ProFuture: shaping the future of microalgae proteins in Europe

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With a global population expected to reach 10 billion by 2050, there is an increasing demand for sustainable proteins sources as an alternative to conventional animal-based foods and feeds.

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Among alternative protein sources, microalgae present themselves as a promising candidate to help face this challenge due to their high nutritional value and low environmental footprint. Nevertheless, to boost the microalgae value chain and make it more sustainable and competitive compared to other protein sources well established in the market, innovative technology and cost-effective production processes must be put in place. That is the core mission of the ProFuture project.

What's the project about?

ProFuture is a European-funded Horizon 2020 research project aiming to scale up microalgae production and prepare for the market uptake of microalgae proteins as ingredients for innovative and sustainable food and feed products.

The project brings together 31 European partners from 13 EU countries in a unique collaboration between researchers, small and medium enterprises, large companies, and associations that are working to:

- make microalgae cultivation more efficient, sustainable and affordable
- improve the production of protein-rich ingredients from microalgae biomasses
- create nutritious and tasty foods and feeds using microalgae proteins
- scale up production and seize the market for microalgae-based foods and feeds.

The project will last for four years (2019-2023) and is coordinated by the Institute of Agrifood Research and Technology under the leadership of Dr Massimo Castellari.

What are microalgae?

Microalgae, also known as phytoplankton, are small plant-like microorganisms, invisible to the human eye, that live in various aquatic environments, where they form the basis of most food chains. Usually, microalgae are made up of a single cell or a small group of cells arranged in a very simple structure that grow rapidly and become a large and colourful biomass rich in nutrients. While they belong to the algae family, they're not to be confused with seaweed (macroalgae)—typically used in Japanese cuisine, such as in sushi—which are more complex multicellular organisms that can reach three metres in length.

ProFuture focuses on three microalgae species approved for food production in the EU: ***Arthrospira platensis*** **(Spirulina),** ***Lemon/lightly Chlorella vulgaris*** and ***Tetraselmis chui*** and one approved exclusively for aquaculture feed: ***Nannochloropsis oceanica***.

Why should they be used in food?

Microalgae can have as much as 60 per cent of their dry mass as protein content, which is often higher than in plant sources such as soybean, rice or pea. More importantly, species such as Spirulina and Chlorella offer a good balance of essential amino acids, which we need to regularly get from the diet. Microalgae are also good sources of polyunsaturated fats, fibre, vitamins, minerals and bioactive compounds (such as astaxanthin, ß-carotene and phycocyanin), which can all add to the nutritional value of conventional food and feed products.

Because the nutritional quality of microalgae varies according to the species and their growing conditions, those factors can be finetuned to positively influence the nutrients in a sustainable and efficient way. ProFuture is focusing on selecting specific strains that present competitive characteristics, such as rapid growth, resilience, a suitable nutritional profile, a light colour, etc. To date, researchers have already selected strains of ***Chlorella vulgaris*** that have a lighter colour and offer more advantageous combinations of amino acids, which will be used to create protein-rich ingredients.

What are the environmental advantages and challenges of microalgae?

In ecological terms, microalgae grow rapidly: four to fifteen times faster than other vegetable proteins such as wheat, legumes and soybeans. This means that microalgae can produce higher amounts of protein in less time, potentially using fewer resources. Like plants, most microalgae are photosynthetic organisms that use carbon dioxide (CO_2), water and sunlight to produce energy and oxygen. However, microalgae can be ten to fifty times more effective in capturing CO_2 and sunlight for photosynthesis compared to plants.

Figure 1: Cultures of different microalgae species at Necton's facilities.

Another advantage is that microalgae do not compete for soil with conventional plant sources, and some species can grow in salt water, which reduces the need for freshwater use. Therefore, it is expected that microalgae-based products can be more sustainable than those made from other protein sources. However, there is still a significant lack of scientific data to support this claim, and ProFuture is conducting extensive research to provide more objective data on the environmental impact using life cycle assessment approaches.

ProFuture has also focused on developing and establishing innovative technologies and processes for microalgae cultivation that can increase the efficiency and sustainability and reduce the costs of microalgae production. Some of the main achievements throughout the last 18 months include the:

- implementation of a new technology (direct air capture) to improve the use of carbon dioxide from the air and lower the carbon footprint of microalgae production
- development of innovative processes—such as an 'off-the-grid' photo-bioreactor, a low-cost cascade reactor and a two-phase production system—to reduce the energy consumption of the microalgae cultivation
- improvement of the performances of two cultivation techniques (mixotrophic and heterotrophic)
- reduction of the environmental impact by using recycled water from previous microalgae cultivation, by-products from spirulina processing (extraction of phycocyanin) and side-streams from agri-food industries (e.g. insect frass).

How can microalgae proteins be used in food and feed production?

After cultivation, harvesting and drying, the microalgae biomass can be converted into two types of protein-rich ingredients: **single-cell proteins** or **protein extracts/isolates.** Single-cell proteins can be used in foods without any further processing, which offers some advantages. In turn, proteins extracted from microalgae cells (protein isolates) often require further purification before being used as food ingredients. Nevertheless, two of the main obstacles to the large-scale production of microalgal-based proteins and ingredients still relate to the high cost of the dry biomass (between 32 and 11 euros per kilo) and the low efficiency of the technologies and processes currently available.

To help overcome these challenges, ProFuture's researchers are working on innovative processing strategies by assessing and comparing different drying, extraction and purification technologies. The goal is to reduce the energy consumption and increase the efficiency of these steps while preserving the nutritional quality and the techno-functional properties of the final products. In the last months, different drying technologies—a key step in the production of ingredients at an industrial scale, but also one of the more demanding in terms of energy—were evaluated and compared with respect to their efficiency and effects on the nutritional and techno-functional quality of the final single-cell ingredients.

Researchers carried out also trials with bead milling and spiral filter technologies to improve protein extraction and solubilisation and obtain suitable protein isolates.

The first experimental powdery ingredients were characterised and compared to understand the differences in their techno-functional properties and applicability in food and feed production.

Figure 2: Bread reformulation at the Institute of Agrifood Research and Technology (IRTA).

Food and feed reformulation

A key expected output in the ProFuture project is the reformulation of ten types of tasty and nutritious food and feed products with microalgal protein-rich ingredients. The goal is to create nutrient-dense versions of conventional food (bread, pasta, vegetable creams and soups, sports drinks and snack bars, and meat sausage alternatives) and feed (for poultry, piglets, fish and shrimps) products that not only contain more protein, but also other valuable nutrients such as phenolic compounds, vitamins and minerals.

To achieve this, researchers have partnered up with food companies to start the first reformulation trials to enrich pasta, vegetable soups and creams, vegan sausages, bread and snack bars with microalgal-based ingredients. The recipes are continuously fine-tuned to improve the final products' nutritional quality while preserving their technological (and typically appreciated) properties.

In parallel, advances in feed reformulation have also been made, including the definition of the experimental designs for the studies with poultry, piglets, fish and shrimps.

From a consumer perspective, microalgae use in foods and drinks still face some challenges, particularly related to the strong colours and typical marine flavours. In ProFuture, a dedicated team is working on understanding the consumers' perceptions, feelings, and preferences towards microalgae products while also identifying the type of consumers most likely to adopt these products. Lab-level studies will be conducted using those results to improve the appearance, texture, aroma and flavour of the final enriched products.

What are the next steps?

In the second part of the project, ProFuture will focus on upscaling the production of selected ingredients, foods and feeds from lab to both pilot and industrial scales. ProFuture's team is expecting to design a portfolio of healthy, affordable and tasty foods using microalgae.

In parallel, a preliminary regulatory assessment has been launched to identify the legal barriers of the EU microalgae market and the specific requirements for the authorisation of innovative microalgae-based ingredients as novel foods in the EU.

Also, a dedicated team is focused on developing a strategic plan to support the business models and the market entry strategies for the innovative microalgae-based ingredients, foods and feeds developed in the ProFuture project.

From an environmental perspective, life cycle assessment (LCA) studies will be associated to a life cycle cost analysis (LCCA) to allow a complete and realistic overview of the microalgae value chain. This will be further reinforced with the results of the value chain mapping that will identify the actors, the constraints, and the strengths and weakness of the microalgae industry in Europe.

This and other exciting news can be found at **www.pro-future.eu**

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