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Mycelium protein: Innovative alternative source for the production of foods

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ABSTRACT

Global demand for protein is increasing at an unprecedented rate, driven by population growth and increased health awareness. On the other hand, the environmental impacts of conventional protein production, including deforestation, excessive water use and greenhouse gas emissions, make it imperative to look for more sustainable alternatives. Mycelium protein responds to this need, guaranteeing nutrition, flavor and sustainability[1]. Today, it is considered a new source of protein due to its nutritional, energy-efficient and environmentally friendly properties. This new raw material has a high protein content, along with a complete and balanced amino acid composition, which makes it great potential to improve human health and treat or prevent diseases.

This file will show the importance that mycelium protein has been gaining in the food industry regarding the replacement of proteins of animal origin and in the development of new products, as well as the form of production.

Keywords: Fungal. Mycelium. Protein. Fermentation. Novel-products.

1 INTRODUCTION

The food industry is facing the challenge of meeting the growing protein demand of a global population expected to reach 9.7 billion people by 2050, while mitigating the associated negative environmental impacts to traditional protein sources. In this context, innovation in alternative protein sources is more than a trend; It is an urgent need to ensure a sustainable and nutritious food future[1].

Proteins, one of the essential macronutrients for human health, are traditionally obtained from animal sources such as meat, fish, eggs and dairy, as well as from plant sources including legumes, nuts and grains. However, animal protein production presents significant challenges, including high environmental costs, ethical and sustainability concerns, and health risks associated with excessive consumption of red meat[2]. On the other hand, although plant proteins are more sustainable, they often face challenges in terms of flavor, texture and nutritional density compared to their animal counterparts[3].

Due to its environmentally friendly, energy efficient and nutritious properties, mycelium protein emerges as an alternative to satisfy dietary needs. This type of protein is an ethical and sustainable alternative, free of ingredients of animal origin, and represents an innovation in the field of alternative proteins, offering both nutritional and environmental benefits.

Currently, mycelial protein (mycoprotein) is obtained by growing *Fusarium venenatum* in a defined substrate and mixed with egg albumen, color and flavor additives to simulate a texture like meat under the trade name Quorn. This product is rich in fiber (6%; 2/3 β-glucan and 1/3 chitin), high in protein(11%), but relatively low in fat (2.9%) [4]

What is Mycelium Protein?

The mycelium is a collection or branching of hyphae that have the texture of a thread and constitute the vegetative body of a fungus. Mycelium is basically classified into 2 types: Vegetative Mycelium, which is responsible for nourishing the fungus. It grows quickly and downwards; and Reproductive Mycelium, which grows towards the surface (Fig 1)[5]. Thanks to the spores, the reproductive mycelium can colonize new environments rich in nutrients[6].

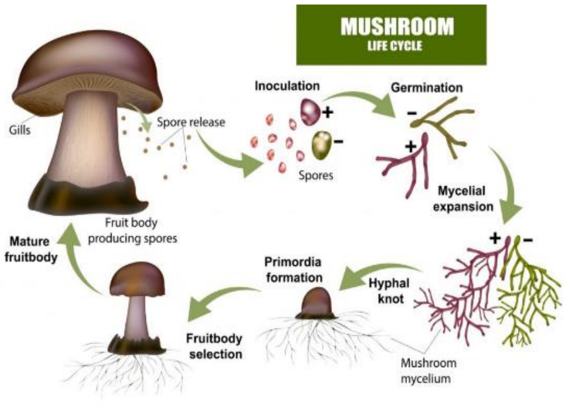

Fig 1. The life cycle of fungi

Nutritional Profile

Results of analysis of the mycelium protein show that it contains all the essential amino acids, many enzymes and a large amount of nutrients. In 100 g of dry matter you have 45 g of protein, 25 g of fiber, 13 g of fat, 10 g of available carbohydrates, as well as a variety of vitamins and minerals[7]. Its fat is largely composed of unsaturated fatty acids, predominantly ω-6 and ω-3, linoleic and linolenic acids, respectively. Dietary fiber is a mixture of chitin and β-glucans. Among the minerals are iron, sodium, zinc, calcium, selenium, manganese, phosphorus[4]. Studies show that these substances have antitumor, immunomodulatory, antiviral, anti-inflammatory, antioxidant, etc. activities. that serve for the treatment and prevention of diseases and improve human health[8].

The current mycelium protein market and commercial landscape

The use of fermentation to produce pure mycelium has gained prominence in the food industry, offering sustainable and nutritious alternatives to traditional meat. Two exemplary cases are the production of Quorn® and Atlas Meat (Ecovative), which use different fermentation methods to achieve similar results in terms of quality and applicability of the mycelium as a meat substitute.

Quorn® Production: Submerged Fermentation

Quorn® emerged in the 1970s, the result of a joint venture between Rank Hovis McDougall and Imperial Chemical Industries. Using a fast-growing fungal soil isolate (*Fusarium venenatum*), the company developed a continuously stirred submerged fermentation process to produce protein-rich mycelium. In the Quorn® production process, *Fusarium venenatum* is grown in large, submerged bioreactors, where the mixture is constantly agitated to ensure an even distribution of nutrients and oxygen. The resulting biomass is then filtered to separate the mycelium from the growth medium. After filtering, the biomass is mixed with binders such as egg albumin or potato protein. This mixture goes through a series of steaming, cooling and freezing steps, which gives it a meat-like texture. Finally, the textured product is pressed to form protein-rich meat analogues. Figures 2, 3, 4 show some of the Quorn products made with mycoprotein that are currently on the market.

Fig 2. Chicken flavor Nuggets

Fig 3. Vegan Chicken Flavor Pieces

Fig 4. Quorn - Vegan Spiced Burger

Atlas Meat Production (Ecovative): Solid State Fermentation

Ecovative, a pioneer in mycelium biotechnology, developed Atlas Meat using solid-state fermentation (SSF) techniques to create meat substitutes. This method is inspired by traditional fermentation processes, such as tempeh production. In Atlas Meat's production process, a solid substrate, generally composed of agricultural waste such as straw or sawdust, is inoculated with spores of fungi of the genus *Rhizopus*. The inoculated substrate is then placed in trays or bags and incubated under controlled temperature and humidity conditions to allow the mycelium to grow. During incubation, the mycelium grows through the substrate, forming a dense, fibrous network that is harvested after a specific period of time. The mycelium biomass is then processed to improve its texture and flavor, making it suitable as a meat substitute. Ecovative has stood out for its innovations in the use of mycelium for various purposes, including biodegradable packaging and construction materials, in addition to food. The Atlas Meat line represents a significant advance in the application of mycelium in food products, offering a sustainable and healthy alternative to traditional meat. The figures 5, 6, 7, 8 show the production of mycelium biomass for analogues meat by SSF of Ecovative industry.

Fig 5. Solid-state fermentation (SSF)

Fig 6. Mycelium biomass

Fig 7. Cut from mycelium biomass

Fig 8. Bacon de mycelium protein

The cases of Quorn® and Atlas Meat illustrate the effectiveness and versatility of fermentation in producing pure mycelium for food. Submerged fermentation, as used by Quorn®, is effective for large-scale production of homogeneous, protein-rich mycelium. Solid state fermentation, adopted by Ecovative for Atlas Meat, allows the use of solid substrates and offers a natural fibrous texture to the mycelium. These methods not only highlight the potential of mycelium as a sustainable and nutritious resource, but also exemplify how biotechnology can transform agricultural waste into high-value-added products, contributing to environmental sustainability and innovation in the food industry.

2 Conclusion

In the last years there has been great development in the characterization of structured foods, due to the potential to imitate the meat of these foods. The use of mycelia has been shown to be a viable alternative due to its richness in proteins, essential amino acids and enzymes. The evolution of studies and techniques will allow the creation of meat analogues that have the desired sensory properties, combined with excellent resource efficiency.

The food industry must be at the forefront of the demands of the current market. There are currently several companies that are developing different food products incorporating alternative sources of proteins obtained through fermentation. However, there are still many issues to be resolved, which makes this topic interesting to study.

3 Acknowledgements

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