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Ganoderma Lucidum Leather as a Sustainable Alternative Potential for Fashion Industry

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Abstract

Leather demand in fashion industry has increased in the recent years, making it more difficult for the leather producers to provide the needed quantity. This matter led to an increase in the number of the livestock farms thus creating other environmental issues as water pollution, deforestation, overgrazing and gas emissions. Beside this, the processing of animal hides into leather requires extra steps that involves toxic chemicals which eventually will get released into the environment. In this regard, one of the solutions we aimed for was the production of fungi leather. Fungi leather requires less water and surface to grow, being obtained through the upcycling of agricultural and forestry waste and by-products, using fungal growth process. There is a wide range of filamentous fungi that can be used for this process, highest yield ones being wood-decaying fungi or white rot fungi from genres *Polyporus sp.*, *Ganoderma sp.*, *Trametes sp.*, *Pleurotus sp.*, *Fomes sp.*. This study focused mainly on the *Ganoderma lucidum* strain and on the production of pure mycelium mats. Pure mycelium mats obtained this way can adopt multiple properties and show promising as substitutes for present petrochemically produced materials or animal leather. The process we used is divided in chemical and physical treatment. The main methods used in chemical treatment were deacetylation of chitin and the cross-linking of chitosan. Following cross-linking the pure mycelium mat (PMM) was subjected to a plasticizer agent. In the end, after physical treatment a minimum viable product was obtained.

Keywords: fungi leather, *Ganoderma lucidum*, mycomaterial, upcycling, mycelium, biodegradable

1. INTRODUCTION

Throughout human history animal leather shifted its' means and use from protective and ritual to a fashion one. Shifting social standards alongside the increasing concerns around environmental sustainability, the use of leather, which would typically be characterized as a co-product of meat production, has been criticized by some as socially irresponsible and environmentally unsustainable [1]. Main issue regarding livestock farms is the growing need of land, causing deforestation, overgrazing and changing in ecosystems dynamics. Likewise, other problems generated by those farms are the considerable amounts of greenhouse gas emissions, environmental damage caused by animal waste [2]

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and water pollution. Therefore, leather industry aggravates those environmental issues by raising the demand of animal leather, and by processing hides, consuming resources and producing pollutants which are toxic and hazardous to the environment, such as chromium, azo dyes, etc. [2].
The increasing environmental challenges and limited resources have led to growing worldwide demand for eco-friendly technologies, and facilitated the emergence of green industries [3]. Another concept that is related to the eco-friendly technologies is circular economy, which is based on using the by-products of different industries such as agriculture and forestry, to create new products that have a value and can be used in different purposes. Thus, minimizing the carbon footprint and the environmental impact, those products aim to be "zero waste".
Fungi are a natural and renewable source of valuable structural polymers, such as chitin, which is located within the cell walls of hyphae [1], making them great candidates for biocomposite production. Fungi-derived leather materials mostly constitute of pressed fiber pulp derived from masses of hyphal filaments grown in a nutritious liquid medium or physically and chemically treated mycelium mat grown on a bed of nutritious medium [1].
For the latter method, the pure mycelium mat (PMM) is processed as shown in **Fig. 1.**
In this context, the current paper aim to present the process of producing one such of a material, results and characterization of final composite.

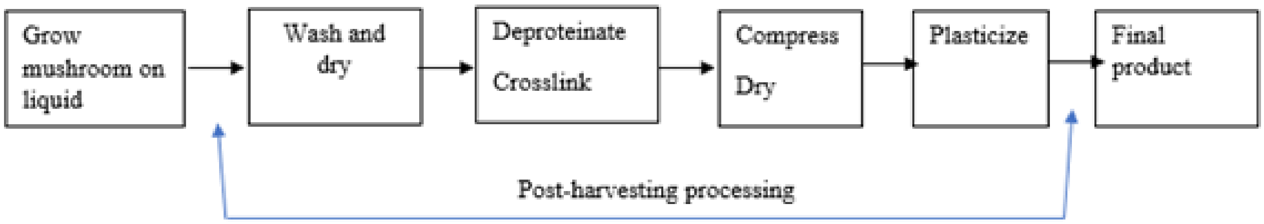

Fig. 1 Mushroom leather production scheme

2. MATERIALS AND METHODS

2.1. Fungal strain

The fungal strain used was *Ganoderma lucidum* from the Culture Collection of Materials Research and Innovation Department, National Research and Development Institute for Textiles and Leather, Bucharest. Fungal strains are stored at low temperatures (2-5°C) on solid medium (MEGxA, Czapek-Dox Agar, Sabouraud Agar, Potato Dextrose Agar) or in liquid medium (Sabouraud, Czapek-Dox).

2.2. Inoculum preparation and culture conditions

Fresh culture was obtained by inoculating 5ml of mycelium in 200mm Petri dishes with 30ml Sabouraud medium (Sigma-Aldrich), then incubated in a Memmert incubator at 28°C for 40 days (time may vary depending on the surface of the dish).
The evaluation of growth was done visually, and it was considered fully grown when the entire surface of the dish was covered with mycellium, as seen in **Fig. 2**.

Fig. 2 *G. lucidum* grown in Petri dish

2.3. Post-harvesting processing

After mycelium growth, the PMM was harvested, washed with distilled water and then dried room temperature (20 to 25°C) for several hours. After it was dried, the PMM undergo chemical treatment, which aims to cross-link the chitosan fibers. This process confers strength and flexibility to the material [4]. PMM has been immersed in 0.1M 200 ml NaOH and glutaraldehyde solution (0.25% w/w) and incubated at 25°C for 24h [5]. Following incubation, the mat was washed with distilled water, dried and pressed at 120°C for 30 s, repeated 3 times. Further, the mycelium mat was immersed in 20% glycerol for 48h. The effect of plasticizers was observed to increase the flexibility, tensile strength, and water-repellence ability of the material [6]. After plasticizing, the PMM was washed and dried room temperature (**Fig. 3**).

Fig. 3 Fungi leather substitute production process: (a) fresh PMM; (b) PMM after cross-link treatment; (c) PMM dried and pressed; (d) final product

3. RESULTS AND DISCUSSIONS

The resulted material is leather-like, thin, flexible, with low tensile strength, resembling more with parchment paper. This product may be considered a minimum viable product (MVP) and subsequently can be tanned, stretched, dyed or processed in other ways, to achieve the leather characteristics. Images of the MVP were taken using a Quanta FEI 200 SEM (scanning electron microscope) to assess the qualitative level of cross-linking in the fungal hyphaes, as seen in **Fig. 4**.

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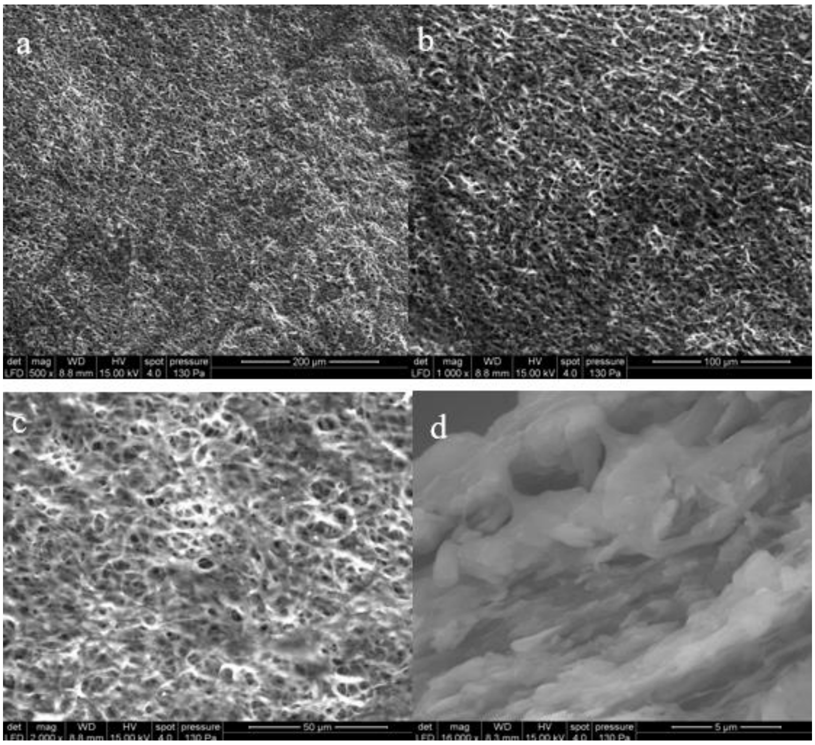
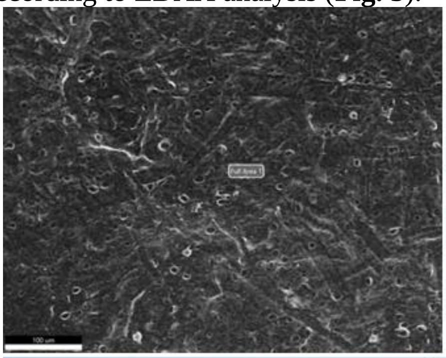


Fig. 4 SEM photos of MVP: (a) 200 µm; (b) 100 µm; (c) 50 µm; (d) 5 µm

This product contains significant amount of carbon, nitrogen, oxygen, sodium, sulfur, silicon and calcium, according to EDAX analysis (**Fig. 5**).



Element	Weight %	Atomic %	Error %
C K	33.55	40.12	9.97
N K	10.63	10.9	14.53
O K	52.75	47.35	10.16
NaK	1.58	0.99	12.66
SiK	0.56	0.28	11.78
S K	0.29	0.13	30.41
CaK	0.64	0.23	22.03

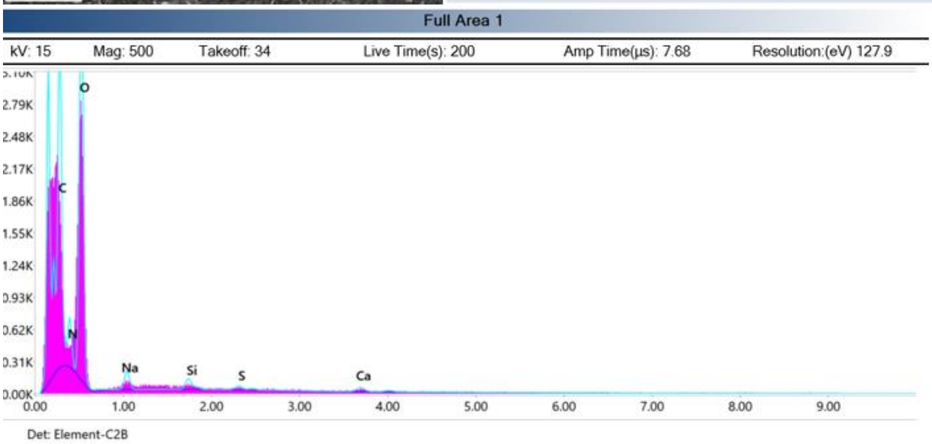


Fig. 5 Element composition of PMM – EDAX analysis

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4. CONCLUSIONS

The resulted material shows a promising starting point in the process of finding an alternative for animal and petrochemically-based leather. In the further production processes, can be considered improvements such as growing a thicker mycelium mat and using a coating agent for dehydration protection. With this in mind, in the upcoming years a better material will be developed and fully functional clothing prototypes will be manufactured. The aim of the entire process is to expand circular economy and produce zero-waste and biodegradable clothing articles that are environment friendly.

5. ACKNOWLEDGEMENTS

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