Valorisation of textile waste with white-rot fungi

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Valorisering av textilavfall med vitrötesvamp

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Abstract

This study investigates the potential for valorisation of textile waste by reviewing its availability, properties, and current waste-management practices, and by compiling existing research on fungal degradation of textile materials. To address key research questions, a literature review was combined with four experiments evaluating the growth of two white-rot fungi on commonly available textiles, including tests of fungal growth on six fabrics, the creation of mycelium–denim biocomposites, measurements of fungal respiration, and SEM analyses of cotton and polyester fibres exposed to white-rot fungal enzyme extracts. Results show that white-rot fungi generally grow better on natural fibres than synthetic ones, with viscose as an exception, and that denim forms a more robust biocomposite with *Ganoderma lucidum* than with *Pleurotus ostreatus*. Respiration tended to be higher on cotton than polycotton, although this was only significant at three points for *P. ostreatus*, and respiration by *G. lucidum* was similar across the two fabrics. Enzymes suspensions of white-rot fungi showed degradative effects on cotton but not polyester. Overall, the findings indicate clear potential for using textile waste as a substrate for white-rot fungi to support biomaterial production and textile waste management, while highlighting the need for further research on fungi–substrate compatibility, degradation mechanisms, and standardised methods for tracking textile degradation.

Keywords: Ganoderma lucidum, Pleurotus ostreatus, Post-consumer textiles, Cotton, Polyester, Polycotton, Denim, Recycling

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Abbreviations

Abbreviation	Description
GL	*Ganoderma lucidum*
PO	*Pleurotus ostreatus*
SEM	Scanning Electron Microscopy
EU	European Union

1. Introduction

Waste from the textile industry is an increasing environmental and societal concern, with large quantities currently accumulating globally. New methods are sought for to turn this waste into valuable resources. Parallel, there is demand for sustainable alternatives to plastics and one option is mycelium-based materials. Despite growing interest in both textile recycling and mycelium-based materials, few studies have looked at how textile waste could be used as a substrate for mycelial growth. Therefore, this thesis explores the potential to use textile waste for cultivation of fungi, thereby addressing both textile waste reduction and sustainable biomaterial production, contributing to the circular bioeconomy.

Globally, 92 million tonnes of textiles were created in 2017 (Kerr & Landry 2017). These quantities stem from factors including fast fashion, poorer quality fabrics (Laitala & Klepp 2020), inefficient management of used and waste textiles due to sorting challenges (Damayanti et al. 2021). Currently, the typical end of life outcomes for textiles includes landfills and incineration (Pensupa et al. 2017). This is problematic from the perspective of circular use of resources, as the production of textiles are resources demanding (Thomas et al. 2024). Additionally, the current strategies cause both environmental and health problems in the areas surrounding the facilities used for textile destruction (de Oliveira et al. 2023; Rogers et al. 2024; Schellenberger et al. 2022).

Simultaneously, there is a growing interest in using mycelium to make materials such as plastic replacements and bio-based textiles (Sivaprasad et al. 2021; Williams et al. 2022). Mycelial degradation of textile waste involves cultivating fungi on used/unwanted textiles and using the partly degraded textile and the produced mycelium (Sangosanya & Pistofidou 2024; Saini et al. 2023). Using textile waste as a growth medium for fungi can contribute to the circular bioeconomy (Shirvanimoghaddam et al. 2020) by using the mycelium and the transformed textiles to make materials. This thesis investigates whether textile waste is a viable substrate for white-rot fungi cultivation to produce a mycelium composite suitable for biomaterial applications. White-rot fungi were chosen due to their high extracellular release of powerful degrading enzymes such as laccase (Kobayashi et al. 2023).

2. Background

2.1 Textile waste and its environmental impact

Textile waste (in the context of this master's thesis) is defined as solid waste made from either natural or synthetic fibres, including both pre-consumer and post-consumer waste (Riemens et al. 2021). In Sweden, textiles for reuse are a separate category from textile waste (Avfall Sverige 2024). The increase in textile waste has led to significant figures worldwide. Globally, 92 million tonnes of textiles were created in 2017 (Kerr & Landry, 2017). In Europe, citizens generate roughly 11 kg of textile waste per person per year (European Environmental Agency, 2021). Focusing on Sweden in 2024, municipalities collected 16,780 tonnes of textiles. Of this amount, 75% was labelled for reuse, 16% for material recycling, and 9% for incineration (Avfall Sverige, 2024). Textiles categorised as reuse, and not in demand in Sweden, are shipped to other countries, often first to European sorting centres like Lithuania where Sweden exported 11000 tonnes of used textiles in 2024 (Martvall & Gustavsson 2025). While a significant portion of these textiles remain in Europe and are reused, final destinations of Nordic used textiles include India and Pakistan (11%), and the African continent (18%) such as Kenya, where traceability is inconsistent and outcomes heterogenous (Watson et al. 2016; Martvall & Gustavsson 2025). Current textile waste management practices include incineration; landfills (Pensupa et al. 2017); and chemical, mechanical, and thermal recycling (Riemens et al. 2021). Problems with current management practices include the inefficiency of textile sorting, environmental effects, and health concerns. A main factor limiting the efficiency of textile recycling is sorting. This is because clothes are often composed of multiple materials and include zippers, buttons, linings, trims, etc. in addition to synthetic and blended fabrics having similar physical characteristics that hinder accurate sorting (Damayanti et al. 2021). Incineration and landfills cause environmental effects such as the release of per- and polyfluoroalkyl substances (PFAS), microplastics, and air pollution (de Oliveira et al. 2023; Schellenberger et al. 2022; Zhou et al. 2022). Incineration and landfills are also associated with negative health effects. Studies have reported that in communities surrounding landfills there are higher rates of respiratory related hospitalisation (Mataloni et al. 2016). Additionally, in studies on human donor nasal epithelium cells exposed to plastic incineration emissions, there are changes suggesting respiratory disease such as inflammation (Rogers et al. 2024). In the European Union, member countries are required as of January 1, 2025, to collect textile waste separately from other household waste (Avfall Sverige 2024). Thus, in Sweden, municipalities have become responsible for collecting textile waste separately (Avfall Sverige 2024).

2.2 Circular Bioeconomy and waste valorisation

The circular bioeconomy in textile waste valorisation integrates biotechnological processes to extend textile lifespans and repurpose post-use materials into new bio-based products (Shirvanimoghaddam et al. 2020). Key techniques for textile waste valorisation in the circular bioeconomy include cascading use and renewable feedstocks, where multi-stage reuse and recycling of textile materials enable their conversion into value-added products such as composites, regenerated fibres, and biochar, while natural fibre wastes like cotton and wool serve as renewable feedstocks that replace virgin resources in new material production (Shirvanimoghaddam et al. 2020). Challenges to the implementation of the circular bioeconomy include feedstock variability (Thomas et al. 2024), issues with the maturity and scalability of recycling and sorting technologies (Lanz et al. 2024), and logistics due to fragmented textile recycling and waste management efforts (Saif et al. 2024). European Union policies and initiatives to promote circular bio-based innovation include: the Circular Economy Action Plan (CEAP), Extended Producer Responsibility for Textiles, and research and innovation funding (European Commission 2019; European Parliament 2025; European Commission 2021).

2.3 Textile waste valorisation pathways

Mechanical recycling is used for fibre recovery from textile waste through processes like shredding (Islam et al. 2025). Inaccurate sorting of mixed fabrics limits mechanical recycling and decreased quality of recycled fibres due to feedstock variability and shorter fibres increase risk for downcycling (Islam et al. 2025). Chemical recycling such as hydrolysis and pyrolysis are current approaches for valorising textile waste (Ghosh et al. 2025). These recycling methods are limited by economic obstacles such as high input costs, energy demands, infrastructure requirements, and extra costs needed to remove dyes and coatings on the fibres as well as issues with blended fibres that reduce fibre quality and product purity (Ghosh et al. 2025). There is currently a transition to biological approaches for textile waste valorisation including enzymatic degradation. Studies have demonstrated that selective enzymatic degradation of components of mixed fibre textiles could achieve complete degradation of natural fibres like wool while leaving polyester fibres in a condition like virgin fibres, thus better for turning into polyester yarn for new textiles (Navone et al. 2020).

2.4 White-rot fungi and textile degradation

White-rot fungi, like *Pleurotus spp*. and *Ganoderma spp*., can degrade lignocellulosic materials by releasing extracellular enzymes such as laccase and

peroxidases from their growing hypha (Kobayashi et al. 2023). The mycelial composites have potential applications in biomaterials, including polystyrene packaging replacements and leather alternatives (Sivaprasad et al. 2021; Williams et al. 2022). Textile waste can serve as a substrate for mycelium cultivation, promoting the circular bioeconomy. However, research on cultivating fungi on solid textile waste remains limited, with most studies addressing fungal degradation of dyes (Kumar et al. 2024) rather than the textile itself. A few studies have explored fungal growth and degradation on textile waste, mainly focusing on remediation and mycelium composite production (Saini et al. 2024; Dussault et al. 2016; Freeman et al. 2024; Fletcher 2025). While fungi can grow on various fibres and create composites, challenges persist due to limited mycelial penetration into fibres and the reliance on controlled laboratory conditions. Further research is essential to address these issues and promote industrial applications.

2.5 Aim

This study will provide information about textile waste, both considering availability and properties, as well as compile information about fungal degradation of textile waste. Additionally, experimental studies were performed, with the aim of evaluating the growth of two white-rot fungal species on commonly available textile waste. In one of the experimental studies the impact of the degrading enzymes of white-rot fungi on cotton (natural fibre) and polyester (synthetic fibre) was explored. This was done with the aim of assessing the risk for formation of microplastics during fungal growth on textile waste.

2.6 Research question

What are the types of textile waste available and of interest to be repurposed for production of a mycelial composite?
Which types of textile waste are suitable for fungal growth?
How do the degrading enzymes of white-rot fungi impact the fibres of cotton and polyester?

2.7 Limitations

The experimental work has been performed with two strains of white-rot fungi, *Pleurotus ostreatus* M2191 and *Ganoderma lucidum* M9726. Six types of textile fabrics were evaluated for fungal growth. The textiles chosen are representative of the fibres most relevant to textile waste in Sweden because they include the two most common fabrics, cotton and polyester, as well as denim jeans (a common garment made from cotton), another pure natural fibre (viscose) and blended fabrics including viscose-linen blend and polycotton. Despite this representative

sample, textile waste is even more diverse and thus not all textile fibres were covered. Materials common in knitwear such as acrylic and wool (Henry et al. 2019) were excluded, and different thicknesses of fabrics in each material were not tested. In addition, real textile waste comes with buttons, zippers and trims (Damayanti et al. 2021) which were not addressed in this paper. To address the time constraints and narrow the scope of this thesis, the fungal degradation of textile dyes, especially in textile wastewater, was excluded. A considerable amount of research has been done on the fungal degradation of dyes (Sun et al. 2023), and these are not included in the study. To simplify the enzyme analysis, only the most common/abundant enzyme used in mycelial degradation of textile fibres, laccase, was measured. Peroxidases and cellulases also contribute to degradation (Kobayashi et al. 2023) and their contributions to the degradation of textiles in this study are unrecorded. However, within the SEM experiment the focus was on the ligninolytic enzymes and cellulase was not measured, so we cannot be completely certain that it is only laccase in the enzyme suspension.

3. Materials and methods

3.1 Introduction to Methods

I used a two-part approach to answer the research questions. First, I conducted a literature review to identify studies, record data, and assess patterns in textile waste and waste management in Scandinavia and the European Union. Second, I performed four experiments to test fungal growth and impact on multiple textile materials and analysed the data generated from these experiments.

3.2 Literature Review Methods

3.2.1 Search Strategy

I conducted the primary portion of my search using Scopus. I started by reading the most cited papers and papers written by the authors with the most publications in each subtopic of my literature review. The searches were conducted between August and October 2025. After the preliminary search of each subtopic, I identified case studies and unanswered questions, then used keywords in Scopus, Web of Science, and Google Scholar to target specific concepts (see Table 1.).

Table 1. Subtopics, keywords, and databases used in literature review.

Subtopic	Keywords	Database(s) Used
Textile Waste	Textile waste, textile waste management, textile recycling, fast fashion, used textile trade, post-consumer textile waste, textile waste Sweden, textile waste Europe, textile sorting	Scopus, Google Scholar
Biodegradation of textiles	Textile biodegradation, fabric, textile fibre, natural fibre, synthetic fibre, blended textile, fungal degradation, mycodegradation, textile waste valorisation	Scopus, Google Scholar
Enzymes in degradation	Laccase, peroxidase, cellulase, lignocellulosic fibre, enzymatic degradation	Scopus, Google Scholar

3.2.2 Inclusion and Exclusion Criteria

My research focuses on solid textile waste; thus, I excluded all papers focusing on textile wastewater. I included studies on Scandinavia, Europe, and countries used textiles are often sent to from Europe. I excluded studies not in English or Swedish. In my preliminary search I included research articles and reviews, but in later studies expanded documents to government briefings and company reports. I screened studies in two stages: first, I reviewed titles and abstracts to remove irrelevant papers, then I read the full texts.

3.2.3 Data Extraction/Analysis

From each study, I recorded the methods, arguments, and interesting examples, then summarised the information in each subtopic to identify patterns and gaps.

3.3 Experimental/Analytical Methods

3.3.1 Study System/Materials

Textiles

The textiles I used included both pure materials with 100% cotton (beige dye, tyg.se), polyester (white dye, tyg.se), and viscose (white dye, tyg.se); and blended fabrics including polycotton (white dye, tyg.se), viscose/linen (70% viscose 30% linen, used, but initially Lindex, black dye), and denim (99% cotton 1% elastane, Erikshjälpen).

Microorganisms

The white-rot fungi *Pleurotus ostreatus* M2191 and *Ganoderma lucidum* M9726 were used in the experiments as agar cultures and grain spawn. Grain spawn was obtained from Mycelia BVBA, Belgium. Agar inoculum was produced on malt agar containing 10 g/L malt extract (Difco, USA) and 15 g/L agar, and plates were cultivated for 14 days before use.

3.3.2 Experiment 1

In Experiment 1, white-rot fungal growth was screened on various textiles (Table 2). First, petri dishes were prepared for fungal inoculation, and 8 circles of each fabric were cut out at a diameter of 8 cm. Then the amount of water absorbed by the cotton fabric was determined by weighing dry and wet fabric. The rest of fabrics had the same amount of water dripped on to them (1.6 ml of water) with a pipette.

Fungi were inoculated onto the textiles using two methods. First, 1 g of grain spawn was placed in the centre of a petri dishes containing circular pieces of each fabric, and second, agar slants were taken with a cork borer (1.5 cm diameter) and

placed in the middle on the soaked textile pieces. The petri dishes were sealed with parafilm, and growth was followed over time by visual observation. Each treatment had two replicates.

After 4, 7 and 14 days, mycelial growth was observed and recorded (Table 2). Designation “X” refers to that growth was noted while “XX” implies significant growth, and “–” implies that no visible mycelial growth was detected. On Day 7, 1 ml of water was added to each petri dish so that fungi would not dry out.

3.3.3 Experiment 2

The denim (99% cotton 1% elastane, Erikshjälpen) was cut into 5 x 5 cm pieces. An amount of 120 g (dw) of this material was used to cast a pot and one pot was produced of each fungal species. The mould was composed of two plastic flowerpots of different size (Figure 1).

Spawn of P. ostreatus and G. lucidum was added in a concentration of 10% (dw/dw) and the moisture content was set to 60% by addition of tap water. Each mould was enclosed in a filter bag suitable for mushroom cultivation (Sac O2, Belgium) and incubated at 22°C. The pots were weighted once a week and watered to avoid desiccation. After 5 weeks the plastic pots were removed and the produced biocomposite, composed of denim and mycelium, was dried at 45°C for 48 h.

Figure 1. A mould was created by using two flowerpots of different size.

3.3.4 Experiment 3

Fungal respiration during their colonisation of the textiles was measured using carbon dioxide loggers (Extech CO210, Nashua, USA), which were placed directly above the gas exchange filter on each inoculated box. Each box was enclosed in a plastic cone with height 45 cm, a closed base, and an open top with

diameter 25 cm. Carbon dioxide emissions were measured once every hour for 12 days. The experiment was performed with 3 replicates of 27 g of dry cotton and polycotton, 10 g of spawn (wet weight), and 56 ml of water in each container.

3.3.5 Experiment 4

The impact of ligninolytic enzyme on textiles were evaluated on pure cotton fibres and pure polyester fibres. White sewing thread of both materials were obtained from a local shop, 100% cotton (Gutermann Col.5709) and 100% polyester (Gutermann Col.800). In all handling of the threads, gloves were used to avoid impacting its surface. Enzymes suspensions were produced as described by Hewage et al. (2025) and both fungi, *P. ostreatus* and *G. lucidum*, were cultivated for 72 h. After this period, the fungal pellets were removed by coarse filtration and remaining debris were removed by centrifugation at 5 000 g for 3 min. The enzyme activity of the suspensions was determined as described in Hewage et al. (2025).

The experiment was set up with eight treatments, including controls, as described in the table below. Petri dishes were used as treatment containers. Threads with a length of 3 cm were cut and added to the different suspensions. Three replicates were used for each treatment. The threads were incubated for 24 h and after this the threads were carefully transferred to distilled water and washed for 5 min. The threads were then dried at 35°C for 2 h and mounted with double-sided adhesive on SEM-stubs. The samples were sputter-coated with gold (Cesington 108 auto, 65 seconds, 20mA). The preparations were imaged using a scanning electron microscope (SEM; Hitachi SU3500) at 5 kV. Gold coating and SEM imagining was performed at the Microscopy Platform, Lund University.

Table 2. The treatments included in Experiment 3.

Treatment	Textile material	Fungus	Initial laccase activity (U/L)	Final laccase activity (U/L)
1	Cotton	None (control)	0	0
2	Polyester	None (control)	0	0
3	Cotton	PO	315 ±1 (undiluted)	197±5
4	Polyester	PO	315 ±1 (undiluted)	197±5
5	Cotton	PO	59 ±5 (diluted)	30±2
6	Polyester	PO	59 ±5 (diluted)	30±2
7	Cotton	GL	64 ±6 (undiluted)	65±5
8	Polyester	GL	64 ±6 (undiluted)	65±5

3.3.6 Summary

The combination of a literature review and experimental analyses provided both a theoretical foundation and empirical evidence to address the possibility of cultivating mycelium on textile waste.

4. Results

4.1 Literature Review

The literature review uses primary studies, review papers, and reports to investigate current knowledge of the fungal degradation of textile waste, enzymatic degradation of cotton and polyester fibres, what properties influence degradability of textile fibres, and what kind of textile waste exists in Sweden and Europe.

4.1.1 Textile waste in Sweden vs EU

Across Europe, clothing textiles are more prevalent than household textiles, although both are significant in post-consumer streams (Lanz et al. 2024). The Fibersort project (UK, Netherlands, France, Belgium, Germany) found that 64% of collected textiles were suitable for rewearing, while the non-rewearable fraction consisted mostly of cotton, polyester, or polycotton (≈75%), with smaller amounts of acrylic (1.7%), wool (1.6%), and viscose (0.9%) (Fibersort 2020). In Sweden, residential textile waste contains 58% cotton, with the remaining 42% mostly mixed fibres and inbound flows to the Siptex facility are predominantly cotton (Hultén et al. 2016; Lidfeldt et al. 2022). The Sorting for Circularity Europe project analysed 21 tonnes of non-renewable and low-value rewearable textiles across Europe in 2021-2022, reporting that the composition was 42% cotton, 32% blends (including 12% polycotton), and 11% polyester (van Dujin et al. 2022). These results indicate that Sweden follows a pattern similar to the rest of Europe, with cotton being common, mixed fabrics substantial, and clothing textiles the main component of post-consumer textile waste.

Table 3. Categories of textile waste in Sweden and other European countries.

Textile Sorting Company/ Project	Countries	Findings	Reference
Fibersort (Interreg NWE)	UK, Netherlands, France, Belgium, Germany	64% collected textiles suitable for rewearing. Of collected textiles that cannot be reworn: almost 75% cotton, polyester or polycotton; 1.7% acrylic, 1.6% wool, and 0.9% pure viscose.	Fibersort 2020
Siptex (Sysav)	Sweden	In their lifecycle assessment use the following assumptions to inform their case studies: (1) Hultén et al. (2016) stated the composition of textile residential waste in Sweden that 58% cotton 42% mostly mixed fractions. (2) current inbound textiles to Siptex plant consist primarily of cotton due to demands of outbound textiles.	Lidfeldt et al. 2022
Sorting for Circularity Europe	Supposed to represent all of Europe	Analysed 21 tonnes of post-consumer textiles in autumn/winter 2021 and spring/summer 2022. Of the non-rewearable + low-value rewearable garments: 42% cotton, 32% blended fabrics and almost half (12%) were polycotton, 11% polyester.	van Dujin et al. 2022

4.1.2 Fungal degradation of textile fibres

Most studies in relation to textiles and white-rot fungi concerns fungal degradation of dyes (Kumar et al. 2024). This is, however, not in the scope of the present study which focuses on the textile itself. Only a small number of studies (5) have examined fungal growth on and degradation of solid textile waste (Table 4). One recent study (Hazelgrove & Moody 2024) had a focus on fungal degradation of textiles with the purpose of producing edible mushrooms. The other four studies have focused on fungal degradation of textile waste solely for the purpose of the remediation of textile waste or producing mycelium composites for biomaterial applications (Saini et al. 2024; Dussault et al. 2016; Freeman et al. 2024; Fletcher 2025). The studies have examined the degradation of both natural, synthetic and blended fibres using predominantly different types of white-rot fungi through enzyme assays, microscopy, and biomass/weight loss. While all studies confirmed that fungi can grow on natural fibres such as cotton, there is a conflict within the literature on whether fungi can grow on and degrade synthetic fibres. There are limitations such as mycelial growth on and not through textile fibres, and use of highly controlled laboratory conditions that leave many questions unanswered about scalability and the industrial application.

Table 4. Detailed information about previous studies on the fungal degradation of textile waste.

Fungi	Textile	Methods	Findings	Reference
White-rot fungi: *Pleurotus ostreatus*, *Pleurotus eryngii*, *Lentinula edodes*. Litter-decomposing fungi: *Agaricus bisporus*	28% cotton, 68% bamboo viscose, 4% elastane (coloured)	GC-MS, SEM, bioinformatics to assess potential degradation enzymes using genomes.	Enzymes identified: laccases, peroxidases, cellulases. *A. bisporus* did not grow on textile after 2 months. All three white-rot fungi appeared to grow on cotton and viscose fibres under SEM. Visible bleaching/dye loss on fabric. Various dye metabolites detected.	Hazelgrove & Moody 2024
Pleurotus ostreatus	Cotton, Polyester (white and coloured)	Dry biomass, water activity, FTIR, SEM, stress and strain analysis of biocomposites	Textiles after fungal growth had 80-90% water decrease. FTIR and SEM confirm fungal growth on cotton fibres. SEM/FTIR analysis was performed on cotton fibres; no data were provided for polyester, so enzymatic effects on polyester surfaces were not reported.	Saini et al. 2024
Trametes versicolor, *Ganoderma lucidum*	Nylon, Polyester	Weight loss pre- and post-inoculation.	Weight loss recorded for both fungi and textiles. Coculture did not improve degradation compared to single culture.	Dussault et al. 2016
Group 1 Ascomycota including: *Aspergillus flavus,*	10 fabrics including: cotton, viscose, polyester, leather, elastane.	Weight loss	Weight loss higher in fabrics with higher percentage of cellulosic materials and leather had least weight loss. Weight loss for each fabric varied significantly with each fungal treatment. *G. australis, G. lucidum and T. versicolor* were most effective fungi degrading cellulose.	Freeman et al. 2024

Aspergillus niger, Trichoderma sp. Group 2 Basidiomycota including: *Ganoderma lucidum, Pleurotus ostreatus, Trametes versicolor*.	Some pure and other blended.			
Pleurotus ostreatus	Combination of polyester, cotton, silk, wool.	Mycelium growth, morphological characteristics, dry biomass.	The texture (cottony or floccose) of mycelium on textiles was key determinant of mycelium development. potato dextrose yeast agar most effective for mycelial growth in fabrics.	Fletcher 2025

4.1.3 Role of enzymes in degrading cotton and polyester fibres

Studies show that cellulases can hydrolyse cotton fibres directly (Egan et al. 2023) and there is a growing number of studies suggesting cutinase degradation ability of polyester, as presented in Table 5. However, studies of the impact of laccase and peroxidase on fibre degradation are lacking. Instead, most studies show that laccase and peroxidase can decolorise dyes on textiles (Zhou et al. 2025; Latif et al. 2021).

Table 5. Fungal derived enzymatic effects on cotton and polyester.

Enzyme	Textile	Methods	Findings	Reference
Cellulases: endoglucanase	Cotton, polycotton, viscose.	Enzyme activity analysis (FPU assay), gravimetric analysis, HPLC, LC-CAD, SEM, XRD, viscometry, DSC, FTIR.	Endoglucanase hydrolyses cotton by breaking glycosidic bonds in cotton.	Egan et al. 2023
Cutinase	Polyester (PET)	Enzyme treatment in Tris–HCl (pH 9, 35 °C, 24 h), FTIR, SEM, contact-angle, moisture regain, wetting time measurements.	Cutinase showed fabric surface modification by increasing hydrophilicity of fabric.	Sooksai et al. 2019

4.1.4 What makes a textile better or worse for fungal degradation?

The characteristics of textile fibres influence how effective fungal degradation can be. In studies on fungal degradation of textile waste by white-rot fungi (Table 4), textiles with higher percentages of natural fibres such as cotton, experienced greater weight loss compared to fibres with more synthetic fibres when inoculated with fungi (Freeman et al. 2024). In the soil microorganism context, Brunšek et al. (2023) identified characteristics that make textile fibres more susceptible to microbial degradation in the soil. These included: hydrophilicity, low degree of polymerisation, less crystallinity, and weaker molecular orientation. However, while viscose fibres are classed as having these characteristics, they degraded less

than expected. The authors suggest this was due to viscose fibres developing a "skin" during spinning which creates a physical barrier, preventing microorganisms and enzymes from penetrating the fibres. Cotton, however, did follow the expected degradation patterns based on its characteristics. Cotton had the highest biodegradation rate due to its large surface area, hydrophilic structure, and cellulose composition. In contrast, polyester (PET) was cited as having a low biodegradation rate due to its high crystallinity, hydrophobicity, and lack of hydrolysable bonds. The study of Brunšek et al. (2023) also examined fungal degradation of polylactic acid (PLA), a synthetic material biodegradable under specific conditions. Their results showed a higher degradation rate than expected – though still less than cotton – the authors suggested that this was due to favourable environmental conditions instead of primarily enzymatic digestion.

4.2 Experimental Study

4.2.1 Experiment 1

Table 6 summarises the average growth on mycelium on the different textiles: cotton, polyester, polycotton, viscose, viscose mix, and denim. The experiment aimed to assess how well the used fungi were able to grow with textiles as a medium. As shown in Table 6, in general both fungi preferred natural fibres to synthetic fibres except for viscose, which had the least fungal growth. The best fungal growth (spread and density) was on linen viscose mix. Both fungi had more growth when spawn was used as inoculum as opposed to agar. *Pleurotus ostreatus* had more visible growth on polycotton whereas *Ganoderma lucidum* had more growth on jeans. *Ganoderma lucidum* grew better on 99% cotton denim than on beige 100% cotton cloth.

Table 6. Growth of the white-rot fungi G. lucidum (GL) and P. ostreatus (PO) on different textiles (Experiment 1).

	DAY 4				DAY 7				DAY 14			
	GL		PO		GL		PO		GL		PO	
Textiles	Agar	Spawn	Agar	Spawn	Agar	Spawn	Agar	Spawn	Agar	Spawn	Agar	Spawn
Cotton 100%	-	X	-	-	-	X	-	X	-	XX	-	XX
Polyester 100%	-	-	-	-	-	X	-	-	-	X	-	-
Denim (99& cotton, 1% elastin)	-	X	-	X	-	XX	X	X	-	XX	-	X
Viscose mix (viscose 70%, linen 30%)	-	XX	-	XX	-	XX	X	XX	-	XX	X	XX
Viscose 100%	-	-	-	-	-	-	-	-	-	X	-	X
Polycotton (polyester 65%, cotton 35%)	-	-	-	-	-	X	-	X	-	X	-	XX

4.2.2 Experiment 2

Both fungal species had colonised the denim when the experiment ended. However, there was considerable difference both in the amount of visible mycelium (Figure 2) as well as the stability of the produced biocomposite. The pot composed of denim and *P. ostreatus* was less colonized and easily fragmented while the pot with *G. lucidum* was dense and very stable. This difference remained after drying.

Figure 2. The pot produced from P. ostreatus (to the left) and with less visible mycelium compared to the pot produced with G. lucidum (to the right).

4.2.3 Experiment 3

In Experiment 3, fungal respiration on cotton and polyester was measured first for *P. ostreatus* and later for *G. lucidum* over a 12-day period. The t-tests indicate the *P. ostreatus* had statistically significant higher values of respiration on cotton than polyester at three points (Figure 3). For *G. lucidum* no statistically significant differences in respiration on cotton and polyester were observed (Figure 4). The standard deviation for the 12-hour average of respiration values is higher in *P. ostreatus* than for *G. lucidum*. On average, respiration averages are also higher for *P. ostreatus* than *G. lucidum*.

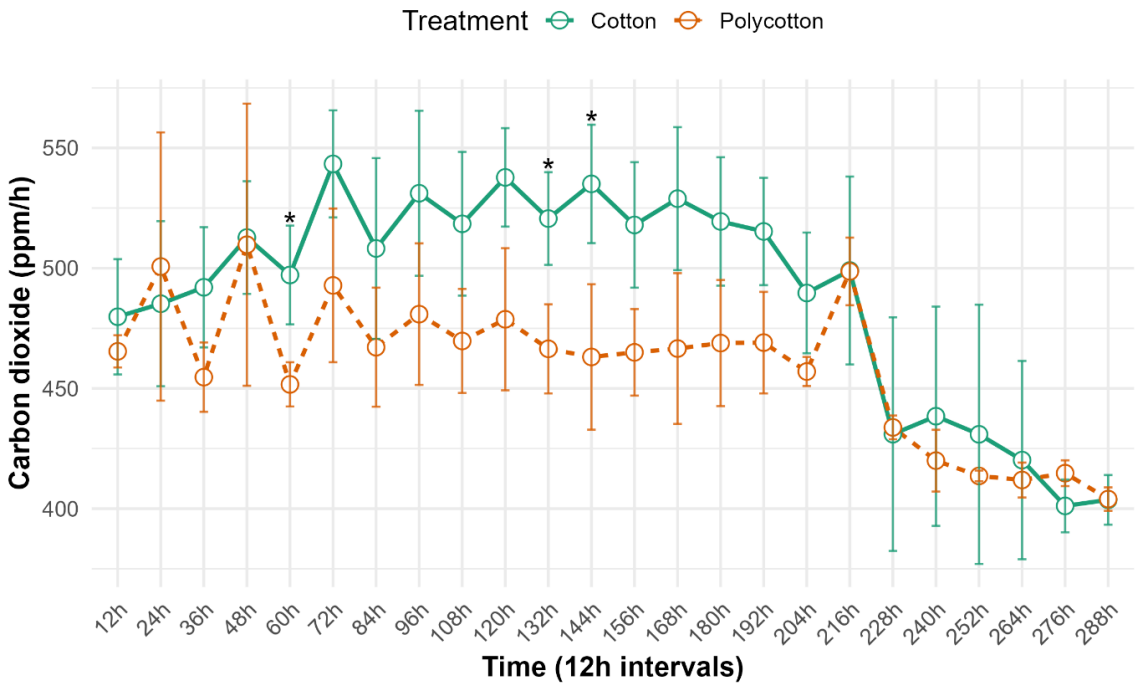


Figure 3. Carbon dioxide respiration of Pleurotus ostreatus on cotton and polycotton over 12-day period. Significant difference ($p<0.05$) in respiration is indicated with an asterisk (*). Mean±std shown, n=3.

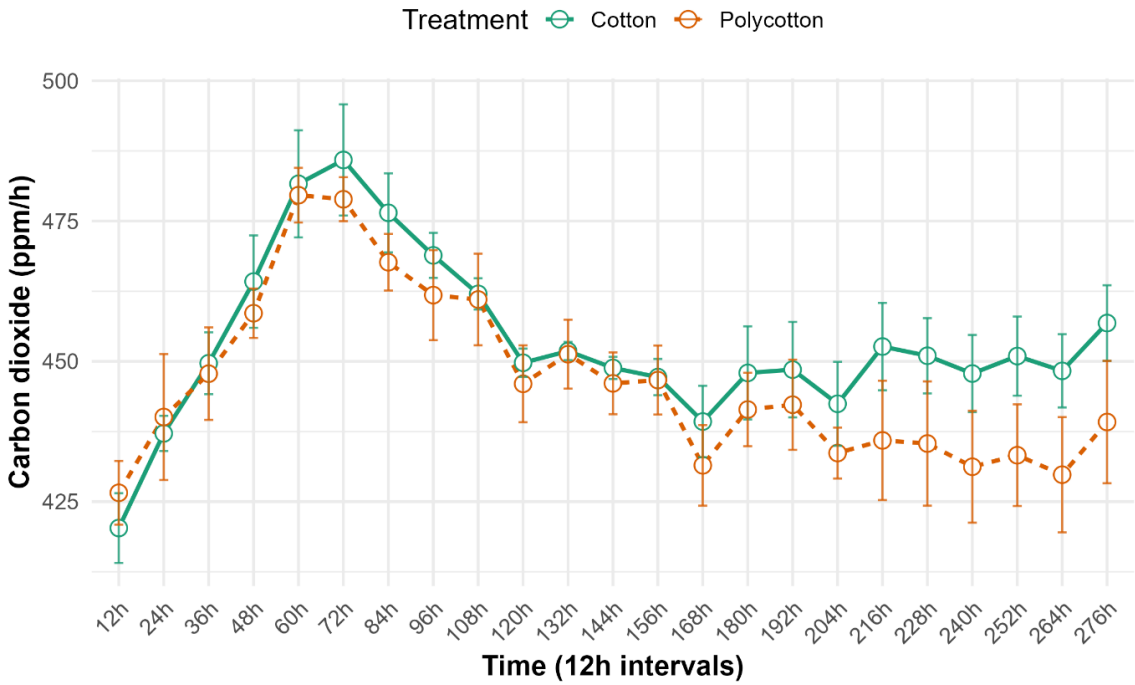


Figure 4. Carbon dioxide respiration of Ganoderma lucidum on cotton and polycotton over 12-day period. Significant difference ($p<0.05$) in respiration is indicated with an asterisk (*). Mean±std shown, n=3.

4.2.4 Experiment 4

Experiment 4 used SEM to visualise differences in fungal degradation on cotton and polyester in relation to their exposure for laccase. The treatments were as described in Table 2. No significant differences in the appearance of the polyester threads at all levels of magnification tested (100x, 1500x, 5000x, 9000x) between the control and the treatments could be observed (Figure 5). In cotton, differences between the control and the treatments were observed. More frayed ends and deep grooves in the threads suggest the enzymes in *P. ostreatus* and *G. lucidum* have some effect on the degradation of cotton fibres (Figure 6). Only images of the impact of the highest activity of the enzyme suspensions of *P. ostreatus* is shown. Still, also, in the suspension with the lower activity some impact of treatment was observed. More images of the impact of the treatments are available upon request.

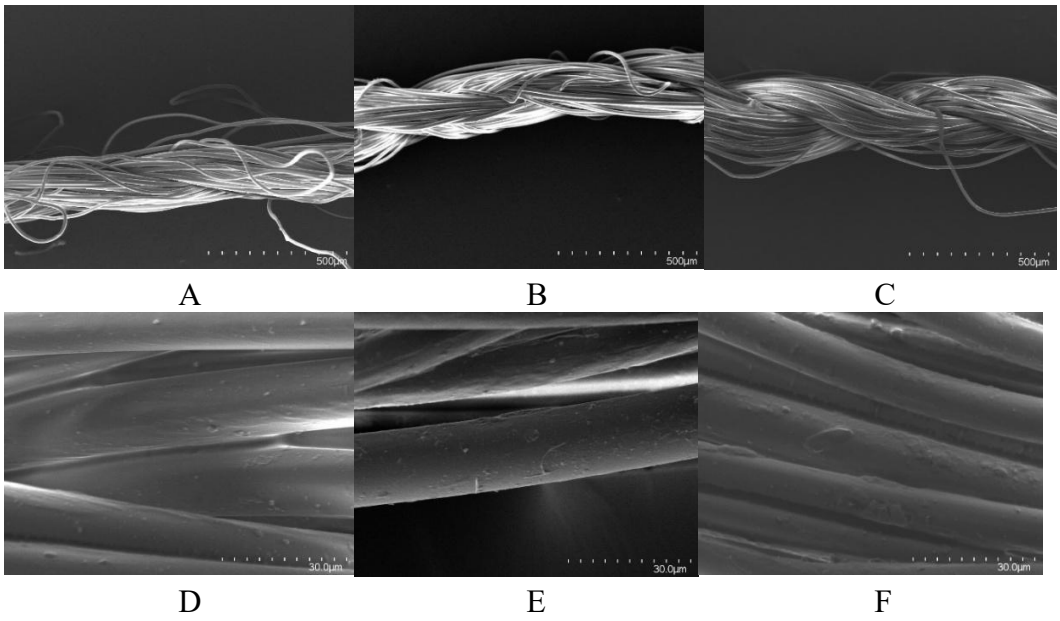
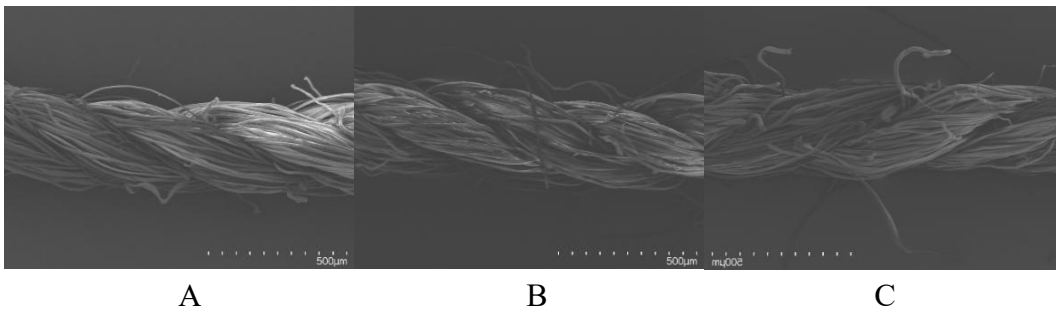
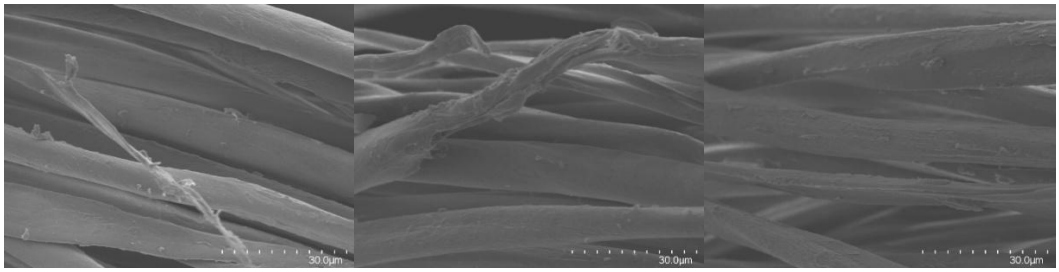


Figure 5. SEM Polyester Comparison of control, PO High, and GL. A) Control 100x B) PO High 100x C) GL 100x D) Control 1500x E) PO High 1500x F) GL 1500x





D E F

Figure 6. SEM Cotton Comparison of control, PO High, GL. A) Control 100x B) PO High 100x C) GL 100x D) Control 1500x E) PO High 1500x F) GL 1500x

5. Discussion

5.1 Identifying textile waste streams for mycelial composites

In Experiment 1, the textiles chosen were pure cotton, polyester, and viscose and, blended polycotton, viscose-linen, and denim (cotton, elastane). The motivation behind the experiment was to determine which textiles were of interest to be repurposed as mycelium composites. The two criteria required for a textile to be of interest for repurposing as mycelium composites are (1) they are common in textile waste and (2) fungi can grow on them. The logic behind this textile selection was that these textiles could function as a representative sample of textile waste because there was a combination of both natural and synthetic fabrics as well as pure and blended fabrics. This decision was validated by the literature review findings because cotton was the most common natural fibre, polyester was the most common synthetic fibre, and polycotton was the most common blended fibre (Hultén et al. 2016; van Dujin et al. 2022; Fibersort 2020). Additionally, blended fibres were repeatedly cited as being of large or increasing significance due to both its quantity and the challenges it poses to textile waste sorting and recycling. The literature review also highlighted interesting disagreements about whether fungi could breakdown synthetic fibres and viscose (Dussault et al. 2016; Brunšek et al. 2023; Freeman et al. 2024). Thus, including these fabrics in our initial experiment, allowed us to further contribute to these conversations. In the following experiments I chose to go further with cotton, polyester, polycotton and denim because they either fit the criteria for a textile to be of interest for repurposing as a mycelium composite or, in the case of polyester, which did not exhibit as noticeable growth, allowed for further comparisons between natural and synthetic fibres.

5.2 Types of waste suitable for fungal growth

In Experiment 1, both fungi grew well on cotton, denim, polycotton, and viscose-linen mix. They grew significantly less on polyester and not at all on viscose. This is interesting because viscose is a natural fibre, but the literature shows some conflicting evidence and opinions about viscose's suitability for fungal degradation. Hazelgrove & Moody (2024) reported that white rot fungi were able to grow on viscose, but in Brunšek et al. (2023) the decomposition of the fabric by soil microbes was less than expected compared to other fabrics and they reasoned it was due to a "skin" on exterior which prevented enzymes penetrating the fibres. My experimental results align with the observations of Brunšek et al. (2023) and supports the suggestion that the structure of viscose prevents fungal growth and

degradation on the fibres despite being a natural fibre. This is an important finding because in a waste sorting and valorisation context, the viscose would be left behind in a mixed fibre degradation by white-rot fungi. Thus, it would need to be separated from other non-degradable textiles prior to fungal inoculation if pure fibres are the intended outcome of this sorting process.

Another area of controversy in the literature is whether fungi can breakdown synthetic textile fibres. In Experiment 1, *P. ostreatus* couldn't grow on polyester and *G. lucidum* had only minimal, sparse growth on polyester, that did not go through the fabric like in the natural and blended fibres. Dussault et al. 2016 suggested white rot fungi can degrade synthetic fibres like nylon and polyester, but in other papers such as Freeman et al. (2024), they suggest that fungi won't breakdown polyester fibres. Thus, treatment with white-rot fungi would be ideal for sorting cotton and polyester textile waste by breaking down the cotton and leaving behind the polyester fibres for further processing. My results lean towards the argument that polyester fibres are not degraded by white-rot fungi, supported by the fact that no impact on polyester fibres were observed when exposed to enzyme suspensions. In textile waste sorting and recycling this would mean pure cotton and polyester blends could be separated using fungi to breakdown the natural fibres leaving polyester behind for reuse or recycling.

In Experiment 3, both fungi were inoculated onto cotton and polycotton, and carbon dioxide respiration was monitored over a period of 12 days. The results suggest that while there is a trend of respiration on cotton being higher than polycotton it was only significant at 3 points on *P. ostreatus*, and with *G. lucidum* the respiration was even more similar between both fabrics. The literature has conflicting ideas about whether blended fibres are as suitable for fungal growth and degradation as pure cotton. Freeman et al. (2024) noticed a pattern of increasing weight loss in fabrics with a higher percentage of cellulosic materials. However, the Experiment 3 results suggest cotton in pure and blended materials largely degraded at similar rate. Thus, future studies should continue to explore the differences in fungal degradation using both weight loss and carbon dioxide respiration to map the patterns of degradation over a longer period in both pure cotton and blended cotton fibres.

5.3 Fungi-derived degrading enzymes on cotton and polyester

In Experiment 4, cotton and polyester threads were inoculated with enzyme extracts of both types of white-rot fungi and the activity of laccase measured, then these threads were examined under SEM for visible signs of degradation. The results suggested enzymes suspension from white-rot fungi are unable to

breakdown polyester but do have some noticeable effect on cotton fibres. In the literature, only a small number of studies have explored the impact of fungal-derived enzymes on the degradation of textile fibres. Instead, most studies look at the degradation of textile dyes where laccase stands out as the most common enzyme, followed by peroxidases (Zhou et al. 2025; Latif et al. 2021). The minimal studies on textile fibres focus instead on cellulases degrading the cellulose in cotton fibres (Egan et al. 2023), and a growing number of studies explore the potential of cutinase to degrade polyester (Sooksai et al. 2019).

In addition to direct fibre depolymerisation, actively growing white-rot fungi secrete extracellular ligninolytic enzymes such as laccase, lignin peroxidase, and manganese peroxidase, which are widely reported for their roles in degrading and decolourising synthetic textile dyes (Kumar et al. 2024). While most existing studies focus on dye degradation, some fibre-specific work has shown that cellulases can break down the cellulose component of cotton fibres (Egan et al. 2023). Because these enzymes are produced by the mycelium, the extent and uniformity of fungal colonisation across a textile substrate may influence how evenly enzymes are delivered into the material—this warrants further investigation.

For pilot-scale and industrial applications, enzyme effectiveness is influenced by environmental conditions such as pH, temperature, and moisture availability, as well as by the presence of residual dyes, finishing agents, and other chemical additives commonly associated with textile waste (Ghosh et al. 2025). These factors are known to affect enzyme performance in dye degradation processes and are also likely to influence enzyme-mediated fibre degradation. Hazelgrove and Moody compared the production of lignocellulosic enzymes, including cellulases, peroxidases, and laccases, across four fungal species based on their presumed importance for textile fibre degradation, highlighting the need for broader enzyme screening approaches. Future studies should therefore combine mechanistic investigations of how fungal-derived enzymes act on specific textile polymers with systematic screening of different white-rot fungi to identify species that produce high concentrations of relevant degradation enzymes. In addition, the influence of fungal colonisation patterns within textile feedstocks on enzyme penetration, substrate accessibility, and overall degradation efficiency should be examined to inform the development of scalable textile valorisation processes.

5.4 Challenges in upscaling

Using textile waste as a mycelium substrate offers several advantages, including an alternative waste reduction strategy, sorting of cotton from polyester in blended fibre waste, and the potential for biomaterial production and co-products,

which would allow European countries to integrate their waste management systems more closely with the circular bioeconomy (European Commission 2019; European Parliament 2025; European Commission 2021). Challenges associated with using textile waste as a mycelium substrate include feedstock variability and pre-processing requirements. Textile waste feedstocks are composed of different fibres, dyes, finishes, and garment additions such as zippers, which will have implications for enzyme activity and colonisation consistency (Islam et al. 2025; Ghosh et al. 2025; Damayanti et al. 2021). Although in this study, feedstocks were not cleaned, sterilised, and sorted prior to fungal inoculation, this is the expectation in industrial practices (Beyer 2023) which could increase added costs. Current methods to monitor fungal degradation of textiles such as weight loss and respiration are also inconsistent across studies and difficult to translate into industrial metrics.

Insights from my experiments on respiration rates and mycelial growth on different textiles suggest more research must be done to establish robust methods of monitoring degradation, comparing different fungi on different textiles, and longer times to study masses of textiles from inoculation to complete or near complete degradation, to be able to successfully scale up mycelium-textile composite production. The results from Experiment 2 suggest that *G. lucidum* and jeans create a robust composite. This experiment also illustrates the broader issue of fungi-substrate compatibility. In Experiment 1, *G. lucidum* showed better growth on denim than *P. ostreatus*, and in Experiment 2, this translated *to G. lucidum* producing a much sturdier flowerpot. This fungi-substrate compatibility has implications for upscaling such as the need to find fungal species that breakdown most fibres evenly or pre-sorting the textile waste for each fungal inoculant depending on the degradation efficiency of each fungal species.

5.4.1 Valorisation pathways and product opportunities

The combination of textile waste and mycelium yields value-added composites that support multiple viable product pathways. Hazelgrove & Moody (2024) have suggested the possibility of using textile substrates to produced fruiting bodies for consumption. However, this production has not yet been successfully demonstrated and there are additional concerns related to food quality such as potential uptake of unwanted substances such as dyes and PFAS (Golovko et al. 2022). Several mycelium-based biomaterials could be made from the textile-mycelium composites including insulation (Babenko et al. 2025), packaging (Wang et al. 2025), and new textiles (Hao et al. 2025). The biocomposite produced in Experiment 2 with denim and *G. lucidum* could potentially have a role in this context and a usage for creation of a formable insulation.

Other valorisation options include the use of co-products from fungal growth including enzyme production such as laccases for industrial applications (Jiao et al. 2025). Also, as mentioned by Freeman et al. (2024), fungi could be used for textile fibre fractionation where natural fibres are degraded, and pure synthetic fibres are left over to be reused. Finally, it has been suggested that the mycelium cultivated on textile waste could have bioremediation applications and be used for degrading harmful chemicals in wastewater (Pundir et al. 2024). However, similar to the use of textile for production of fruiting bodies, there are concerns related to potential release of compounds such as microplastics and unwanted substances from the partly degraded textile that needs to be addressed in this context. As the polyester fibre appeared completely untouched (Figure 5; Figure 6), i.e. the results do not indicate any increased risk of leakage of small plastic fragments (microplastics) when polycotton is exposed to enzymes from white rot fungi, this may not be a concern.

5.4.2 Fruiting bodies: biological plausibility and safety concerns

The use of textile waste as a substrate has also been discussed in relation to the potential production of fruiting bodies, particularly for edible fungi (Hazelgrove & Moody, 2024). However, this application remains highly speculative. Hazelgrove and Moody were unsuccessful in inducing fruiting body formation on textile substrates, despite successful fungal colonisation and dye bioremediation. This suggests that while textiles may support vegetative mycelial growth, they do not readily provide the environmental or nutritional conditions required for reproductive development.

Fruiting body formation in mushroom-forming fungi is often triggered by environmental deterioration and nutrient limitation, which act as developmental signals rather than favourable growth conditions (Sakamoto, 2018). In this context, the small fruiting bodies observed in Experiment 1 may represent a stress-induced reproductive response to the harsh, nutrient-poor textile substrates rather than an indication of substrate suitability. This distinction is important, as fruiting under stress does not imply nutritional adequacy or safety for food production.

Hazelgrove and Moody (2024) further highlight that if fruiting bodies were to be produced on textile substrates, significant safety concerns would need to be addressed. These include the potential uptake of dye breakdown products, finishing agents, and elastane residues, as well as the possible incorporation of microplastics into fungal tissues. While these risks have not yet been empirically demonstrated, they cannot be ruled out and would require comprehensive

chemical and microplastic analyses before any edible application could be considered.

Taken together, these findings suggest that while fruiting body formation on textile waste may be biologically plausible under certain conditions, it currently represents a high-risk and poorly characterised application. At present, the most viable and responsible uses of fungal growth on textile substrates remain within non-food domains, including biomaterials, enzyme production, fibre fractionation, and bioremediation.

5.4.3 Pre-treatment and contamination control

Previous studies prepared textiles for fungal inoculation using an autoclave (Dussault et al. 2016; Saini et al. 2024; Fletcher 2025), suspension in methanol vapour (Freeman et al. 2024), or standard washing machine (Hazelgrove & Moody 2024). In this study, none of the fabrics were sterilised or pretreated prior to fungal inoculation. In Experiment 1, petri dishes with agar plugs showed signs of mould growth especially on viscose and polyester. However, in all experiments using spawn, mould was not an issue because the growth of mycelia from the spawn was rapid and dense enough to outcompete mould. When upscaling, to prevent contamination of large quantities of textile feedstocks, the methods used in previous studies: autoclavation, suspension in methanol vapour, and machine washing; should be tested for cost and energy efficiency.

5.5 Methodological reflections

5.5.1 Fungal inoculation

In Experiment 1, textiles were inoculated with fungi through two methods, agar and spawn. The use of spawn is a novelty compared to previous studies, all studies presented in Table 3 used agar plugs to inoculate textiles. Spawn allows for a quick and even distribution of mycelium due to multiple growth initiation points (Beyer 2023). Additionally, inoculation with higher amounts of spawn is correlated with faster mycelial growth (Idowu et al. 2016). This difference could explain why the textile substrates inoculated with spawn grew much faster than the agar plugs and why the spawn inoculated petri dishes had little to no visible contamination, while the petri dishes inoculated with agar plugs had more visible mould growth. Including spawn in this study, with its faster and more vigorous growth, enabled results to be seen in shorter time frames. Additionally, it sustained production of a large enough volume of mycelium to conduct carbon dioxide respiration measurements.

5.5.2 Cultivation conditions

Cultivation conditions for white-rot fungi, such as water content, can substantially influence fungal metabolic activity and colonisation, which in turn may affect the extent and rate of textile degradation. Saini et al. (2024) reported that decreasing moisture content can deactivate fungal activity, indicating that sufficient water availability is essential for sustained growth and degradation processes. In their study, water activity was monitored indirectly using relative humidity, highlighting its importance as a factor in fungal-mediated material breakdown.

Although water activity was not actively monitored in this study, efforts were made to standardise moisture availability across samples. Equal volumes of water were added to each fabric prior to fungal inoculation, and in Experiment 1, additional water was applied halfway through the incubation period to prevent desiccation. For future pilot-scale and industrial applications, continuous monitoring of humidity using humidity sensors or meters would be essential to maintain conditions conducive to fungal activity and consistent degradation. Furthermore, future studies should aim to determine the optimal humidity ranges for fungal degradation across different textile types, as moisture requirements may vary depending on fibre composition and structure.

5.5.3 Species of fungi chosen

While all previous studies (Table 3) utilised white-rot fungi, the species differed. *P. ostreatus* was the most common while *G. lucidum* was used in other studies but less frequently. Also, *Trametes versicolor* which was not included in this study, was evaluated in several earlier studies (Table 3). *G. lucidum* and *P. ostreatus* were selected because they were the most common candidates for production of biomaterials in the literature (Madusanka et al. 2024).

5.5.4 Scanning Electron Microscopy (SEM)

SEM was a common method used to measure fungal growth on different materials (Table 3). The reason for using SEM in Experiment 4 differed from previous studies as the goal was to visualise enzymatic degradation of textile fibres (Figure 5; Figure 6) instead of fungal growth and dye degradation (Hazelgrove & Moody 2024). The rationale behind this decision was to generate direct visual evidence of enzymatic action on fibre morphology, which was necessary for interpreting degradation behaviour but would not have been captured by SEM images focused on fungal coverage or pigmentation changes. Capturing fungal growth on SEM presents more obvious visual differences than enzymatic degradation, however in both cases the images remain largely qualitative and interpretive rather than

quantitatively reliable, reflecting the early stage of methodological development for this fungal growth/degradation on textiles purpose.

5.5.5 Analysis of fungal growth: weight loss vs. carbon dioxide respiration

To measure fungal growth on textile, and thereby textile degradation, previous studies have used weight loss of textiles before and after fungal inoculation (Freeman et al. 2024). In Experiment 3, carbon dioxide meters were used to measure fungal respiration. The thought behind using fungal respiration, instead of weight loss, was to capture ongoing fungal activity as it occurs, giving a clearer indication of metabolic degradation than weight loss. Future research should combine both methods, to better map the process of fungal degradation on different textiles.

5.5.6 Time

The final notable difference to previous studies is the time; my experiments lasted for much shorter time periods (i.e. 14 days for Experiment 1) compared to many of the other studies done (i.e. 30/60 days; Freeman et al. 2024). A shorter timeframe was used due to limited time and resources. Potentially a longer timeframe may have allowed more pronounced results in Experiment 1. However, in Experiment 3, fungal respiration values showed a curve with low values towards the end, indicating the fungi had used up the nutrients available in the textiles and a longer measuring time would probably not yield better results. Additionally, in Experiment 4 an enzyme extract was used and the activity of this suspension decreased over time.

6. Conclusion

Using textiles as a substrate for white-rot fungi to produce biomaterials and support textile waste management shows clear potential, though further research is needed before it can be implemented at industrial scale. Key knowledge gaps remain, including fungi-substrate compatibility, the mechanisms by which white-rot fungi and their enzymes degrade textiles, and the development of standardised methods for measuring and tracking the degradation process. This need is underscored by the scale of the problem: in Europe, citizens generate roughly 11 kg of textile waste per person per year, and in Sweden alone municipalities collected 16,780 tonnes of textiles in 2024, of which 75% was labelled for reuse, 16% for material recycling, and 9% for incineration. Given that most textile waste consists of cotton, polyester, and polycotton, the findings of this study are particularly relevant. Results indicate that white-rot fungi grow more effectively on natural fibres (with the exception of viscose), that the extracellular enzymes produced by the white-rot fungi exhibits some degradative effects on cotton fibres while the polyester fibre is unaffected, and that *G. lucidum* and denim can together form a robust biocomposite. These insights provide a useful foundation for future work aimed at advancing fungal-based textile recycling and biomaterial production.

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Popular science summary

Every year, millions of tonnes of textiles are thrown away, and much of the waste ends up in landfills or is burned. These waste management practices are a waste of resources and can release harmful substances into the environment thereby posing risks to human health. That means finding better ways to reuse textile waste pose an important challenge that needs addressing. One potential solution is using textile waste as a growing material for fungi to form a composite that could be used to make biomaterials. The study tested how two types of fungi grew on different textiles, including natural fabrics such as cotton and synthetic fabrics such as polyester. It also examined whether the fungi could create a stable material with the textiles and cause visible damage to textile fibres after exposure. The results showed that fungi generally grew better on natural fabrics than on synthetic ones. Cotton supported strong fungal growth, while polyester was much less suitable. Viscose, despite being plant-based, behaved more like synthetic textiles and did not support fungal growth. Denim and one of the fungi used formed a robust composite material which have potential for further development. Enzyme activity from the fungi was also able to damage cotton fibres, suggesting the ability to breakdown textile waste. Overall, the findings indicate that textile waste has potential to be reused as a medium for fungal growth and biomaterial production. While further research is needed to better match fungi with suitable fabrics and to understand how textiles breakdown over time, this approach could help reduce textile waste and support the development of more sustainable materials.

Appendix

Table 7. 12-hour average and standard deviation for carbon dioxide respiration of Pleurotus ostreatus on cotton and polyester

Hour	Treatment	Average	Standard Deviation
12h	Cotton	479,8	24
24h	Cotton	485,2	34,3
36h	Cotton	492,1	25
48h	Cotton	512,8	23,4
60h	Cotton	497,2	20,5
72h	Cotton	543,4	22,2
84h	Cotton	508,2	37,6
96h	Cotton	531,2	34,3
108h	Cotton	518,4	29,9
120h	Cotton	537,8	20,5
132h	Cotton	520,6	19,3
144h	Cotton	535,1	24,6
156h	Cotton	518	26,1
168h	Cotton	528,9	29,7
180h	Cotton	519,4	26,7
192h	Cotton	515,3	22,3
204h	Cotton	489,7	25,1
216h	Cotton	499	39,1
228h	Cotton	431	48,6
240h	Cotton	438,4	45,6
252h	Cotton	430,9	53,9
264h	Cotton	420,2	41,2
276h	Cotton	401,1	11
288h	Cotton	403,7	10,3
12h	Polycotton	465,4	6,7
24h	Polycotton	500,7	55,8
36h	Polycotton	454,7	14,4
48h	Polycotton	509,8	58,6
60h	Polycotton	451,7	9,2
72h	Polycotton	492,8	31,9
84h	Polycotton	467,1	24,7
96h	Polycotton	480,9	29,5
108h	Polycotton	469,7	21,6
120h	Polycotton	478,8	29,5
132h	Polycotton	466,5	18,5

144h	Polycotton	463,1	30,2
156h	Polycotton	465	18
168h	Polycotton	466,6	31,3
180h	Polycotton	468,9	26,2
192h	Polycotton	469,1	21,1
204h	Polycotton	457	6,1
216h	Polycotton	498,7	14
228h	Polycotton	433,8	4,9
240h	Polycotton	420	12,9
252h	Polycotton	413,6	2,2
264h	Polycotton	411,9	7,2
276h	Polycotton	414,8	5,3
288h	Polycotton	404	4,9

Table 8. T-test for carbon dioxide respiration of Pleurotus ostreatus on cotton and polyester.

Hour	t-stat	p-value
12h	1,001	0,41
24h	-0,409	0,707
36h	2,241	0,105
48h	0,082	0,94
60h	3,505	0,044
72h	2,248	0,096
84h	1,58	0,2
96h	1,926	0,128
108h	2,288	0,091
120h	2,844	0,054
132h	3,509	0,025
144h	3,199	0,035
156h	2,896	0,051
168h	2,5	0,067
180h	2,341	0,079
192h	2,606	0,06
204h	2,191	0,146
216h	0,015	0,989
228h	-0,1	0,93
240h	0,675	0,561
252h	0,556	0,634
264h	0,342	0,763
276h	-1,934	0,152

288h	-0,051	0,963

Table 9. 12-hour average and standard deviation for carbon dioxide respiration of Ganoderma lucidum on cotton and polyester

Hour	Treatment	Average	Standard Deviation
12h	Cotton	420,3	6,2
24h	Cotton	437,2	3,1
36h	Cotton	449,7	5,5
48h	Cotton	464,2	8,2
60h	Cotton	481,6	9,5
72h	Cotton	485,9	9,9
84h	Cotton	476,5	7
96h	Cotton	468,9	4
108h	Cotton	462	2,8
120h	Cotton	449,8	2,5
132h	Cotton	451,8	1,6
144h	Cotton	448,8	2
156h	Cotton	447,2	3,2
168h	Cotton	439,3	6,4
180h	Cotton	447,9	8,3
192h	Cotton	448,5	8,5
204h	Cotton	442,4	7,5
216h	Cotton	452,6	7,8
228h	Cotton	451	6,7
240h	Cotton	447,8	6,9
252h	Cotton	450,9	7
264h	Cotton	448,3	6,5
276h	Cotton	456,8	6,7
12h	Polycotton	426,6	5,7
24h	Polycotton	440,1	11,2
36h	Polycotton	447,8	8,2
48h	Polycotton	458,6	4,4
60h	Polycotton	479,6	4,9
72h	Polycotton	478,9	3,9
84h	Polycotton	467,7	5
96h	Polycotton	461,8	8
108h	Polycotton	461	8,2
120h	Polycotton	446	6,8
132h	Polycotton	451,3	6,1
144h	Polycotton	446,1	5,5

156h	Polycotton	446,7	6,1
168h	Polycotton	431,5	7,2
180h	Polycotton	441,4	6,5
192h	Polycotton	442,3	8
204h	Polycotton	433,7	4,5
216h	Polycotton	435,9	10,6
228h	Polycotton	435,4	11,1
240h	Polycotton	431,2	10
252h	Polycotton	433,3	9,1
264h	Polycotton	429,8	10,3
276h	Polycotton	439,2	10,9

Table 10. T-test for carbon dioxide respiration of Ganoderma lucidum on cotton and polyester.

Hour	t-stat	p-value
12h	-1,293	0,266
24h	-0,433	0,702
36h	0,325	0,764
48h	1,046	0,371
60h	0,328	0,765
72h	1,137	0,349
84h	1,761	0,16
96h	1,367	0,267
108h	0,201	0,856
120h	0,89	0,45
132h	0,152	0,892
144h	0,815	0,485
156h	0,132	0,904
168h	1,407	0,233
180h	1,071	0,348
192h	0,926	0,407
204h	1,737	0,172
216h	2,198	0,099
228h	2,093	0,119
240h	2,376	0,084
252h	2,666	0,06
264h	2,634	0,069
276h	2,383	0,089

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