SERVICE AND THE BOOTT MILL

At approximately the same time the Boott Mill was in its heyday, the United States was enriching and diversifying its national identity through a series of environmental and social initiatives. Among these was the creation of a National Parks system distinguished by the idea that land should be set aside for the enjoyment and benefit of the public, as well as for the preservation of its natural beauty and wildlife. America's first national park was formed in the state of California when American president Ulysses S. Grant signed the Yellowstone National Park Protection Act on March 1, 1872 (Dilsaver, 2016).
President Theodore Roosevelt in particular, was instrumental in promoting such efforts and even expanded the scope of protected lands through the Antiquities Act of 1906, which allowed presidents to designate national monuments (Lee, 1971).
The National Park Service (NPS) was officially established in 1916 with the passage of the Organic Act, signed into law by President Woodrow Wilson (Library of Congress, N.D.). This act created a single federal agency responsible for managing all national parks and monuments, ensuring their protection for future generations.
Key milestones in the service's history include the expansion of protected lands during the New Deal era, the environmental movement of the 1960s, and the addition of diverse sites that reflect the cultural and historical heritage of the United States, such as civil rights monuments and Native American heritage sites. Through the years, the system expanded to include not only parks but also national seashores, lakeshores, recreation areas, and historic sites (Butcher, 1969). The 1960s and 1970s saw further growth in the system, as public awareness of environmental issues increased, and new laws such as the National Historic Preservation Act and the Wilderness Act were established to protect cultural and natural resources (Harmon & Conard, 2016). Today national historic sites, national monuments, and urban parks are integral components of the U.S. National Park System (NPS) that extend the scope beyond traditional wilderness parks. Although their primary focus differs—cultural preservation, natural protection, or urban recreation—they all contribute to the overarching mission of the NPS to conserve resources for public enjoyment, education, and inspiration. They allow the NPS to reach more people in varied environments, from rural areas to bustling cities, while safeguarding the country's natural, cultural, and historical legacy. They also generate a considerable amount of socio-economic value and inform America's national self-image (Soukup & Machlis, 2021). [1]
The early national parks primarily provided opportunities for access only for those with greater means with a social or cultural proclivity for nature and wild places. The recent development of the National Park System with units in the vicinity of cities and in recreationally popular places has broadened those opportunities for access and thereby broadened the audience for and constituency of national parks. It is particularly important that all Americans benefit from the social covenant that national parks represent (2021, p. 589).
At the very point Lowell and its mills were in sharpest decline, the National Park System provided an opportunity to recognise the important social and economic contributions that the fibre culture of the region had made to the fabric of American and global society. During the 1960s, a group of Lowell community members and civic leaders, like their visionary forebear Kirk Boott, sought an integrated approach to both honour the town's manufacturing and cultural legacy while revitalising the town and restoring pride in the region. One idea was a proposal to have the industrial mill site recognised

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as a site of national historic significance by the National Park Service. This idea was developed and refined until, in 1978 it was recognised by Congress through the establishment of the Lowell National Historical Park and the Lowell Historic Preservation Commission (Forrant, 2022).
After improvements on a few downtown buildings, the "movement quickly gained momentum, benefiting from a new public appreciation for industrial architecture and a belated realization that preservation should embrace working class history and culture" as well as the natural environment (National Park Service, 1992, p. 88).
The landmark decision to convert the old Lowell mill created the opportunity to revitalise socio-economic opportunities and restore civic pride by recognising the important role it had played in the industrial revolution and of New England culture. It also honoured the contributions of the rural labourers, women, and new immigrants in the creation of American labour laws and social welfare initiatives, and promoted Lowell's place as an important player in the planetary flow of fibre's influence.

CONTRIBUTIONS TO REGIONAL REVITALIZATION

Today, the weaving room full of looms within the Boott Cotton Mills Museum within Lowell National Historical Park operates solely to give visitors insights into the region's past. Visitors can witness power looms and other historic machinery, operating much as they did in the 19th century, allowing visitors to see and hear the machines in action and gain a sense of what it must have been like to work in the mills. There are numerous exhibits highlighting the role of the 'mill girls' and later immigrant workers that include historical artifacts, personal stories, and photographs that lend a human side to the American Industrial Revolution, labor history, and the social and cultural transformations that took place in Lowell.
Guided tours of the historic textile mills, canals, and worker housing are available and park rangers lead educational programs, offer workshops and give demonstrations that focus on historic crafts, such as design, weaving, and other trades connected to Lowell's industrial past. Young visitors can participate in the Junior Ranger program, which encourages children to explore the park, learn about its history, and complete activities that earn them a Junior Ranger badge. There are also summer camps, internships, and service-learning opportunities (National Park Service, 2024a)
The park has opportunities for virtual learning experiences as well. Anyone interested in Lowell's history but unable to visit in person can engage via virtual field trips, ranger talks, and webinars. Collaboration with local universities, such as the University of Massachusetts Lowell, allow for ongoing research opportunities that inevitably inform educational materials including brochures, maps, self-guided tour guides, publications and research reports, and a variety of public programming. Teachers and scholars can access a wealth of online materials through the park's website, including lesson plans, primary source documents, and interactive media related to the industrial history of Lowell (ibid.).
Additionally, the park hosts annual events recognising and celebrating the diverse cultural heritage of Lowell, including music festivals, ethnic celebrations, and special historical reenactments. For example, during the summer of 2024, the museum hosted a photographic exhibit about the contributions of Portuguese immigrants to the life and culture of the mills and Lowell society.
The state of Massachusetts is home to sixteen national parks. Six of these are National Historic Parks and the remainder are a combination of scenic trails, historic sites, recreation areas, and seashores (National Park Service, 2024b). According to the most recent aggregate data, these sites are host to nearly eight million visitors annually and generate more than a billion US dollars in what the National Park Service refers to as Economic Benefit from National Park Tourism (ibid., 2024c). These benefits include visitor spending, job creation, and secondary effects from labour income, as well as economic output to the national economy and relative value added. In the five year period from 2019 to 2023, the Lowell Historic Park hosted more than one million visitors (ibid.).
In addition to enjoying the park's resources, those people parked, ate, shopped, and stayed in the region creating value for the businesses and communities in the area surrounding the park. The visitors were also engaged with local businesses, park employees, and various services. Admission to the Boott Cotton Mill Museum is $6 USD for adults and $3 for student and seniors. Despite a lack of specific data on visitor demographics we can assume more than five million dollars was

generated in museum entry fees alone. If visitors also paid for a canal tour (Adults $12, seniors $10, youth/students $8), the number is closer to fifty million. Any purchases at the park store, local eateries, or accommodation stays increase that number further while also generating business and employment opportunities for local people. Even with such cursory data, it is clear the national park designation ensures a continuation of economic opportunity associated with the mills that would not otherwise be present after the closing of the mills for textile production.

The rich array of historical, cultural and educational resources the park contains ensures the mills still shape regional identity and make a critical contribution to the socio-economic revitalisation of the region. Heritage tourism based on fashion, design and textile manufacturing now creates economic opportunities for residents, myriad opportunities for community engagement and partnerships with local organisations, while also educating the public about the material, social and economic contributions of textile mills in Massachusetts.

BROADER IMPLICATIONS

Research by Wayland Barber (1994), St. Clair (2019) and Postrel (2021), demonstrate that tremendous influence of fibre and textiles in shaping culture and civilization. The New England cotton mills have a small role within this global textile history. The evolution of the Boott Cotton Mills in Lowell, Massachusetts therefore offers an intriguing interdisciplinary case study for analysing the industrial, socio-economic, and cultural effects of textiles, as well peripheral perspective for fashion and design studies.

For example, as the mills produced and made standard fabrics more accessible to wider populations, designers could create garments for broader audiences, setting the stage for the rise of ready-to-wear fashion in the late 19th and early 20th centuries. The Boott museum displays a variety of the plain and patterned textiles they produced that reflected both consumer demand and evolving aesthetic trends. Advances in machinery allowed for more intricate designs that could be produced in step with changing tastes in clothing and interior textiles as well as seasonal fashion cycles, underscoring the growing link between manufacturing schedules and consumer fashion trends. Furthermore, while mechanization enabled mass production, traditional craftsmanship and artisanal methods continued to influence the development of more specialized and intricate textiles such as tweeds and calicoes that reflected global designs and fed the demands of haute couture. The Boott Cotton Mill and its transformation into a National Historic Park is a fascinating example offering multifaceted insights into New England's relationship with fibre, fashion and design, and the role that fibre textiles played in bringing the world to America's doorstep and vice versa. Cotton fibres were central to the industrialization and social transformation of New England. The textile mills that processed the cotton brought significant economic growth and transformed the social dynamics within these industrial communities, first by their reliance on women and later on immigrant labour pools. They also urbanised rural areas and linked local New England and American economies with global trade and migratory networks. When cotton production diminished due to changes in global manufacturing and trade, the community stagnated.

The innovative collaboration that transitioned the Boott Cotton Mill into a National Historic Park underscores the potential of preserving historical industrial sites as cultural and educational resources that can also improve economic opportunities. The Mill and museum displays bridge several fields of research (e.g., history, socio-economics, fashion and design, and cultural studies) by showcasing period textiles and machinery, historical garment construction as well as the evolution of textile design and related technologies. For example, one museum display highlights the journey of fabric and design from natural fibres for clothing to synthetic materials used in space travel and medicine. The displays also showcase the mill's role in shaping cultural and economic landscapes related to fashion and design by highlighting the tensions of an industry reliant on workers desperate enough to put up with difficult, dangerous working conditions, low wages and limited rights; namely, women, immigrants and racial minorities. While acknowledging the unpleasant realities of exploitative labour practices, the Historic Park and Museum site also celebrates the richness of culture these groups brought to the region and creates current opportunities for inclusion and cooperation. By maintaining a tangible connection to the past and fostering opportunities for educational and economic development in the

present, the Boot Cotton Mill acts as a valuable example of the potential for historical narratives about fashion and design within the textile industry, to restore, enhance and generate civic pride in a region.

This example of the Boott Cotton Mill and its transformation into a National Historic Park opens up several avenues for future research on the contribution and consequences of fibre manufacturing and other industries for educational, tourism and policy issues. For example, comparative analyses of similar industrial heritage sites, both within the United States and internationally could explore how different regions preserve and interpret their industrial pasts and the varying impacts on local economies and communities.

The innovative approaches taken for preserving and disseminating the resources at the Boott Cotton Mill Museum provides insights into the role that modern technologies might play. For example, investigating the role of digital technologies, such as virtual reality and digital archives, in enhancing the accessibility and engagement of industrial heritage sites could be a valuable area of study. This includes exploring how these technologies can be used to preserve and interpret historical narratives for broader audiences.

Other research might build on this study to delve deeper into the socio-economic impacts of heritage tourism on local communities, focusing on job creation, economic revitalization, and cultural preservation. This includes evaluating the effectiveness of public engagement strategies used by heritage sites. For example, by engaging local communities in research about their industrial heritage richer, more nuanced insights may be found. This approach could include oral histories, collaborative exhibitions, and community-led conservation efforts.

The Lowell National Historic Park resources and educational programming suggests a rich opportunity for community-engaged and integrated learning, from primary education through to higher education, on the history and ethics of fibre textile production and aspects of the fashion industry's influence on culture and society. This includes opportunities to develop relevant teaching materials that engage students with historical and contemporary issues. Furthermore, public engagement with these sites through interactive exhibits, public lectures, and community workshops can enhance historical and current understanding related to fibres, fabric, and the global fashion industry

Finally, the Lowell story creates interesting opportunities for other studies that could provide policy recommendations for the conservation and public or touristic use of industrial heritage sites. This includes exploring funding mechanisms, legal frameworks, and best practices for balancing preservation with social and economic development.

The potential for future research related to this preliminary study are broad and interdisciplinary, and bring opportunities to deepen understanding of the historical, cultural, and economic, dimensions of fibres and textile production. These insights can inform heritage conservation, educational initiatives, and policy development related to tourism, among other things.

CONCLUSIONS

This paper contributes to theoretical discussions on the agency of fabric, particularly cotton fibres and the fashions they produced, in shaping historical and cultural narratives. It treats fibre not merely as a commodity but as a material with its own history, culture and influence, enriching our understanding of how everyday materials affect human life and society. This case analysis highlights the role of the Boott Cotton Mill in constructing cultural identity within the region. By preserving and interpreting the history of the mill, we see how industrial heritage sites can serve as symbols of shared history and civic pride, influencing both regional and national identities and spurring innovations that can create new socio-economic. Additionally, we gain insights into the importance of public engagement with historical sites that may allow communities to reflect on their past and itsimplications for the present and future. This process can thereby foster a deeper appreciation for the material and immaterial heritage associated with fibres, and textiles, fashion and design, while sustaining viability in the post-industrial economy.

REFERENCES

Blewett, M. H. (1982). Surviving hard times: The working people of Lowell. Lowell Museum.

--. (1990). The last generation: Work and life in the textile mills of Lowell, Massachusetts, 1910-1960. University of Massachusetts Press.

Butcher, D. (1969). Exploring our national parks and monuments (6th ed., rev.). Houghton Mifflin.

Library of Congress. (n.d.). Brief history of the national parks. National Parks Maps Collection.

Retrieved October 27, 2024, from https://www.loc.gov/collections/national-parks-maps/articles-and-essays/brief-history-of-the-national-parks/

National Park Service. (1992). Lowell: The story of an industrial city (National Park Service Handbook No. 140). U.S. Department of the Interior. Available online at https://www.nps.gov/lowe/learn/photosmultimedia/waltham_lowell.htm

--. (1999). The Waltham-Lowell System and Boston Associates. Retrieved July 11, 2024, from https://www.nps.gov/lowe/learn/photosmultimedia/waltham_lowell.htm

--. (2024a). For kids. Retrieved October 10, 2024, from https://www.nps.gov/lowe/planyourvisit/justforkids.htm

--. (2024b). Massachusetts – List view. Retrieved August 19, 2024, from https://www.nps.gov/state/ma/list.htm?program=all

--. (2024c). Visitor spending effects: Economic contributions of national park visitor spending. Retrieved August 19, 2024, from https://www.nps.gov/subjects/socialscience/vse.htm

Dilsaver, L. M. (Ed.). (2016). America's national park system: The critical documents (2nd ed.). Lanham, MD: Rowman & Littlefield Publishers.

Dublin, T. (1994). Women at work: The transformation of work and community in Lowell, Massachusetts, 1826-1860. Columbia University Press.

Forrant, R. (2022). The Rise, Fall and Resurrection of Lowell, Massachusetts. Historical Journal of Massachusetts, 50(1–2), 106–XII.

Gross, L. F. (2000). The course of industrial decline: The Boott Cotton Mills of Lowell, Massachusetts, 1835-1955. Johns Hopkins University Press.

Harmon, D., & Conard, R. (2016). The Evolution of the National Park Service: A Hundred Years of Changing Ideas. The George Wright Forum, 33(2), 230–251. http://www.jstor.org/stable/44131255

Kenngott, G. (1912). The record of a city: A social survey of Lowell, Massachusetts. New York: Macmillan Co.

Lee, R. F. (1971). The Antiquities Act of 1906. Washington, D.C.: National Park Service.

Mullin, J. R., & Kotval, Z. (2021). Towards the creation of model mill cities in New England: the planning contributions of the Boston manufacturing company in Waltham, Massachusetts. Planning Perspectives, 36(3), 609–616. https://doi.org/10.1080/02665433.2021.1873171

Postrel, V. (2021). The fabric of civilization: How textiles made the world. Basic Books.

Stanton, C. (2006). The Lowell experiment: Public history in a postindustrial city. Amherst, MA: University of Massachusetts Press.

St. Clair, K. (2019). The golden thread: How fabric changed history. Viking.

Soukup, M. A., & Machlis, G. E. (2021). National parks as American covenants. Parks Stewardship Forum, 37(3), 585–591.

Wayland Barber, E. (1994). Women's work: The first 20,000 years. W. W. Norton & Company.

Yafa, S. (2006). Cotton: The biography of a revolutionary fiber (pp. 112-113). New York: Penguin Books.

FROM SHEEP TO SHELF

A CASE STUDY ON CIRCULARITY AND VALUE-SHARING IN AUSTRALIAN WOOL'S GLOBAL VALUE CHAIN

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Abstract

Wool, as a natural and renewable fibre, embodies the core principles of a circular economy through its durability, biodegradability, recyclability into value-added products, extending its utility. Unlike many textiles that were produced locally, wool has been part of a global supply chain since the Middle Ages, spanning large-scale farming and cloth production across different regions. Despite its historical significance, wool now represents just 1% of total fibre production, with demand steadily decreasing due to compounded factors, including criticism over animal welfare and negative environmental assessments. This paper uses Timothy Morton's (2013) concept of hyperobjects, alongside animal ethics and environmental sustainability, to explore wool as a material and cultural fibre embodying vast, interconnected processes across time and space, bridging agriculture, manufacturing and design. It presents the case of M.J. Bale, an Australian menswear brand, and global partners including a Tasmanian grower, Italian spinners and weavers, and Japanese tailors. In Australia, wool's rich cultural heritage is tied to the nation's history and economy, yet the country retains little manufacturing. The paper advocates for value-shoring, a partial deglobalisation approach where supply chain partnerships are based on shared environmental, ethical, and social values.

Keywords: *Wool; Hyperobjects; Animal ethics; Australia; Value-shoring*

INTRODUCTION AND RESEARCH ISSUE

Wool production has existed for millennia: first as local, household production, and with the growth of cities and population in the Middle Ages, as the product of large-scale farming and manufacturing practice across Europe, from the Mediterranean to England (Power 1941). The production of wool involves numerous actors and processes for breeding, grazing, shearing, washing, spinning and weaving, with the fibre stretching across many geographical and cultural contexts. Sheep are key agents in this process, as producers of wool and part of a larger ecosystem as their grazing patterns and interaction with the environment impact the land and ecosystems they inhabit. As such, wool is a natural and renewable fibre that straddles between two industries, the agricultural and the cultural through fashion and textiles, embedding material and immaterial values. As an agricultural industry, it embeds material values related to husbandry maintenance and the environment, and immaterial values related to animal ethics (Ferrero-Regis 2020). As part of the fashion industry, wool embeds both material values through processing, manufacturing, and immaterial values through designing according to styles and trends (Ferrero-Regis 2020). As a fibre, wool inherently supports the principles of a circular economy through its durability, biodegradability and recyclability. However, it is crucial to note that being a circular fibre does not equate to sustainability, as each state of production

must be critically examined. As Segre-Reinach (2022) points out, the living animal often disappears from view during the fashion production process but resurfaces in both the physical material and the symbolic meaning of the final product.

In this article, 'wool' specifically refers to Merino wool, which is predominately produced and exported by Australia. Wool holds a significant cultural and economic place in Australia's history, once serving as the country's primary fibre until the 1950s when it was gradually overtaken by synthetic fibres like nylon and polyester, as well as natural fibres like cotton (Ferrero-Regis, 2020). Globally, demand for woollen garments has gradually diminished due also to volatile trading patterns. Wool currently accounts for only 1% of the world's global fibre market (Textile Exchange 2023). Despite this, Australia remains the largest exporter of Merino wool, accounting for 80% of global supply, while experiencing a significant decline in its domestic manufacturing capabilities, with much of the processing shifting to China (Australian Wool Innovation Limited, n.d.). A Deloitte (2024) feasibility report suggests that relocating portions of the wool supply chain back to Australia is only viable with substantial government and private investment. Australian Merino wool is highly regarded for its quality, with finer fibres below 18.5 microns that are soft and suitable for high-end fashion, while coarser wool is typically used for more robust products like carpets or blankets. The premium nature of Merino wool contrasts with fibres like cotton, which, despite having a larger market share, generally occupies a lower price bracket in the global market.

This paper investigates wool as both a material and immaterial fibre, whose manufacturing process has been connected to cultural practices across the planet for a long time. Through the case study of the Australian wool brand, M.J. Bale, this paper examines the brand's leadership in wool and its commitment to responsibility, provenance and circularity, achieved through a collaborative network involving Tasmanian growers, Italian spinners and weavers and Japanese tailors. The paper argues for 'value-shoring', a process of partial deglobalisation and supply chain shortening that favours collaboration between companies with shared environmental, ethical and social values. Timothy Morton's (2013) idea of hyperobjects supports this paper's analysis of wool's position as an object dispersed in space and time, from farm through to in its final form as a designed and manufactured object as a fashion product on the shelf.

METHOD

This paper adopts a value chain methodological approach to investigate the complex processes involved in wool production, presenting a case study of the Australian menswear brand M.J. Bale, and its collaboration with Simon Cameron and Vitale Barberis Canonico (VBC). The study builds on fieldwork conducted in Tasmania in 2018 with Cameron, owner of Kingston Wool Farm and the prior research and publications of lead author. It expands on this foundation with further research, including an interview conducted by both authors with M.J. Bale's Sustainability Manager, Athena Savvas, in 2024. The interview focused on how value-shoring supports the brand's transition towards a circular economy. Field work, interviews and publicly available reports from the fashion industry government and non-government organisations, enabled cross-checking of sustainability and animal ethics information and claims on the businesses' websites.

THEORETICAL FRAMEWORK

Wool's production is a process that spans years, from the breeding of sheep to the final product, and its supply chain is extensive, from wool farming in different regions of the planet, stretching from India, to South Africa, South America, China, Australia and New Zealand, to the long process leading to a clean wool fibre and spinning and weaving (fig. 01). This wool is a material that embodies vast, interconnected processes across time and space. Morton's (2013) concept of hyperobjects, alongside animal ethics and environmental sustainability supports the theoretical framework and the findings of this paper. According to Morton (2013), hyperobjects are entities so massively distributed across time and space that they transcend local contexts and are difficult for humans to fully comprehend. Morton's (2013) framework is particularly relevant to understanding wool's position in the textile global value chain. Although Morton (2013) does not expand on animals as part of hyperobjects' systems, he does consider planetary flows and human interventions. By conceptualising wool through Morton's (2013) hyperobjects framework, this study

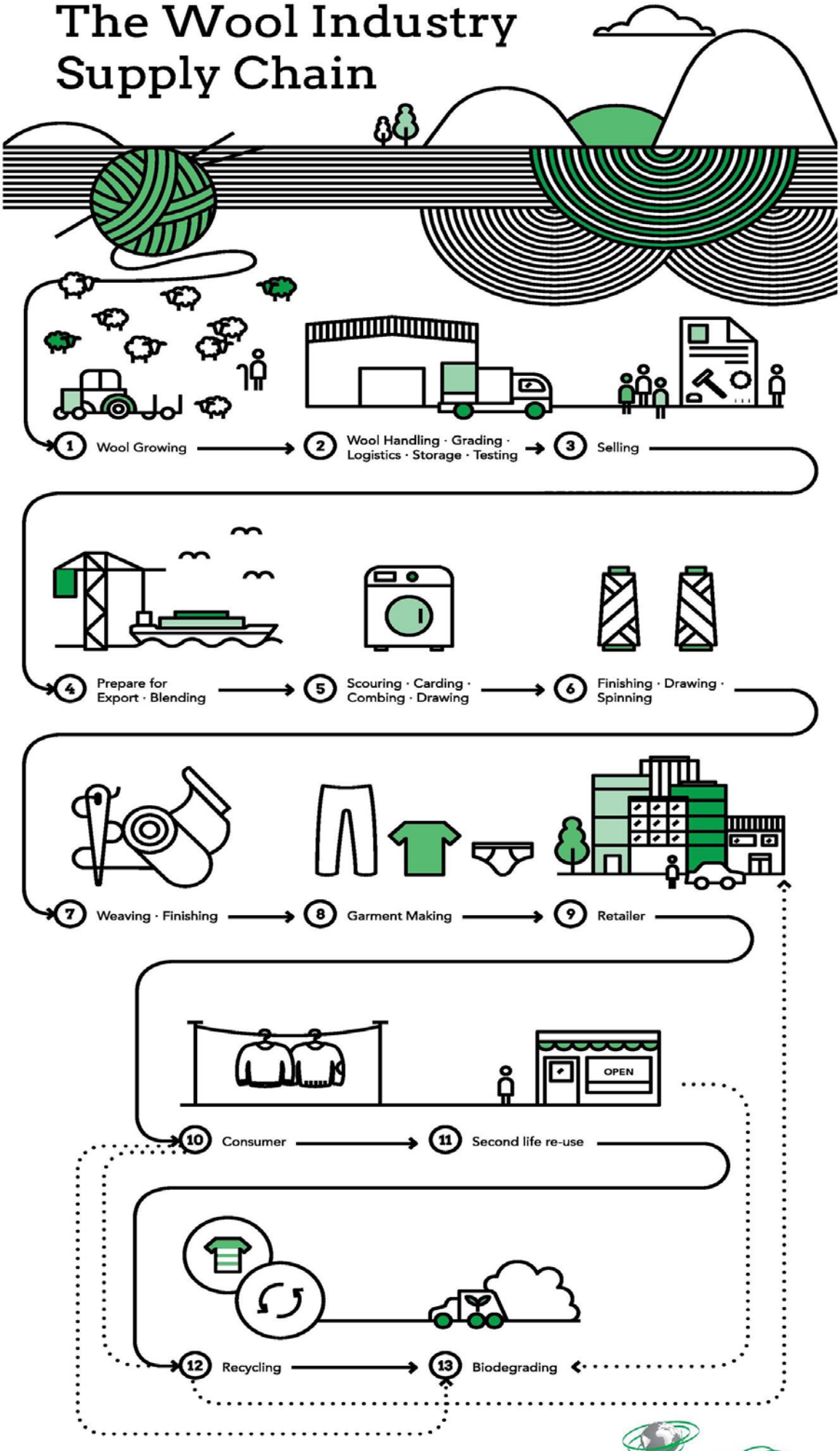
The Wool Industry
Supply Chain
1 Wool Growing
2 Wool Handling · Grading · Logistics · Storage · Testing
3 Selling
4 Prepare for Export · Blending
5 Scouring · Carding · Combing · Drawing
6 Finishing · Drawing · Spinning
7 Weaving · Finishing
8 Garment Making
9 Retailer
OPEN
10 Consumer
11 Second life re-use
12 Recycling
13 Biodegrading

Fig. 01

capture the object's inherent complexity.
The collaboration between M.J. Bale, Italian spinners and weavers, and Japanese and Chinese tailors in the creation of the Kingston Line, redefines wool's global value chain by focussing on environmental and ethical values, challenging the traditionally economy-driven distribution of materials and practices across geographies that form hyperobjects. This value-shoring, also akin to friend-shoring (Attinasi et al 2023), can include sourcing materials from farmers known for their low-impact grazing, humane treatment of sheep or practicing regenerative agriculture; working with manufacturers who specialise in processing fine wool; and preserving traditional localised practices in tailoring. However, while companies may share similar values, this alignment does not inherently increase sustainability or ethical practices in the value chain as other companies in the supply chain may tend to continue to prioritise traditional approaches and cost-efficiency and mass production. Instead, a value-shoring approach focuses on creating value through ethical and sustainable practices, which is built on each actor's engagement with the environment, ethics, circularity and re-establishment of locality and heritage. This case study also examines the limitations of this approach, particularly in the context of global pressures and the complexities of the wool supply chain. In this context, the term 'supply chain' is used to describes the general linear movement of goods from raw material to final product, while 'value chain' refers to discrete chains and their value-add processes and stakeholder interactions.

ETHICAL DIMENSION OF WOOL PRODUCTION

Sheep, described as a "key animal in the history of farming" (Morehead, 2014, p. 1), hold a significant and long-standing role in human culture. The wool industry involves a diverse range of actors—producers, manufacturers, and consumers—all contributing to the complex processes that shape wool as a commodity (Pawson & Perkins, 2013). Human labour, especially in rural communities, plays an essential role throughout the wool lifecycle, from selective breeding and sheep care to the labour-intensive practice of shearing. These traditions, deeply rooted in cultural history, reflect the evolving human-sheep relationship in wool production and highlight emerging conversations on posthumanism and post-anthropocentrism (Braidotti, 2013). This shift raises critical ethical questions about the treatment of sheep and human responsibilities toward these sentient beings, urging a rethinking of human-animal relationships within the wool industry, particularly in the context of sustainability and circularity.
Since the release of Peter Singer's (2015) *Animal Liberation* nearly 50 years ago, the distinctions between human and non-human, particularly animals, have become blurred, prompting a revaluation of the forms of agency, and compelling the fashion industry to acknowledge the importance of animal welfare. Over the past decade, a shift in fashion studies towards ethics, inequalities and decoloniality has culminated in the emergence of a strong ethical and political orientation of critical fashion studies in the early 2020s (Segre-Reinach 2022). This shift towards integrating animals into complex system thinking has introduced new challenges, questions, possibilities and resolutions within the wool industry. The intersection of posthumanism and critical fashion studies has prompted organisations like PETA to advocate for animal liberation, particularly raising awareness about animal abuse in the fashion industry. Wool is often cited as a problematic animal-derived product as it is not 'natural' due to selective breeding. This refers to the Australian Merino sheep as the result of crossbreeding, initiated from Iberian Merinos, and continuing from the end of 1700s when the Merino sheep was imported to the country (Woolmark Company, n.d.). The effect of crossbreeding has led to high-quality wool production for economic gain, however this genetic mark-up is now engendered in the animal, which must be shorn regularly to prevent death. Because of its high genetic diversity, there may be the possibility to breed the Merino sheep back to a century ago (Kijas et al 2012). However, it would be impossible to re-wild a sheep that has moved places since the Neolithic.

ENVIRONMENTAL DIMENSION OF WOOL PRODUCTION

Wool's complex global value chain from farming to retail and disposal means the fibre's environmental footprint, such as greenhouse gas emissions from sheep and land degradation, extends far beyond the immediate act of producing and consuming wool. Wiedemann et al. (2020) found that the highest emissions come from wool fibre production,

followed by processing greasy wool which requires significant energy, and garment care. Consequently, the environmental impacts of wool occur globally and often in unpredictable ways.

Lifecycle Assessments (LCAs) are commonly used in sustainability reporting to compare the environmental impacts of different fibres. For example, Circumfauna (n.d.), an initiative by Collective Fashion Justice, compared the carbon emissions of Australian wool and cotton, finding that an Australian wool knit sweater emits approximately 27 times more greenhouse gases than a cotton knit sweater. Recent claims from PETA (Collective Fashion Justice, n.d.) and the Higg Index suggest that wool has the third-highest climate impact of any material, after silk and alpaca wool. However, the Higg Index, developed by the Sustainable Apparel Coalition (SAC), has been challenged for its governance and methodology (Tabuchi, 2022). Notably, the Higg Index is supported by major brands that heavily rely on polyester and oil-derived fibres and critics argue that polyester is represented as having a lower environmental impact (Deeley, 2022). The Higg Index has been rejected by companies such as Kering, Adidas, and the Norway Consumer Authority (Kent, 2022), and criticised for only measuring impacts from cradle to factory gate, neglecting waste pollution at the end of a garment's life and failing to account for wool's biodegradability post-consumer use (Laitala et al, Klepp & Henry, 2018).

While LCAs offer valuable insights, they can be misleading if they do not consider end-of-life impacts. For example, the Woolmark Company's Global Wardrobe Study (2018) found that wool garments last over 50% longer on average than cotton garments, stressing the importance of including the use phase in LCA studies. The environmental impact of woollen garments is significantly influenced by their frequency and duration of use i.e. increasing wear from 109 to 400 times can reduce impact by up to 68% (Wiedemann et al., 2021). Additionally, the International Wool Textile Organisation (2020) highlights that wool has been "readily recyclable" for over 200 years, with fibres often being mechanically shredded and respun into new yarns or for industrial uses like insulation. However, academic focus on upcycling wool waste into new textiles or garments is emerging (Martin & Herlaar, 2021; Surjit, 2024; Wiedemann et al., 2022). While wool's environmental impact is significant and complex, a holistic assessment that accounts for its full lifecycle, including biodegradability and garment longevity, is crucial to gain a more accurate and holistic understanding of its impact.

CASE STUDY

This case study follows M.J. Bale's value chain: from fibre producers to manufacturers to consumers. Founded in 2009 by Matt Jensen, M.J. Bale specialises in high-quality menswear, covering a wide range of styles, including formal wear, business attire, casual wear and accessories. M.J. Bale is particularly known for their tailored suits which use premium materials, such as merino wool, and offers ready-made and bespoke tailoring options. The brand's sustainability strategy is rooted in its commitment to natural fibres and their provenance. According to Athena Savvas, M.J. Bale's Sustainability Manager (personal communication, August 10, 2024), over 90% of the brand's materials are derived from natural sources, including single-source wool, cotton and linen, with synthetic fibres being minimal and primarily used for functional purposes such as stretch in chinos and recycled nylon in swimwear.

FIBRE PRODUCTION

M.J. Bale sources wool from farmers who view themselves as "land custodians, the carers of their lands and their animals" (A. Savvas, personal communication, August 10, 2024). In 2016, M.J. Bale partnered with Cameron, owner of Kingston Wool Farm in Tasmania's Midlands. The Cameron's family has managed Kingston since 1821, with current land extension dating back to 1905 (S. Cameron, personal communication, April, 16, 2018). Kingston wool is renowned for its superfine quality, with fibres ranging from 13.5 and 16 mm microns (fig. 02), and its long staple length. The farm's 3,000-hectare property is partially preserved in a pre-colonial state, serving as a biodiversity hotspot with 8% of Tasmania's endangered plant species (S. Cameron, personal communication, April, 16, 2018). Ethical land management practices at Kingston include limited sheep numbers and rotation between pastures which follows self-herding or self-shepherding practices (Massy 2017) as well as reducing the need for mulesing, which Cameron stopped around 2008, and chemical fertilisers (S. Cameron, personal communication, April 16, 2018). Savvas noted the sheep with the highest quality wool are those left out to graze,

Fig. 02

adding that shearing benefits the sheep, preventing the wool from becoming matted and dirty, and seasonal shearing ensures the sheep have more warmth during the winter months (A. Savvas, personal communication, August 10, 2024). Sheep at Kingston Wool Farm are managed with an emphasis on their well-being, following the Five Freedoms principles of animal welfare—freedoms from hunger, discomfort, pain, fear and distress—developed from the Brundell Report in 1965 and adopted by the World Organisation for Animal Health (WOAH) in the "Terrestrial Animal Health Code" (WOAH 2024). These principles have evolved into the Five Domains of animal welfare (Mellor & Burns, 2020).The focus on sheep welfare at Kingston aligns with M.J. Bale's values and contributes to the production of ethical wool.

TEXTILE AND GARMENT PRODUCTION

M J. Bale sources exclusively Australian wool for its garments, Savvas explained: "it's purchased through the usual kind of process. We work back with our fabric suppliers to be able to do that. And we work with several others of a similar calibre of VBC, particularly in Italy, to provide us with high quality fabrics" (A. Savvas, personal communication, August 10, 2024). Vitale Barberis Canonico (VBC) is a wool mill that has been in operation since 1663, and is an important node in the manufacturing of M.J. Bales' garments. Still in the hands of the original family, VBC oversees all phases of wool processing, from washing to weaving and finishing. Kingston, one of the 3,000 farmsteads supplying wool to VBC, is part of a broader network of wool producers located in Australia, New Zealand, South Africa, China, Argentina and Uruguay. VBC demonstrates its commitment to sustainability through sourcing from farms with strict animal welfare practices, transparent supply chain information via digital passports and a waste management system that recycles or partially recovers 97% of textile waste (Vitale Barberis Canonico 2023, 2024). In terms of garment manufacturing, M.J. Bale's suppliers are located in countries like China and Japan and "reuse off cuts in their local economies to reduce waste and operational costs" (A. Savvas, personal communication, August 10, 2024). In Japan, M.J. Bale suits are manufactured by the tailors in the Iwate prefecture known for its heritage tailoring. These shared values and coordinated efforts not only enhance product quality, but facilitate collective action in addressing key challenges such as waste reduction, animal welfare and resource efficiency.

CONSUMER ENGAGEMENT

M.J. Bale's circularity strategy focuses on extending garments lifecycles, recognising that "in circularity, there is no one solution" (A. Savvas, personal communication, August 10, 2024). Savvas noted that previously, the brand's responsibility ended at the point of sale (A. Savvas, personal communication, August 10, 2024). However, as the brand's sustainability strategy evolved, M.J. Bale recognised the need to extend its responsibility: "we just had our 15th birthday. You know, the truth of that matter is, it means that there are probably garments that have the M.J. Bale logo on it that are no longer being worn" (A. Savvas, personal communication, August 10, 2024).

The ReBale initiative is a key component of this strategy, accepting all wool garments, regardless of condition, for either recycling or repurposing. Returned garments are assessed and categorised into "wearable" and "unwearable" (A. Savvas,

personal communication, August 10, 2024). Wearable items are considered for donation or resale through charity partnerships, while unwearable items are sent to partners like UPPAREL in Melbourne to be downcycled. Savvas highlights the practical considerations of this approach:

"It would be very hard to think about trying to collect all our jumpers here, just to send them back to Italy, just to get them back here again. So it's trying to explore what is also the least impactful way of being able to put our garments into more of a circular loop" (A. Savvas, personal communication, August 10, 2024). This program reflects the brand's recognition of its ongoing responsibility for its products: "with ReBale, we've decided to accept all M.J. Bale products ever purchased with our label on it, coming back to the idea that it has our logo on it, and so therefore it's our responsibility" (A. Savvas, personal communication, August 10, 2024). Consumers are incentivised to return their wool garments via loyalty points. Savvas acknowledged "there are challenges of caring for men's suits, including sizing changes and repair difficulties", and emphasised the importance of educating consumers on garment care (A. Savvas, personal Despite wool's recyclability, Australia lacks skills and infrastructure to fully capitalise on these opportunities. Current limitations in machinery and trained personnel pose challenges to scaling up these efforts: "scale is necessary for textile recycling, with one machine or training people not enough" (A. Savvas, personal communication, August 10, 2024). Deconstruction and repurposing old clothing were mentioned as a "potential for redesigning and reusing materials, but [there are] limited skills in Australia to do this" (A. Savvas, personal communication, August 10, 2024). This gap in the value chain represents a significant challenge for advancing circularity in the Australian fashion industry.

DISCUSSION

M.J. Bale's collaboration with Kingston Farm in Australia and Italian mill, VBC, highlights the importance of value-shoring through the shortening of value chains founded on shared values of heritage, ethical production and traceability. Despite the global nature of this value chain, M.J. Bale's emphasis on single-origin wool and local connections anchor the production process in shared values of provenance, craftsmanship and care for the environment. Kingston Farm, which has been family-owned and operated since 1821, exemplifies how heritage and local knowledge contribute to sustainable wool production. Similarly, VBC's presence in the Biella district, where wool processing has deep roots dating back 360 years, reflects the importance of place and tradition in creating high-quality products.

The complex value chain of wool - produced in Australia, processed in Italy, and tailored in Japan or China – carries ethical and environmental considerations at each step. This collaboration prioritises locality, traceability and animal welfare, addressing the normally obscured totality of wool as a hyperobject (Morton, 2013). In other words, these shared values allow the three companies to collaborate on sustainability goals even though they operate in different geographical locations to reduce the time space of wool as a hyperobject. The collaboration highlights a crucial point: relocating manufacturing to Australia is not always feasible due to the high cost of infrastructure and skills. For example, M.J. Bale benefits from VBC's local knowledge, craftsmanship, and established recycling systems in the Biella district, which cannot be easily replicated elsewhere. The value of such partnerships lies in recognising the necessity of the global value chain while striving to improve sustainability practices across all nodes. This also aligns with growing demands for accountability in fashion, brings together diverse local practices into a more cohesive and visible global process.

The ReBale initiative marks a move towards closing the loop and extended product responsibility, with M.J. Bale accepting all wool garments for recycling or repurposing. However, the lack of sufficient recycling machinery and trained personnel in Australia has hindered broader adoption of processing practices. Savvas emphasises the need for localised solutions to reduce the environmental impact of using overseas reprocessing infrastructures. Despite the inherent recyclability of wool, the absence of large-scale facilities and trained workers in Australia means that the potential for wool recycling remains largely untapped. Savvas highlighted the need for industry-wide collaboration to build the necessary capabilities to support circularity at scale. These challenges exemplify the complexity of implementing circularity at a systemic level, especially in a globalised industry where wool production and garment manufacturing are deeply global and entangled with historical,

cultural and economic factors.

CONCLUSION

The interactions between humans (farmers, workers, consumers) and non-human elements (sheep, land, climate) within the wool industry-illustrate the entangled relationships that define wool as a hypberobject. Hyperobjects, by their very nature, resist simplification and call for global cooperation to address the issues related to production, trade, ethics and environmental impact. The case study showcases how a collaboration between an Australian wool grower, an Italian mill, Japanese tailors and an Australian fashion brand can establish environmentally conscious practices by promoting biodiversity reconstruction through local knowledge, with due consideration for the well-being of non-humans (animals) at the heart of the complex wool supply chain. M.J. Bale's efforts to engage consumers in circular practices and collaborate with suppliers on waste reduction reflect a commitment to circularity. However, challenges persist in scaling these efforts, particularly in recycling infrastructure and developing robust deconstruction and repurposing capabilities. Wool alone cannot challenge the dominant global textile and garment industry but can highlight the need to care for human and non-human impacts of our clothing. Value-shoring, exemplified by M.J. Bale's long-term partnerships built on trust and shared values, emerges as a collaborative strategy to address the complex challenges of globalised production that individual entities cannot solve alone.

REFERENCES

Attinasi, M.G., Boeckelmann, L. & Meunier, B. (2023). Friend-shoring global value chains, a model-based assessment, ECB Economic Bulletin, 2/2023. https://www.ecb.europa.eu/press/economic-bulletin/focus/2023/html/ecb.ebbox202302_03~d4063f8791.en.html

Australian Wool Innovation Limited (n.d.) Quality wool processing education in China. https://www.wool.com/news-events/news/quality-wool-processing-education-in-china/#:~:text=Most%20Australian%20wool%20is%20processed,technology%20used%20to%20process%20it

Braidotti, R. (2013). The posthuman. Cambridge: Polity Press.

Circumfauna. n.d. Australia is the leading wool exporter, and a leading cotton exporter. So which fibre is more climate friendly? https://circumfauna.org/wool-v-cotton-emissions

Deeley, R. 2022. Dutch, Norwegian Regulators Issue Guidance on Controversial Higg Tool. Business of Fashion, 11 October. https:// www.businessoffashion.com/news/sustainability/dutch-norwegian-regulators-issue-guidance-on-controversial-higg-tool/

Deloitte (2024). Ensuring a sustainable future for Australia's wool supply chain – Phase 2. Wool Producers Australia, 5 February. www.deloitte.com/au/deloitte-access-economics

Ferrero-Regis, T. (2020). From Sheep to Chic: Reframing the Australian Wool Story. Journal of Australian Studies, 44(1), 48–64. https://doi.org/10.1080/14443058.2020.1714694

International Wool Textile Organisation (2020). Recycled Wool. https://iwto.org/wp-content/uploads/2020/04/IWTO_Recycled-Wool.pdf

Kent, S. (2022, November 3). Can Fashion's Favourite Sustainability Standard be Saved? Business of Fashion. https://www.businessoffashion.com/articles/sustainability/sac-higg-index-sustainability-standards-greenwashing/?utm_source=newsletter_dailydigest&utm_medium=email&utm_campaign=Daily_Digest_031122&utm_content=intro

Kijas , J. W., Lenstra, J. A., Hayes, B., Boitard, S., Porto Neto, L. R., San Cristobal, M., Servin, B., McCulloch, R., Whan, V., Gietzen, K., Paiva, S., Barendse, W., Ciani, E. (2012). Genome-wide analysis of the world's sheep breeds reveals high levels of historic mixture and strong recent selection. Plos Biology, 7 February. https://doi.org/10.1371/journal.pbio.1001258

Laitala, K., I.G. Klepp &, H enry, B. K. (2018). Use phase of apparel: A literature review for Life Cycle Assessment with focus on wool, Consumption Research Norway – SIFO, Oslo and Akershus University College of Applied Sciences. DOI: 10.13140/RG.2.2.25769.90729

Martin, M. and & S. Herlaar, S.. (2021). Environmental and social performance of valorizing waste wool for sweater production. Sustainable Production and Consumption, 25, 425-438. doi: https://doi.org/10.1016/j.spc.2020.11.023.

Massy, C. (2017), Call of the reed warbler: A new agriculture, a new Earth. Univeristy of Queensland Press. Mellor, D., & Burns M. (2020). Using the five domains model to develop welfare assessment guidelines for thoroughbred horses in New Zealand. N Z Vet J., 68, 150–6. doi: 10.1080/00480169.2020.1715900

Morehead, Sarah (2014). The Sheep Value Chain and 'Wool Out' Sheepskin as a Sustainable Material. Transition: Re-thinking textiles and surfaces, 26-27 November 2014, Huddersfield.

Morton, T. (2013). Hyperobjects: Philosophy and ecology after the end of the world. University of Minnesota Press.

Pawson, E. and & H. Perkins, H.. (2013). Worlds of wool: Recreating value off the sheep's back. New Zealand Geographer, 69(3), 208-220. doi: https://doi.org/10.1111/nzg.12032.

PETA (n.d.). Wool industry greenwashing mislead consumers. Collective Fashion Justice. https://www.peta.org.au/issues/environment/wool-industry-greenwashing-misleads-consumers/

Power, E. (1941). The Wool Trade in English Medieval History. Being: The Ford Lectures. University of London. https://historyofeconomicthought.mcmaster.ca/power/WoolTrade.pdf

Segre-Reinach, S. (2022). Per un vestire gentile. Pearson Education Resources.

Singer, P. (2015/1975), Animal Liberation. Penguin Smith, T., Ehrnström-Fuentes, M., Hagolani-Albov, S.E., Klepp, I.G. &, Tobiasson, T.S. (2022). Rethinking the (Wool) Economy. In: Klepp, I.G., Tobiasson, T.S. (Eds.), Local, Slow and Sustainable Fashion. Palgrave Macmillan. https://doi.org/10.1007/978-3-030-88300-3_6

Surjit, R. (2024). Recycling of Wool: Making Wool More Sustainable. In S. Jose, S. Thomas & G. Basu (Eds.), The Wool Handbook (pp. 559-576). Woodhead Publishing,.

Tabuchi, H. (2022, June 22). How Fashion Giants Recast Plastic As Good For The Planet. New York Times. https://www.nytimes.com/2022/06/12/climate/vegan-leather-synthetics-fashion-industry.html

Textile Exchange (2023). Materials Market Report 2023. https://textileexchange.org/knowledge-center/reports/materials-market-report-2023/

Vitale Barberis Canonico. (2023). Sustainability Report. https://vitalebarberiscanonico.it/public/uploads/2024/05/Sustainability-Report-2023-ENG.pdf.

Vitale Barberis Canonico. (2024). Transparency Digital Passport. https://vitalebarberiscanonico.com/news-and-events/transparency-digital-passport/.

Wiedemann, S. G., Biggs, L., Nebel, B., Bauch, K., Laitala, K., Klepp, I. G., Swan, P. G., & Watson, K. (2020). Environmental impacts associated with the production, use, and end-of-life of a woollen garment. The International Journal of Life Cycle Assessment, 25, 1486–1499. https://doi.org/10.1007/s11 367-020-01766-0

Wiedemann, S. G., Biggs, L., Nguyen, Q. V., Clarke, S. J., Laitala, K., & Klepp, I. G. (2021). Reducing environmental impacts from garments through best practice garment use and care, using the example of a Merino wool sweater. International Journal of Life Cycle Assessment, 26(2021), 1188-1197. https://doi.org/ 10.1007/s11367-021-01909-x

Wiedemann, S. G., Biggs, L. Clarke S. J. &and Russell, S. J.. (2022). Reducing the Environmental Impacts of Garments through Industrially Scalable Closed-Loop Recycling: Life Cycle Assessment of a Recycled Wool Blend Sweater. Sustainability, 14(3), 1081.

World Organisation for Animal Health (WOAH). (2024). Terrestrial Code Online Access. https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/

Woolmark Company. (2018). Global Wardrobe Study. https://www.woolmark.com/industry/newsroom/lca/

Woolmark Company. (n.d). The history of Merino wool. https://www.woolmark.com/fibre/the-history-of-merino-wool/

FASHIONING FIBER FUTURES

THE FIBERSHED APPROACH TO REVITALIZING REGIONAL FIBER NETWORKS

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Abstract

In less than 100 years, the fashion and textile industry has transformed from local to global supply chains. Today, the industry is dominated by synthetic fiber production which produces garments that contribute to a variety of environmental and social issues such as microplastic pollution, increased carbon emissions, and abundant waste. In recent years, a response led by Fibershed has emerged which embraces a return to local fiber systems with a sincere focus on sustainable practices. Using instrumental case study, this study evaluates Fibershed's approach to establishing regional fiber networks and offers possibilities for future expansion of Fibershed's practices through policy and the inclusion of Indigenous and Black American knowledge and experience in order to create a more sustainable fashion future.

Keywords: *Fiber, Fibershed, Localism, Policy*

INTRODUCTION

Globalization under capitalism has created a vast network of players in a complex fiber and textile system of growth and production, transforming the textile industry from local natural fibers to a synthetic industry. Prior to industrialization, the American fashion industry consisted of natural fibers including flax, hemp, wool, and cotton. The role of cotton in industrializing the American South through chattel slavery is commonly known, yet the growth of textile production in the Northeast was also crucial to economic development (Rivard, 2002). Since the first synthetic fiber, nylon, was created by Du Pont in 1935, fashion companies have exploited the shorter production cycle to create more garments, diversify market offerings, and meet consumer demand (Handley, 1999). For the sake of increasing production and profit, fashion companies have become sources of dangerous labor conditions, unethical wages, environmental pollution, and resource extraction (Schlossberg, 2019). Due to a growing global middle class and increasing prosperity in the wealthiest countries, clothing production doubled from 2000-2015 (Ellen MacArthur Foundation, n.d.). To remain profitable in an increasingly competitive industry, modern fashion companies rely on synthetic fibers due to their lower production costs when compared to natural fibers, leading to negative effects on the environment (Niinimäki et al., 2020). For over 60% of synthetic fibers, the production process begins

with fossil fuel extraction (World Apparel Fiber Consumption Survey, 2013). It is estimated that 342 million barrels of oil are consumed during production annually (Ellen MacArthur Foundation, 2017). Furthermore, garments created with synthetic fibers made from non-renewable fossil fuel resources shed microplastics with every wear and wash. Through laundering and the eventual discarding of the garment, these microplastics pollute soil (Yang et al., 2021), oceans (Boucher & Friot, 2017), and bloodstreams (Leslie et al., 2022). Synthetic textiles, dyes, and finishes also contain carcinogens, neurotoxins, and endocrine disruptors that negatively impact human health (Burgess & White, 2019).

LOCAL FIBER

Local fiber models serve as a foil for the modern industrial textile and fiber system. These models reclaim preindustrial localism, focusing on producing the natural fibers that have lost ground through industrialization. Producers in this model are smaller and often serve multiple roles within the system, including farmer, designer, fiber processor, textile producer, and entrepreneur within smaller communities and geographic regions (Morrow, 2023). A common fixture of the local fiber movement over the last several decades is the festival circuit. Festivals like New York Sheep and Wool in Rhinebeck, NY, draw in large crowds of designers and makers interested in local products (Adams, 2022). While these festivals draw fiber enthusiasts, the most prominent organization in the local fiber movement supporting fiber production and development is Fibershed.

FIBERSHED

Fibershed is a non-profit organization founded in northern California by Rebecca Burgess in 2010. The organization consists of 71 fibersheds – local networks of fiber and textile production, derived from the slow food movement and the concept of watersheds. In comparison to current textile production, Fibershed sets itself apart by considering "all the people, plants, animals, and cultural practices that compose and define a specific geography" (Burgess & White, 2019, p.7). By focusing on the 'source of the raw material, the transparency with which it is converted into clothing, and the connectivity among all parts, from soil to skin and back to soil,' Fibershed creates a place-based textile sovereignty aiming to include rather than exclude (Burgess & White, 2019, p. 7). "Place doesn't always travel," (Liboiron, 2021, p. 151) indicating that local wisdom is local for a reason; it is not universal. Fibershed's system is strategically local. As their affiliate network grows, the Fibershed model also spreads. Its flexibility allows for a continued focus on local knowledge and needs which sets an example for the fiber industry at large.

METHODOLOGY

To evaluate the potential of local fiber models, this research centers the Fibershed initiative in the U.S. as an instrumental case study to gain insight into feasibility of local models (Stake, 2013; Patton, 2015), with a secondary focus on regional fiber networks and the interplay of domestic textile industry policy. A thematic content analysis of secondary source material was conducted to evaluate the Fibershed model and determine how the model meets future social and environmental needs of the fashion system. First, existing research on the global fiber industry and local fiber systems regarding social, economic, and environmental impacts was reviewed. Next, to identify how the Fibershed system differs from the modern industrial textile production system, materials published directly by and in association with Fibershed were analyzed. These sources include the Fibershed website, blog, annual reports dating back to 2020, white papers, the Weaving Voices and Soil to Soil podcasts, affiliate social media accounts, and the book, Fibershed: Growing a Movement of Farmers, Fashion Activists, and Makers for a New Textile Economy, written by the founder and Executive Director, Rebecca Burgess, in partnership with Courtney White (2019). Analysis of affiliate Fibersheds was focused on the New York Textile Lab. Fiber, textile, and fashion legislation (both proposed and implemented) within the U.S. and its member states from 2014 to 2024 was analyzed for themes and connections to local fiber networks and aligned priorities. The evaluation of Fibershed as a large-scale model for industry change was limited by the use of secondary source materials.

FINDINGS

To align with the three pillars of sustainability, the analysis of Fibershed's current practices are presented within the context of fashion sustainability (Daukantienė, 2023). Economic, environmental, and social aspects of Fibershed are categorized

according to product and consumer orientations in the fashion, textile, and apparel industries. While Fibershed's focus is developing and strengthening local fiber systems, attention to the products created with these fibers is limited to facilitating relationships between corporate buyers and connecting regional producers to local markets. Below, we connect Fibershed's efforts in the fiber industry to existing approaches to sustainability in the fashion industry in order to evaluate Fibershed as a sustainable model for fiber system development and identify areas where the model can extend to promoting slow fashion and a circular economy.

ECONOMIC ASPECTS OF FASHION SUSTAINABILITY

Fibershed recognizes the importance of creating economic viability for an alternative fiber system by working within ideas of circularity and regional development.

THE SOIL-TO-SOIL SYSTEM

Fibershed practices a Soil-to-Soil system, an adaptation of circular design, where fiber production is centered around the soil. Once fibers are harvested, they become garments that return to the land through composting. Unlike other circular models, this system deemphasizes reuse, recycling, and repair. Prioritizing natural fibers for their quick compostability creates opportunities for more sustainable practices in fiber farming such as carbon sequestration (Burgess & White, 2019). On Earth, carbon is stored in the oceans and soil. Due to anthropogenic climate change, the carbon content of our soil has decreased (Ontl & Schulte, 2012). To encourage carbon sequestration fiber farming, Fibershed formed the Climate Beneficial™ Agriculture program to increase carbon drawdown, work with land stewards to implement best practices, and certify Climate Beneficial farms. Through this program, 8,746 tons of carbon emissions were sequestered from 2019 to May 2021 through just 66 fiber producers (Fibershed, 2023a). In 2021, seed grants amounting to over $66,000 were awarded to 17 producers with an estimated carbon drawdown impact of over 4,000 tons of carbon in the next 20 years. To radically change current fiber production practices, programs like Climate Beneficial Agriculture are needed to develop environmentally friendly agricultural methods. By implementing methods that benefit the soil and environment, Fibershed aims to achieve a net positive impact for fiber farming on Earth.

However, less than 1% of all clothing is recycled into new clothing, while another 14% is recycled into other objects (Ellen MacArthur Foundation, 2017), leaving a gap for potential reuse. Fibershed does not significantly engage with how to utilize existing fiber for good reason; the fiber recycling process is as complex as the local fiber movement Fibershed promotes. However, natural fibers have the potential to be reused, reducing the need for new fibers. Contemplating reuse within the Soil-to-Soil system, for example, would create feedback loops that lengthen the time between fiber cultivation and its return to soil, decreasing the needed annual yield from fiber farming.

REGIONAL FIBER MANUFACTURING INITIATIVE

In order to create a truly local and resilient fiber system, increased investment in national fiber manufacturing is needed. Once apparel manufacturing moved overseas in the 1980s, most domestic fiber mills closed, leaving a lack of structural support for processing locally grown fibers (Oh & Suh, 2003). Today, the U.S. fiber and textile industry is stratified according to regional issues hindering full production. In the Central Plains Region, existing fiber farmers need infrastructure support such as mills, processing, and weaving facilities (LeHew et al., 2022) which Fibershed aims to facilitate. In the 10 years since Fibershed was founded, two regional mills were established through the Regional Fiber Manufacturing Initiative which assists potential mill owners with engineering plans and financial support (Fibershed, n.d.-b). Despite these ongoing efforts, today, the northern California Fibershed can support knitting production for all fibers, but spinning is limited to small scale wool operations, and unavailable for cotton and bast fibers (Fibershed, 2023). These mills keep fiber production as close to the point of origin as possible, but structural obstacles remain.

SOCIAL ASPECTS OF FASHION SUSTAINABILITY

Fibershed builds networks of social connections between producers, buyers, and consumers that produce sustainable local systems.

FACILITATING A LOCAL MARKET FOR SLOW FASHION

Sustainable local products are cost-intensive and cannot be consumed like disposable fast fashion products. To reduce consumer apprehension around longer lead times and higher costs, Fibershed approaches consumer education as community engagement. Each Fibershed facilitates interactions between local producers and corporate buyers, thereby benefiting multiple stakeholders throughout the textile supply chain. Producers gain access to fiber industry peers for a small membership fee, which begins at $40 for the original Northern California network. This network spans 51 counties in northern and central California where 191 members including farm owners, millers, textile designers, dyers, and apparel designers are designated as producers. Membership also provides access to Fibershed's Instagram and Facebook connections which provide relevant updates and advertisements while educating the public about the benefits of the Fibershed system. Fiber farmers and processors become fiber educators who share their firsthand experiences with students of all ages, backgrounds, and knowledge levels creating "an environment for public engagement" (Trejo & Lewis, 2017, p. 122) that brings newcomers into the fold. Public classes also increase slow fashion skills needed to make and maintain garments within the local economy. This focus on developing artisanal skills eschews big business models and empowers consumers to become makers.

PRODUCT TRACEABILITY AND TRANSPARENCY

To increase consumer knowledge of textile waste, product traceability and transparency is necessary. However, this is limited within the Fibershed system. For final products, Fibershed provides Climate Beneficial verification labels which includes care labels made from organic cotton and hang tags created with recycled paper and soy ink (Fibershed, 2023b). However, information on end-products created through Fibershed systems is limited.

Most Fibersheds host producer markets featuring fiber products for small scale knitting and weaving projects. Like farmer's markets (Warsaw et al., 2021), these markets connect producers directly to customers, providing opportunities for education through informal conversation and fiber farm tours. Producer markets also match inventory to interested buyers, ensuring that excess fiber is delivered to interested buyers.

At the New York Textile Lab, a small amount of products are sold directly through the website. Most of these products are made from yarn sourced from multiple farms in the purchasing cooperative, Carbon Farm Network. Within the co-op, designers collaborate to source fibers and make yarns for commercial textile products. Products are priced on a sliding scale meant to empower consumers while also offsetting production costs. The lower end of the scale reflects wholesale discounts made possible through bulk production. Limited products are available directly through Fibershed websites. In December 2024, 12 products were offered on NY Textile Lab's website. Five were sold out and one, a knit hat, was priced according to the sliding scale ($45, $65, and $85). Price transparency facilitates access to local goods for a range of customers. Facilitating community spending is crucial to Fibershed's long-term success. 73% of every $100 spent at a local business remains in the community (Robinson & LaMore, 2010). Investing in community wealth building ensures that wealth created through strategic localism efforts is recirculated for the community's benefit (Brett, 2024) in order to pay wages, increase school funding, and decrease product transportation costs. As the Fibershed affiliate network grows, generational knowledge spreads to support local business needs.

ENVIRONMENTAL ASPECTS OF FASHION SUSTAINABILITY

PRODUCT TRACEABILITY AND TRANSPARENCY

Fibershed recognizes that more is not needed, but a better approach to what exists is necessary. Current efforts cite cutting-edge technology as the ultimate solution to environmental issues. However, recent research indicates that technology development in agriculture is insufficient to fully overcome the challenges of climate change (Allwood, 2021; Moscona & Sastry, 2022). In Louisiana, the Acadiana Fibershed supports a coalition of producers that grow Acadian Brown Cotton, a regional heirloom variety (Fibershed, 2023c). Fibershed's local approach to fiber production also extends to regenerative garment design. In one example, the final garment, created with three shades of locally grown and milled yarn sourced

focusing on production networks, crafting pieces that will outlive the wearer, and eschewing trends in favor of land and community relationship-based design.

HONORING HISTORICAL LAND RELATIONSHIPS

By connecting local fiber networks and advocating for more sustainable farming practices, Fibershed presents a model that supports local economies and sustainable agriculture. However, fiber production does not take place in a vacuum. Laborers, such as farmers and millers, are integral to the fiber farming process and many face a lack of income and resources (Trejo & Lewis, 2017).

Fiber work in the U.S. is entangled with racialized agricultural histories, including land dispossession, chattel slavery, and sharecropping. Over the past century, Black farmers in the U.S. have decreased from 14% to a mere 1.4% (Aminetzah, 2021). The long term effects of USDA loan discrimination (Tyler & Moore, 2013), inequitable and segregated extension programs (Ramirez Solis & Montgomery, 2021), and social ills linger in this diminished representation. Black farmers still encounter significant discrimination and barriers to obtaining federal support, including miscommunications, inconsistent application standards, and a lack of transparency around approval processes (Russell et al., 2021). This discrimination has been meaningful enough to warrant a $2.2 billion payment toward farmers who have experienced discrimination from federal funding programs under the Inflation Reduction Act's Discrimination Financial Assistance Program (United States Department of Agriculture, 2024). While this is a step in the right direction, there is still more to do to increase Black American representation in fiber farming. The Fibershed model, with its focus on strategic localism, has the potential to reincorporate the generational knowledge and lived experiences of marginalized communities that has been erased in mainstream fiber agriculture.

One of the responsibilities of any land-based organization is to recognize indigenous sovereignty. Burgess worked with dyers in Thailand and farmers of the Navajo nation prior to creating Fibershed. Through this experience, she recognized "the indigenous understanding that plants are our relatives and deserve our respect" (Burgess & White, 2019, p. 49). This focus on indigeneity is also evident in the Weaving Voices podcast, where Burgess interviewed the Diné people of the Navajo nation, who shepherded Navajo Churro sheep for centuries. In Diné culture, sheepherding practices connect generations. Colonizers subjugated the Diné by stealing or murdering their sheep, which was devastating to Diné livelihood (Burgess, 2022). By promoting heritage making practices like hand knitting and traditional dye methods, Fibershed also shares indigenous histories alongside their present ventures. After recognizing indigenous sovereignty and building connections with communities, it is necessary for organizations to make progress toward concrete restitution goals. In this sense, Fibershed and other local fiber organizations must work towards creating opportunities for self-determinism of indigenous fiber workers, financial and social support, as well as supporting movements toward land restitution.

As a non-profit organization, Fibershed measures impact through progress towards mission fulfilment. Their commitment to building regional fiber systems includes driving investment in climate benefiting practices in fiber farming and manufacturing. To achieve a "de-colonized and equitable soil-to-skin" textile system, Fibershed redistributes their grants through several funds: Carbon Farm Seed Fund, Affiliate Network Micro-Grants, and the Fibers Fund (Fibershed, n.d.-a). Since their establishment, Fibershed has provided $772,631 in financial support to producers, processors, and community engagement. Since 2020, Fibershed has granted $301,631 to implement 72 carbon farm practices at individual farms through the Carbon Farm Seed Fund. In collaboration with the Sustainable Agriculture and Food Systems (SAFSF), Fibershed has also issued $240,000 in grants to support development related to flax, hide tanning, and natural dyes. Together, these organizations support small natural fiber and textile producers and processors in the U.S., including the Black Fiber Cohort. This cohort of Black owned and operated textile businesses provides individualized technical assistance and support to address previous devaluing of Black, Indigenous, and People of Color farmers who have been left out of carbon reduction and climate improvement programs (Seed2Shirt, 2022). With additional funding support from the USDA, Fibershed will invest over $18 million in wool and cotton growers in nine states (California, Montana, Wyoming, Indiana, South Dakota, Tennessee, Georgia, North Carolina, and New York) until March 2028.

To support Historically Underserved Farmers, affected farmers will receive up to $2,500 as an incentive for participating. These efforts aid in asserting "fiber farming as a sustainable, scalable option for Black growers" (Siegele, 2024).

DOMESTIC FIBER POLICY

Inasmuch as corporations often control governments, governments can stimulate change within corporations through policy. Fibershed maintains that government policy is needed to force companies to move forward as corporations have a responsibility to the environment and humankind that supersedes other commitments. Within the American legislative scope, interest in fiber and fashion policy is increasing, but passing legislation at a national level remains a challenge. The FABRIC Act, introduced in 2022, is one example of this issue (S.4213). This proposal sought to implement fair wages and promote onshoring of production using tax incentives. While the Act garnered press attention and conversation, it was immediately moved to committees in both the House and Senate and never reemerged for a vote. This is in stark contrast to legislative efforts in the European Union, where individual nations and the governing body of the EU have proposed and passed multiple recent legislative efforts (European Commission, n.d.). Most recently, Maine Representative Chellie Pingree spearheaded the creation of a congressional Slow Fashion Caucus to develop legislation that focuses on emissions reduction, sustainable sourcing, improved recycling, and waste reduction (Borst, 2024). Critically, one of the early backers of this initiative is Fibershed.

At the state level, policy has focused on producer responsibility, supply chain transparency, and worker rights. New York and California have led the way in policy development. While New York has been unable to pass substantive legislation at the state level thus far, policy efforts like the FABRIC Act (S.4213, 2022) have influenced action in other states, including Massachusetts (H.420, 2023) and Washington (S.B. 5965, 2024). Other governmental action in New York is influencing the local fiber landscape in the state, including the addition of fiber in New York State Grown and Certified products to target ethical consumers (n.d.) and the governor's funding of the Fashion Innovation Center to provide a New York-based, sustainable textile pipeline to the state's fashion industry (During New York Fashion Week, 2023). In Fibershed's home state of California, policy efforts target corporate responsibility beyond the boundaries of fashion, but have had greater success in being signed into law. Large corporations, including fashion companies, will soon be required to report their greenhouse gas emissions if conducting business in California (SB253, 2023). Workers in California's robust garment industry must also be paid properly, with the elimination of piece rate payments (SB62, 2021). These policies codify Fibershed's priorities, showcasing how Fibershed, and the local fiber movement more broadly, are aligned with future legal precedents for the fashion industry.

Unfortunately, most current policy initiatives fall short of the comprehensive reform championed by Fibershed. Looking to historical fiber and textile policy may present a solution. Much of the initial wool industry in the U.S. resulted from an embargo on British wool leading up to the war of 1812 (Vaughan, 1947). After the war, tariffs helped the U.S. fiber industry stay afloat as the domestic market began to see international competition once again. Focusing policy on creating financial incentives for domestic and local production while taxing fiber and textiles that travel further could strengthen local supply chains and help achieve Fibershed's mission.

CONCLUSION

Similar to other types of farming, fiber farming continues to be a difficult pursuit for individuals of marginalized identities (Berkey, 2017). Government policies and community practices keep farmland in the hands of those with the most economic and social capital. Even when these individuals can purchase land to cultivate, menial raw fiber prices have made it difficult for small farms to survive. Current infrastructure only increases this difficulty as small producers struggle to find fiber processing facilities that can work with their small batch fibers. If the needs of marginalized fiber farmers can be identified and prioritized, a shift in the fiber farming industry may be possible. Further engagement is needed on the part of Fibershed and its affiliates to broaden the scope of diversity initiatives and develop plans for substantive action, but local policy efforts are a strong starting point. Current practices degrade biodiversity, destroy soil, overutilize water, and otherwise contribute to poor environmental conditions.

Furthermore, the current industrial fiber system isolates workers into functional silos, limiting the ability to work across and within the system. Many of the practices that Fibershed advocates for, such as applying compost, and planting hedgerows, windbreaks, or cover crops, are remarkably simple. These changes shift the quality of life on Earth for people, plants, and animals, with greater water retention, more biodiversity, higher crop yields, and increased carbon levels in soil. Ultimately, they move us toward the goal of less but better, a goal that can center local communities and marginalized people.

To align with the three pillars of sustainability, the analysis of Fibershed's current practices are presented within the context of fashion sustainability (Daukantienė, 2023). Economic, environmental, and social aspects of Fibershed are categorized according to product and consumer orientations in the fashion, textile, and apparel industries. While Fibershed's focus is developing and strengthening local fiber systems, attention to the products created with these fibers is limited to facilitating relationships between corporate buyers and connecting regional producers to local markets. We connect Fibershed's efforts in the fiber industry to existing approaches to sustainability in the fashion industry in order to evaluate Fibershed as a sustainable model for fiber system development and identify areas where the model can extend to promoting slow fashion and a circular economy. Lastly, while Fibershed's current model focuses on production and distribution, initiatives such as their Soil-to-Soil farming system, Climate Beneficial apparel labels, and attention to developing heirloom fibers connects these efforts to the eventual end-user: consumers. This is not an obvious aspect of Fibershed's mission but applicable to their vision. Perhaps future work rests on the collective ownership of the means of fashion production to ensure a major shift in working conditions, environmental consequences, and the usefulness of our things (Moscona & Sastry, 2022). Fibershed and the legislative action that stands beside it have offered us a tactical guidebook for a better path forward.

REFERENCES

Adams, R. (2022, October 22). Young Knitters Discover a Decades-Old Wool Festival. The New York Times. https://www.nytimes.com/2022/10/22/style/ny-sheep-wool-festival.html

Allwood, J. (2021, November 16). Technology will not solve the problem of climate change. Financial Times. https://www.ft.com/content/207a8762-e00c-4926-addd-38a487a0995f

Aminetzah, D., Brennan, J., Davis, W., Idoniboye, B., Noel, N., Pawlowski, J., & Stewart, S. (2021, November). Black farmers in the US: The opportunity for addressing racial disparities in farming. McKinsey & Company. https://www.mckinsey.com/industries/agriculture/our-insights/black-farmers-in-the-us-the-opportunity-for-addressing-racial-disparities-in-farming

An Act to establish fashion sustainability and social accountability in the commonwealth, H.420. Massachusetts 193rd Congress (2023).https://malegislature.gov/Bills/193/H420

An Act Relating to the environmental impacts of fashion, S.B. 5965. Washington 68th Legislature (2024). https://lawfilesext.leg.wa.gov/biennium/2023-24/Pdf/Bills/Senate%20Bills/5965.pdf

Brett, M. (2024). Rewiring local economies: Community wealth building for a just transition. Future Economy Scotland. https://www.futureeconomy.scot/publications/63-rewiring-local-economies-community-wealth-building-for-a-just-transition

Berkey, R. E. (2017). Environmental Justice and Farm Labor. Taylor & Francis.

Boucher, J., & Friot, D. (2017). Primary microplastics in the oceans: A global evaluation of sources. IUCN International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2017.01.en

Borst, E. (2024, June 28). Dems launch caucus on fashion's climate, waste impacts. E&E News by Politico. https://www.eenews.net/articles/dems-launch-caucus-on-fashions-climate-waste-impacts/

Burgess, R., & White, C. (2019). Fibershed: Growing a Movement of Farmers, Fashion Activists, and Makers for a New Textile Economy. Chelsea Green Publishing.

Burgess, R. (Host). (2022, November 30). A life woven together between shepherd and sheep (No. 5) [Audio podcast episode]. In Weaving Voices. Whetstone Media. https://www.whetstonemagazine.com/radio/weaving-voices/episode-5

Climate Corporate Data Accountability Act, SB-253, California Senate (2023). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202320240SB253

Daukantienė, V. (2023).

Analysis of the sustainability aspects of fashion: A literature review. Textile Research Journal, 93(3–4), 991–1002. https://doi.org/10.1177/00405175221124971

During New York Fashion Week, Governor Hochul Announces Consortium of Universities, Businesses, and Industry Leaders to ManageNew York's Fashion Innovation Center. (2023, September 13). Governor Kathy Hochul. https://www.governor.ny.gov/news/during-new-york-fashion-week-governor-hochul-announces-consortium-universities-businesses-and

Ellen MacArthur Foundation. (2017) A New Textiles Economy: Redesigning fashion's future. https://ellenmacarthurfoundation.org/a-new-textiles-economy

Ellen MacArthur Foundation. (n.d.). Fashion and the circular economy- deep dive. https://www.ellenmacarthurfoundation.org/fashion-and-the-circular-economy-deep-dive

Employment: garment manufacturing, SB-62, California Senate (2021). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB62

European Commission. (n.d.). How is the EU making fashion sustainable? Retrieved September 20, 2024, from https://environment.ec.europa.eu/topics/circular-economy/reset-trend/how-eu-making-fashion-sustainable_en

FABRIC Act, S.4213, 117th Congress (2022). https://www.congress.gov/bill/117th-congress/senate-bill/4213

Fashion Environmental Accountability Act. S4746A, New York Senate (2023). https://legislation.nysenate.gov/pdf/bills/2023/S4746A

Fibershed (2023a). 2023 Fibershed Carbon Farm Report. https://fibershed.org/carbon-farm-report/

Fibershed. (2023b). Climate Beneficial Fibers. Fibershed. https://fibershed.org/wp-content/uploads/2023/03/CB-Designer-brochure-Mar2023-Final.pdf

Fibershed. (2023c). Fibershed Annual Report 2023. Retrieved January 3, 2025, from https://fibershed.org/wp-content/uploads/2024/03/FS_2023_AnnualReport_v13_02142024_digital_spreads_optimized.pdf

Fibershed. (n.d.-a). Mission & Vision. Retrieved January 3, 2025, from https://fibershed.org/mission-vision/

Fibershed (n.d.-b). The Regional Fiber Manufacturing Initiative. Retrieved December 10, 2022, from https://fibershed.org/programs/regional-textile-economies/the-regional-fiber-manufacturing-initiative/

Handley, S. (1999). Nylon: The story of a fashion revolution: a celebration of design from art silk to nylon and thinking fibres. Johns Hopkins University Press.

LeHew, M. L. A., Hiller, K. Y., & Doty, K. (2022, September 15). Exploring Barriers to a Sustainable and Regional Fibershed in the Central Plains of the United States. Breaking Boundaries. Breaking Boundaries. https://doi.org/10.31274/itaa.13699

Leslie, H. A., van Velzen, M. J. M., Brandsma, S. H., Vethaak, A. D., Garcia-Vallejo, J. J., & Lamoree, M. H. (2022). Discovery and quantification of plastic particle pollution in human blood. Environment International, 163, 107199. https://doi.org/10.1016/j.envint.2022.107199

Liboiron, M. (2021). Pollution is colonialism. Duke University Press.

Miller, K. V., Diddi, S., & Morris, K. D. (2022, December 31). Regenerative Garment Design Within a Colorado Fibershed. Innovate to Elevate. Innovate to Elevate. https://doi.org/10.31274/itaa.15984

Morrow, O. (2023). A place-based approach to regional fiber economies. In S. Luckman, & N. Thomas (Eds.), Craft Communities (pp. 62-70). Bloomsbury. https://doi.org/10.5040/9781474259675.0013

Moscona, J., & Sastry, K. (2022). Inappropriate Technology: Evidence from Global Agriculture. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3886019

New York State Grown & Certified (n.d.) Animal & Plant Fiber. https://certified.ny.gov/animal-plant-fiber

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. Nature Reviews Earth & Environment, 1(4), 189–200. https://doi.org/10.1038/s43017-020-0039-9

NY Textile Lab (n.d.). Survey Results. (n.d.). Retrieved December 11, 2022, from https://www.newyorktextilelab.com/survey-results

Oh, H., & Suh, M. W. (2003). What is happening to the US textile industry? Reflections on NAFTA and US corporate strategies. Journal of Fashion Marketing and Management: An International Journal, 7(2), 119–137. https://doi.org/10.1108/13612020310475456

Ontl, T. A., & Schulte, L. A. (2012). Soil Carbon Storage. Nature Education Knowledge, 3(10). https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790/

Patton, M. Q. (2015). Qualitative Research & Evaluation Methods. 4th ed. Sage.

Rivard, P. E. (2002). A new order of things: How the textile industry transformed New England. Univ. Press of New England.

Robinson, N., & LaMore, R. (2010). Why Buy Local? An Assessment of the Economic Advantages of Shopping at Locally Owned Businesses. Michigan State University Center for Community and Economic Development. https://ced.msu.edu/upload/reports/why%20buy%20local.pdf

Schlossberg, T. (2019). Inconspicuous consumption: The environmental impact you don't know you have (First edition). Grand Central Publishing.

Seed2Shirt. (2022, October 7). Climate Beneficial Fiber Partnership. See2Shirt. https://seed2shirt.com/climate-beneficial-fiber/

Siegele, L. (2024, October 30). Rebuilding Equity: Tameka Peoples and Seed2Shirt Lead a Regenerative Future for Black Farmers in Fashion. Fibershed. https://fibershed.org/2024/10/30/rebuilding-equity-tameka-peoples-and-seed2shirt-lead-a-regenerative-future-for-black-farmers-in-fashion/ \

Stake, R. E. (2013). Multiple case study analysis. Guilford press.

Trejo, H. (2014). Exploring The New York Slow Fashion Value Chain: Local Animals, Fibers, And Knitwear. https://ecommons.cornell.edu/handle/1813/38988

Trejo, H., & Lewis, T. (2017). Slow Fashion and Fiber Farming: Nexus for Community Engagement. Fashion Practice, 9(1), 120–142. https://doi.org/10.1080/17569370.2016.1220544

Tuck, E., & Yang, K. W. (2012). Decolonization is not a metaphor. Decolonization: Indigeneity, Education & Society, 1(1), 1–40.

Tyler, S., & Moore, E. (2013). Plight of Black Farmers in the Context of USDA Farm Loan Programs: A Research Agenda for the Future. Professional Agricultural Workers Journal, 1(1). https://tuspubs.tuskegee.edu/pawj/vol1/iss1/6

United States Department of Agriculture. (2024b). What They are Saying: Leaders Across the Country Praise Biden-Harris Administration Actions to Provide Financial Assistance to Farmers Who Experienced Discrimination [Press Release]. https://www.usda.gov/media/press-releases/2024/08/01/what-they-are-saying-leaders-across-country-praise-biden-harris

Warsaw, P., Archambault, S., He, A., & Miller, S. (2021). The Economic, Social, and Environmental Impacts of Farmers Markets: Recent Evidence from the US. Sustainability, 13(6), 3423. https://doi.org/10.3390/su13063423

World Apparel Fiber Consumption Survey. (2013). Food and Agriculture Organization of the United Nations and International Cotton Advisory Committee.

Yang, L., Zhang, Y., Kang, S., Wang, Z., & Wu, C. (2021). Microplastics in soil: A review on methods, occurrence, sources, and potential risk. Science of The Total Environment, 780, 146546. https://doi.org/10.1016/j.scitotenv.2021.146546

FAMILIARIZING WITH FUNGI FOR THE TEXTILE SECTOR

A FIRST-PERSON JOURNEY INTO NEW MATERIALIST TECHNOLOGIES, FROM LEATHER TO YARN

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Abstract

Fungi are called into action to engage in the literary debate on new materialism and sustainable technologies, proposing an alternative ontology, due to the discussions they have increasingly sparked across various disciplines in recent years. Specifically, the growing interest towards fungi and the fungal world has contaminated fashion, challenging textile research and its supply chain. The phenomenon that intertwines fungi and fashion therefore calls for a deeper understanding of their role and implications for both fashion theories and design practices.
As a consequence, this interdisciplinary study aims to illustrate the main material typologies, their processing and the impacts of these tangible applications, highlighting fungal leather as a viable alternative to conventional animal leather.
This study offers insights into global recent material innovations, exploring how the market and consumers perceive these next-generation materials, as well as how they adapt to the existing fashion supply chain. Framed within the new materialist theoretical perspective, which urges a return to the intrinsic material value of goods and their experiences, the study aims to enhance the entanglement among the multitude of actors in the ecological system: humans, technologies and materials. To decentralize the human perspective, this study is written in the first person by fungi (e.g. "we fungi") and aims to provide a deeper technical comprehension of the nature of their raw material sources. We fungi advocate for being recognized not as passive resources but as active contributors to low-impact production processes, emphasizing the need for a closer dialogue between designers and material scientists.

Keywords: *Fungi; Fungal Leather; Sustainability; Material R&D; New Materialism*

EVERYONE'S CRAZY ABOUT US MUSHROOMS

Historically, we fungi have often been relegated to the background compared to the fascination that has seen ferns and algae being collected in herbariums for aesthetic pleasure (Ehrman and Watson, 2018; Hunt, 2005). Indeed, since ancient times, we have been useful to humans not only for dietary purposes, but also linked to psychotropic rituals influencing the arts (Samorini, 2001) and used for therapeutic purposes through the so-called mycotherapy (Cocchi and Siniscalco, 2013).
More recently, our role has expanded to include soil regeneration or mycoremediation and has inspired the literary debate in rather novel ways. In fact, since 2019, there has been a significant increase in interest regarding our way of life and our adaptability to human uses. Besides seeing mycological books like Merlin Sheldrake's (2020) become bestsellers, in various disciplinary fields we have become the subject of a growing curiosity. To name a few examples: within anthropology the book by Anna Tsing (2015), within popular culture and subcultural communities the book by Doug Bierend (2021), within cultural and gender studies the book by Yasmine Ostendorf-Rodríguez (2023). This phenomenon has led to the emergence of a mycophilia even within fashion studies and design. Focusing on our tangible material manifestation, rather than as a decorative motif – such as the psychedelic prints popularized by the Hippie movement in the 1970s that inspired Stella

McCartney Summer 2022 Fashion Fungi collection – there is still confusion. Therefore, our first-person contribution, enriched by on-site visits and discussions, aims to clarify our role in the contemporary fashion industry. We seek to reconstruct the complex interplay inherent in this hybrid subject by spanning various disciplinary fields – textile engineering, material science, biology, corporate and market sustainability reports – to propose new ways to fruitfully intertwine with fashion theories and design practices. According to the new materialist theoretical perspective, which interprets the current epoch as characterized by an ongoing "material turn," it is not surprising that our role as fashion design material source requires deeper analysis. In this context, the work of Anneke Smelik (2018) interweaves new materialism with the posthuman philosophy to analyze unique fashion design practices that highlight the entangled nature of humans, technologies and materials (both organic and inorganic). As fungi, it is crucial to explain the insights we offer towards low-impact production processes and to advocate for not being treated as another of nature's passive resources to be exploited and extinguished by human will. To this end, the objective of our contribution is to provide a clear and detailed overview of our typologies and their corresponding impact, primarily focusing on fungal leather as an alternative to conventional animal leather. We hope that increased knowledge in the field will foster a more effective dialogue between designers and material researchers, leading to product embodiments that respect the cultural heritage, the planet and the precious interrelations among all beings.

METHODOLOGY

This study is supported by the literature and on-site visits, as well as attendance at seminars and various meetings with material scientists, technicians, designers, textile engineers and mycologists. These activities were part of the doctoral research conducted by Clizia Moradei at Università Iuav di Venezia between 2021 and 2024.
Notable on-site visits include six months of fieldwork at the Italian material R&D center Pangaia Grado Zero, dedicated to implement Muskin leather, and a visit to the Biotechnology Lab at the University of Borås (Sweden), which focuses on developing fungal leather and yarn. Key meetings include discussions with a representa from the Chinese material R&D center Pureway Biotechnology, which is launching mycelium leather, and conversations with mycologist Enrico Bizio, one of the founders of the Società Veneziana di Micologia.
To introduce the material content of the study, it branches out from our two identified typologies, which will be analyzed in detail, namely fungal leather (comprising two sub-categories form mycelium and fruiting body) and fungal yarn. Beyond outlining the main properties, significant emphasis will be placed on the processes to provide a clear overview that can guide not only non-scientists, such as fashion designers and product developers, but also fashion theorists seeking to engage with the topic. The common characteristics of these innovations are: the companies' efforts to preserve the natural quality of our original resources to reduce the environmental impact of material waste; and the promotion of small-scale production, which, though it may appear limiting, offers an opportunity for a paradigm shift that is less human-centered. These characteristics define these approaches to material innovation as new materialist technologies.

OUR TANGIBLE POTENTIAL

When discussing us fungi in the fashion industry the reference is to the leather market[1], which, measured in terms of bovine, ovine, caprine and buffalo hides, had a global production volume of approximately 13.4 million tons in 2022 (Textile Exchange, 2023: 6). However, year by year since 2020, online searches for leather have decreased by 3.5%, while those for vegan leather have increased by 69% (Hakansson et al., 2023: 13). Collective Fashion Justice and Material Innovation Initiative have proposed the 2023 report that investigates the future and alternatives to animal leather, revealing that 75% of Australians, almost 78% of British and 90% of Chinese respondents would prefer, given the choice, non-animal leather made from next-generation materials (Hakansson et al., 2023: 14–15). Consumers' answers highlight the growing awareness of the negative impact of the tanning industry on ethical and environmental issues and offer the opportunity for the fashion industry to guide them towards more responsible choices.

1 Their raw material prices are also equivalent to the luxury leather market.

Comparing the impact of animal leather with synthetic and next-generation leather, the CO2 emissions per m² of material produced are: bovine leather 110 kg, PU/synthetics 7-15.8 kg, bio-based PU 8.2 kg, Mirum[2] 0.8-2.1 kg (Hakansson et al., 2023: 19). From 2013 to 2022, new companies engaged in developing next-generation leathers and their total grew from 18 to 65 (Hakansson et al., 2023: 23). Material Innovation Initiative includes in the category of next-generation materials those with a biomass percentage greater than 50%: plant-derived, mycelium, cultured animal cells, microbial cultures, recycled materials and blends (Hakansson et al., 2023: 11).

A group of biopolymers are those in which plant biomass (pineapple fiber, cactus leaves, apple scraps and others) is combined with for 30-80% polylactic acid PLA (a biodegradable thermoplastic polymer of biological origin) mixed with PHA (polyesters naturally produced by microorganisms), PBS (an aqueous saline solution that ensures flexibility) or frequently with conventional polymers (Gullingsgrud, 2023: 90–99: 110). A second group of biopolymers, still in the experimental stage, are obtained from the fermentation of microorganisms, such as bacterial cellulose. Mycelium and fungal fruit body leather do not fall by definition under these two categories. In the first case, this is because they are not fibers but microfibers, and in the second case, because they are not produced from a natural fermentation process of microorganisms. Nonetheless, our leather manifestations are closely akin that they belong to the same category of bio-based leathers. Similarities reside in the tactile and aesthetic level; whereas differences reside in our strong commitment to promote production systems powered by renewable energy and more symbiotic material-designer developmental processes.

Cataloging and describing the diverse types and ongoing experimental technologies of fungal-based leathers is not an easy task. This difficulty arises from several factors, often underscored and critiqued by industry insiders, including: the complexity of the literature on the subject, the industrial secrecy and limited disclosure of Technology Readiness Level (TRL) data by supplier representatives. These obstacles obstruct clear communication with designers and consumers, thereby contributing to the greenwashing trend. Thus, a first-hand exploration of our world – touching our material samples and visiting our production sites – is essential.

After a notable downturn starting in 2022, exacerbated by Bolt Threads' cessation of production in July 2023 (Bittau, 2023), investments in start-ups developing materials such as plant-based and lab-grown leather, silk and fur reached $500 million in 2023 – a nearly 10% increase from the previous year; although these numbers are lower than the record $1.1 billion in investments reached in 2021, it is promising news for the sector (Kent, 2024; Material Innovation Initiative, 2024).

MYCELIUM LEATHER

For mycelium production we fungi are grown in automated vertical cultivation on a solid substrate (solid fermentation) or in bioreactors[3] on a liquid substrate (liquid or submerged fermentation) (Gandia et al., 2021) (fig. 1). The composition of the substrate maintains the characteristics of the natural substrate; therefore it is plant-based and usually uses industrial waste, such as rice husk, cotton waste, straw or sawdust[4]. The distinction between the two techniques lies in the fact that in the former case, cultivation time is slower but more advanced level of technical and quantitative scalability has been achieved, whereas in the latter case, cultivation is faster but its scalability is constrained. While solid-state cultivation requires approximately two weeks for mycelium cultivation and growth to yield a mycelium sheet, liquid-state cultivation requires only two days, followed by biomass drying phase for storage[5]. Our most commonly used fungal varieties are: saprophytic and parasitic fungi in solid fermentation, where our fruits are continuously harvested to encourage mycelial proliferation; filamentous fungi in liquid

2 Plant-based leather introduced by Natural Fiber Welding.

3 Similar to the ones uses for brewing.

4 Even if the variety cultivated is an edible mushroom, to consider a product edible it must grow on a cultivation substrate that is in accordance with certain certifications. As a result, the fruiting products of these crops generally constitute biodegradable waste.

5 It should be noted that biomass is processed wet and stored in frozen state into refrigerators, therefore, it is rarely dried. 20 kg of wet mycelium correspond to 5 kg of dried mycelium, which is equal to the volume of approximately eleven full plastic shopping bags.

Fig. 01

fermentation, commonly known as molds, which spontaneously do not produce fruiting bodies. Cultivation occurs in a controlled environment that ensures mycelium purity, isolating it from contaminating agents such as other molds, yeasts and bacteria. The mycelial hyphae, extracted and collected by biologists in Petri dishes, naturally possess a foamy texture due to the flow of protoplasm. Enzyme action then creates a lignocellulosic material film, which is subsequently dried to preserve its obtained shape (Jegadeesh et al., 2022: 2; Kumla et al., 2020). This mycelium film is known as compressed mycelium, a rectangular sheet of variable dimensions[1]. In the most advanced stage developed by the R&D center MycoWorks, the base fabric, which enhances the material's strength, is made of vegetable fibers integrated into a single layer thanks to the hyphae growing around and inside them through liquid fermentation (Mycoworks, n.d.)[2]. This process avoids adhesives for subsequent fabric lamination, as implied by solid fermentation. However, the majority of mycelium leather alternatives belong to the category of laminated nonwoven textiles. Because mycelial cellular components are not constant, atmospheric agents can cause degradation. Thus, plasticization, cross-linking processes and other surface finishing applications are necessary yet critical to align with the objective of reducing environmental impact while preserving the natural quality of the raw biomass (Jegadeesh et al., 2022). The bioengineering of the mycelial root apparatus, distinctive to each producer, could potentially

1 The manufacturer Pureway Biotechnology, for example, markets it in the size of 80X45 cm.

2 To learn about MycoWorks' mycelium manufacturing process, watching the video on the center's website is recommended.

allow for future 'programming' based on required properties and avoiding subsequent harmful treatments.
Among the pioneers of mycelium leather are the material R&D centers: Bolt Threads with Mylo, MycoWorks with Reishi, Mogu and Squim with Ephea™, Ecovative with the AirMycelium technology. Apart from Mogu that is based in Italy, the others are located in the United States (the first two in California, the latter in New York State). However, it should be noted that in recent years, China has contributed for the 75% to global mycelium production (Straits research, n.d.). Proof of this is the Chinese material R&D center Pureway Biotechnology, which launched Meri™ in Spring 2024. An interesting pilot-scale example is also the VTT Technical Research Center of Finland that developed a technology for the continuous mycelium film production resembling latex membrane (Vandelook at al., 2021).
Mylo was adopted by Adidas in 2020 for the Stan Smith sneakers model and by Stella McCartney for a selection of garments and accessories. A further development of Reishi, named Sylvania, in 2021 embodied Hermès' Victoria bag, remaining in prototype stage (Lottersberger and Celeste, 2021). MycoWorks' Reishi is considered the first mycelium leather to meet the luxury fashion industry standards, as Fine Mycelium™ technology allows it to undergo the same artisanal treatments as animal leather (Mycoworks, 2023). Lastly, Ephea™ was adopted for outerwear and accessories by Balenciaga's Fall/Winter 2022-23 collection.

AMADOU LEATHER

Another type of fungal leather is primarily derived from the fruiting body of the fungi Fomes Fomentarius or Phellinus, from parasitic or saprophytic fungal varieties, it is also known as Amadou fungus, Hoof fungus or Tinder fungus (Darabán, 2022). Traces of it have been found in Neanderthal man remains, indicating its likely historical use as tinder for fire (Marinis and Brillante, 1998: 102–120; Raimondi, 2006: 26). The material obtained from the Amadou fungus is referred to as Amadou Leather or German Felt.

Fig. 02

Aesthetically, it resembles suede leather with a slight iridescent effect and irregular striations, while its unique feature is its extreme softness to the touch. It is biodegradable (Bustillos et al., 2020), highly absorbent, antibacterial (Kolundžić et al., 2016; Seniuk et al., 2017) and has poor mechanical properties (Bustillos et al., 2020; Meyer et al., 2021). It is an irregular, fragile material with a natural aesthetic and it is difficult to dye. These limitations are posing significant challenges today.
Separated from the plant on which it thrives, processing begins with manual knife peeling of the fruiting body (fig. 2). The outer shell, extremely woody, is currently discarded. The soft central pulp is boiled and steamed, then manually stretched and thinned before being further pressed. The resulting pieces, which roughly correspond to the size of the original fruiting body, are hung to dry. This drying process sometimes leaves marks from clothespins on the edges of the samples. The samples are frozen at -25°C for two weeks to eliminate any insects or larvae inside. After quarantine, they are thawed and stored in non-airtight boxes[1].
In Europe, Amadou leather has been used as hemostatic absorbents, oral tampons, bend-aids, clothing items, body ornaments (jewelry), accessories (bags, gloves, hats), fly-drying pads for fishing, burned for its sedative effect on animals and insects, as well as bottle corks (Ainsworth, 1976; Gandia et al., 2021; Harding, 2008; Papp et al., 2017; Schmidt, 2006; Schwarze, 2013; Stamets, 2005). In central European regions like Bavaria, Thuringia and ancient Bohemia, it was produced in quantities reaching 50 tons annually until 1890 (Schmidt, 2006). Today, it is still produced in the

1 The full manufacturing process has been reconstructed thanks to the information generously shared by Pangaia Grado Zero.

Fig. 03

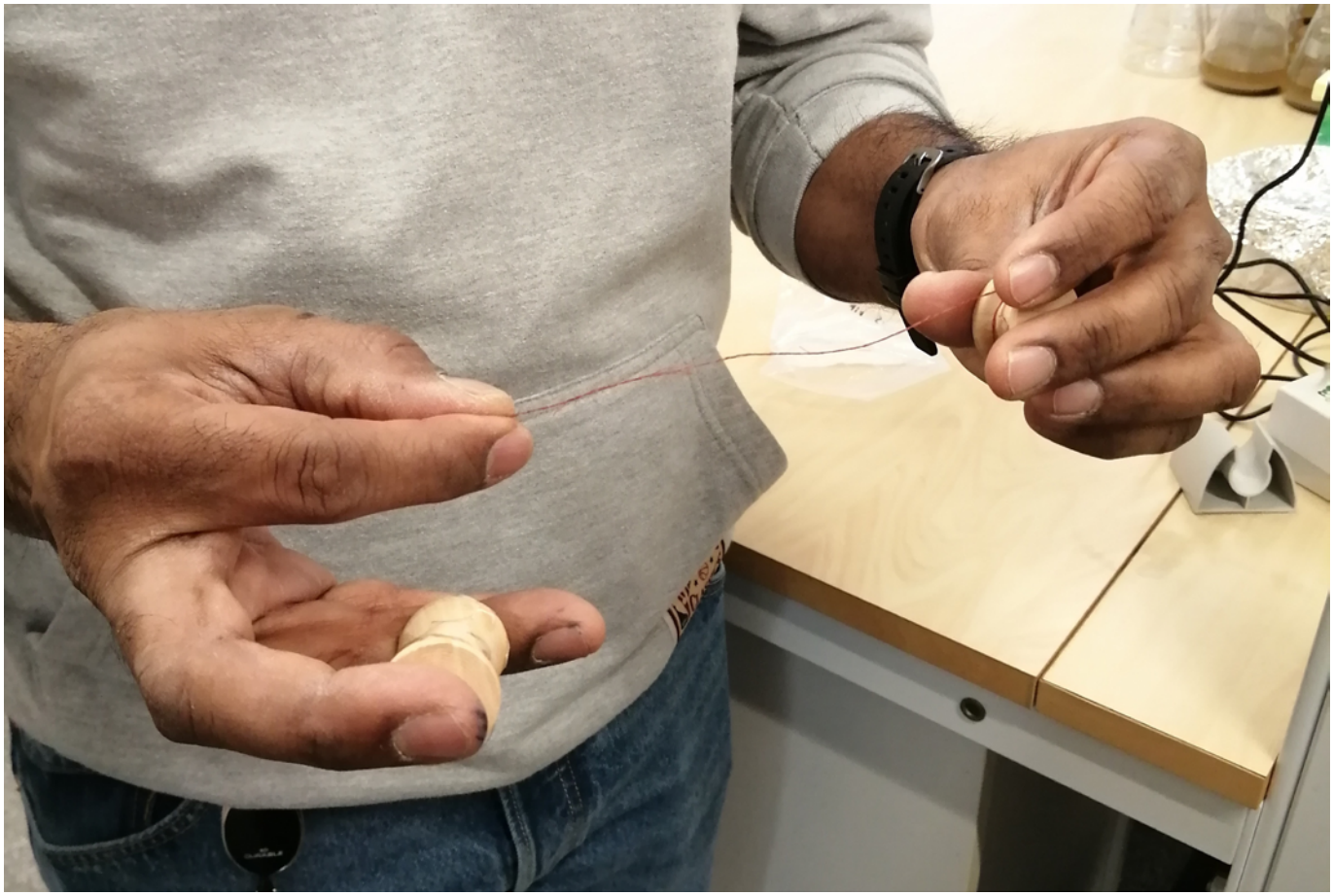

Fig. 04

rural areas of Bohemia and Transylvania (Papp et al., 2017; Stamets, 2005). Studies indicate that the Toplàsz people of Corund in Transylvania still work with Amadou from Fomes Fomentarius and Fomitopsis Betulinus, harvested in July and August (Papp et al., 2017). Amadou processing is limited to small-scale artisanal production, and its products are locally known but less recognized globally. As documented by Finnish designer and doctoral candidate Mari Koppanen, focusing on the story of Mr. Imre, one of the oldest craftsmen in the village of Corund, this knowledge has been passed down through generations and is nowadays at risk of extinction (Koppanen et al., 2023). There are very few intermediaries who trade the raw material; in addition, online trading platforms for finished products evidence their naive artisanal nature, limiting the appeal to the fashion industry. Conversely, significant is the work of Life Materials, division of the Italian material R&D center Pangaia Grado Zero, which trades it as Muskin. Life Materials not only takes care of its commercial distribution but also is committed to implement and scale Muskin for the industry. The challenge is to re-convert the existing textile supply chain by leveraging the expertise and machinery of local tanning industries (fig. 3).

FUNGAL YARN

In rare cases, we fungi appear as filament for yarn. In fact, we are not yet commercially available in such a state, however ongoing experimentation continues to explore our potential. The project coordinated by Professor Akram Zamani at the Biotechnology Lab of the University of Borås in Sweden (January 1, 2019 - January 16, 2023) encompasses various research branches aimed at contributing to the reuse of agri-food industry waste (particularly bread), used as cultivation substrates for fungi[2]. One branch of the research unit focuses on obtaining fungal yarn and nonwoven textiles from fungi, using respectively

2 The details of the project and process come from the on-site visit to their laboratory on April 4, 2024.

wet spinning and wet laying processes (liquid fermentation). The outcomes include samples of twisted yarn approximately 20 cm long, which to the touch resemble rough paper yarn (fig. 4). Unfortunately, scalability limitations of such experimentation hinder its application potential for design prototypes. This fiber appears promising for medical applications due to its antibacterial properties, skin compatibility and soothing effect.

DISCUSSION

In regard to the environmental issue, the application of our leather and yarn alternatives in material technology is gaining traction because of its high biocompatibility and renewability, as well as its affordable – ease of biomass cultivation and short growth period – and carbon-neutral growth processes (Amobonye et al., 2023). Accordingly, Louis Quijano et al. (2021: 901) claim that the chemical production of bio-based equivalents of synthetic fibers has its pros, nonetheless, also its cons: the advantage is that the production of biosynthetic fibers reduces the ecological impacts and overreliance of non-renewable resources, the disadvantage is the argument that states how biosynthetic fibers indulge the issue of overproduction to comply with the market.

In disagreement with the second aspect and except for the case of yarn, by virtue of the fieldwork and visits it is argued that the small-size R&D realities presented in the study like Pangaia Grado Zero, Pureway Biotechnology and the VTT Center, are able to challenge the productive paradigm. This is possible for their direct and close collaboration with the textile industry and fashion brands, by promoting more awareness in their interlocutors in order to orient them towards the benefits of a rather reduced scale of application.

Given the potential of the technological material innovations illustrated, the limits must also be remarked: the costs of leather alternatives, which are currently equivalent to the luxury leather market; low tensile strength of the fruiting body leather and yarn; the pilot scale level of the majority of these processes.

If the theoretical premise supports the foundation of a new materialist vision for both professional interpreters and consumers, as well as the establishment of new materialities and new materialist technologies that are overall more beneficial for the planet – as demonstrated by the insights gathered so far – this paper contributes to new materialist discussions within both fashion and non-fashion studies on theoretical and practical levels. Overall, the study provides valuable data that should inspire interdisciplinarity and strengthen the foundation for future research to continue the concrete exploration of our world.

FUNGAL FUTURES

In conclusion, all the three fungal matter typologies described, collectively demonstrate that we fungi represent not only a sustainable alternative to animal leather but also a conceptual revolution in the fashion industry, posing an interdisciplinary challenge. It is crucial for fashion designers and material developers to adopt a collaborative mindset, engaging with a wide range of professionals to effectively address our unique biological characteristics. This implies re-discovering and historicizing previous technologies to integrate them with contemporary innovations, framing and signifying them within the "material turn." Transitioning from animal and synthetic leather to fungal-derived materials requires a paradigm shift beyond mere aesthetic and functional considerations, embracing a systemic approach that values our ability to grow and regenerate sustainably. Only through comprehensive and clear dissemination, deep understanding and appreciation of our intrinsic properties, can we fully harness our innovative potential to seamlessly integrate into the fashion products of tomorrow, contributing to the creation of a fashion future that is ethically and ecologically responsible.

CAPTIONS

[Fig. 01] Mycelium substrate preparation for liquid fermentation, Biotechnology Lab of the University of Borås. Credits of the author.

[Fig. 02] Mushroom foraging and peeling. Courtesy of Pangaia Grado Zero.

[Fig. 03] Life Materials' Muskin implementation tests using conventional tanning industry machinery. Courtesy of Pangaia Grado Zero.

[Fig. 04] Fungal filament shown by PhD Kanishka Wijayarathna, Biotechnology Lab of the University of Borås. Credits of the author.

REFERENCES

Ainsworth, G. C. (1976). Introduction to the History of Mycology. Cambridge University Press.

Bierend, D. (2021). In Search of Mycotopia: Citizen Science, Fungi Fanatics, and the Untapped Potential of Mushrooms. Chelsea Green Publishing.

Bittau, L. (2023). Frenano ancora i materiali next-gen. Flop per la pelle vegetale Mylo. Pambianco News. https://www.pambianconews.com/2023/07/04/frenano-ancora-i-materiali-next-gen-in-stand-by-la-pelle-vegetale-mylo-379388/

Bustillos, J., Loganathan, A., Agrawal, R., Gonzalez, B. A., Gonzalez Perez, M., Ramaswamy, S., Boesl, B., & Agarwal, A. (2020). Uncovering the Mechanical, Thermal, and Chemical Characteristics of Biodegradable Mushroom Leather with Intrinsic Antifungal and Antibacterial Properties. ACS Appl. Bio Mater., 3(5), 3145–3156. https://doi.org/doi.org/10.1021/acsabm.0c00164

Cocchi, L., & Siniscalco, C. (2013). Micoterapia: Speranze, illusioni, realtà. Sempre più spesso consigliati prodotti a base di funghi come integratori. Alimenti&Bevande, XV(6), 26–33.

Darabán, I. (2022, October 16). The World's Last Amadou Makers—Korond III. Medium. https://medium.com/@istvan.daraban/the-worlds-last-amadou-makers-korond-iii-9694114ffa4a

Ehrman, E., & Watson, E. (Eds.). (2018). Fashioned from Nature, exhibition catalogue (London, Victoria and Albert Museum, 21 April 2018—27 January 2019). V&A Publications.

Gandia, A., van den Brandhof, J. G., Appels, F. V. W., & Jones, M. P. (2021). Flexible Fungal Materials: Shaping the Future. Trends in Biotechnology, 39(12), 1321–1331. https://doi.org/10.1016/j.tibtech.2021.03.002

Gullingsgrud, A. (2023). Sustainable Fibre Toolkit 3. Stiftelsen Svensk Textilforskning. https://www.teko.se/?s=sustainable+fibre+toolkit+3

Hakansson, E., Gladman, S., & Bailey-Cooper, N. (2023). Full leather report. Under their skin: A just transition beyond leather. Collective Fashion Justice, Material Innovation Initiative.

Harding, P. (2008). Mushroom Miscellany. Collins.

Hunt, S. E. (2005). "Free, Bold, Joyous": The Love of Seaweed in Margaret Gatty and Other Mid-Victorian Writers. Environment and History, 11(1), 5–34.

Jegadeesh, R., Da-Song, K., Hyun-Seok, K., Deuk-Sil, O., & Hyun-Jae, S. (2022). Mycofabrication of Mycelium-Based Leather from Brown-Rot Fungi. Journal of Fungi, 8(3), 317. https://doi.org/10.3390/jof8030317

Kent, S. (2024, January 16). Are new materials ready to go mainstream? The Business of Fashion. https://www.businessoffashion.com/articles/sustainability/next-generation-materials-biofabricate-mycoworks-mushroom/

Kolundžić, M., Grozdanić, N. D., Dodevska, M., Milenković, M., Sisto, F., Miani, A., Farronato, G., & Kundaković, T. (2016). Antibacterial and cytotoxic activities of wild mushroom Fomes fomentarius (L.) Fr., Polyporaceae. Industrial Crops Products, 79, 110–115. https://doi.org/10.1016/j.indcrop.2015.10.030

Koppanen, M., Koppanen, K. I., & Ahotupa, K. (Directors). (2023). The hatmaker [Documentario]. https://mubi.com/en/se/films/the-hatmaker

Kumla, J., Suwannarach, N., Sujarit, K., Penkhrue, W., Kakumyan, P., Jatuwong, K., Vadthanarat, S., & Lumyong, S. (2020). Cultivation of Mushrooms and Their Lignocellulolytic Enzyme Production Through the Utilization of Agro-Industrial Waste. Molecules, 25(12). https://doi.org/doi.org/10.3390/molecules25122811

Lottersberger, A., & Celeste, S. (2021, October 14). Investments in high-science pioneers: How international fashion companies are funding innovative start-ups to forge a circular economy. Responsible Fashion Series. Can Fashion Save the World?, Antwerp. https://www.uantwerpen.be/en/conferences/responsible-fashion/about/

De Marinis, R. C., & Brillante, G. (1998). Otzi l'uomo venuto dal ghiaccio. La mummia del Similaun (pp. 102–120). Marsilio.

Material Innovation Initiative. (2024). 2023 State of the industry report: Next-gen materials. https://materialinnovation.org/reports/2023-state-of-the-industry-report-next-gen-materials/

Meyer, M., Dietrich, S., Schulz, H., & Mondschein, A. (2021). Comparison of the Technical Performance of Leather, Artificial Leather, and Trendy Alternatives. Coatings, 11(2), 226. https://doi.org/10.3390/coatings11020226

MycoWorks to open world's first commercial-scale Fine MyceliumTM plant in September. (2023, August). Mycoworks. https://www.mycoworks.com/mycoworks-to-open-worlds-first-commercial-scale-fine-mycelium-plant-in-september#:~:text=MycoWorks'%20proprietary%20Fine%20Mycelium%20production,the%20luxury%20industry's%20performance%20standards

Our technology Fine MyceliumTM. A breakthrough in materials science and biotechnology. (n.d.). Mycoworks. Retrieved June 30, 2024, from https://www.mycoworks.com/materials

Ostendorf-Rodríguez, Y. (2023). Let's become fungal. Mycelium teachings and the arts. Valiz.

Papp, N., Kinga, R., Bencsik, T., & Czégényi, D. (2017). Ethnomycological use of Fomes fomentarius (L.) Fr. And Piptoporus betulinus (Bull.) P. Karst. In Transylvania, Romania. Genetic Resources and Crop Evolution, 64, 101–111. https://doi.org/10.1007/s10722-015-0335-2

Raimondi, B. (2006). L'accensione del fuoco nella preistoria europea. Dati sperimentali sulla confricazione dei legni e sulla percussione delle pietre. Quaderni Del Museo Di Storia Naturale Di Livorno, 19, 23–49.

Samorini, G. (2001). New Data from the Ethnomycology of Psychoactive Mushrooms. International Journal of Medicinal Mushrooms, 3(2–3), 257–278. https://doi.org/10.1615/INTJMEDMUSHR.V3.I2-3.1670

Schmidt, O. (2006). Wood and Tree Fungi. Biology, Damage, Protection and Use. Springer.

Schwarze, F. W. M. R., Engels, J., & Mattheck, C. (2013). Fungal Strategies of Wood Decay in Trees. Springer Science & Business Media.

Seniuk, O. F., Gorovoj, L. F., Beketova, G. V., Savichuk, H. O., Rytik, P. G., Kucherov, I. I., Prilutskay, A. B., & Prilutsky, A. I. (2011). Anti-infective properties of the melanin-glucan complex obtained from medicinal tinder bracket mushroom, Fomes fomentarius (L.: Fr.) Fr. (Aphyllophoromycetideae). International Journal of Medicinal Mushrooms, 13, 7–18. https://doi.org/10.1615/intjmedmushr.v13.i1.20

Sheldrake, M. (2020). Entangled life: How fungi make our worlds, change our minds & shape our futures. Random House.

Smelik, A. (2018). New materialism: A theoretical framework for fashion in the age of technological innovation. International Journal of Fashion Studies, 5(1), 33–54. https://doi.org/doi: 10.1386/infs.5.1.33_1

Stamets, P. (2005). Mycelium Running: How Mushrooms Can Help Save the World. Ten Speed Press.

Straits research. (n.d.). Global Mycelium Market Grows Steadily at a CAGR of 7.8%. Retrieved June 4,

2024, from https://straitsresearch.com/press-release/global-mycelium-market-growth

Textile Exchange. (2023). Materials Market Report 2023. https://textileexchange.org/app/uploads/2023/11/Materials-Market-Report-2023.pdf

Tsing, A. L. (2015). The mushroom at the end of the world: On the possibility of life in capitalist ruins. Princeton University press.

Vandelook, S., Elsacker, E., Van Wylick, A., De Laet, L., & Peeters, E. (2021). Current state and future prospects of pure mycelium materials. Fungal Biology and Biotechnology, 8(20). https://doi.org/doi.org/10.1186/s40694-021-00128-1

Grows Steadily at a CAGR of 7.8%. Retrieved June 4, 2024, from https://straitsresearch.com/press-release/global-mycelium-market-growth

Textile Exchange. (2023). Materials Market Report 2023. https://textileexchange.org/app/uploads/2023/11/Materials-Market-Report-2023.pdf

Tsing, A. L. (2015). The mushroom at the end of the world: On the possibility of life in capitalist ruins. Princeton University press.

Vandelook, S., Elsacker, E., Van Wylick, A., De Laet, L., & Peeters, E. (2021). Current state and future prospects of pure mycelium materials. Fungal Biology and Biotechnology, 8(20). https://doi.org/doi.org/10.1186/s40694-021-00128-1

FIBRE FANTASIES

A CRITICAL EXAMINATION OF WELLNESS CLAIMS IN TEXTILE MARKETING

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Abstract

With an increase in consumer demand for health and lifestyle products, some fashion and textile apparel brands are referencing problematic sources or misinterpreting scientific claims on the health benefits of textile fibres to sell wellness products in a saturated market. This paper unpacks the textile fibre wellness phenomenon under ethical consumption greenwashing frameworks, specifically referencing the mystified storytelling tactic adapted by wellness brands from luxury brand marketing strategies. Through case studies of linen and bamboo from online clothing brands, it examines spiritual greenwashing practices alongside technical and scientific claims about fibre frequencies and anti-microbial properties. The aim is to highlight the conflicting issues at play in wellness textile marketing and the need for more textile expertise, stronger guidelines and legislation to assist brands and consumers to navigate this complex terrain in an ethical manner.

Keywords: *Wellness textiles, Ethical Consumption, Fibre Marketing, Spiritual Greenwashing, Mystified Storytelling*

INTRODUCTION

There are many factors which contribute to the misinterpretation or misunderstanding of scientific properties of textiles and the ethical sourcing and production of fibres. The manufacturing of fibre, yarn and fabric, particularly for technical sportswear and online wellness clothing brands, is based in Global South countries such as China, India, Turkey and Bangladesh, while garment design often takes place in the Global North, specifically in Australia, North America or Europe. With thousands of kilometres in between design and manufacturing there is potential for disparities in communication and understanding to occur, even more so if a language barrier is involved. Historically, fibres and textiles have been critically linked to the success and flourishing of human beings, whether constructed to procure food, provide shelter, or make clothing. Textiles have become so commonplace to our existence that we have perhaps forgotten that textiles are complex materials. Fibres are harvested and carded or extracted and extruded, typically spun into yarns and increasingly blended. Yarns are then looped or interlaced, typically classed by structure: either woven, knitted or non-woven. Modern textile materials include composites, films, and exhibit smart and active capabilities. Textile products are simultaneously both ancient, imbued with cultural importance; and innovative, engineered with finishes to heal wounds or track health data

as examples. Now more than ever we are seeing the flow on effect of this complexity in instances of textile fibre and wellness claims when self-proclaimed experts are quoted out of context, or scientific claims are misinterpreted by brands. Concurrently, there is a growing movement across the globe to tighten restrictions on greenwashing claims (European Commission, 2023; Parliament of Australia, 2023). Although many countries already have existing legislation in place to protect consumers from false and misleading claims, such as the Australian Competition and Consumer Commission, the Consumer Guarantees Act in New Zealand, and the Federal Trade Commission in the United States, such laws are infrequently enforced. A notable exception is the 2021 case involving the Australian activewear brand Lorna Jane. The brand was fined $5 million AUD for false claims about its LJ Shield Activewear, which purportedly 'eliminated,' 'stopped the spread,' and 'protected wearers against viruses including COVID-19' (Australian Competition and Consumer Commission, 2021). While this case serves as a cautionary tale for wellness brands to tread carefully with product claims, regulatory bodies appear ill-equipped to address the broader scope of misleading claims at the intersection of wellness, fashion, and textiles.

There is also a rising demand for specialised textile products in the health and lifestyle wellness market. The Global Wellness Institute (GWI) defines wellness as the 'active pursuit of activities, choices, and lifestyles that lead to a state of holistic health' (Global Wellness Institute, n.d. defining wellness section, para. 1). The wellness industry's exclusive commodities–those marketed as unique or special, prescribe alternative, many times unregulated and privatised solutions to health and lifestyle concerns. These alternatives are often spiritual in nature, and many respond to both ethical consumption patterns and greenwashing marketing tactics.

This paper examines the misconstrued scientific claims made by online wellness clothing brands, specifically in relation to the fibre frequencies and anti-microbial capabilities of linen and bamboo. This paper is structured in two parts: First, we provide an overview of the wellness industry and the relevant literature on ethical consumption and fibre and textile greenwashing. Second, we discuss the linen and bamboo case studies under the key concept of 'mystified storytelling' in relation to the fibre's technical properties, traditional uses, analysis of marketing claims in contrast to scientific evidence. The insights gathered at the intersection of wellness and luxury marketing, and textile product claims, advances the scholarship on greenwashing.

OVERVIEW OF THE WELLNESS INDUSTRY, ETHICAL CONSUMPTION AND GREENWASHING

The wellness industry functions and thrives by emulating fashion and luxury marketing strategies. Many of its products target affluent consumers with environmental, social and ethical concerns. This rising industry represented a global worth of USD 5.6 trillion in 2022 (Global Wellness Institute, 2023), making it more than three times larger than the 2022, USD 1.48 trillion global pharmaceutical industry (Statista, 2024). Its economic and cultural significance is most evident on social media, due to the rise of fashion, health and lifestyle influencers and self-branding strategies that capitalise on personal narratives and perceived authenticity tactics (Banet-Weiser, 2012; Duffy & Hund, 2019). The wellness industry encompasses eleven sectors including: personal care and beauty; healthy eating, nutrition, and weight loss; physical activity; wellness tourism; public health, prevention and personalised medicine; traditional and complementary medicine; wellness real estate; mental wellness; spas; workplace wellness; thermal/mineral springs (Global Wellness Institute, 2023). Wellness products capitalise and commodify the universal pursuit of wellbeing through aspirational and often expensive products and experiences. Many of these wellness products and garments are found engaging in practices of greenwashing and miscommunication of health and spiritual claims as ethical consumption marketing strategies. Ethical consumption is a broad range of consumptive tendencies in the wellness industry encompassing attributes of social justice, environmental concerns, and personal well-being (Lewis & Potter 2011). Ethical consumption is also understood as a form of micropolitical practices (Littler, 2009). It aligns with the aestheticization and politicization of everyday life (Featherstone, 2007), where consumer choices reflect moral values and lifestyle aesthetics. Yet simultaneously, the ethical or conscious consumer is forced to navigate a crowded and oftentimes confusing and paradoxical consumptive information landscape. This is due to entangeld

ethical, spiritual and traditional luxury attributes. This pattern of consumption mobilizes cultural and moral capital, often employing luxury branding strategies such as mystified storytelling to appeal to consumers seeking to express their ethical stance through purchases. Mystified storytelling is a branding concept derived from luxury brand management (Kapferer & Bastien 2012) theory and relates to luxury brands use of elite advertising (Luna Mora & Berry, 2022; Saviolo & Corbellini, 2009), or capitalisation on the mythological and dream-like aspects of the brand rather than the technical or performance attributes of the products. This branding strategy assists wellness brands in creating legitimacy and authenticity by blurring the lines between textile technical performance, health attributes, environmental impact, and personal well-being. For example, wellness narratives are often expressed through personal stories of triumph over adversity. Claims made by wellness influencers or 'lifestyle gurus' (Baker & Rojek, 2020, p. 394) often give preference to anecdotal observations of consumption, often expensive and sophisticated products and ingredients. Many of these commodities operate at a premium market price due to the added, specialised attributes often blurring the lines between environmental, social and spiritual concerns rather than supporting the premium price through scientific evidence. Some examples of ethical consumption attributes include terms such as: local, organic, fair-trade, zero-waste, non-toxic, vegan and cruelty free; blending or sometimes intersecting with traditional luxury attributes such as high quality, uniqueness, rare materials, mystified techniques, hand-crafted, limited, personalised and exclusive.

The broad and often confusing range of spiritual, luxury and sustainable attributes marketed through wellness products and the clothing brands discussed in this paper can also be understood as a form of greenwashing. Greenwashing, similar to ethical consumption is a concept that can take multiple forms and has been examined through different disciplines (Nemes et al., 2022), it is also broadly recognised as a deceptive environmental communication technique (Mousavi et al., 2024) which fashion and textiles businesses engage with to achieve legitimacy (Berthelot et al., 2003) and to express the brand's commitment to sustainability (Mousavi et al., 2024). Greenwashing in fashion and textiles presents a serious challenge, as brands often misrepresent their environmental efforts and hinder actual progress towards sustainability (Mousavi et al., 2024). The literature on textile greenwashing often focuses on misleading claims and information in lifecycle assessment, lifecycle cost and eco-labelling (Mousavi et al., 2024). However, there is little to no literature on greenwashing strategies from a spiritual or wellness perspective, especially at the intersection of wellness fashion and textile brands and luxury. As such, this paper will discuss practices of spiritual greenwashing in the marketing strategies of wellness and fashion textiles.

The wellness industry's growth and convergence with ethical consumption, practices of spiritual greenwashing and luxury's mystified storytelling evidences the intersection of hyper individualism, the rise of miscommunication through social media, and new signifiers of economic and social class. Well-being is now understood as wealth and affluence rather than happiness and satisfaction. Along with the incorporation of sustainable, ethical, environmental, and spiritual concerns, the wellness industry drives new moral values of contemporary consumer culture in the context of the experience and transformation economy (Pine & Gilmore, 2011).

WELLNESS AND LIFESTYLE TEXTILES

Wellness advocates often reject conventional western paradigms, favouring personal experience, independent research, and conclusions derived from diverse sources. Historically, this scepticism has been directed towards western medicine, pharmaceutical industries, and processed food systems (Baker & Rojek, 2020). More recently, this rejection has expanded to include claims made by brands regarding the health benefits of textile fibres. The wellness industry, characterised by its largely unregulated nature, allows for significant experimentation and interpretation. Dunn (2023) describes wellness branding as:

'more than just a product or service—it's a lifestyle. A strong wellness brand captures the essence of holistic health and well-being and communicates it to customers in a clear and authentic way. It communicates to your customers who you are, what you do, and why you do it' (para. 7). Wellness branding merges luxury marketing strategies, lifestyle aspirations, and personal narratives with holistic well-being concepts to promote ethical consumption. While this approach effectively aligns

brand identity with consumer values, it frequently lacks rigorous scientific validation regarding the actual composition and properties of the textiles being marketed. The functionality and health benefits of many technical textile products—such as firefighter protective clothing, seatbelts, life jackets, and stab-resistant vests—are well-documented through controlled scientific testing. These textiles are engineered to perform specific safety-related functions and tested to ensure they perform as designed. In contrast, some wellness brands market their products as having health benefits based solely on the properties of the fibres used, without conducting the necessary scientific testing to substantiate these claims. While textile fibres possess measurable properties that can be enhanced through processes like spinning, weaving, and finishing, textile science recognises that fabric properties are influenced by more than just fibre type (Van Amber, 2013). Nonetheless, marketing in the consumer wellness sector often persists in attributing performance claims to fibre characteristics alone.

METHODOLOGY

This paper uses textual analysis to examine two wellness claims made by online clothing brands: the beneficial frequencies of bast fibres and the anti-microbial capabilities of bamboo. The two case studies were brought to the authors' attention through collegial, social, or familial circles. Rather than offering a comprehensive analysis, this paper aims to highlight the existence and prevalence of such phenomena. A search engine-based sampling method was used to view and select textile wellness blog posts to unpack and discuss. Simple Google keyword searches revealed wellness brands often use snippets of existing sources that align with wellness ideas, without properly critiquing the origin or context. In some cases, brands conflate similar but scientifically distinct ideas. Wellness textile brand narratives often incorporate key elements of wellness marketing, such as aspirational lifestyle branding, holistic health, brand origin stories, and values. The selected textual analysis method allows for the identification of highly visible and potentially influential online cases. Key questions include:

- What fibre wellness claims are being made, and how do they demonstrate ethical consumption and mystified storytelling?
- What sources are cited to support fibre-related claims, and how do these claims engage in spiritual greenwashing through misleading information?

CASE STUDY: LINEN-RELATED MARKETING NARRATIVES

Linen has become strongly associated with the wellness industry, as evidenced by its prevalence in lifestyle and leisure products marketed towards consumers seeking an organic or 'clean living' lifestyle. As fashion is heavily predicated on novelty, and its marketing logics are being emulated by wellness brands (Luna Mora et al., 2018), there is a pressure for brands, designers and manufacturers to constantly innovate and develop new and novel materials. However, linen is an ancient fibre, with the potential for material innovation possibly limited, leading brands to focus on marketing innovation instead.

The relationship between linen fibre frequencies and wellness lifestyle ideals has been trending on social media in 2024, most referencing a 2013 article by two Rabbis, Dr Yellen and Dr Yellen featured in a self-published quarterly online journal: Hebrews Today. The following excerpts illustrate how two online clothing brands market bast fibre products using these unverified frequency claims. The first example comes from a blog post from an 'ethically made linen clothing' brand, titled 'Good vibrations - the healing powers of linen':

'...So why has mankind since time immemorial placed such value on linen? Why is it so special and why is it so often referred to as having healing or holy powers? In 2003, a Jewish doctor called Heidi Yellen ran a study on the healing frequencies of various fabrics and their effect on the human body... Linen and pure wool however both resonate at a tremendous 5000 hz - that's 50 times the natural frequency of the human body! Thus the healing and positive potential of these fibres on the body is exponential! Interestingly, God's warning not to mix the two fibres together is also proven by science. Heidi's study found that the energy field of wool flows in the opposite direction to the energy field of linen and thus the fields collapse and cancel each other out' (Manufacture De Lin, n.d. para.4).

Here, the use of mystified storytelling can be identified with the reference to 'a time immemorial' linking longevity with material value and providing a historical and/or mythological reference as justification for perceived legitimacy of the studies on healing frequencies. Ethical consumption attributes and specialised language such as 'electromagnetic

can also be identified with the mix of technical field resonance of 5000hz' next to spiritual and religious claims such as 'God's warning not to mix the two fibres'. The lack of hierarchy of ideas and the convergence of value of religious and spiritual beliefs next to supposed scientific claims, health attributes, and self-transformation promises creates a paradoxical and confusing message to ethical consumers who are eager to know more about the concept of fibre frequencies and the potential health benefits they may bring.

To further highlight this paradoxical marketing strategy, an Australian online yoga brand has taken an alternate approach, this time referencing the testing equipment and measurements used to quantify textile frequencies, rather than religious references. The following excerpt is from a blog post titled 'The Frequency of clothing: what fabrics support your health?':

'A study by Dr Heidi Yellen suggests that the fabrics in our wardrobe influence our wellbeing in ways we never imagined. Grounded in bioenergetics, the study reveals that everything vibrates at its own unique frequency. Dr Yellen conducted her research with the Ag-Environ machine, a unique instrument that she used to measure the frequencies of fabrics. This digital machine was developed by a retired Texas A&M professor, Bob Graham. Initially designed to analyse the signature frequencies of agricultural commodities. Its application in Dr. Yellen's study offered a means to quantify the vibrational qualities of different fabrics in relation to human health. Like organic cotton, hemp mirrors the human body at an impressive frequency of 100' (Freeman, 2024).

Yellen and Yellen's 2013 paper lacks a methodology, and excludes citations from reliable sources, challenging the credibility of their scientific claims. The Ag-Environ machine used to measure fibre frequencies appears in no other scientific literature. Various wellness brands citing Yellen and Yellen 2013 assign hertz (Hz) values to different fibres. For example, linen and wool allegedly measure 5,000 Hz (Manufacture De Lin, n.d., para. 4; Freeman, 2024, para. 6). However, these measurements lack scientific or technological explanation.

Linen is not the only fibre which has been claimed to have healing properties – far infrared fibres (FIR) – are also marketed as reflecting energy waves, capitalising here both on the wellness and yoga trend of 'good vibes and good energy' and the health benefit of relieving pain and healing a multitude of physical ailments. However, in contrast to linen, FIR fibres are synthetic, typically created by blending an FIR ceramic powder together directly with the fibre polymer to create a FIR yarn (Dyer, 2011).

Linen has remained a premium fibre, lending itself to fine, lightweight fabrics. Like all natural cellulose fibres, linen has a high moisture regain and thus dyes easily, but linen textiles are often comfortable to wear due to their high permeability to air and water vapor. Linen also has a high natural lustre, which can be increased in the finishing process through pressure (Kadolph, 2014). Thus, these combined properties of linen make it a valuable and desirable consumer fibre. Given linen's ancient origin, with Egypt being the source of some of the oldest documented linen fabrics, linen lends itself perfectly to mystified storytelling and spiritual greenwashing.

CASE STUDY: BAMBOO YOGA LEGGINGS

Within the wellness industry, the business of yogawear is expected to reach USD $40 billion globally by 2028 (Smith, 2024). Many yogawear brands, including global players such as Alo Yoga and Lululemon Athletica, are known for capitalizing on the growing consumer demand for performance and technical garments and fabrics, and ethical, environmental, and health-conscious fabrics and fibres. Yogawear brands address these performance and functionality features using descriptive attributes of the fabrications such as 'quick-drying', 'four-way stretch', 'sweat-wicking', 'anti-microbial', and 'breathable', amongst others. Yogawear brands also address ethical, moral, and spiritual concerns by stating the attributes of their signature fabrications. Examples include: 'made with love and 'intention', 'guilt-free', and 'supportive, sculpting, soft, and eco-conscious'. Brands are adopting a form of mystified storytelling that transcends beyond the purely functional aspects of garments.

Technical fabric properties like 'wicking' and 'quick-drying' are often misunderstood and misused in marketing, despite extensive research. Scientific definitions often differ from consumer perceptions, and performance claims are typically oversimplified. For example, most consumers believe the term 'wicking' means that the fabric is able to 'wick' sweat and moisture away from the skin or between multiple layers of fabric.

However, within the scientific community, the term 'wicking' could also mean a fabric's ability to wick water from a reservoir (Kissa, 1996). 'Wicking' between layers of fabrics has been reported only to occur when fabrics have complete contact between the layers and are fully saturated with water – conditions which may not always be exactly replicated during wear (Zhuang et al., 2002). In reality, fabric properties such as drying time are related to absorption, which is a result of complex interactions between fibre type, yarn structure, and fabric construction (Laing et al., 2007; Adler & Walsh, 1984), rather than being determined by a single factor. For example, Studio K, a Bali-based yogawear brand, sells leggings and activewear made primarily from bamboo and other certified organic fibres. The brand promotes itself as 'earth-loving, ethical, and eco-friendly' (Studio K, n.d., home page), blending fashion, functionality, and environmental consciousness to appeal to 'conscious women' who care about their environmental impact (Studio K, n.d., About us). Their products are described as soft, silky, durable, and ethically produced, embodying the fusion of spiritual, health, environmental, and social concerns that drive ethical consumption and spiritual greenwashing.

This aligns with Pierre Bourdieu's concept of cultural capital (1984/1986), where specialized knowledge and education create distinction, as well as Michele Lamont's concept of moral capital (1992), linking ethical consumption with higher moral standards and good taste. Studio K's use of certified bamboo suggests not only economic and cultural capital but also moral superiority, appealing to consumers who value sustainability and ethical practices. The brand reinforces this moral capital by emphasizing the careful sourcing of its fabrics, claiming to offer 'guilt-free, long-lasting quality'.

However, Studio K complicates its narrative through engagement with mystified storytelling, particularly with its signature bamboo fabric. Products like the Eira High-Rise Bamboo Leggings ($129 AUD) are marketed as 'organic fabric that feels like a second skin' made from 'OEKO-TEX certified bamboo' (Studio K, n.d., Eira High-Rise Bamboo Leggings) with 'low-impact dyes' (Studio K, n.d., Sustainability), but it is unclear whether the bamboo was cultivated using organic farming principles, leaving consumers to question the brand's true environmental stewardship. Similarly, the Runa High-Waisted Bamboo Undies ($49 AUD) are promoted as having 'antibacterial, moisture-wicking, and antifungal bio-agents' (Studio K, n.d., Runa High-Waisted Bamboo Undies), claims which are likely tied to perceived consumer beliefs and values of health and hygiene. It is well known that anti-microbial properties of bamboo fibres are generally unsubstantiated (Afrin et al., 2012) yet claims of the anti-microbial properties of bamboo persist within the textile market. Bamboo is often misrepresented in the marketplace, with both brands and consumers perceiving bamboo as a natural fibre when most products labelled as bamboo are actually a semi-synthetic fibre more accurately known as viscose or sometimes bamboo viscose. This conflating of bamboo and viscose or rayon made using bamboo as feedstock has been so prevalent within the industry that in 2022 the United States Federal Trade Commission started fining companies for labelling products as bamboo when they were actually viscose rayon (SGS, 2022). Whether a product is composed of bamboo or viscose (of bamboo origin) is of particular relevance to anti-microbial properties. Whilst the bamboo plant is understood to have some natural anti-microbial properties, once bamboo is manufactured into viscose through a process which involves dissolving the bamboo pulp into carbon disulfide, no anti-microbial properties remain. This is reiterated by the US Federal Trade Commision: 'There are no definitive studies to validate that the natural antimicrobial properties of the bamboo plant are retained in the resulting rayon fibre. The FTC notes that when bamboo is used as the cellulose source, the resulting rayon does not retain any of the natural antimicrobial properties of the bamboo plant. It is believed that the chemicals used to dissolve the plant material would eliminate its natural antimicrobial properties' (SGS, 2022, para.5).

CONCLUDING REMARKS AND RECOMMENDATIONS FOR RESPONSIBLE MARKETING

The decline in specialized textile knowledge, particularly in Australasia, where programs like Clothing and Textile Science at the University of Otago and the Bachelor of Textiles (Design) at RMIT University have been discontinued over the last five years, has concentrated expertise in manufacturing countries such as Bangladesh and

China. This shift contrasts with the widespread availability of fashion marketing knowledge, which poses a risk of developing and promoting products without proper scientific verification.
Brands often leverage perceived credible sources to create compelling marketing narratives, a strategy known as 'mystified storytelling' (Kapferer & Bastien 2012; Luna Mora & Berry 2022). This approach, common among wellness textile brands, emphasizes dream-like attributes and founding myths over technical or performance qualities. It is crucial for consumers to understand the origins and validity of these types of claims. When brands reference objective properties, they should be verified by science to ensure accuracy. Additionally, brands must handle religious, spiritual, or cultural claims with care to avoid misinterpretation and misappropriation.The authors acknowledge the legitimacy of non-western scientific claims, and the subjective nature of preferences for certain fibres and fabrics. This paper highlights the ethical implications of misinterpreting scientific evidence to market textiles in the wellness sector. Entangling spiritual, sustainable and luxury attributes cause consumer confusion and hinders actual progress towards sustainability. Misrepresentation of claims can lead to serious consumer risks, particularly when products are believed to have health benefits. Despite not being marketed as medical devices, wellness products with strong health-related messages can be easily misinterpreted by consumers who lack specialised knowledge. Textile experts can play a vital role in interpreting test results and providing context for performance claims, thereby enhancing transparency and consumer trust. There is a growing need for brands to substantiate their marketing claims with scientific evidence, either through product testing or peer-reviewed research. Strict legislation around consumer products claims already exists to protect consumers, with increased legislation, especially around 'green' or 'eco' claims being introduced to combat greenwashing. Brands making wellness claims about products need to ensure that they are not engaging in spiritual greenwashing. Brands must prioritize accurate and honest communication to ensure consumer safety and maintain credibility in the marketplace.

REFERENCES

Adler, M. M., & Walsh, W. K. (1984). Mechanisms of transient moisture transport between fabrics. Textile Research Journal, 54(5), 334-343.

Afrin, T., Tsuzuki, T., Kanwar, R. K., & Wang, X. (2012). The origin of the antibacterial property of bamboo. Journal of the Textile Institute, 103(8), 844-849.

Australian Competition & Consumer Commission (ACCC). (2021). Lorna Jane pays $5 million over false 'anti-virus activewear' claims. ACCC. https://www.accc.gov.au/media-release/lorna-jane-pays-5-million-over-false-anti-virus-activewear-claims

Baker, S. A., & Rojek, C. (2020). The Belle Gibson scandal: The rise of lifestyle gurus as micro-celebrities in low-trust societies. Journal of Sociology (Melbourne, Vic.), 56(3), 388–404. https://doi.org/10.1177/1440783319846188

Banet-Weiser, S. (2012). Authentic TM : the politics of ambivalence in a brand culture (1st ed.). New York University Press. https://doi.org/10.18574/9780814739372

Berthelot, S., Cormier, D., & Magnan, M. (2003). Environmental, disclosure research: Review and synthesis. Journal of Accounting Literature, 22, 1–44.

Bourdieu, P. (1984). Distinction: a Social Critique of the Judgement of Taste. Cambridge, MA: Harvard University Press.

Bourdieu, P. (1986). The Forms of Capital. In Richardson, J.,(Ed.), Handbook of Theory and Research for the Sociology of Education. T: Greenwood, pp. 241–58.

Dunn, N. (2023). The Importance of a strong brand in the wellness space. Forbes. https://www.forbes.com/councils/forbesbusinesscouncil/2023/06/01/the-importance-of-a-strong-brand-in-the-wellness-space/

Duffy, B., &Hund, E. (2019). Gendered Visibility on Social Media: Navigating Instagram's Authenticity Bind. International Journal of Communication, 13, 20.

Dyer, J. (2011). Infrared functional textiles. In Functional textiles for improved performance, protection and health (pp. 184-197). Woodhead Publishing.

European Commission. (2023). Proposal for a Directive on Green Claims. European Commission. https://environment.ec.europa.eu/publications/proposal-directive-green-claims_en

Featherstone, M. (2007), Consumer Culture and Postmodernism, 2nd ed. Theory, Culture & Society (Unnumbered). Los Angeles; London: SAGE

Freeman, E. (2024, February 14) The Frequency of clothing: what fabrics support your health. Zone. https://www.zonebylydia.com/blogs/sustainable-living/the-frequency-of-clothing-what-fabrics-support-your-health?srslti-d=AfmGlobal Wellness Institute. (n.d.). Defining Wellness. https://globalwellnessinstitute.org/what-is-wellness/

Global Wellness Institute. (2023). Wellness Economy Statistics and Facts. https://globalwellnessinstitute.org/press-room/statistics-and-facts/

Kadolph, S. J. (2014). Textiles (Pearson new international edition). Pearson.

Kapferer, J.-N., & Bastien, V. (2012). The Luxury Strategy: Break the Rules of Marketing to Build Luxury Brands (2nd ed.). Kogan Page.

Kissa, E. (1996). Wetting and Wicking. Textile Research Journal. 66:10, 660-668.

Laing, R. M., Wilson, C. A., Gore, S. E., Carr, D. J., & Niven, B. E. (2007). Determining the Drying Time of Apparel Fabrics. Textile Research Journal, 77(8), 583–590. https://doi.org/10.1177/0040517507078232

Lamont, M. (1992). Money, morals, and manners: the culture of the French and American upper-middle class. Chicago: University of Chicago Press.

Lewis, T., & Potter, E. (2011). Ethical consumption: a critical introduction. Routledge. https://doi.org/10.4324/9780203867785

Littler, J. (2009). Radical consumption: shopping for change in contemporary culture. Open University Press/McGraw-Hill Education.

Luna Mora, J., Berry, J., & Salen, P. (2018). The Yoga Industry: A Conscious Luxury Experience in the Transformation Economy. Luxury (London), 5(2), 173–196. https://doi.org/10.1080/20511817.2018.1560693

Luna Mora, J., & Berry, J. (2022). Creative Direction Succession in Luxury Fashion: The Illusion of Immortality at Chanel and Alexander McQueen. Luxury (London), 9(2–3), 117–140. https://doi.org/10.1080/20511817.2022.2194039

Manufacture De Lin. (n.d.) Good Vibrations – the healing powers of linen. Manufacture De Lin. https://manufacture-delin.com/blogs/blog/healing-powers-of-linen

Mousavi, K., Kowsari, E., Ramakrishna, S., Chinnappan, A., & Gheibi, M. (2024). A comprehensive review of greenwashing in the textile industry (life cycle assessment, life cycle cost, and eco-labeling). Environment, Development and Sustainability. https://doi.org/10.1007/s10668-024-04508-6

Nemes, N., Scanlan, S. J., Smith, P., Smith, T., Aronczyk, M., Hill, S., Lewis, S. L., Montgomery, A. W., Tubiello, F. N., & Stabinsky, D. (2022). An Integrated Framework to Assess Greenwashing. Sustainability, 14(8), 4431-. https://doi.org/10.3390/su14084431

Parliament of Australia. (2023). Greenwashing. Senate Inquiry. https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Greenwashing

Pine, B. J., & Gilmore, J. H. (2011). The experience economy (Updated edition.). Harvard Business School Press.

Saviolo, S., & Corbellini, E. (2009). Managing Fashion and Luxury Companies. Florence: Editorial Etas.

SGS. (2022). US FTC Fines Companies for False Labeling on So-Called "Bamboo" Textiles. SGS. https://www.sgs.com/en/news/2022/05/safeguards-06322-us-ftc-fines-companies-for-false-labeling-on-so-called-bamboo-textiles

Smith, P. (2024). Yoga wear market value worldwide 2020-2028. Statista. https://www.statista.com/statistics/1227325/revenue-of-the-yoga-apparel-market-worldwide/

Statista. (2024). Global pharmaceutical industry - statistics & facts. https://www.statista.com/topics/1764/global-pharmaceutical-industry/#topicOverviewStudio K. (n.d.). Home Page. Studio K. https://studiokyogawear.com/en-au?

Studio K. (n.d.) About Us. Studio K. https://studiokyogawear.com/en-au/pages/about-us

Studio K. (n.d.) Eira High-Rise Bamboo Leggings. Studio K. https://studiokyogawear.com/en-au/products/eira-high-rise-bamboo-leggings-chestnut?

Studio K. (n.d.). Runa High-Waisted Bamboo

Undies. Studio K. https://studiokyogawear.com/en-au/products/runa-high-waisted-bamboo-undies-deco-rose?

Studio K. (n.d.). Sustainability. Studio K. https://studiokyogawear.com/en-au/pages/serious-sustainability

Van Amber, R. (2013). Sock fabrics: The effect of fibre type, yarn type and fabric structure on selected properties [Doctoral dissertation]. University of Otago.

Yellen, BH., & Yellen, H. (2013). Tikkun Olam to heal the world | Healing Flax. Hebrews Today. Hebrew Conservative Union.

Zhuang, Q., Harlock, S. C., & Brook, D. B. (2002). Transfer wicking mechanisms of knitted fabrics used as undergarments for outdoor activities. Textile Research Journal, 72(8), 727-734.

FROM BIO-BASED TO FOSSIL-BASED TO BIO-BASED

EXPLORING THE POTENTIAL OF HEMP AS A MATERIAL FOR NEXT-GEN FUR

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Abstract

Fur as a status-affirming adornment has been historically significant in fashion. There are three main categories of fur and fur-like materials: animal-based, synthetic, and next-generation (next-gen) fur. Animal-based fur is controversial and associated with ethical and environmental concerns, including animal welfare and the use of toxic chemicals. Synthetic fur is typically made from fossil-fuel-derived polymers like acrylic, which successfully mimic the properties of animal hairs in fur, such as aesthetics and touch. These non-renewable, fossil carbon-based fur replacements do not biodegrade, contributing to the plastics crisis in landfills and through fibre shedding. Next-gen furs made from bio-based, regeneratively sourced materials could mitigate this problem because the shed fibres would biodegrade naturally. This paper reports on preliminary findings from an ongoing study investigating the potential benefits of using hemp fibre as the hair in next-gen fur. Extensive material experiments demonstrate that hemp fibre can be used to produce a visually pleasing, appealing-to-touch, fur-like surface. Further research will investigate the base materials of next-gen furs, as well as the scalability of these new materials.

Keywords: *Next-gen Textiles; Material Design; Regenerative Systems; Hemp Fibre; Circular Economy.*

INTRODUCTION

This paper reports on preliminary findings from an ongoing study investigating the potential of hemp as a material for the next generation of fur-like materials, here referred to as next-gen fur. In this study, hemp fibre is used for the hair part of the fur alternative. While other animal-based materials usually utilise either the skin or fibre, fur is composed of both (Rawling et al., 2024). Thus, base materials for next-gen furs are also being investigated within the project but are outside the scope of this paper.

Before the Industrial Revolution, all raw materials used to produce garments could be considered natural or biologically based (Burgess & White, 2019). Presently, even biologically generated fibres are usually embedded with substances that significantly affect their degradation processes (Athey & Erdle, 2022). As fibre shed occurs, these fibres find their way into ecosystems and end up negatively affecting the environment (De Falco et al., 2020). In principle, animal-based fur is a natural material (Popescu & Hoecker, 2007) that is part of nature's carbon cycle, which refers to the natural activity of carbon exchange involving the atmosphere, oceans, and land (Ghiat & Al-Ansari, 2021). Complex ecosystems on Earth depend on the relative stability of the carbon cycle (Malhi et al, 2020) and in addition to carbon in circulation through biological and other processes, a large amount of fossil carbon is stored in the ground as gas, oil and coal. When fossil carbon is extracted

and used in large quantities, the carbon cycle is gradually destabilised. Thus, part of the efforts to stabilise the carbon cycle must include keeping as much fossil carbon in the ground as possible and creating materials from biological regenerative sources.

However, even though fur is a natural material, prior to being applied to fashion products its production and finishing typically involve toxic substances that affect its natural biodegradation (Bijleveld et al., 2011). Still, animal welfare tends to be the main point of discussion. Consequently, commonly used alternatives are synthetic, which addresses the animal rights aspect but neglects anthropogenic emissions and microplastic pollution (Gladman et al., 2024). To mitigate the challenges that both animal-based fur and synthetic fur alternatives present, a transition to animal- and petrochemical-free materials is expected, justifying the growing interest in next-gen alternatives (Gladman et al., 2024). Due to the extremely limited number of next-gen fur innovators (Rawling et al., 2024) and even more limited scholarly research on next-gen fur alternatives, this research aims to address this gap in the literature by discussing the potential benefits of using hemp to mimic the hair part of a next-gen fur alternative to mitigate problems, such as fibre shedding-related pollution.

CONTEXT

This research investigates the potential of hemp in replacing the hair part of fur in next-gen fur, as part of a broader transition from an extractive, either animal- or petrochemical-based system to a bio-based regenerative system. This paper reviews current research in the field to establish the gaps in knowledge and avenues for further investigation to mitigate the impact related to animal-based and synthetic fur materials, such as the ones related to fibre shedding.

This research asks: What impacts of animal-based fur and synthetic fur alternatives could be addressed by a next-gen material in which the hair part is replaced by hemp fibre?

In response to the research question, the challenges of using animal-based fur and synthetic fur alternatives for applications in the fashion industry are presented in conjunction with a discussion of the properties expected from next-gen fur alternatives in a fashion context. The potential of hemp fibre as the hair component in next-gen fur materials is then discussed, drawing from both literature and empirical work.

ANIMAL-BASED FUR

The use of fur as a status-affirming adornment has been historically present in fashion (Faiers, 2020, p. 112). Even the first fur clothes can be considered hunting trophies, demonstrating that clothes were already a symbol of rank distinction (Faiers, 2020 p. 82) usually associated with power, be it the one originated from the animal kingdom or the social status brought by wearing fur clothes (Faiers, 2020, p. 56). Just the act of wearing fur may already be perceived as a promotion since it often instigates curiosity concerning how the wearer sourced the material (Taylor, 2024). It also incites proximity, simulating transferring the animal's characteristics to the wearer (Faiers, 2020, p. 52); it is a material that evokes almost primitive memories (Kwasny, 2019; Fairs, 2021) often associated with 'the wildness and ferocity of the animal kingdom' in opposition to 'the furrier's art' (Faiers, 2020, p. 86). However, fur is a controversial material (Gladman et al., 2024) due to a series of environmental and ethical concerns, including animal welfare, eutrophication and carbon emissions from fur farming (Bijleveld et al., 2011).

A major challenge with fur farming is that it is considered inefficient, especially because most farmed fur animals (e.g. mink, fox, raccoon dog) are carnivores, so other animals are needed for feed. For instance, producing one kilogram of mink fur (equivalent to eleven mink) demands over five hundred kilograms of feed (Bijleveld et al., 2011). Turning skinned fur into fashion products also requires processing, treatments and finishing, which consume electricity, transportation fuel, and toxic chemicals (Bijleveld et al., 2011). At the end of life, most animal-based fur products end up in landfills (Gladman et al., 2024). A 2011 study conducted by CE Delft found European mink to have the highest impact among all materials except for water depletion, while the presence of hazardous chemicals exceeded European regulations (Bijleveld et al., 2011). However, the lack of thorough and up-to-date life cycle assessments for animal fur and other alternatives prevents a precise comparison between materials (Bijleveld, 2013). Furthermore, fur farming can be a public health risk (Warwick et al., 2023). A study conducted by Lindh et al. (2023) on fur farms inthe South and Central Ostrobothnia regions of Finland,

verified an outbreak of highly pathogenic avian influenza (HPAI) A(H5N1) infections amongst foxes, American minks and raccoon dogs. Although no human infections were detected, the study highlights the risk of a serious problem. During the COVID-19 global pandemic, SARS-CoV-2 infection was detected in farmed minks (Oreshkova et al., 2020), which led to over fifteen million mink being killed in Denmark (Larsen et al., 2021).

Historically, the controversy over fur as a fashion material has led to several bans and specific legislation. These bans can be classified into either governmental or organisational that promote full or partial bans on fur sales or on fur production (Fur for Animals, n.d.). The first fur farming ban happened in the UK in 2000, followed by Belgium, Italy and France; the EU is the second largest producer of fur behind China (Fur for Animals, n.d.). In addition, California, which accounted for almost one-quarter of all fur sales in the United States, has banned the sale of fur starting in 2023 (California Legislative Information, 2019). Concerning organisational bans, the first major fashion brand to ban fur was Calvin Klein in 1994 (Spindler, 1994), while the first magazine to ban fur was InStyle in 2018 (PETA, 2018). Copenhagen Fashion Week banned fur in 2022, followed by London Fashion Week in 2024 (Bramley, 2024). Overall, at present, over one thousand design and retail brands have pledged to not use or sell animal fur, including Kering (Lange, 2023). The ways in which luxury conglomerates like LVMH and Kering approach fur vary significantly (Smith, 2024). While LVMH is known for pressuring its own maisons to avoid banning animal-based fur, Kering announced in 2021 that the material has 'no place in luxury' and encourages replacements, especially next-gen (Smith, 2024). So, even though bans often lead to more desire and imitation (Faiers, 2020 p. 66), they also serve as a trigger for innovation (Material Innovation Initiative, 2024).

ARTIFICIAL FUR

At present, there are three main categories of fur and fur-like materials: animal-based fur, synthetic fur alternatives, and next-gen fur (Gladman et al., 2024). In synthetic fur alternatives, synthetic fibres, usually polyester, acrylic, or modacrylic, are used to mimic the hair in animal fur (Gladman et al., 2024). Their fossil carbon or petrochemical origin, which also enables the material's successful properties, tends to be forgotten when garments are worn (Stanes & Gibson, 2017). Still, at the expected pace, the global market size of synthetic fur is estimated to grow at a Compound Annual Growth Rate (CAGR) of almost 18.92% from 2024 to 2028, representing a significant growth of USD 184.2 million (Technavio, 2024), which also means a growing production of toxic pollutants associated with the material, including PCBs, dioxins, nitrous oxide, hydrogen cyanide, as well as flame retardants and antimicrobial agents (Gladman et al., 2024). Moreover, considering that fur is composed of both skin and fibre (Rawling et al., 2024), the environmental impact of synthetic fur's backing also becomes an important part of the material's creation (Bijleveld, 2013).

As demonstrated by Stanes & Gibson (2017), the two key elements of fashion consumption, aesthetics and touch, can be extensively explored by using synthetics. Nevertheless, even though some current synthetic fur alternatives may be considered more sustainable than animal-based fur when comparing carbon footprints and, obviously, animal welfare (Bijleveld, 2013), these cause extensive environmental damage, including microplastic pollution (Gladman et al., 2024). Microplastics can be defined as primary or secondary, depending on the production source. Primary refers to the microplastics purposefully created in a size smaller than 5 mm within (European Chemical Agency, n.d.), whereas secondary refers to the microplastics generated through the fragmentation of larger plastics (Boucher & Friot, 2017). It is important to distinguish between microfibres and microplastics because the first concerns only the fibre diameter, while the second sets a maximum length of 5 mm and also covers the material's origin (Zhang et al., 2021). Fibre shedding from textiles naturally occurs during material/garment production (Cai et al., 2020), use (De Falco et al., 2020) -including maintenance, such as washing and drying (Mahbub & Shams, 2022) - and at the end of life (Zhang et al., 2021). In the case of microfibres, Athey & Erdle (2022) point out that anthropogenic microfibers can be defined as natural, semisynthetic or synthetic based on feedstock and production. However, although often underestimated, the shedding of natural and semisynthetic fibres is also significant because these fibres usually contain chemical additives and finishes that cause environmental pollution and should not be ignored. Additionally, a study conducted by De Falco et al.

that fibre release into the air is as significant as fibre release into water.
Microplastic pollution harms ecosystems, such as coral reefs and soil-based ecosystems and organisms that depend directly on topsoil (Huang et al., 2021; Roy et al, 2023). Globally, it is estimated that the amount of textile-related microplastics entering the oceans ranges between 200 and 500 tonnes per year (European Environmental Agency, 2022), and even though synthetic fur garments tend to be washed less frequently (Ecopel, n.d.), the plasticity of synthetic materials can elicit in the wearer the perception that the material might promote sweat and retain body smells, which can lead to repeat washings (Stanes & Gibson, 2017). Thus, since microplastic pollution is a problem that cannot be ignored, and textile design-related interventions to better manage fibre sheds are necessary, understanding the main sources of microplastic release is critical to designing strategies to mitigate the problem (Cai et al., 2020). To enable a transition that could possibly reduce fibrous microplastics shed, measures should include developing bio-based and biodegradable alternatives (Zhang et al., 2021). Mazzitelli et al. (2024) reinforce the significance of considering the fibre's nature when selecting textiles, while a study conducted by Cai et al. (2020) points out the significance of the production process when addressing microplastic fibre release; as an example, considering the samples analysed in the research, laser-cut samples shed almost twenty times fewer microplastic fibres than scissor-cut ones.

NEXT-GEN FURS AND HEMP

New technologies enable the creation of textile materials that can cause less environmental damage (Lee et al., 2021) while also avoiding some ethical issues. Next-gen furs aim to solve some of these issues by maintaining high performance while prioritising animal- and petrochemical-free alternatives (Gladman et al., 2024). In addition, next-gen fur offerings should aim to improve performance features and be cost-competitive. For instance, Gladman et al. (2024) comprehensively discuss the potential advantages of developing next-gen fur and the existing market gap that such materials could address. Critical attributes expected from next-gen fur options include the ability to accept non-toxic dyes, the ability to be created with multiple patterns and textures, as well as the material's 'lustre and softness' comparable to the currently available options (both animal-based or synthetic). Simultaneously, fibre shedding and release must be mitigated while using biobased inputs to create a material that is either recyclable, biodegradable or responsibly disposed of at end-of-life. Recommendations for next-gen fur also include reduced maintenance, pleasant or absent odour, flame retardancy, hypoallergenic properties (due to proximity to the skin), thermal resistance, and satisfactory appearance. In addition, since both animal-based and synthetic furs tend to elicit a desire to touch them, that should be transferred to next-gen alternatives (Gladman et al., 2024).
The first known alternative to animal-based fur dates back to a 1365 BCE woollen-cloth hat - made of a dense collection of extremely fine (10 - 20 mm long) knotted cords - found in Denmark that belonged to a Bronze Age warrior, referred to as the Muldbjerg man (Faiers, 2020, p. 151). Decades later, Tutankhamun's tomb, which featured supplies provisions for his journey to the afterlife, also included two 'leopard skins': one real skin and one fake (Faiers, 2020 p. 200). These alternatives to fur are believed to have been considered expensive materials considering the skill and time involved in their production. Rather than imitating fur, they celebrate fur's ability to be translated into a new skilled expression (Faiers, 2020, p. 151). Thus, from that perspective, fur alternatives do not necessarily need to be direct replacements and can have their own value. In more recent examples, for the Autumn/Winter '24 season runways, fur was one of the biggest trends (Tag Walk, 2024), including fur-like alternatives, such as Diesel's denim insets used to produce carefully crafted furry garments and accessories (Gordon, 2024), and Gabriela Hearst's fur-looking woven cashmere coats (Taylor, 2024). Even though these alternative materials do not yet present the same range of properties as animal-based fur, they are valuable for the market as exemplars.
To date, the lead author has conducted over one hundred material experiments as part of an ongoing research project, to identify opportunities for using hemp fibre to mimic animal hair in next-gen fur materials. In figure 1, a comparison between long hemp fibre (natural and bleached) and sheepskin (applied to a Fendi handbag (Fendi, n.d.)) is made to demonstrate opportunities for the material. The experiments demonstrate that hemp fibre can be a viable alternative to animal hair in some next-gen furs. It can create a visually

Fig. 01

pleasing surface that is also appealing to touch. Where hemp fibre shows particular promise as a material for next-gen fur is in mitigating the impact of fibre shedding. It is clear from the research and material experiments to date that in comparison to animal-based and synthetic fur materials, in a next-gen fur with the hair composed of hemp fibre, the impact from fibre shedding - which occurs with all materials - is greatly reduced. This is due to hemp fibre being readily biodegradable (Gedik & Avinc, 2020), therefore not contributing towards microplastic pollution during use (Zhang et al., 2021), and promoting less environmental damage if landfilled at the end of life (Liu et al., 2023). Although textile production will always have some environmental impacts, the fashion industry can implement various practices to reduce it. Hemp can demonstrably be a valuable addition to this strategy (Muthu & Dhondt, 2021). Industrial hemp (Cannabis sativa L.) is an annually grown multipurpose plant. Evidence of hemp being used as a textile dates back to around 6000 years ago in Asia. However, the peak production and use of hemp occurred in the last three centuries (Ranalli & Venturi, 2004), until the early 1900s, when many countries banned marijuana due to its psychoactive effects and, based on misinformation, included hemp in the ban (Rawson, 2018). Recently, the interest in hemp has been growing again. The global industrial hemp market, estimated at USD 5.49 billion in 2023, is expected to grow at a CAGR of 17.5% from 2024 to 2030, potentially reaching USD 16.82 billion (Grand View Research, 2024). In a 2005 study conducted by Cherrett et al. (2005)

comparing twelve scenarios involving hemp, organic hemp, cotton, organic cotton, and polyester based on energy requirements, carbon dioxide emissions, ecological footprint, and water usage, the results revealed that organic and traditionally produced hemp had the lowest footprint. Hemp is a fully biodegradable, low-input, fast-growing, and high-yield crop (Gedik & Avinc, 2020) that requires minimal pesticides, herbicides, or fertilisers (Muthu & Dhondt, 2021), and its extensive root system significantly reduces the need for irrigation (Zatta et al., 2012). Moreover, hemp fabrics are non-allergenic (Kostic et al., 2008), offer good UV protection (Kocić et al., 2019), and have excellent thermal conductivity, which facilitates heat transfer between the human body and the textile, helping to keep the wearer warm in cold temperatures and cool in warm temperatures (Stanković et al., 2019). In a recent report on reducing the impact of textile-based goods purchased by the city of New York, prepared by the Local Law 112 Task Force (Gabriel et al., 2024), the benefits of using hemp fibre include biodegradability, renewability, strength, natural mildew and pest resistance, hypoallergenic nature, potential reduction of soil erosion and its value as in crop rotation. Hemp is rated as low in environmental risk, while animal fur is rated high. The risks associated with hemp fibre include restricted availability related to drug stigma, the potential use of pesticides (even if not required), and the impact of chemical retting, which can be mitigated. Risks with fur include animal welfare and slaughter, carbon dioxide emissions, intensive water and land use, eutrophication, forced labour/worker exploitation, and toxic chemical exposure. The report also covers synthetic fibres such as acrylic, and it associates them with several environmental risks, including microfiber pollution and limited end-of-life solutions.

The production and consumption of fur have been historically linked to innovation (Faiers, 2020 p. 225) and when comparing the production volume of traditional animal-based materials, it becomes clear that targeting materials that share a smaller part of the market can promote more positive consequences. Still, consumer acceptance is an important consideration for all next-gen fur materials. A study by Seidu et al. (2024) on sustainable material innovations within circular fashion revealed that price is a key factor consumers consider when purchasing bio-based materials. As animal-based fur is part of the luxury market segment, a next-gen fur could offer price parity with currently available alternatives (Gladman et al., 2024). For instance, concerning the potential for consumer adoption of next-gen alternatives in the United States, Szejda (2023) conducted a study with over a thousand participants. Among the 54% who indicated an intention to purchase either traditional fur or a fur alternative within the next five years, 62% expressed a preference for next-gen alternatives. However, despite this positive indication, there often exists an intention-behaviour gap among consumers (Rausch & Kopplin, 2021), primarily because adopting next-gen alternatives frequently entails sacrifices, such as higher costs or reduced durability (Griskevicius et al., 2010).

Further research opportunities include the fixing of hemp fibre to a base that mimics an animal's skin. Future research will also investigate the possibilities for scaling hemp as a material for next-gen further. It is still unclear whether existing supply chain technologies would support the production of such materials. For instance, the technologies used to manufacture synthetic furs could not be used to reproduce the materials created as part of this research; so, future research will investigate the scalability of these materials.

CONCLUSION

This paper has explored the potential of hemp fibre as a source for the hair component in next-gen fur materials, as part of larger transitions from fossil-based towards bio-based fashion and textile systems. Fibre shedding from textiles naturally occurs during material/garment production (Cai et al., 2020), use (De Falco et al., 2020) - including maintenance, such as washing and drying (Mahbub & Shams, 2022) - and at the end of life (Zhang et al., 2021). Fibres shed from animal-based fur, which is a controversial material for several reasons (Gladman et al., 2024), could be, in theory, considered biodegradable and natural; however, the additives and finishings added to the material often affect its natural origins and how degradation occurs (Athey & Erdle, 2022). Synthetic alternatives, which solve some of the challenges related to animal-based fur, such as animal welfare and cost, are also significantly harmful to the environment and are petrochemical-based (Gladman et al., 2024). Consequently, it makes sense to consider these factors when designing a next-gen fur textile, which should be an animal- and petrochemical-free

alternative. Based on hemp's natural properties, including biodegradability, renewability, strength, natural mildew and pest resistance, hypoallergenic nature, potential reduction of soil erosion and benefits when used as intercrop (Gabriel et al., 2024), hemp fibre could be a promising option to serve as the fibre part of fur in next-gen fur design. In this case, the fibres shed from the material could significantly promote less environmental impact and become part of nature's carbon cycle (Liu et al., 2023). However, it is essential to understand that the majority of research papers available investigating anthropogenic pollution caused by fibre sheds do not account for natural fibres, so the extent to which that could affect the environment is still inconclusive and could be currently underestimated (Athey & Erdle, 2022). Still, hemp demonstrates promise, as it is a low-impact fibre to grow in regenerative agriculture; it can also be coloured easily with bio-based dyes, and it biodegrades readily when the fibre is shed as well as at the end of life.

This paper has reported on preliminary findings from an ongoing study investigating the potential of using hemp as an alternative for the fibre part of fur in next-gen fur design, which could have several benefits, such as reduced impact promoted by fibre shed. Future research will further investigate the base materials for such next-gen furs, as well as the possibilities for scaling up the manufacturing of these materials.

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CAPTIONS

[Fig. 01]On top, two experiments demonstrating the potential of using hemp fibre to mimic animal hair in next-gen fur compared to a sheepskin Fendi bag (bottom).

REFERENCES

Athey, S. N., & Erdle, L. M. (2022). Are We Underestimating Anthropogenic Microfiber Pollution? A Critical Review of Occurrence, Methods, and Reporting. Environmental Toxicology and Chemistry, 41(4), 822–837. https://doi.org/10.1002/etc.5173

Bijleveld, M. (2013). Natural mink fur and faux fur products, an environmental comparison. CE Delft. https://cedelft.eu/wp-content/uploads/sites/2/2021/04/CE_Delft_22203_Natural_mink_fur_and_faux_fur_products_FINAL_1375779267.pdf

Bijleveld, M., Korteland, M. & Sevenster, M. (2011). The environmental impact of mink fur production. CE Delft. https://www.furfreealliance.com/wp-content/uploads/2021/06/CE-Delft-The-environmental-impact-of-mink-fur-production.pdf

Boucher, J. & Friot, D. (2017). Primary microplastics in the oceans: a global evaluation of sources. IUCN, Gland, Switzerland. https://portals.iucn.org/library/sites/library/files/documents/2017-002-En.pdf

Bramley, E. V. (2024). Skins and feathers are as cruel as fur, the fashion industry is told. The Guardian. https://www.theguardian.com/fashion/2024/mar/31/skins-and-feathers-are-as-cruel-as-fur-the-fashion-industry-is-told

Burgess, R. & White, C. (2019). Fibershed: Growing a Movement of Farmers, Fashion Activists, and Makers for a New Textile Economy. Chelsea Green Publishing.

Cai, Y., Mitrano, D. M., Heuberger, M., Hufenus, R., & Nowack, B. (2020). The origin of microplastic fiber in polyester textiles: The textile production process matters. Journal of Cleaner Production, 267, 121970-. https://doi.org/10.1016/j.jclepro.2020.121970California Legislative Information (2019). Assembly Bill No. 44 CHAPTER 764. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB44

Cherrett N., Barrett, J., Clemett, A., Chadwick, M. & Chadwick, M.J. (2005). Ecological footprint and water analysis of cotton, hemp and polyester. Stockholm Environment Institute, Stockholm. https://mediamanager.sei.org/documents/Publications/SEI-Report-EcologicalFootprintAndWaterAnalysisOfCottonHempAndPolyester-2005.pdf.

De Falco, F., Cocca, M., Avella, M., & Thompson, R. C. (2020). Microfiber Release to Water, Via Laundering, and to Air, via Everyday Use: A Comparison between Polyester Clothing with Differing Textile Parameters. Environmental Science & Technology, 54(6), 3288–3296. https://doi.org/10.1021/acs.est.9b06892

ECOPEL (n.d.). THE TRUTH ABOUT FAUX FUR & SUSTAINABILITY. https://www.ecopel.com/article-03---the-truth-about-faux-fur---sustainability.html

European Chemical Agency (n.d). Microplastics. https://echa.europa.eu/hot-topics/microplastics#:~:text=These%20small%20pieces%20

European Environmental Agency (2022). Microplastics from textiles: towards a circular economy for textiles in Europe. https://www.eea.europa.eu/publications/microplastics-from-textiles-towards-a

Faiers, J. (2020). Fur: a sensitive history. Yale University Press.

Fairs, M. (2021). Climate change is "a design project needing lots of attention" says William McDonough. Dezeen. https://www.dezeen.com/2021/06/21/carbon-climate-change-design-project-william-mcdonough-interview/

Fendi (n.d.). Fendi Origami Medium - Beige sheepskin bag that can be transformed (Product Code: 8BH414A984F1734). https://www.fendi.com/au-en/woman/bags/fendi-origami-medium-beige-sheepskin-bag-that-can-be-transformed-8bh414a984f1734

Fur for Animals (n.d.). A Guide To Fur Bans Around The World. https://respectforanimals.org/a-guide-to-fur-bans-around-the-world/

Gabriel, M. B., Westervelt, A., Schreiber, J. & Islam, M. I. (2024). Achieving Impact Reductions for Textile-Based Goods Purchased by the City of New York: Analysis and Recommendations or the Implementation of Local Law 112 of 2021. Local Law 112 of 2021 Task Force, New York, New York. City of New York.

https://static1.squarespace.comstatic/5f5f02dd9b510014eef-4fc4f/t/66cc2ae684ff6667f5d2cffc/1724656375219/AcheivingImpactReductionsForTextilesLL112_August+2024.pdf

Gedik, G., & Avinc, O. (2020). Hemp Fiber as a Sustainable Raw Material Source for Textile Industry: Can We Use Its Potential for More Eco-Friendly Production? In Sustainability in the Textile and Apparel Industries (pp. 87–109). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-38541-5_4

Ghiat, I., & Al-Ansari, T. (2021). A review of carbon capture and utilisation as a CO2 abatement opportunity within the EWF nexus. Journal of CO2 Utilization, 45, 101432-. https://doi.org/10.1016/j.jcou.2020.101432

Gladman, A. S., Rawling, N., Chang, C., Dow, T. D., Erixon, C., & Weathers, O. (2024). What Makes Fur, Fur? Material Innovation Initiative. https://materialinnovation.org/wp-content/uploads/MII-What-Makes-Fur-Fur-Report-Digital.pdf

Gordon, G. (2024). Diesel Turned the Whole World Into Voyeurs for Fall/Winter 2024. Savoir Flair. https://www.savoirflair.com/article/diesel-fall-winter-2024/9968c3fa-3c39-475a-839d-8aa1c71ff1a9

Grand View Research (2024). Industrial Hemp Market Size & Trends. https://www.grandviewresearch.com/industry-analysis/industrial-hemp-market#:~:text=Industrial%20Hemp%20Market%20Size%20%26%20Trends,17.5%25%20from%202024%20to%202030.

Griskevicius, V., Tybur, J. M., & Van den Bergh, B. (2010). Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation. Journal of Personality and Social Psychology, 98(3), 392–404. https://doi.org/10.1037/a0017346

Huang, W., Chen, M., Song, B., Deng, J., Shen, M., Chen, Q., Zeng, G., & Liang, J. (2021). Microplastics in the coral reefs and their potential impacts on corals: A mini-review. The Science of the Total Environment, 762, 143112–143112. https://doi.org/10.1016/j.scitotenv.2020.143112

Kocić, A., Bizjak, M., Popović, D., Poparić, G. B., & Stanković, S. B. (2019). UV protection afforded by textile fabrics made of natural and regenerated cellulose fibres. Journal of Cleaner Production, 228, 1229–1237. https://doi.org/10.1016/j.jclepro.2019.04.355

Kostic, M., Pejic, B., & Skundric, P. (2008). Quality of chemically modified hemp fibers. Bioresource Technology, 99(1), 94–99. https://doi.org/10.1016/j.biortech.2006.11.050

Kwasny, M. (2019). Putting on the Dog: The Animal Origins of What We Wear. Trinity University Press.

Lange, K. E. (2023). Cutting cruelty out of fashion. The Humane Society of the United States. https://www.humanesociety.org/news/cutting-cruelty-out-fashion

Larsen, H. D., Fonager, J., Lomholt, F. K., Dalby, T., Benedetti, G., Kristensen, B., Urth, T. R., Rasmussen, M., Lassaunière, R., Rasmussen, T. B., Strandbygaard, B., Lohse, L., Chaine, M., Møller, K. L., Berthelsen, A.-S. N., Nørgaard, S. K., Sönksen, U. W., Boklund, A. E., Hammer, A. S., Belsham, G. J., Krause, T. G., Mortensen, S., Bøtner, A., Fomsgaard, A. & Mølbak, K. (2021). Preliminary report of an outbreak of SARS-CoV-2 in mink and mink farmers associated with community spread, Denmark, June to November 2020. Euro Surveillance : Bulletin Européen Sur Les Maladies Transmissibles, 26(5), 1-. https://doi.org/10.2807/1560-7917.ES.2021.26.5.210009

Lee, S., Congdon, A., Parker, G., & Borst, C. (2021). UNDERSTANDING 'BIO' MATERIAL INNOVATIONS: A PRIMER FOR THE FASHION INDUSTRY. Biofabricate & Fashion For Good. https://fashionforgood.com/wp-content/uploads/2020/12/Understanding-Bio-Material-Innovations-Report.pdf

Lindh, E., Lounela, H., Ikonen, N., Kantala, T., Savolainen-Kopra, C., Kauppinen, A., Österlund, P., Kareinen, L., Katz, A., Nokireki, T., Jalava, J., London, L., Pitkäpaasi, M., Vuolle, J., Punto-Luoma, A.-L., Kaarto, R., Voutilainen, L., Holopainen, R., Kalin-Mänttäri, L., Laaksonen, T., Kiviranta, H., Pennanen, A., Helve, O., Laamanen, I., Melin, M., Tammiranta, N., Rimhanen-Finne, R., Gadd, T. & Salminen, M. (2023). Highly pathogenic avian influenza A(H5N1) virus infection on multiple fur farms in the South and Central Ostrobothnia regions of Finland, July 2023. Euro Surveillance : Bulletin Européen Sur Les Maladies Transmissibles, 28(31), 1-. https://doi.org/10.2807/1560-7917.ES.2023.28.31.2300400

Liu, J., Liu, S., Zhu, L., Sun, L., Zhang, Y., Li, X., & Wang, L. (2023). Carbon Neutrality Potential of Textile Products Made from Plant-Derived Fibers. Sustainability, 15(9), 7070-. https://doi.org/10.3390/su15097070

Mahbub, M. S., & Shams, M. (2022). Acrylic fabrics as a source of microplastics from portable washer and dryer: Impact of washing and drying parameters. The Science of the Total Environment, 834, 155429–155429. https://doi.org/10.1016/j.scitotenv.2022.155429

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: threats, opportunities and solutions. Philosophical Transactions of the Royal Society of London. Series B. Biological Sciences, 375(1794), 20190104–20190104. https://doi.org/10.1098/rstb.2019.0104

Material Innovation Initiative (2024). The Critical Timing of Next-Gen Fur. Youtube. https://www.youtube.com/watch?v=9XyHJm3rstM

Mazzitelli, M., Papile, F., & Del Curto, B. (2024). Materials selection and fashion design: strengthening reflections on fibre's nature in fibres and textiles selection. Discover Sustainability, 5(1), 180–17. https://doi.org/10.1007/s43621-024-00294-3

Muthu, S. S., & Dhondt, F. (2021). The Future of Hemp in the Fashion Industry. In Hemp and Sustainability (pp. 109–123). Springer. https://doi.org/10.1007/978-981-16-3334-8_8

Oreshkova, N., Molenaar, R. J., Vreman, S., Harders, F., Oude Munnink, B. B., Hakze-van der Honing, R. W., Gerhards, N., Tolsma, P., Bouwstra, R., Sikkema, R. S., Tacken, M. G., de Rooij, M. M., Weesendorp, E., Engelsma, M. Y., Bruschke, C. J., Smit, L. A., Koopmans, M., van der Poel, W. H., & Stegeman, A. (2020). SARS-CoV-2 infection in farmed minks, the Netherlands, April and May 2020. Euro Surveillance : Bulletin Européen Sur Les Maladies Transmissibles, 25(23), 1-. https://doi.org/10.2807/1560-7917.es.2020.25.23.2001005

PETA (2018). Victory! 'InStyle' Is First Major Fashion Magazine to Ban Fur. https://www.peta.org/blog/instyle-magazine-bans-fur/

Popescu, C., & Hoecker, H. (2007). Hair - The Most Sophisticated Biological Composite Material. ChemInform, 38(42), no-no. https://doi.org/10.1002/chin.200742268

Ranalli, P., & Venturi, G. (2004). Hemp as a raw material for

industrial applications. Euphytica, 140(1–2), 1–6. https://doi.org/10.1007/s10681-004-4749-8

Rausch, T. M., & Kopplin, C. S. (2021). Bridge the gap: Consumers' purchase intention and behavior regarding sustainable clothing. Journal of Cleaner Production, 278, 123882-. https://doi.org/10.1016/j.jclepro.2020.123882

Rawling, N., Dow, T. D., Erixon, C., & Weathers, O. (2024). White Space #1: Sub-Categories with Limited Innovation 2024. Material Innovation Initiative. https://materialinnovation.org/wp-content/uploads/White-Space-1_Sub-categories-with-limited-innovation_Report_Digital_Final-1.pdf

Rawson, J. M. (2018). Hemp as an Agricultural Commodity. Congressional Research Service. https://sgp.fas.org/crs/misc/RL32725.pdf

Roy, T., Dey, T.K. & Jamal, M. Microplastic/nanoplastic toxicity in plants: an imminent concern. Environ Monit Assess 195, 27 (2023). https://doi.org/10.1007/s10661-022-10654-z

Seidu, R. K., Eghan, B., & Acquaye, R. (2024). A Review of Circular Fashion and Bio-based Materials in the Fashion Industry. Circular Economy and Sustainability (Online), 4(1), 693–715. https://doi.org/10.1007/s43615-023-00303-z

Smith, P. J. (2024). Op-Ed | Fashion's Fur Debate Has Never Been a Clean Fight. Business of Fashion. https://www.businessoffashion.com/opinions/sustainability/lvmh-fur-marc-jacobs-activist-campaign-bully/

Spindler, A. M. (1994). Calvin Klein Will Stop Making Furs. The New York Times. https://www.nytimes.com/1994/02/11/business/calvin-klein-will-stop-making-furs.html

Stanes, E., & Gibson, C. (2017). Materials that linger: An embodied geography of polyester clothes. Geoforum, 85, 27–36. https://doi.org/10.1016/j.geoforum.2017.07.006

Stanković, S. B., Novaković, M., Popović, D. M., Poparić, G. B., & Bizjak, M. (2019). Novel engineering approach to optimization of thermal comfort properties of hemp containing textiles. Journal of the Textile Institute, 110(9), 1271–1279. https://doi.org/10.1080/00405000.2018.1557367

Szejda, K. (2023). Next-gen materials: A 2023 assessment of the potential for U.S. consumer adoption. Consumer Research Report. North Mountain Consulting Group. https://materialinnovation.org/wp-content/uploads/2023-US-Consumer-Research-Report-1.pdf

Tag Walk (2024). Womenswear Trends Fall/Winter 2024. https://www.tag-walk.com/en/trends/woman/fall-winter-2024

Taylor, E. (2024). Why Is Fur—Real and Pretend—Everywhere Again? Vogue. https://www.vogue.com/article/why-is-fur-real-and-pretend-everywhere-again

Technavio (2024). Artificial Fur Market size is set to grow by USD 184.2 million from 2024-2028, Growing prominence for online shopping to boost the market growth, Technavio. PR Newswire. https://www.prnewswire.com/news-releases/artificial-fur-market-size-is-set-to-grow-by-usd-184-2-million-from-2024-2028--growing-prominence-for-online-shopping-to-boost-the-market-growth-technavio-302180136.html

Warwick, C., Pilny, A., Steedman, C. & Grant, R. (2023). One health implications of fur farming. Front. Anim. Sci. 4:1249901. https://doi.org/10.3389/fanim.2023.1249901

Zatta, A., Monti, A., & Venturi, G. (2012). Eighty Years of Studies on Industrial Hemp in the Po Valley (1930--2010). Journal of Natural Fibers, 9(3), 180–196. https://doi.org/10.1080/15440478.2012.706439

Zhang, Y.-Q., Lykaki, M., Alrajoula, M. T., Markiewicz, M., Kraas, C., Kolbe, S., Klinkhammer, K., Rabe, M., Klauer, R., Bendt, E., & Stolte, S. (2021). Microplastics from textile origin - emission and reduction measures. Green Chemistry: An International Journal and Green Chemistry Resource: GC, 23(15), 5247–5271. https://doi.org/10.1039/d1gc01589c

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).

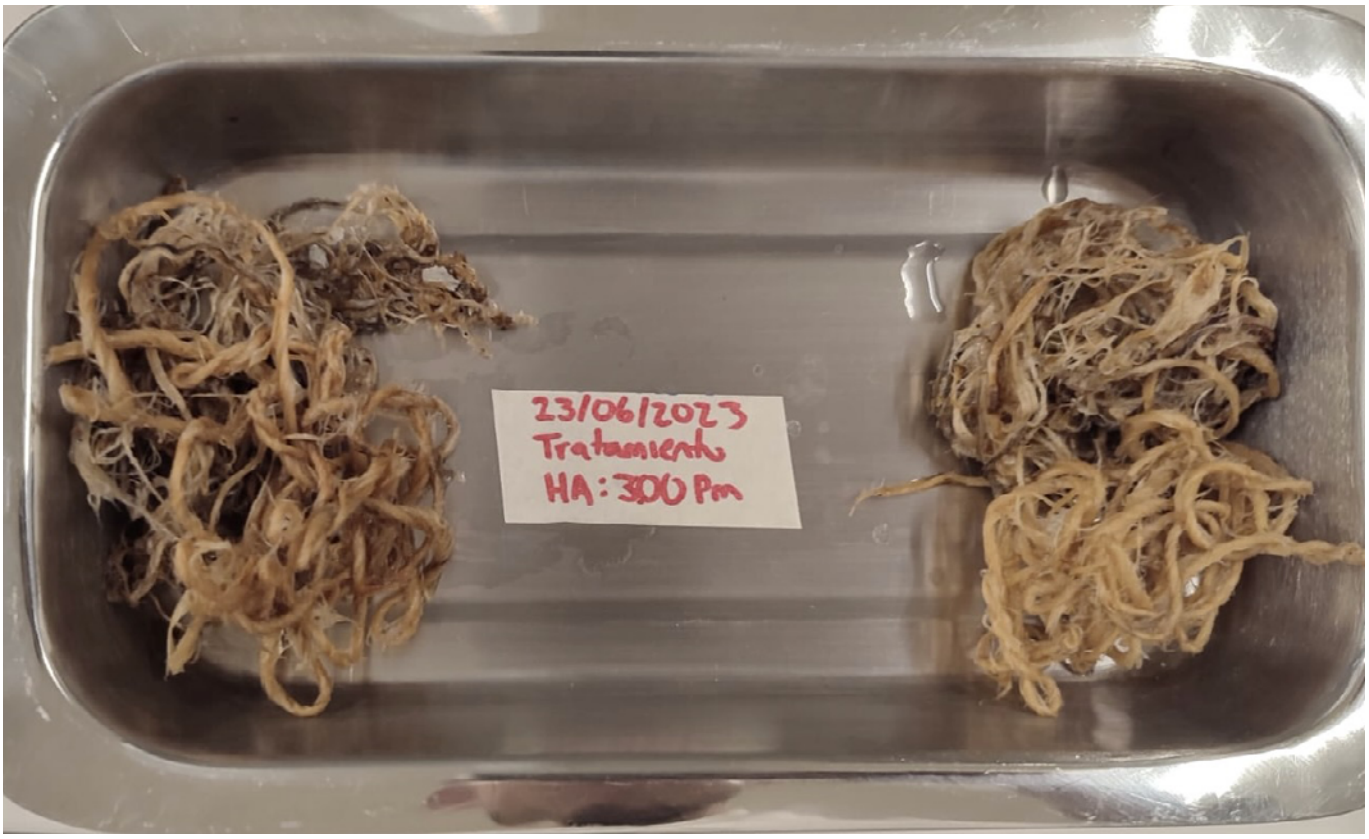

Fig. 02

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

REFERENCES

Biodesign Challenge. (n.d.). Retrieved January 14, 2025, from https://www.biodesignchallenge.org/

Bonime, W. (2018). PETA & Stella McCartney BioDesign Challenge Winners Create Animal Free Wool. Forbes. https://www.forbes.com/sites/westernbonime/2018/07/09/peta-stella-mccartney-biodesign-challenge-winners-create-animal-free-wool/

Ceschin, F., & Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. Design Studies, 47, 118–163.

Dela Cruz, C. (2016). Piñatex: Sustainable leather alternative made from pineapple leaf fibers. Ananas Anam. https://www.ananas-anam.com/

European Commission. (n.d.). Circular economy action plan. Retrieved January 19, 2025, from https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

Glazunova, L. (2024). Cities must step up to rescue circular economy innovations. Circle Economy. https://www.circle-economy.com/blog/cities-must-step-up-to-rescue-circular-economy-innovations

Hernández, M., & Ortiz, M. (2023, June 13). Protocolo tratamiento enzimático para fibras vegetales. Universidad de los Andes.

Ingrouille, M., & Eddie, B. (2006). Plants: Diversity and Evolution. Cambridge University Press.

Jonaitienė, V., Jankauskienė, Z., & Stuogė, I. (2016). Hemp Cultivation Opportunities and Perspectives in Lithuania. In R. Fangueiro & S. Rana (Eds.), Natural Fibres: Advances in Science and Technology Towards Industrial Applications (pp. 407–414). Springer Netherlands. https://doi.org/10.1007/978-94-017-7515-1_32

Klepp, I. G., & Tobiasson, T. S. (Eds.). (2022). Moxic suave Isfahan sala de estar alfombra cuadrada colección tradicional recámara alfombra de forro polar antideslizante alfombras clásico floral decoración del hogar alfombras interiores al aire libre guardería 6' x 6'.

Kumar, S., Singh, R., Kumar, V., Rani, A., & Jain, R. (2017). *Cannabis sativa:* A Plant Suitable for Phytoremediation and Bioenergy Production. In K. Bauddh, B. Singh, & J. Korstad (Eds.), Phytoremediation Potential of Bioenergy Plants (pp. 269–285). Springer. https://doi.org/10.1007/978-981-10-3084-0_10

McKinsey & Company. (2020). How the fashion industry can reduce its carbon footprint | McKinsey. https://www.mckinsey.com/industries/retail/our-insights/fashion-on-climate

Mellick, Z., Payne, A., & Buys, L. (2021). From Fibre to Fashion: Understanding the Value of Sustainability in Global Cotton Textile and Apparel Value Chains. Sustainability, 13(22), Article 22. https://doi.org/10.3390/su132212681

Nath, A., Das, K., & Dhal, G. C. (2023). Global Status of Agricultural Waste-Based Industries, Challenges, and Future Prospects. In R. Neelancherry, B. Gao, & A. Wisniewski Jr (Eds.), Agricultural Waste to Value-Added Products: Technical, Economic and Sustainable Aspects (pp. 21–45). Springer Nature. https://doi.org/10.1007/978-981-99-4472-9_2

Obregón, C., Ortiz, M., Hernández, M., Hinestroza, J. P., & Danies, G. (2023). Preparation, Extraction, and Processing of Water-Retted *Cannabis Sativa L.* Fibers. Journal of Natural Fibers, 20(1), 2166647. https://doi.org/10.1080/15440478.2023.2166647

Pilco, C. R. J., Davila, J. D. C., Amangandi, N. M. T., & Tandapilco, M. V. P. (2023). Obtención de fibras textiles a partir de residuos orgánicos: Obtaining textile fibers from organic waste. LATAM Revista Latinoamericana de Ciencias Sociales y Humanidades, 4(1), Article 1. https://doi.org/10.56712/latam.v4i1.355

Plannthin, D.-K. (2016). Animal Ethics and Welfare in the Fashion and Lifestyle Industries. In S. S. Muthu & M. A. Gardetti (Eds.), Green Fashion: Volume 2 (pp. 49–122). Springer. https://doi.org/10.1007/978-981-10-0245-8_3

QWSTION. (n.d.). BANANATEX®: The world's first durable, biodegradable, and plastic-free fabric made purely from Abacá banana plants. Retrieved January 14, 2025, from https://www.bananatex.info/

Singer, P. (2023). Animal Liberation Now.

Small, E. (2017). Classification of *Cannabis sativa L.* in Relation to Agricultural, Biotechnological, Medical and Recreational Utilization. In S. Chandra, H. Lata, & M. A. ElSohly (Eds.), *Cannabis sativa L.* - Botany and Biotechnology (pp. 1–62). Springer International Publishing. https://doi.org/10.1007/978-3-319-54564-6_1

Smelik, A. (2023). Polyester: A Cultural History. Fashion Practice, 15(2), 279–299. https://doi.org/10.1080/17569370.2023.2196158

Smith, T., Ehrnström-Fuentes, M., Hagolani-Albov, S. E., Klepp, I. G., & Tobiasson, T. S. (2022). Rethinking the (Wool) Economy. In I. G. Klepp & T. S. Tobiasson (Eds.), Local, Slow and Sustainable Fashion: Wool as a Fabric for Change (pp. 133–170). Springer International Publishing. https://doi.org/10.1007/978-3-030-88300-3_6

Sullivan, K. (2018, July 2). Meet Woocoa—A New "Wool" Made From Coconuts and Other Plants. PETA. https://www.peta.org/blog/peta-cosponsors-global-biodesign-chal-lenge-help-discover-vegan-wool/

Syrett, H., & Lammas, F. (2023). Fashion CEO Agenda 2023—Global Fashion Agenda. https://globalfashionagenda.org/resource/fashion-ceo-agenda-2023/

CHALLENGES AND SOLUTIONS FOR RECOVERING MIXED FIBER WASTE FROM KNITTED USED TEXTILES

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Abstract

Pure new wool is rarely found as a quality in German used clothing sorting plants. On the other hand, large quantities of synthetic fiber-wool blends are produced as a waste product of the fast fashion industry. The multiple blends in particular lead to a high loss of value. Previous studies have shown that fiber blends with up to seven different fibers are in circulation within one piece of clothing. Better qualities find their second use in second-hand stores, while lower qualities are categorized and sorted in sorting plants according to their material composition and have so far mostly been processed as filling and insulating materials.
In order to recycle these fibers for the clothing sector, two areas of mechanical recycling are being analyzed and modified within my PhD research.
The finer sorting, as well as the subsequent cutting and tearing process, have a significant influence on the fiber dissolution of the textile surface, as well as on a process-stable yarn production.
Varying fiber blends from used clothing need to be prepared in a process-stable manner so that they can be used as standard raw materials in the future.

Keywords: *Post Consumer Waste, Recyclability, Mechanical Recycling, Process Optimization, Shredded Fibres*

INTRODUCTION

Do we know our currently available resources in the field of fibre recycling?
We usually know the mixing ratios of pre-consumer waste, as waste from production, because it is about virgin fibres and yarns, where the fibre mixtures are known. However, the knowledge gap arises mainly with the mostly unknown material blends of our post-consumer waste, as we not know how it can be re-spun into new yarn and which renewed blend ratios are suitable for this.
Our current knowledge of fibres relates in particular to the sustainable aspects of our available virgin fibres, from cotton, wool, synthetic fibres and the impact of fast fashion. We know that all fibres, no matter how sustainably they are marketed, have their drawbacks in terms of the environment or animal welfare due to the requiered quantity. Therefore, it would be most sustainable not to produce anything from virgin fibres or at least to reprocess the previously used fibres from the pre- & post-consumer waste and to use them as an available resource of equal value in order to reduce the consumption of virgin fibres.
Robin Wall Kimmerer wrote in her book, Braiding sweetgrass:”We have a choice. If the whole world is a commodity - what poverty. If the whole world is a circulating gift - what wealth.”(Kimmerer, 2021)
As an environmental biologist with an indigenous background, she is very much concerned with the holistic consideration of nature and the human being, an aspect I find entirely neglected in the

context of the textile chain and the active awareness of fast fashion. The holistic view of the textile chain and the resources available to us as designers in terms of fibres is an essential point of my research. To address this problem, the most logical decision would be to stop producing new items. The growing second-hand market and the slow fashion movement offer approaches to counteracting the problem. With my background in fashion design, however, my goal is to develop solutions on an industrial scale that enable designers to continue creating new items, but that incorporate processes across the entire textile chain. In my PhD research, titled Re: value-Holistic consideration of the wool fibre cycle for clothing textiles, in particular the recovery of mixed fibre waste from knitted post consumer waste, I focus on the recovery of mixed-fibre waste from post-consumer knitted textiles. This involves developing a recycling process that addresses the problems of fast fashion waste and uses the design process to transform discarded materials into higher-value clothing. The design process must be rethought in the future by integrating the entire textile chain and adopting a Design for Recycling perspective, in order to ultimately recognize clothing as a valuable, preferably circulating commodity, rather than designing for linear consumption.
This includes to actively integrate recycled fibres in the design process, cancel toxic dying processes, design more in similar color ranges and use the huge field of complex knitting & weaving bindings for our designs. The focus in the design should be increasingly on the longevity and future recycling potential of the product.
If we talk about recycled fibres, this leads to the essential question: How recyclable is our current clothing and: What influence does the admixture of synthetic fibres have on future recyclability, especially to wool fibres from our current available post-consumer waste generated by fast fashion? Textile engineers as well as textile and fashion designers are based on a multitude of natural and synthetic fibres that can be mixed in almost unlimited combinations and mixing ratios for further processing in the textile chain, leading to an even greater variety of garments. On the one hand, this playing field opens up a great many possibilities due to the constantly changing fashion trends and our everyday sensitivities, but it also leads to very complex mixing ratios between natural fibres and cellulose-based and/or petroleum-based synthetic fibres that are currently hardly recyclable in terms of their recyclability. In this respect, it is important to find out to what extent we as textile engineers as well as textile and fashion designers need to rethink together at the beginning of the textile chain in order to be able to better guarantee the recyclability of our worn clothing in the future.
My research approach is based on intensive research in the field of wool mixed fibers, a part of recycling that currently receives little attention. The reasons for this are the excessively expensive labor costs for a currently manual sorting process and the different compositions of the wool blends, which differ greatly in their physical textile properties. It is difficult to derive consistent parameters for yarn production. The shredded wool produced from the wool blend fibers, which is currently used for insulation materials and thus downcycled, must be researched in order to use the fibers within the clothing industry cycle and transfer them to recycling. The raw material for the research-related experiments is obtained from locally available resources. The term downcycling refers to products whose quality is inferior to the original material. A classic example is the production of shredded fibers from old clothes, which are used as insulating material in the construction and automotive industries. The term recycling, on the other hand, includes products of equivalent quality, such as fiber-to-fiber recycling, where the yarn produced can be used again for the production of textile surfaces. The term upcycling includes products whose quality is higher than that of the original material due to a material upgrade (fig. 01).

SIGNIFICANCE AND CLASSIFICATION OF MIXED FIBER WASTE

As a result of the properties of petroleum-based synthetic fibers, such as polyacrylic, polyester, polyamide, etc., the following known improvements for textiles result from the targeted use of blends with natural fibers, especially with wool (Hofer, 1981):
- reduction of felting tendency
- increased wearing time
- lightweight fabric due to the low fiber density
- dimensional stability
- dries quickly
- good heat retention due to thermofixed crimped structures
- greater freedom of movement thanks to the use of elastane.

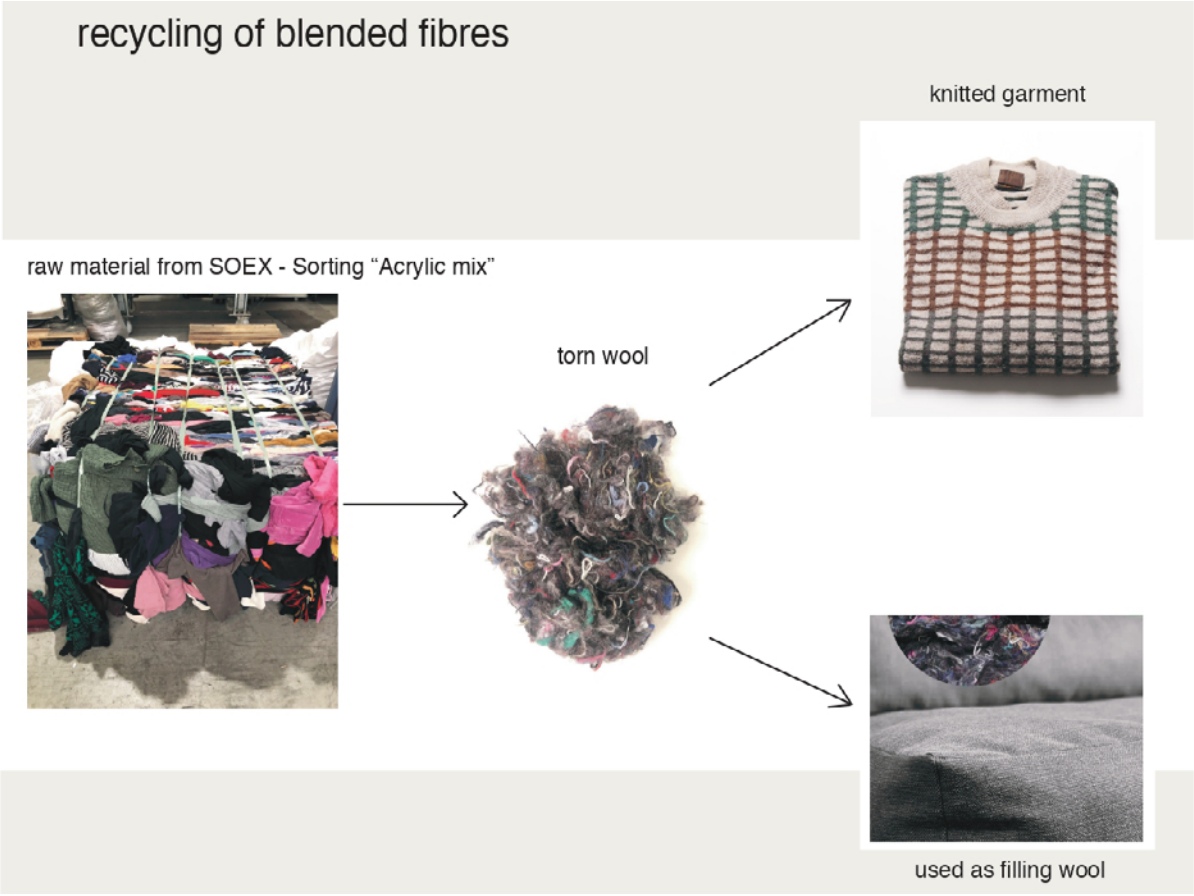

Fig. 01

With the property profiles mentioned, the wide range of synthetic fibers can be used in practically unlimited variations with natural fibers as well as mixed with each other.
Particularly in the area of leisure and sportswear as well as in the use of workwear and health clothing, blends with synthetic fibers have gained massive acceptance over the last few decades.
While fiber blends of natural and synthetic fibers were originally used to enhance the undesirable properties of the natural fibers, the natural fibers are now often added as alibi fibers in order to retain a natural component which, however, is hardly relevant for the textile properties due to its low admixture. These developments make it clear that future recycling steps in the manufacture of textiles have not been and will not be taken into account.
Systems and processes in the sense of the circular economy as it is described in the book Cradle to Cradle(Braungart & McDonough, 2021) as well as in the book Circular Design For Fashion (Ellen MacArthur Foundation, 2021) and the resulting design for recycling approach lead to a sustainable direction with regard to increased recycling cycles. Accordingly, the use of monofibers will play an important role in the future, as will the implementation of adapted recycling processes that take into account the current situation and the associated problems of multiple blends.
The variety of textile properties for our everyday demands on our clothing is not achievable through the use of natural fibers anymore, so synthetic fibers make a large part of our wearing comfort possible in the first place. The use of blended fibers in the apparel sector is a major driver for fast fashion for cost-cutting reasons. Here, the approach is to add natural fibers for the natural-looking character rather than to achieve special properties. This indifference of fiber blends leads to blend ratios of now standard three up to seven components within a garment.
If one considers the fact why synthetic fibers are used so indefinitely in blended fibers in terms of their modified properties, the essential question is why synthetic fibers are separated, especially in the chemical recycling process, than to use their properties within the existing blends, in which they were originally used for.
In order to achieve recycling of these blends for the clothing sector, the areas of sorting and the cutting-tearing process in mechanical recycling are analyzed and modified in this research project.

RECYCLING

The current state of the art in recycling is very diverse. The recyclability of monofibers and blends with a high proportion of natural fibers is already established on the market and is increasingly being used in the reuse of new garments. Customer acceptance continues to grow and recycled fibers serve as a figurehead for sustainable clothing.
Various processes are used to recycle mixed fibers. Mechanical, chemical and thermal recycling are among the most commonly used processes.
Mechanical recycling is used in particular for pure wool and wool blends, whereby a high proportion of pure wool in the blends is currently a prerequisite for further yarn processing.
Chemical recycling is mainly used for cotton blends with petroleum-based synthetic fibers. Among other things, the starting materials are depolymerized, the basic structure of the original polymer is changed or the chemical compounds are broken down by decomposition reactions (Cherdron & Krichel, n.d.a). The HKRITA has been researching the field of chemical fiber recycling for polycotton blends since 2016 with the development of the "Green Machine" in cooperation with H&M (HKRITA Hong Kong Research Institute for Textiles and Apparel, n.d.).
In thermal recycling, the textile waste is thermally utilized, for example in a waste-to-energy plant, and thus used one last time to generate energy. (Cherdron & Krichel, n.d.b)

SORTING

The fine sorting of knitted synthetic fiber/wool blends and the cutting/tearing process define the starting material for recycled yarn in order to ensure process-stable spinnability and good processability in the textile surface.
According to two German used clothing sorting plants, Texaid (Böschen, 2016), and SOEX (Steckert, 2022), around 50% of the used clothing collected is reused and sold on in second-hand stores. The remaining 50% is recycled, of which 16% is processed for use as shredded fibers. With around 50,000 tons of used clothing a year being sorted daily by companies such as SOEX and Texaid, this equates to around 8,000 tons a year that could be used as a useful resource for the clothing industry. However, pure new wool is rarely found as a quality in those 16%. In contrast, large quantities of synthetic fiber-wool blends are produced as a waste product of the fast fashion industry. Above all, the existing multiple blends lead to a high loss of value. My previous investigations have shown that fiber blends with up to seven different fibers are in circulation within one piece of clothing, which are further processed into filling and insulation material. For the clothing industry, this resource has so far been considered unattractive or currently not yet usable, as it is hardly possible to derive consistent parameters for the further process steps for the tear fibers due to their unknown compositions. Torn fibers are therefore used as such and are no longer used in yarn production.
Until now, better qualities have been sent to sorting plants in Italy, Belgium or Eastern Europe to be used for wool or cotton recycling (Böschen, 2016). In Italy, in the Prato area, wool has been recycled to a very high standard for the clothing industry on an industrial scale for many decades.
Companies such as Manteco (Manteco, n.d.), Comistra (Comistra, n.d.) or Re:verso (re:verso, n.d.) process knitted textiles with a high wool content from post-consumer and pre-consumer waste, whose materials and machine parameters are partly known due to the pre-consumer waste content.
Pre-consumer waste, as production waste from the textile industry, differs from post-consumer waste, as the term for used clothing, in terms of the unmixed and mostly known material compositions (Maetschke, 1978).
Furthermore, only knitted used clothing with a high proportion of pure wool is processed. Cellulose-based fibres or impurities are removed via carbonization processes; used clothing with a too high proportion of petroleum-based fibres is not processed. This ensures stable yarn production by using a clearly defined starting material.
In order to counteract the given fiber shortening in the area of mechanical recycling and the associated poorer yarn properties, new fibers are proportionally added as support fibers. Further processing in the examples mentioned is often carried out with petroleum-based synthetic fibers in order to make the overall quality more tear-resistant and durable.

METHODS FOR DIFFERENTIATED SORTING WITH REGARD TO MULTIPLE BLENDS

Differences in properties of the often not clearly identifiable synthetic fiber-wool blends influence the spinning behavior. To achieve recyclability of these fibers within the clothing sector, the research

project will analyze meaningful subcategories in addition to the existing sorting, based on fiber compositions. These subcategories include knit structure, stitch size, yarn twist, and yarn quality. These parameters significantly influence both the separation and integration of the fibers in the textile surface. The higher the twist of the yarns, the more difficult is the fiber separation. Similarly, very dense knits complicate the separation process.
For the planned experimental series, two comparison bales of the article Acrylic Mix, each weighing approximately 500 kg from the company SOEX (SOEX Textil-Verwertungsgesellschaft m.b.H., n.d.), were analyzed. To ensure a repeatable processing, categories of preferred fibre mixtures from post-consumer waste were developed. Acrylic Mix consists of knitwear in a variety of fiber types, including both mono and multi-fiber materials. This fabric is primarily used for further processing into shredded fibers(Maetschke, 1978).
Shredded fibres include all fiber materials that are obtained by tearing, as a mechanical shredding process, from textile surfaces such as woven, knitted or non-woven fabrics, as well as ready-made textiles, such as used clothing.
The sorting, in preparation for the planned experimental series, was carried out in three steps:

1. Raw sorting by fiber materials, distinguishing between plant and animal fibers, as well as cellulose or petroleum-based synthetic fibers. All cellulose-based fibers (cotton, linen, viscose, lyocell, modal, etc.) were removed due to the significantly different fiber lengths and fiber properties compared to wool blend fibres. All wool fibers, both as mono-materials and within the mixtures with petroleum-based synthetic fibers, thus serve as the basic material for the experiments.
2. Fine sorting using existing labels: detailed analysis of the mixed fibers.
3. Sorting by stitch geometry: determination of the stitch count per length unit and area unit according to the German standard DIN EN 14971(DIN, 2006).

The results from the raw and fine sorting showed that the goods largely consist of 100% petroleum-based synthetic fibers or mixed fibers, while only 4% consisted of pure wool.
Post-consumer waste varies between summer and winter goods, and consequently, the wool content may change. The described sorting was carried out in March 2023, containing mostly winter goods..

CUTTING PROCESS

The calculated mean value for an optimum cut size of the knitted starting material does not currently take into account the stitch geometry of the knitted fabric.
The planned adaptation of the cutting process in relation to the stitch geometry will result in parameters for a more repeatable yarn production process that shortens the necessary fiber lengths as little as possible, depending on the knitted fabric for further recycling cycles. The preceding fine sorting based on knitting structure, stitch size and yarn twist is crucial for this.

DESIGN OF EXPERIMENTS IN RELATION TO EXISTING MULTIPLE MIXTURES

To ensure a more fiber gentle separation of the textile surfaces, the conventional multi-step tearing process is being questioned with the adjusted cutting method. To investigate the influence of the tearing on fiber shortening, a parallel experiment excluding the process stages of tearing was conducted. The separation down to single fibers was carried out exclusively on the carding machine.
The following experiments were conducted for wool and polyacrylic fibres as mono-material and in mixtures:

1. Cutting and carding (cut sizes: 6x20mm, 13x30mm, 20x40mm)
2. Cutting, two tearing passages, carding (cut size: 50x50mm)
3. Cutting, four tearing passages, carding (cut size: 50x50mm).

By varying cutting dimensions and conducting several tearing passages, the degree of contamination of the carding rollers, the fiber dissolution, and the retention of fiber lengths can be analysed.
The execution of the previous experiments was carried out in collaboration with the Saxon Textile Research Institute and the Technical University of Chemnitz at the Institute of Textile Technologies and was developed at the laboratory scale on the following machines:

- Guillotine cutting system: R45 from Pierret Industries
- Tearing technology: Servo60 tearing machine from AUTEFA Solutions Germany GmbH
- Opener and carder: Ramella

RESULTS OF THE CUTTING PROCESS

In the current cutting process, the conveyor belt is loaded with the goods to be cut in several layers

disregarding the yarn direction. The resulting irregularly cut goods complicate the comparability. Therefore the knitted used clothing was cut open along the yarn direction across the conveyor belt. This allows the fibre length reductions to be calculated with regard to the stitch geometry.
With pure new wool, precise cuts in the desired cutting size were achieved with minimal deviations. Cutting trials with petroleum-based synthetic fibers, especially with wool-polyacrylic blends, revealed several challenges that significantly complicate further processing into yarn.
Elastane, being a highly stretchable fiber, is carried along with the cutting motion and is therefore hardly cut through resulting in large textile surfaces remaining as perforated but not cut goods (fig. 02).
For both mono-material and mixtures of polyacrylic fibres, the cutting resulted in majorly melted edges (fig. 03).
The heat is generated by the friction between the metal surfaces during the cutting movement. This can lead to the formation of neps in the torn fibers.
In addition to fiber shortening, nep formation is another problem occurring in mechanical recycling, which leads to inconsistencies in processing steps following(Kugler & Liebhold, n.d.). A precise cutting result without melted edges is therefore crucial for fiber separation.
In large recycling facilities, the tearing passages are directly linked to the cutting system, resulting in shredded fibers as the final product. In this state, the resulting melt edges are not visible. To what extent these affect the spinning process or whether this factor is irrelevant for further processing will become apparent during yarn production. These experiments are planned to take place in 2025.

CONCLUSION

The European Green Deal and extends the previous Ecodesign Directive to almost all types of products placed on the market within the EU. The aim is to strengthen the circular economy and extend product lifetimes. In particular, reprocessing and recycling are named as target-oriented measures.
As long as the industry is undergoing this change, it is important to continue researching solutions that take our currently available resources into account. The extent to which fibre blends can be processed economically and ecologically in the future must be further analysed.
The research approach presented takes into account the resources currently available, even if this means working on solutions for the fast fashion problem and the associated multiple mixtures. It was important to consider the interlinked processes in the industry separately and to evaluate their results individually in order to be able to modify them in the next step.
This was particularly important in the area of sorting. The current shredded post consumer waste is of inferior quality and is therefore still used far too little for the clothing industry. This process step was significantly improved by the three-stage sorting method described above.
Furthermore, problems were identified in the conventional cutting process, which can lead to significant impurities and associated irregularities in yarn production.
In initial yarn trials, correlations between the stitch geometry, the cut length and the resulting fibre shortening have already been established. The final results as well as comparisons with different yarn production processes are planned for 2025.By working closely with partners from industry from the outset, this research was intended to facilitate the transfer of results to an industrial scale.

Fig. 02

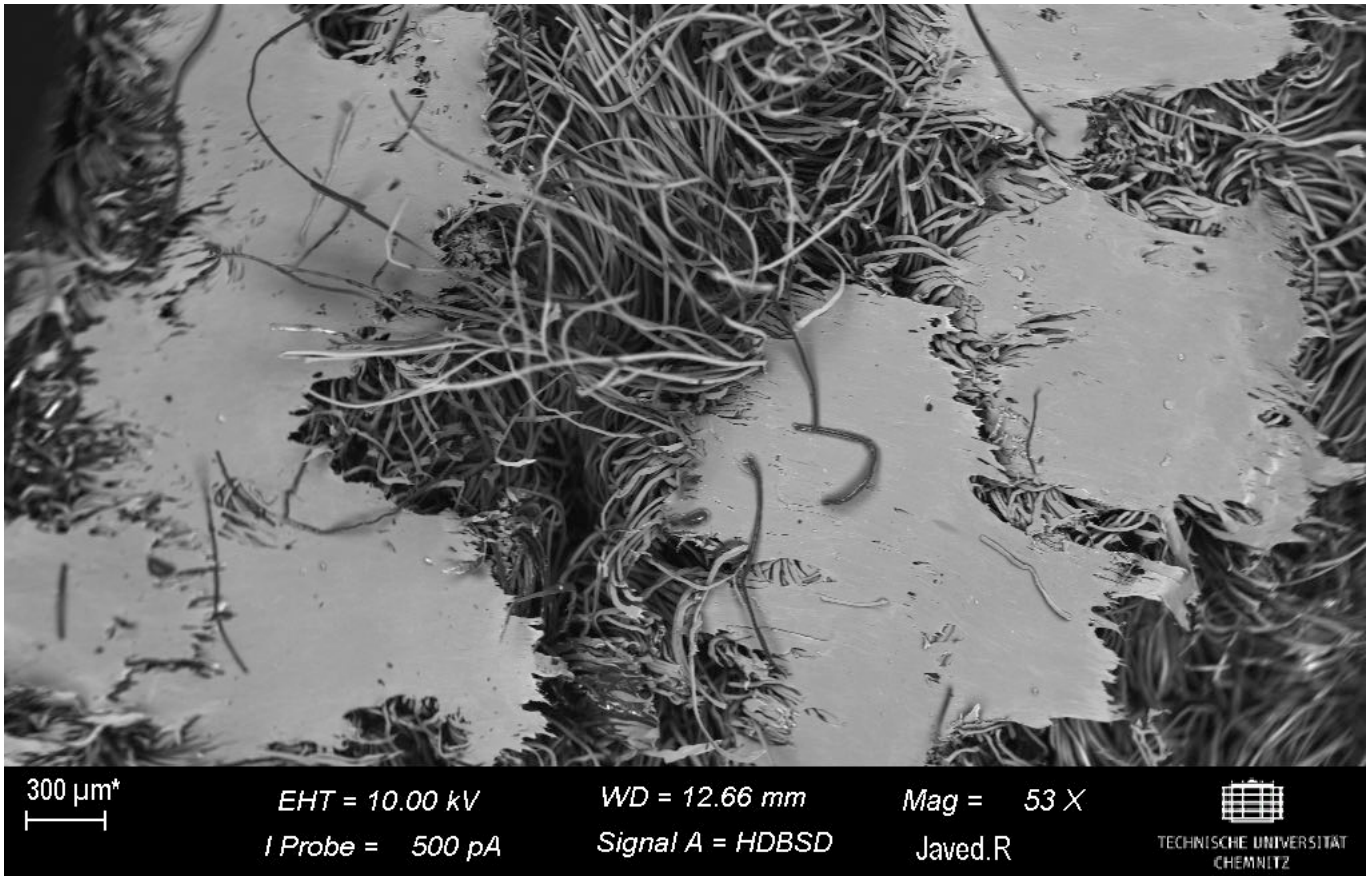

Fig. 03

All experiments were conducted on lab-scale machines modelled on the larger equipment used in recycling and yarn production.
This research connect design and engineering research questions to create more sustainable solutions for the clothing industry with an holistic approach.

CAPTIONS

[Fig. 01] Post- Consumer-Waste – upcycling vs. Downcycling strategy: Magdalena Kohler

[Fig. 02] Stitch Geometry of the knitted Post-Consumer-Waste: Magdalena Kohler

[Fig. 03] Cut result of a wool blend with elasthane: Magdalena Kohler

REFERENCES

Böschen, M. (2016). Sustainable textile recycling - a global challenge. In P. Buchenau, M. Geßner, C. Geßner, & A. Kölle (Eds.), Chefsache Nachhaltigkeit (pp. 255-268). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-11072-7_16

Braungart, M., & McDonough, W. (2021). Cradle to Cradle: Remaking the way we make things (K. Schuler & U. Pesch, transl.; 7th edition, unabridged paperback edition). Piper.

Cherdron, B., & Krichel, A. (n.d.). Economic potentials of textile recycling and hydrogen production from textile waste in Bavaria. 1st edition.

Comistra. (n.d.). Retrieved 9 July 2024, from https://comistra.com/

DIN. (2006). DIN EN 14971. https://www.din.de/de/mitwirken/normenausschuesse/nmp/veroeffentlichungen/wdc-beuth:din21:83764846

Ellen MacArthur Foundation. (2021). Circular design for fashion. Ellen MacArthur Foundation Publishing.

HKRITA Hong Kong Research Institute for Textiles and Apparel. (n.d.). Green Machine. Retrieved 10 July 2024, from https://www.hkrita.com/en/our-innovation-tech/projects/green-machine-phase-2

Hofer, A. (1981). Fabrics. 1: Textile raw materials, yarns, effects (5th ed. (23rd-26th ed.)). Deutscher Fachverlag.

Kimmerer, R. W. (with Ströle, W., & Pflüger, F.). (2021). Braiding sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants (E. Ranke, transl.). aufbau.

Kugler, G., & Liebhold, F. (n.d.). Recycled fibres: Nits test with MDTA 4 and NTDA module. re4tex, Chemnitz.

Maetschke, O. (1978). Investigation of alternative spinning lines for the processing of secondary fibres. RWTH Aachen.

Manteco. (n.d.). Retrieved 9 July 2024, from https://manteco.com/ Re:verso. (n.d.). Retrieved 9 July 2024, from https://www.re-verso.com/

SOEX Textil-Verwertungsgesellschaft m.b.H. (n.d.). https://www.soex.de/Steckert, D. C. (2022, May 18). Sorting textile wastes by means of Nir-Spectroscopy. re4tex Colloquium, Chemnitz.

STITCHING SUSTAINABILITY

THREADS AS CATALYST OF CHANGE IN FASHION

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files.
Competing Interests: The Author(s) declare(s) no conflict of interest
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Abstract

In the ever-evolving fashion landscape, sewing threads—traditionally seen as minor garment components—are emerging as powerful catalyst of change, empowering designers to integrate sustainability into their creative processes. This paper explores the transformative role of disassembly-enabling materials in fostering sustainability within the apparel industry, focusing on a groundbreaking case study in textile innovation.
By examining how heat-dissolvable sewing threads and thermal disassembly systems facilitate efficient garment recycling, this study highlights their potential to drive a paradigm shift in fashion design. A single case study methodology is applied to investigate an innovative approach that integrates advanced materials, automated disassembly, and circular economy principles to enhance environmental performance while preserving aesthetic and functional integrity.
Through this lens, the authors illustrate how threads can transcend their conventional role, becoming key enablers of fiber-to-fiber recycling and waste reduction. This exploration underscores the importance of viewing garment construction not just as a manufacturing process but as a strategic intervention for sustainability. By embedding Design-for-Disassembly (DfD) and Active Disassembly principles into production methods, this research challenges designers to rethink material choices—positioning threads as dynamic catalysts shaping fashion's transition toward circularity.

Keywords: *Threading Sustainability, Sustainable Innovation, Circular Fashion, Design for Disassembly, Active Disassembly.*

INTRODUCTION

The fashion industry embodies a paradoxical role as a powerful cultural influencer and a significant driver of socio-environmental degradation. While the industry exerts considerable influence on social and cultural dynamics, it simultaneously has profound adverse effects on environmental health and the depletion of finite resources, mainly due to its perpetuation of a consumerist economic model characterized by mass production (Jardim, 2023). Reports from the European Union (2022) and the Hot or Cool Agency (Coscieme et al., 2022) elucidate these adverse impacts, highlighting the invasive processes inherent to the industry. Several scholars further articulate how the industry's practices restrict fashion experiences and sustain unsustainable production patterns globally (Bertola & Colombi, 2024; D'Itria & Aus, 2023; Coscieme, Manshoven, et al., 2022; Niinimäki et al., 2020; Fletcher, 2018).

The environmental impacts of the fashion industry are both profound and pervasive, marking it as one of the most resource-intensive sectors globally. A significant contributor to global environmental degradation, the fashion industry is responsible for approximately 10% of global carbon emissions (European Parliament, 2020). This significant carbon footprint results from the entire lifecycle of garments—from raw material extraction, including the energy-intensive processes of producing synthetic and organic fibers and dyes, to the transportation and retail phases (Niinimäki

et al., 2020). The reliance on fossil fuels for energy and the emission of greenhouse gasses throughout production processes exacerbate the industry's impact on climate change (Coscieme et al., 2022). Textile waste further compounds the sector's environmental footprint. The fashion industry generates an estimated 40 million tons of textile waste annually, a significant portion of which is disposed of in landfills or incinerated (Kent, 2024). This waste occupies valuable landfill space and contributes to greenhouse gas emissions through methane release from decomposing textiles and CO2 emissions from incineration (Gupta et al., 2022).

Water consumption is another critical issue (Bailey et al., 2022). The fashion sector is one of the largest consumers of freshwater, utilizing vast amounts for dyeing and finishing processes. For instance, it is estimated that producing a single cotton T-shirt requires around 2,700 liters of water, equivalent to one person drinking over two and a half years (Muthu, 2018). This pollution, laden with harmful chemicals and dyes, disrupts the natural balance, leading to severe environmental and health repercussions (Rana, 2024). The discharge of untreated wastewater from textile manufacturing facilities contaminates rivers and lakes, adversely affecting aquatic ecosystems and local communities and impacting the social aspect of workers' health and community safety (D'Itria, 2023). Furthermore, the fashion industry faces other significant social issues deeply intertwined with its global supply chain. Workers, particularly in developing countries, often endure poor working conditions, low wages, and exploitation due to rapid production cycles that demand cost-cutting at the expense of worker welfare (Neiveling, 2024; Seidu et al., 2024).

According to the aforementioned, the pervasive and severe social and environmental exploitation within the fashion industry establishes it as a significant global concern for environmental and social justice (Parvin et al., 2020). The sector challenges are predominantly a consequence of the linear development model that dominates the fashion sector (Dissanayake & Weerasinghe, 2021). This model, a remnant of the first industrial revolution, adheres to a cradle-to-grave paradigm that depletes natural resources and discards them without considering their potential for regeneration or reuse (Braungart & McDonough, 2009). It fosters overproduction, encourages compulsive consumerism, and leads to the early disposal of garments due to their physical and semiotic obsolescence. Consequently, this system drives irresponsible practices such as excessive consumption and premature disposal of fashion products.

Given these challenges, it is essential to reevaluate traditional linear development models and adopt sustainable frameworks such as the circular economy. The European Commission increasingly recognizes this model as the leading paradigm for separating sustainable fashion innovation from resource exploitation (EUR-LEX - 52020DC0098 - EN - EUR-LEX.) (n.d.). https://eur-lex.europa.eu/legal-content/EN/ section, bolstered by the direct testimony of one of the authors who serves as the Chief Technology Officer of the analyzed company and provides unique insights, underscores how yarns enable designers to reevaluate their practices through sustainable innovation. Section 4 concludes the article by exploring how the presented case study lays the groundwork for future research. It considers how design can be leveraged to formulate new strategies for fostering sustainable innovation in the fashion industry.

METHODOLOGY

This study employs a single-case study methodology to examine the transformative potential of advanced technologies in promoting sustainability within the fashion industry. This approach suits this research because it provides in-depth and contextually rich insights into complex phenomena (Yin, 1994). Single-case studies are a valuable research methodology for conducting thorough and holistic examinations. Focusing on a single case allows for exploring detailed aspects of the subject that might be overlooked in broader studies (Levy, 1988). Single-case studies are distinguished from multiple-case studies by their focus on one particular instance rather than replicating across several cases. The author acknowledges that although this approach necessitates careful consideration of validity and reliability, single-case studies offer several distinct advantages for this study compared to multiple-case studies. Indeed, this streamlined approach is particularly advantageous for developing high-quality theories, as single-case studies often produce more affluent and nuanced theoretical insights. The depth of analysis afforded by single-case studies allows this

study to profoundly understand the subject under investigation. This methodology provides detailed descriptions of phenomena and is particularly useful when focusing on specific individuals or small groups (Gustafsson, 2017).
The chosen case involves a pioneering textile company – Resortecs ® - that has integrated cutting-edge materials and manufacturing processes to enhance environmental performance while maintaining high aesthetic and functional standards in garment production.
Data was collected through multiple methods to ensure a comprehensive case understanding. Initially, the authors gathered secondary data from various sources, such as interviews, scientific articles, sector-specific magazines, and industry and government reports (SECRID, 2024; Ozsevim, 2023; Serafin, 2023; EMF, 2021; Pourhashemi, 2021). This process allowed for the case study framework to be built, and the analysis was conducted using thematic coding to identify key patterns and themes related to using innovative technology in sustainable fashion design. These themes were then examined within the broader theoretical framework of the circular economy, as proposed by the Ellen MacArthur Foundation's Vision of a Circular Economy for Fashion (2022). This phase highlights how integrating these yarns can facilitate closed-loop production systems within the design for disassembly paradigm. Specifically, this analysis identified a clear pathway: Fashion products are designed, engineered, and produced to be easily disassembled, enabling them to be reused, remade, recycled, and, when appropriate and after maximum utilization, safely disposed of/composted (Fig. 1) thanks to active disassembly technologies. The disassembly occurs automatically without manual intervention. From this phase, the study also examined the challenges and opportunities faced by fashion companies in implementing circular practices, particularly emphasizing the critical role of material recycling and the lack of adequate recycling enablers. A primary barrier identified in the literature is the insufficient awareness and education regarding circularity within companies and among their workforce (Dissanayake & Weerasinghe, 2022). This lack of knowledge contributes to the limited economic understanding of recycled textiles, as businesses remain uncertain about their market potential and the long-term benefits, thus hindering the full adoption of circular models (Leal Filho et al., 2019). Another major obstacle is the underdevelopment of technologies for material and disassembly, which forces the industry to rely on labor-intensive and costly manual processes (Sandwick, 2019). The absence of advanced textile-to-textile recycling technologies further complicates efforts to establish circular systems. Modern textiles are made from diverse materials, colors, and finishes, and scaling up recycling processes—whether chemical or mechanical—presents both technical and economic challenges (Pedersen, Earley, & Andersen, 2019). Additionally, the inefficient systems for collecting and sorting materials at the end-of-life stage add complexity to the recycling process, preventing the effective implementation of circular practices (Dissanayake & Weerasinghe, 2022). In response to these challenges, the case study suggests potential solutions to overcome these barriers. The company seeks to contribute to a more sustainable future for the fashion and textile industry by advancing innovative recycling practices and developing the necessary technology and infrastructure.
In a further refinement phase, first-hand data was provided by the valuable insights of one of the two authors, who serves as the company's Chief Technology Officer and is directly involved in the transformations described.
Collecting and integrating first-hand data was crucial for obtaining a nuanced and in-depth understanding of the subject. First-hand data, provided directly by one of the authors, provided rich, contextualized insights that secondary data alone cannot offer. This type of data enabled the authors to capture the complexities and subtleties of real-world practices, often revealing underlying dynamics and processes that are not readily apparent in external reports or literature.
The subsequent section presents the case study, emphasizing the role of yarns as the industry's connective threads. These yarns act as powered by active disassembly, guiding the designer and enabling novel scenarios for creating and destroying fashion goods.

RESULTS AND DISCUSSION

The fashion industry has a major environmental impact, generating large amounts of waste, pollution, and carbon emissions. Most garments are made using a linear production model, where clothes are designed, produced, worn, and then discarded—often ending up in landfills or

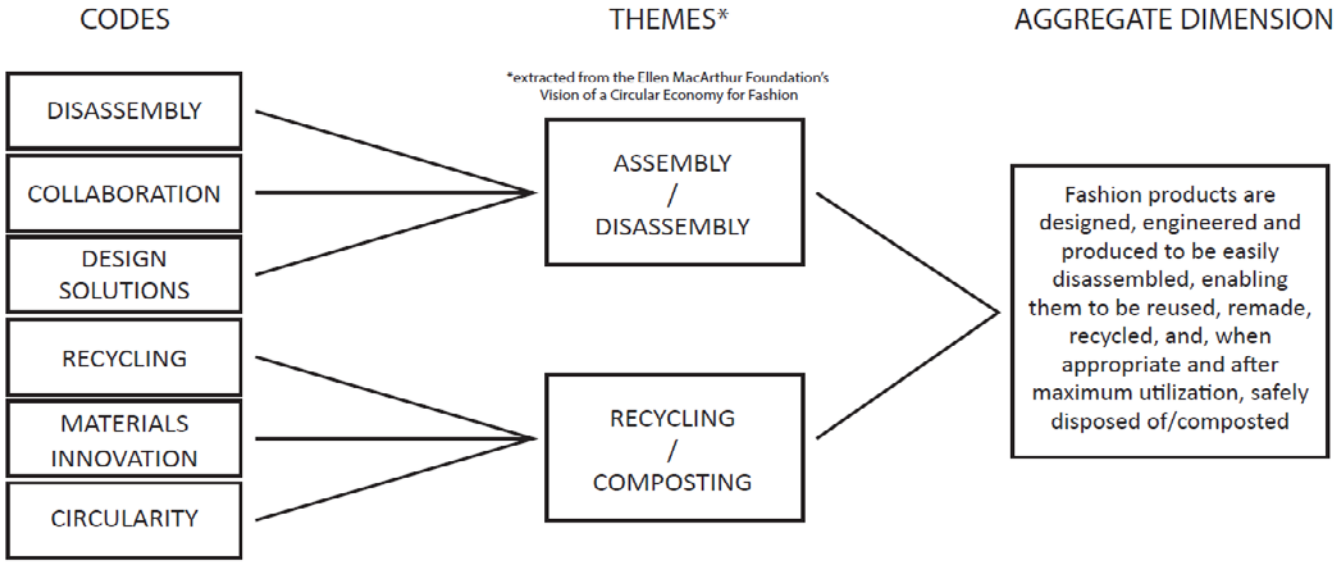

Fig. 01

incinerators. This system wastes valuable materials and contributes to resource depletion and climate change.

One of the biggest challenges in textile recycling is the complexity of garment disassembly. More than 75% of clothes are made with different materials, stitching threads, zippers, and trims, making it difficult to separate and recycle or pre-processing fibers efficiently. Existing recycling methods struggle to process these mixed-material garments, limiting the potential for fiber-to-fiber recycling. New solutions are needed to make garment recycling easier and more effective.

This research focuses on the case study of Resortecs, a Belgian start-up pioneering a novel approach to garment disassembly. Founded in 2017 by Cédric Vanhoeck and Vanessa Counaert, Resortecs developed Smart Stitch™, a patented heat-dissolvable sewing thread, and Smart Disassembly™, the world's first thermal disassembly system. These technologies enable garments to be easily disassembled at controlled temperatures, allowing for the removal of non-recyclable disruptors and improving the efficiency of textile recycling. Resortecs' approach aligns with circular economy principles, offering a scalable and industrially viable solution to one of the most pressing sustainability challenges in fashion.

By analyzing Resortecs' technology and its potential impact on the industry, this study provides critical insights into the integration of active disassembly solutions, their feasibility for large-scale adoption, and their role in shaping a more circular textile ecosystem.

The integration of Design-for-Disassembly (DfD) and Active Disassembly principles into garment production is fundamental to enabling circularity in the fashion industry, as they redefine how textiles are designed, used, and ultimately recycled. Historically, garments have been manufactured with durability and aesthetics as primary considerations, while End-Of-Life (EOL) recyclability was largely overlooked. This has led to a widespread reliance on multi-material compositions and complex constructions, which, while beneficial for performance and design, create significant barriers for recycling.

Design-for-Disassembly (DfD) is an approach that ensures products are intentionally engineered for easy and efficient disassembly at their EOL. This principle is widely used in industries such as electronics and automotive manufacturing, where components must be systematically separated for repair, reuse, or recycling. In textiles, applying DfD means that garments must be designed with future recyclability in mind, ensuring that materials can be efficiently recovered without excessive labor, cost, or contamination.

Active Disassembly, on the other hand, refers to a more advanced approach where disassembly is triggered by an external stimulus, such as heat, vibration, or chemical activation, to facilitate the automated removal of components. Unlike conventional mechanical or manual disassembly processes, Active Disassembly reduces the need for manual intervention, significantly improving

processing efficiency and material purity. Resortecs' Smart Stitch™ technology is a prime example of Active Disassembly applied to textiles.

By embedding heat-dissolvable sewing threads into garment construction, Resortecs enables garments to be dismantled at controlled temperatures (150–200°C), triggering the precise breakdown of seams while leaving the rest of the fabric intact. This controlled disassembly process allows for the automatic removal of disruptors—such as zippers, buttons, elastics, and reflective trims—that traditionally hinder textile recycling. By integrating Smart Stitch™, brands and manufacturers can preserve complex garment designs without sacrificing recyclability, directly addressing the fashion industry's longstanding trade-off between design freedom and circularity (Pourhashemi, 2021).

Unlike conventional sustainability recommendations that promote mono-material use and simplified garment structures, Resortecs' approach allows for material diversity while maintaining full recyclability. This paradigm shift moves the industry beyond linear production models toward a truly integrated circular system in which materials are recovered, repurposed, and reintegrated into the textile supply chain.

By embracing Design-for-Disassembly and Active Disassembly, Resortecs is fundamentally reshaping how garments are conceived, produced, and recycled, demonstrating that sustainability and innovation can coexist without compromising design complexity or performance. This shift improves the economics of textile recycling and also aligns with the growing regulatory push for circularity, setting a new standard for how the industry approaches sustainability at scale.

To complement its innovative stitching technology, Resortecs developed Smart Disassembly™, the world's first thermal disassembly system, which ingeniously merges the precision of manual dismantling with the speed and consistency of automated processes. Traditional manual disassembly methods, while precise, are labor-intensive and slow, often resulting in prohibitively high costs for textile recyclers. On the other hand, conventional mechanical disassembly processes lack the finesse to separate mixed materials without contamination, limiting their efficacy.

Smart Disassembly™ bridges these gaps by utilizing controlled thermal processes to selectively disassemble garments, effectively removing disruptors such as zippers, buttons, elastic bands, and reflective trims. The system operates up to 15 times faster than manual disassembly, significantly boosting operational efficiency and throughput. This acceleration is crucial not only for reducing labor costs but also for enabling recycling facilities to handle larger volumes of textile waste, thereby enhancing overall material recovery rates.

Achieving up to 90% material recovery, Smart Disassembly™ effectively doubles the efficiency of standard mechanical disassembly techniques. By maintaining a controlled environment with reduced oxygen levels, the system prevents oxidation, a common issue that leads to fabric degradation during high-temperature processing. This protective atmosphere is particularly important for preserving the integrity of natural fibers such as cotton, wool, and silk, which are prone to burning or weakening when exposed to conventional thermal treatments. The result is recycle-ready materials that retain their quality and structural integrity, making them viable for fiber-to-fiber recycling, thus closing the loop in textile production.

Furthermore, the closed-loop heat recovery system is another cornerstone of Smart Disassembly™' design (Ozsevim, 2023) (Fig. 2). Conventional disassembly methods often involve high energy inputs, contributing to the overall carbon footprint of the recycling process. In contrast, Smart Disassembly™ captures and recycles the heat generated during the disassembly process, using it to power subsequent cycles. This not only reduces the system's energy consumption but also aligns with broader sustainability goals by minimizing the environmental impact of textile recycling operations.

Integrating Smart Disassembly™ into existing textile waste management infrastructures offers substantial advantages for brands, recyclers, and sorters. By automating the removal of disruptors and mixed materials, the system reduces dependency on manual labor, thereby cutting costs and increasing processing capacity. This scalability is essential for addressing the vast amounts of textile waste generated globally and is a critical step toward realizing circular economy principles within the fashion industry. The ability to efficiently separate and reclaim materials from complex, multi-fabric garments represents a transformative shift, positioning active disassembly as a cornerstone technology for the future of sustainable textiles.

Resortecs' innovative technologies have already

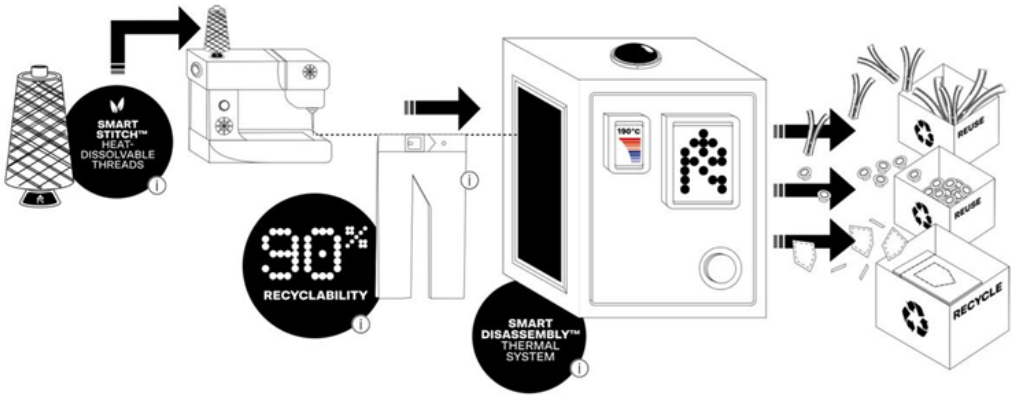

Fig. 02

been adopted by leading fashion brands, demonstrating their applicability at an industrial scale.

- HNST Studio, (https://www.letsbehonest.eu/), the Antwerp-based label dedicated to creating jeans that embody transparency and circularity, has integrated Smart Stitch™ into its denim collection, enabling fully recyclable jeans and reducing the reliance on virgin materials.

- Decathlon has incorporated heat-dissolvable stitching into its ski jackets (https://resortecs.com/decathlon-launches-recyclable-ski-jacket-with-resortecs-technology/) and swimwear, (https://resortecs.com/resortecs-x-decathlon-industrialising-recyclable-swimwear/), ensuring that garments can be easily dismantled at EOL without compromising performance during use.

- Sioen, a leader in workwear production, has partnered with Resortecs to develop protective garments that maintain safety standards while being fully recyclable.

Despite the technological advancements and environmental benefits of Resortecs' Smart Stitch™ and Smart Disassembly™, several economic and structural challenges must be addressed before achieving full-scale industrial adoption.

One of the most significant barriers to widespread adoption of textile recycling technologies is economic viability. Today, most recycling processes remain at Technology Readiness Level (TRL) 5-6, meaning they are in the pilot or demonstration phase rather than fully industrialized. As a result, production costs remain high and unpredictable, making it difficult for brands and recyclers to commit to large-scale investment. Additionally, the low volume of recycled textiles currently processed exacerbates cost disparities. Because economies of scale have not yet been achieved, recycled materials are systematically more expensive than virgin materials, creating a financial disincentive for brands to transition to circular solutions. This economic imbalance remains a key obstacle to large-scale industrial adoption.

Another fundamental challenge is determining who should bear the additional cost of circular textile systems. In a traditional linear production model (produce-use-dispose), costs are typically absorbed by the weakest entity in the supply chain—often garment manufacturers or recyclers, who have the lowest margins and the least bargaining power.

For circular solutions like Resortecs' to be fully implemented, cost-sharing mechanisms must be developed. Potential strategies include:

- Extended Producer Responsibility (EPR), where regulatory frameworks require brands to finance recycling costs rather than externalizing them to lower-tier suppliers;

- consumer involvement through green pricing models, where a portion of the recycling cost is embedded in product pricing, similar to existing eco-labeling schemes;

- and public-private partnerships (PPP), where governments and institutions provide financial incentives, subsidies, or tax reductions for brands that integrate circular solutions.

Without fair cost distribution, the financial burden will continue to fall on the weakest entities, discouraging adoption and limiting circularity's

economic sustainability.
For Smart Stitch™ and Smart Disassembly™ to reach full-scale adoption, stronger infrastructure for textile sorting and recycling must be developed. Currently, most existing facilities are not designed to handle garments disassembled at scale, creating bottlenecks in processing and material reintegration. Moreover, investment in industrial-scale fiber-to-fiber recycling plants remains limited. Even as regulatory pressure increases, such as the mandatory textile waste sorting regulation set to take effect in 2025 in the EU, the financial ecosystem has yet to catch up. Resortecs' collaborations with brands like Decathlon and Sioen demonstrate progress toward systemic adoption, but broader public and private investments are needed to scale up recycling capacity and reduce processing costs.
Even if brands adopt circular solutions, market demand for recycled textiles remains inconsistent. Consumer preferences often prioritize cost and aesthetics over sustainability, meaning that high production costs of recycled textiles are difficult to justify in competitive pricing strategies. A shift in consumer behavior—supported by eco-labeling, awareness campaigns, and regulatory incentives—is essential to drive demand for circular fashion at scale. Without this market pull, even the most advanced recycling technologies risk stagnation due to insufficient adoption.
For Resortecs and similar innovations to achieve full industry integration, a multi-stakeholder approach is required, addressing technological, economic, and regulatory barriers simultaneously. While the Smart Stitch™ and Smart Disassembly™ systems provide tangible technical solutions, overcoming economic uncertainty, infrastructure limitations, and cost distribution inequalities remains the next critical challenge for scaling circular textile solutions.
The creation of a textile waste management consortium in Benelux and France, led by Resortecs, represents a crucial step in accelerating industrial adoption. This initiative will bring together manufacturers, collectors, and recyclers to establish an economically viable circular system, with Smart Disassembly™ lines projected to process 3,000 tons of textile waste annually by 2026.
The findings of this study reinforce the importance of embedding recyclability at the design stage rather than relying solely on end-of-life waste management strategies. Resortecs' heat-dissolvable thread and thermal disassembly system showcase a scalable, systemic approach to sustainable fashion, challenging traditional linear production models by making textile circularity both feasible and cost-effective.
Furthermore, the successful implementation of Smart Stitch™ and Smart Disassembly™ across various textile categories—apparel, workwear, footwear, and home textiles—illustrates their broad applicability and potential for industry-wide transformation.
Ultimately, this study highlights that Resortecs' solutions are not just technological innovations, but catalysts for systemic change—empowering designers, manufacturers, and recyclers to embrace circularity at scale.

CONCLUSIONS

In conclusion, the findings from this study underscore the transformative potential of Resortecs' heat-dissolvable thread and Smart Disassembly™ system in accelerating circularity within the fashion industry. By integrating Design-for-Disassembly (DfD) and Active Disassembly principles, Resortecs enables brands to maintain design complexity while ensuring full recyclability—overcoming the long-standing trade-off between creativity and sustainability.
This case study highlights how technological innovation in garment construction can directly impact material recovery, waste reduction, and the transition to a circular textile economy.
Resortecs' approach demonstrates that sustainability can be embedded at the design phase rather than being an afterthought at the end of a product's lifecycle. By facilitating efficient garment disassembly, improving fiber-to-fiber recycling, and reducing dependency on virgin materials, this innovation provides a compelling model for industry-wide adoption. Moreover, it aligns with emerging regulatory pressures, such as Extended Producer Responsabilityy (EPR) and mandatory textile waste sorting, reinforcing the urgency for scalable circular solutions.
However, the widespread adoption of circular production models remains dependent on overcoming key challenges, including economic feasibility, infrastructure development, and industry-wide collaboration. Cost distribution across the supply chain, investment in textile sorting and fiber-to-fiber recycling facilities, and shifts in consumer behavior are critical factors

shifts in consumer behavior are critical factors in determining the success of these solutions. Resortecs' ongoing collaborations with brands like Decathlon, Sioen, and HNST Studio highlight the real-world applicability of its technology, yet further investments are needed to scale its impact. The present study lays a foundation for future research by illustrating how design innovation can catalyze sustainable practices within the fashion industry. Future investigations can build upon this foundation to explore the scalability of emerging solutions, their application across diverse garment types, and their integration into existing manufacturing processes. Additionally, further research could explore consumer acceptance and market readiness for such innovations, offering insights into the effective promotion and implementation of sustainable products.

Moreover, the insights derived from Resortecs' approach highlight the critical importance of interdisciplinary collaboration in advancing sustainability in fashion. Engaging with designers, material scientists, and industry stakeholders is essential to refining new sustainable solutions and ensuring their feasibility at scale. This collaborative approach should extend to educational institutions, where sustainability principles and innovative design practices can be embedded into curricula—preparing the next generation of fashion professionals to prioritize circularity.

Designers are positioned at the forefront of these changes and play a pivotal role in shaping whether such technologies gain widespread adoption or remain confined to niche applications. Their decision-making—balancing cost, aesthetics, and production feasibility—directly influences the success of innovation in the fashion industry. By embracing new materials and disassembly technologies, designers can lead the transition toward circularity, ensuring that sustainability does not come at the expense of creativity.

Ultimately, this article demonstrates that a simple change in thread can foster design innovation, not merely as a functional or aesthetic enhancement but as a powerful lever for systemic change within the fashion industry. Resortecs' Smart Stitch™ and Smart Disassembly™ challenge linear production models, offering a scalable, economically viable path toward sustainability. By embedding recyclability at the core of garment design, these innovations set a new benchmark for responsible fashion—ensuring that circularity becomes a standard rather than an exception.

CAPTION

[Fig. 01] Coding Process (D'Itria, 2024).

[Fig. 02] Resortecs Technology (Resortecs, 2022).

REFERENCES

Bertola, P., & Colombi, C. (2024). Can fashion be sustainable? Trajectories of change in organizational, products and processes, and socio-cultural contexts. Sustainability: Science, Practice and Policy, 20(1), 2312682.

Bailey, K., Basu, A., & Sharma, S. (2022). The Environmental Impacts of Fast Fashion on Water Quality: A Systematic Review. Water, 14(7), 1073.

Casciani, D., & D'Itria, E. (2024). Fostering Directions for Digital Technology Adoption in Sustainable and Circular Fashion: Toward the Circular Fashion-Tech Lab. Systems, 12(6), 190.

Claxton, S., & Kent, A. (2020). The management of sustainable fashion design strategies: An analysis of the designer's role. Journal of Cleaner Production, p. 268, 122112.

Coscieme, L., Manshoven, S., Gillabel, J., Grossi, F., & Mortensen, L. F. (2022). A framework of circular business models for fashion and textiles: the role of business-model, technical, and social innovation. Sustainability: Science, practice and policy, 18(1), 451-462.

Coscieme, L. et al., 2022. Unfit, Unfair, Unfashionable: Resizing Fashion for a Fair Consumption Space, The Hot or Cool Institute. Germany. Retrieved from https://coilink.org/20.500.12592/rcwq5z on 02 Jan 2025. COI: 20.500.12592/rcwq5z.D'Itria, E., & Aus, R. (2023). Circular fashion: evolving practices in a changing industry. Sustainability: Science, Practice and Policy, 19(1), 2220592.

D'Itria, E. (2023). Fashion design matter: the role of design in guiding a sustainable transformation in Europe. In Vaes, K., & Verlinden, J. C. (Eds.), Connectivity and creativity in times of conflict (pp. 136–141). Academia Press.

Dissanayake, D. G. K., & Weerasinghe, D. (2021). Towards circular economy in fashion: Review of strategies, barriers, and enablers. Circular Economy and Sustainability, 1–21.

EMF (2022). Vision of a circular economy for fashion. Ellen MacArthur Foundation. https://www.ellenmacarthurfoundation.org/our-vision-of-a-circular-economy-for-fashion

EMF (2021, June 23). Resortecs. Retrieved January 2, 2025, from https://secrid.com/en-us/stories/what-design-can-do-resortecs/

European Commission. (2022, March 30). EU strategy for Sustainable and Circular Textiles. Retrieved April 2, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0141

European Commission (2019). Support report mapping sustainable fashion opportunities for SMEs. Retrieved April 2, 2024, from: https://ec.europa.eu/growth/sectors/fashion/high-end-industries/eu#report.

European Parliament. (2020, December 29) . The Impact of Textile Production and Waste on the Environment (infographics) | Topics | European Parliament. Www.europarl.europa.eu. https://www.europarl.europa.eu/topics/en/article/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographics#:~:text=Greenhouse%20gas%20emissions

what-design-can-do-resortecs/
European Commission. (2022, March 30). EU strategy for Sustainable and Circular Textiles. Retrieved April 2, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0141
European Commission (2019). Support report mapping sustainable fashion opportunities for SMEs. Retrieved April 2, 2024, from: https://ec.europa.eu/growth/sectors/fashion/high-end-industries/eu#report.
European Parliament. (2020, December 29) . The Impact of Textile Production and Waste on the Environment (infographics) | Topics | European Parliament. Www.europarl.europa.eu. https://www.europarl.europa.eu/topics/en/article/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographics#:~:text=Greenhouse%20gas%20emissions
Fletcher, K., Castiglioni, A., Romano, G., & Bergamin, A. (2018). Moda, design e sostenibilità. Postmedia Books.
Gupta, R., Kushwaha, A., Dave, D., & Mahanta, N. R. (2022). Waste management in fashion and textile industry: Recent advances and trends, life-cycle assessment, and circular economy. Emerging trends to approaching zero waste, 215–242.
Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study.
Hardon, L. (2023, October 18). Resortecs Head of Communications & Branding, Davidson Leite. https://secrid.com/en-us/stories/what-design-can-do-resortecs/
Jardim, M. (2023). The Fashion of Global Warming: between counterculture and trend, discursive translations in post-consumerism. Recherches en communication, 55, 157-174.
Kent, S. (2024, July 2) . The Waste Opportunity: How Fashion Could Turn Trash into Treasure. The Business of Fashion. https://www.businessoffashion.com/articles/sustainability/the-waste-opportunity-how-fashion-could-turn-trash-to-treasure/#:~:text=Every%20year%2C%20roughly%2040%20million,just%20a%20fast%20fashion%20problem.
Leal Filho, W., Ellams, D., Han, S., Tyler, D., Boiten, V. J., Paço, A., & Balogun, A. L. (2019). A review of the socio-economic advantages of textile recycling. Journal of Cleaner Production, 218, 10-20.
Levy, S. J. (1988). Information technologies in universities: An institutional case study. Northern Arizona University.
Muthu, S. S. (Ed.). (2018). Circular Economy in Textiles and Apparel: Processing, Manufacturing, and Design. Woodhead Publishing, United Kingdom.

Ozsevim, I. (2023, January 6). Resortecs: Bringing about the Circular Economy in Fashion [Review of Resortecs: Bringing about the Circular Economy in Fashion]. https://procurementmag.com/articles/Resortecs-bringing-about-the-circular-economy-in-fashion
Parvin, F., Islam, S., Akm, S. I., Urmy, Z., & Ahmed, S. (2020). A study on the solutions to environmental pollution and worker's health problems caused by textile manufacturing operations. Biomed. J. Sci. Tech. Res, 28(4), 21831–21844.
Pedersen, E. R. G., Earley, R., & Andersen, K. R. (2019). From singular to plural: exploring organizational complexities and circular business model design. Journal of Fashion Marketing and Management: An International Journal, 23(3), 308-326.
Pourhashemi, P. (2021, September 27). Cédric Vanhoeck: one stitch at a time [Review of Cédric Vanhoeck: one stitch at a time]. WBDM. https://www.wbdm.be/en/news/cedric-vanhoek-one-stitch-at-the-time/
Rana, N. (2024). The Environmental Impact of Fashion. In Threaded Harmony: A Sustainable Approach to Fashion (pp. 5–16). Emerald Publishing Limited.
Sandvik, I. M., & Stubbs, W. (2019). Circular fashion supply chain through textile-to-textile recycling. Journal of Fashion Marketing and Management: An International Journal, 23(3), 366-381.
SECRID (2024, September 25).Resortecs. Retrieved January 2, 2025, from https://secrid.com/en-us/stories/what-design-can-do-resortecs/
Seidu, R. K., Ofori, E. A., Eghan, B., Fobiri, G. K., Afriyie, A. O., & Acquaye, R. (2024). A systematic review of work-related health problems of factory workers in the textile and fashion industry. Journal of Occupational Health, 66(1), uiae007.
Serafin, A. (2023, April 27). Stitching them up [Review of Stitching them up]. European Investment Bank. Retrieved July 30, 2024, from https://www.eib.org/en/stories/recycling-clothes-resortecs
Yin, R. (1994). Case study research: Design and methods (2nd ed.). Thousand Oaks, CA: Sage Publishing.

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