

Food-grade phycocyanin from *Spirulina* by membrane separation

Since ancient times, mankind has always sought strategies and remedies to alleviate or eliminate the pain caused by accidents or illnesses. For millennia, empirical practices have been based on the use of herbal medicines. In the last century, with the advent of modern chemistry, the techniques of synthesizing active pharmaceutical ingredients (API) were perfected. This led to large-scale production and enabled many more people to have access to a large quantity of medicines to find, cure, treat, or prevent a disease.

A recent analysis by the European Commission (EC) in 2021 found that around 80% of active ingredients by volume are imported into Europe from just five countries, with China supplying 45 % of active ingredients and the rest coming from India, Indonesia, the USA and the UK. Since January 2023, the European Union has been facing a shortage of over-the-counter medicines. The reasons for this are the growing demand due to COVID-19 and the increased transport difficulties following the start of the war in Ukraine. These factors are forcing European companies to diversify their imports and/or bring production back to Europe. Reshoring is an economic phenomenon that consists of companies that had previously relocated their production returning home.

The pharmaceutical sector is very important in Italy. It is characterized by high capacity and specific production, highly specialized personnel and consistent investment in research and development, with the aim of reducing the environmental impact and costs of medicines. According to Federfarma, the Italian pharmaceutical sector recorded a total turnover of 25.84 billion euros in 2022, an increase of 4.5% compared to 2021.

In recent years, we have also witnessed a market change driven by an increasingly attentive consumer concerning the environmental sustainability and naturalness of products. As a result, the demand for medicinal products with active ingredients of natural origin, also known as phytochemical compounds (PC) or phytonutrients, is increasing.

These are bioactive components present in foods such as fruits, vegetables, seeds, leaves, roots, etc., and are divided into categories concerning their chemical structure. Although there are tens of thousands of phytochemicals, only a small number have been isolated and identified. The biodiversity of plant resources is potentially infinite and provides a unique and renewable resource for the discovery of potential new active ingredients useful in the fields of nutraceuticals, cosmetics, and pharmaceuticals. In this new and innovative context, ISGREEN comes into play.

ISGREEN is a small enterprise active in developing bioderived products based on *Spirulina microalgae* cultivated in photobioreactors under controlled conditions. So far, his marketed products have been based on the use of the whole microalgae cells. In fact, ISGREEN has already implemented processes for harvesting *Spirulina* and drying it. On the other hand, the unique quality of *Spirulina* produced by ISGREEN in terms of

purity (absence of contamination) opens for new high added-value formulations based on bioactive ingredients contained within the *Spirulina* cell.

Spirulina biomass has been certified as Novel Food in Europe, and it is used as a functional food. The Global *Spirulina* Market was valued at \$393.6 million in 2019 and is projected to reach over \$900 million by 2027. The compound annual growth rate (CAGR) is projected of around 9.5% during the forecast period, i.e., 2023-28. The growth of the market is driven primarily by the mounting awareness about the benefits of *Spirulina* with antioxidants, nutraceuticals, and high effectiveness on skin health properties. The growing application of *Spirulina* across different sectors owing to its high nutritional content is the most prominent aspect projected to drive the *Spirulina* Market through 2028.

Furthermore, the global bioactive ingredients (BI) market size was valued at USD 173.22 billion in 2022 and is anticipated to grow at a CAGR of 7.9% from 2023 to 2030. Bioactive ingredients are increasingly used for developing functional food & beverages and dietary supplements. However, consumer behavior change, coupled with policies aiming at the environmental sustainability of industrial processes, driving the pharmaceutical industry in new research to identify new plant-based ingredients for their medicine.

Spirulina consists of numerous bioactive ingredients, the most important of which in terms of quantity is phycocyanin. Phycocyanin is a blue-colored photosynthetic pigment, a special protein that absorbs light at around 620 nm and emits it by fluorescence at 640 nm. It is known for its anti-inflammatory and immune-stimulating antioxidant properties. It can neutralize free radicals and reduce oxidative stress, which contributes to healthy cells and the prevention of chronic diseases such as heart disease, diabetes, and neurodegenerative diseases. It is also used as a food colorant in soft drinks, ice cream, candies, fermented milk, desserts, and cake decorations. It is the only natural blue dye approved in Europe.

However, there are still several limitations associated with the extraction methods used to purify phycocyanin. Indeed, to obtain a pure and stable phycocyanin, it is important to choose appropriate extraction methods. Nowadays, several methods are known to break down the cell wall of spirulina, but the separation of phycocyanin from other compounds is often not easy. This increases extraction costs and results in large amounts of unusable biomass due to the purification techniques used.

In this project, ISGREEN and CNR-ITM (the Institute on Membrane Technology of the National Research Council of Italy) explored the extraction of phycocyanin by membrane technology. This clean, safe, and low-energy input technology allows the production of phycocyanin extract of high purity and eliminates the risk of external contamination.

In addition, this process has countless positive externalities, such as reducing biomass waste, increasing tradable products, reducing the use of chemicals, reducing extraction times and costs, and improving workplace safety. Furthermore, with this technology, almost all the water used in the process can be recovered and reused, either for the growth of spirulina or as a biostimulant for agricultural crops.



Thanks to this project, ISGREEN and CNR-ITM can contribute to enhancing Europe's competitiveness in the production of natural-based bioactive ingredients derived from *Spirulina* and purified by clean membrane technology.

Furthermore, the innovative production based on advanced technologies is going to be located in Calabria, a region that needs to reduce its delay in industrialization and technology innovation. This means that the impact of the Democase INNOMEM BioMiMe will be beneficial also from the socioeconomic point of view, enhancing both the sustainability and inclusiveness of an underdeveloped geographical area.

For more information, you can get in touch with us by sending an email

CNR-ITM: lidietta.giorno@cnr.it giuseppe.barbieri@cnr.it

ISGREEN: f.guzzo@isgreen.it j.liotti@isgreen.it