Mycoproteins and yeast proteins in food industry

Sumitha K. Reddy[1,2] and Ronald P. de Vries[1]
1 Westerdijk Fungal Biodiversity Institute; 2 Department of Molecular Sciences, Swedish University of Agricultural Sciences

Mycoproteins and yeast proteins are an important part of the protein transition due to clear advantages in terms of their nutritional value, availability, and environmental impact. However, for these protein sources to attract higher demand in the future, production costs need to be optimized and product prices lowered through scale-up and technical innovations.

Mycoproteins and yeast proteins are examples of disruptive technologies in food industry that will play a major role in transforming nutrition and health in challenging times of food shortage and rapidly growing human population. Mycoproteins and yeast proteins were already pursued as a protein source in the 1900s, during a protein crisis identified by the Food and Agricultural Organization (FAO) of the United Nations and World War I, respectively (Trinci). However, with advancements in plant breeding techniques and improvement in crop yields, the commercial interest in these proteins decreased due to lack of optimized production processes, food safety evaluation hurdles and high prices. The recent revival of interest in these proteins can be attributed to the demand for high quality sustainable protein and interest in healthy alternatives to meat. At present, only few companies are involved in production and marketing of yeast and mycoproteins as food. Given their healthy nutritional profile, low-cost production potential, and resilience to climate or landscape limitations mycoproteins are promising protein alternatives. However, food safety evaluation hurdles, consumer acceptance, and high prices due to lack of optimized production processes hinders their commercial potential.

Case study: Quorn mycoprowtein

Production of the mycoprotein Quorn involves three primary steps (Trinci). Step 1 is the **production of biomass**: Continuous flow airlift fermentation is used to grow pure cultures of *F. venenatum* for production of biomass at a rate of 300-350 kg/hr. A complete defined medium is used, containing glucose and ammonium, supplemented with biotin, and growth conditions are maintained at 28-30°C and pH 6. The culture is checked for production of mycotoxins every 6 hours. Cultures after 400 hours are not reused to prevent the production of highly branched mutants. The second step is **heat treatment of the biomass**: The produced biomass contains up to 12% of ribonucleic acid (RNA), considered as undesirable for food applications. Therefore, the biomass is subjected to heat treatment above 68°C for 30 to 45 minutes to facilitate the degradation of RNA. Following this treatment, the biomass is centrifuged to collect the mycoprotein as a paste with 75% water. The removal of RNA by heat treatment is an essential step in converting the fungal biomass into edible mycoproteins. The third step is **texturizing**: The collected mycoprotein is mixed with a binder, flavors, and coloring ingredients in a mixer at high pressure, steamed at 90°C and frozen rapidly to -18°C for 30 minutes. Rapid chilling leads to controlled ice crystal formation resulting in a meat-like texture for mycoproteins.

Mycoproteins

Mycoproteins are defined as edible filamentous fungal biomass rich in proteins and dietary fiber, and capable of being processed into meaty textures (Tim J. A. Finnigan et al.). In contrast to mushrooms where the fruiting body is used as the food source, mycoproteins are produced from the mycelial mass of filamentous fungi (T. Finnigan et al.). After extensive studies and approvals according to food safety standards, mycoprotein from the filamentous fungus, *Fusarium venenatum,* was initially approved in UK and European markets to be used as food ingredient in 1985 and 1991, respectively (Ciani et al.). In 2002, the Food and Drug Administration of the USA designated mycoproteins as Generally Recognized As Safe (GRAS) (Tim J. A. Finnigan et al.). Presently, mycoproteins are available in 17 countries and accepted as meat alternative worldwide. The main factors contributing to the stability of a meaty texture in mycoproteins are the branching of the fungal biomass into hyphae and the controlled interhyphal crosslinking with the binder to mimic meat texture. The hyphae in the mycoprotein are 400-700 µm long and 3-5 µmin diameter, with a branch frequency of 1 per 250-300 µm, similar to the connective tissue in meat muscle fiber (figure 1). Generally, egg albumin or milk powder is used as the binder for crosslinking the hyphae, but egg albumin can be replaced with other binders, to promote mycoprotein as vegan alternative.

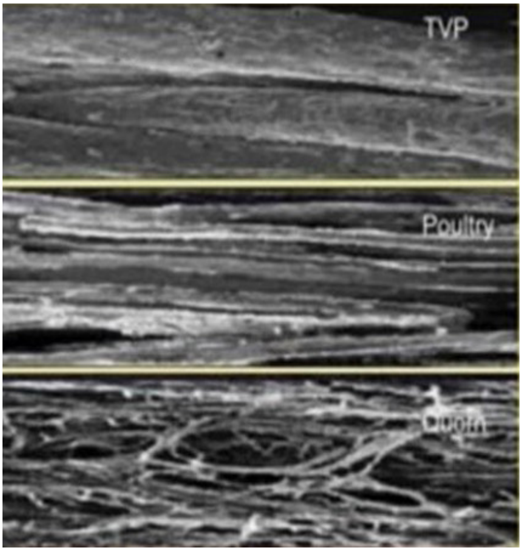

Figure 1: Comparison of microfibril structure (a) TVP; Texturized Vegetable Protein, (b) poultry (c) Quorn protein (T. Finnigan et al.)

Table 1: Comparison of nutritional profile for alternative proteins (Godfray)

Nutrient (per 100 gram of wet weight)	Soya (tofu)	Pea protein	Algae	Cultured beef	Myco-protein
Energy, kcal	82.9	81.0	290.0	241.0	85.0
Protein, g	9.9	5.4	57.4	25.1	11.0
Total fat, g	5.2	0.4	7.7	14.6	2.9
Saturated fatty acids, g	0.9	0.1	2.6	2.8	0.7
Total carbohydrate, g	1.2	14.4	23.9	0.6	3.0
Sugars, g	0.7	5.6	3.1	–	0.5
Dietary fiber, g	1.1	5.7	3.6	–	6.0

Yeast proteins

Biomass obtained from *Sacharomyces cerevisiae*, *Yarrowa lipolytica,* and other yeasts have several applications in the food industry, as flavor ingredient or nutritional supplement of vitamins and minerals (Ciani et al.). Yeast biomass is also high in protein, and in fact contains high-quality proteins with up to 30% of biomass (Otero et al.). Yeast proteins produced on different sources, such as byproducts from the brewery process, have been evaluated for their nutritive value and protein quality, and are mainly used in the feed industry as protein supplements (Ciani et al.). However, their functional, structural, hydration and organoleptic properties are in par with rheological and sensory characteristics for the proteins used in food applications (Otero et al.). Although yeasts like *S. cerevisiae* have GRAS status for use in food, undesirable functional properties of yeasts, like high RNA content (10%) and the undigestible yeast cell wall with allergenic effects, limit human consumption of yeast protein in bulk quantities. Heat treatment and drying alleviates some of these undesirable properties, allowing yeast biomass to be used as dietary supplement (Ciani et al.). Heat treated, dried yeast biomass is commercially available as nutritional yeast, marmite, and vegemite, which are all produced by *S. cerevisiae* (Ciani et al.). They are known to have high protein content along with vitamins and minerals (Ciani et al.; Ritala et al.). Technical advancements in processing yeast biomass are rapidly evolving to make yeast protein fit for human consumption. Recently, a complete yeast protein, Proteissimo 101, was launched in the alternative protein market, where yeast is fermented and processed by a patented technology, making it fit for human consumption. Proteissimo 101, is promoted to be clean labeled, with no off-taste and mainly used for vegan cheese and meat alternatives (https://biospringer.com/en/our-expertise/). This new trend of using yeast for its protein content re-establishes the value of this microorganism in the field of alternative proteins and nutrition.

Nutritional value, consumer acceptance and clinical significance

Both mycoprotein and yeast protein are high-quality proteins without extensive processing requirement compared to other alternative protein sources. In terms of their amino acid content and digestibility, they score better than plant-based proteins. The protein digestibility corrected amino acid score (PDCAAS) for mycoprotein and yeast protein is established as 0.94-0.99 and 0.64-0.94 respectively (Ciani et al.). Nutritionally, mycoproteins are considered to be high in proteins and dietary fiber and low in cholesterol and fat, especially saturated fat (Tim J. A. Finnigan et al.). In comparison, yeast proteins have a lower protein content and dietary fiber, but they score better in terms of perception due to absence of off-taste compared to mycoproteins.

A mycoprotein diet has been clinically proven to lower cholesterol and reduce the glycemic response (Tim J. A. Finnigan et al.). In comparison, yeast proteins are also clinically proven to have probiotic effect and decrease the antinutritional activity of phytases and neutralize mycotoxins (Ritala et al.).

In relation to consumer acceptance and regulatory approval, the new trend of using yeast for its protein content comes with the greatest advantage of consumer acceptance in terms of an organism already used in the food industry, which is a challenge for many other microbial proteins. As example, it took almost 15 years for mycoproteins to get regulatory approval and considerable consumer acceptance. Quorn products are still not approved in some countries like Canada.

Environmental impact, land use and role in future food system

Based on a recent report from 2018 on the comparative analysis of the environmental footprint certified by the independent agency carbon trust (Table 2), mycoprotein has a good potential for being an environmentally friendly alternative for meat products (T. Finnigan et al.). In terms of land usage, given the fact that both mycoproteins and yeast proteins can be produced at large scale by fermentation, a process reducing the land use and dependence on season and harvest, they have a considerable advantage compared to plant-based proteins. The current challenge for mycoprotein production includes dependence on a single carbon source, of wheat derived glucose, in a unique pretreated process, which elevates the cost of the production compared to conventional meat (Figure 2). Technologies for large-scale sustainable production of mycoproteins and yeast proteins are rapidly evolving and is still the major bottleneck for commercialization of product. Despite the challenges, production of mycoproteins and yeast proteins will contribute to the future of global food security.

Table 2: Comparison of environmental impact*

Source	Carbon (kg CO_2/kg)	Land (ha/kg)	Water (L/kg)
Soy	1	0,0014	2668
Beef *	121	0,0049	21800
Chicken	6	0,0007	3970
Pork	8	0,0012	5995
Mycoprotein	1	0,0002	776

*carbon trust report 2018

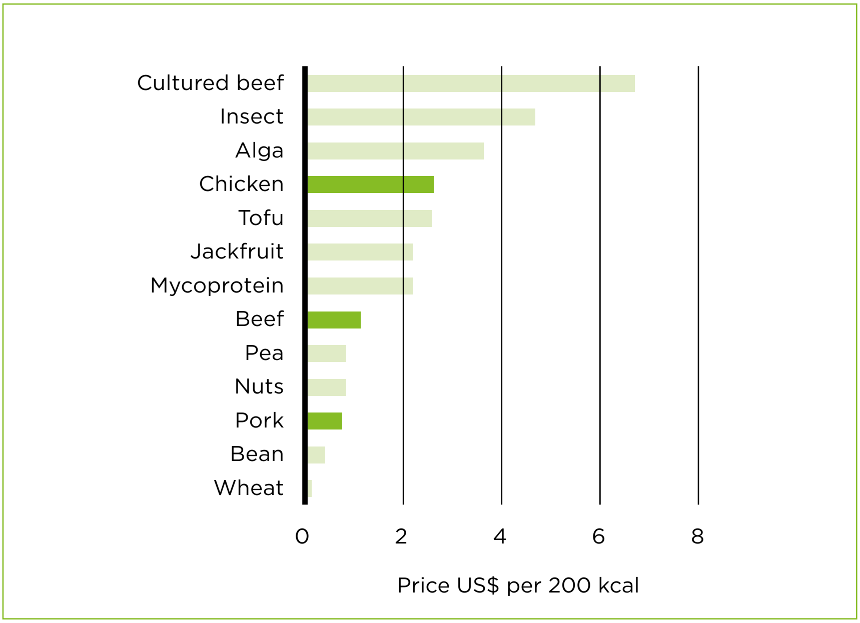

Figure 2: Price comparison: Estimated price comparison of different protein sources (Godfray).

Future perspectives

Mycoproteins and yeast proteins are major contenders in a rapidly innovating alternative protein market. Alongside with the growing consumer interest in alternative proteins, in 2010, the patent for production of mycoprotein expired for Marlow foods, resulting in new entrants in the field of mycoprotein production. Many startups are investing in sustainable processing and patenting technologies for mycoprotein and yeast protein production from less expensive feedstock and optimizing for net zero waste production. Some promising startups have successfully launched mycoprotein products at competitive prices, including steak, chicken breast, and minced meat and large manufacturing facilities are being built. At present, the alternative protein market, specifically for mycoprotein and yeast protein is limited to Europe followed by North America. Even though the market outlook looks promising, optimizing the production costs, and decreasing the prices along with consumer acceptance play a major role in deciding the place of these in the rapidly innovating alternative protein market. After all, a great-tasting and healthy product at an affordable price is required for frequent procurement and consumer acceptance.

References

- Ciani, M., et al. (2021). Microbes: Food for the Future. *Foods*, *10*(5). https://doi.org/10.3390/foods10050971
- Finnigan, T., et al. (2017). Chapter 19 - Mycoprotein: A Healthy New Protein with a Low Environmental Impact. *Sustainable Protein Sources*, Nadathur, S.R. et al. (Eds.), Academic Press, 305-325. https://www.sciencedirect.com/science/article/pii/B9780128027783000196
- Finnigan, T.J.A., et al. (2019). Mycoprotein: The Future of Nutritious Non-meat Protein, a Symposium Review. *Current developments in nutrition*, *3*(6), nzz021-nzz021, PubMed. https://doi.org/10.1093/cdn/nzz021
- Godfray, H.C.J. (2019). Meat: The Future Series. *World Economic Forum*, © 2019 World Economic Forum. Available under the terms of the CC-BY-NC-ND licence (https://creativecommons.org/licenses/by-nc-nd/4.0/)
- https://biospringer.com/en/our-expertise/
- Otero, M., et al. (2011). Yeast and Its Derivatives as Ingredients in the Food Industry. *Biotecnologia Aplicada*, *28*, 272-275.
- Ritala, A., et al. (2017). Single Cell Protein—State-of-the-Art, Industrial Landscape and Patents 2001–2016, *Frontiers in Microbiology, 8*(2009). https://doi.org/10.3389/fmicb.2017.02009
- Trinci, A.P.J. (1992). Myco-Protein: A Twenty-Year Overnight Success Story. *Mycological Research*, *96*(1), 1-13. https://doi.org/10.1016/S0953-7562(09)80989-1