Dr. Miguel García Guerrero,

Chief Science Officer of AlgaEnergy, is a Full Professor, a Member of the Royal Sevillian Academy of Sciences, and one of the pioneers in applied research on microalgae, with over four decades dedicated to the study of these organisms. He holds several patents on bioprocesses involving microalgae, has written about hundred articles on microalgae, and has supervised 15 doctoral theses. He has held various positions in different institutions, including Vice President of the Spanish National Research Council (CSIC), Director of the Institute of Plant Biochemistry and Photosynthesis and the "Isla de la Cartuja" Research Center, and Director of the CSIC Foundation.

Finding the right culture

Without microalgae there would be no oxygen and no humans. They have an illustrious past, but what about their future role in agriculture?

Dr. Miguel García Guerrero has devoted his scientific career to the studying microalgae and answering that question. New AG International takes the opportunity to find out where the fascination began for Dr. Guerrero and how it led from the laboratory to the boardroom.

Where did the fascination with microalgae begin?

Throughout my scientific career, I have worked with a variety of organisms. It was early evident to me that microalgae, despite being quite simple from a structural standpoint, yet display many functional analogies with higher plants, thus being valuable model organisms for the unravelling of complex photosynthesis-based processes. About three billion years ago, an ancestor of modern microalgae discovered how to capture sunlight and use this energy to split water and generate assimilatory power to drive its biosynthetic metabolism: oxygenic photosynthesis had been invented, a capability that not only sparked a biological revolution but also altered the physicochemical characteristics of planet Earth. Microalgae can thrive in liquid medium with minimal requirements: light and simple inorganic nutrients. This allows a fast growth and development of microalgal cultures both at the laboratory, to perform research, and in large scale photobioreactors, for applied purposes.

There are some 70,000 species of microalgae. Can you give us some of your favourite examples of their different characteristics and curious properties?

That's a challenging question, but the first microalgae I would highlight is Chlorella. It was the first microalgae I experimented with, so there's a sentimental attachment to it. Chlorella has also grown to become a major and widely popular microalgae.

Throughout my journey, I've worked with filamentous nitrogen-fixing blue-green microalgae, such as Nostoc and Anabaena. This group adds the remarkable ability to fix nitrogen from the atmosphere and convert it into organic nitrogen, similar to what ammonia factories do, but under normal temperature and pressure conditions. It's a true marvel of nature.

Another microalga that greatly motivated me and to which I've dedicated much of my research is Haematococcus pluvialis. This microalga typically grows green when it has sufficient nutrients, but under stress—mainly from nutrient depletion—it accumulates a valuable carotenoid called astaxanthin, turning red in the process. My research focused on understanding the biochemical and genetic mechanisms behind this transformation, as well as the practical potential it offers. It's one of the three most significant microalgae to me.

It was known from scientific literature that Haematococcus pluvialis changes from green to red, but this shift was believed to be quite extreme, going from a metabolically active green form to a dormant red cyst. What made my research particularly interesting was identifying the conditions in which the microalga could remain metabolically active like in its green state, while still producing and accumulating astaxanthin. An improved methodology was developed involving a one-step-only continuous production strategy. The improved capacity, as well as the high quality of the reddish biomass product, makes the system a real alternative to the traditional two-stage option generating hard-walled red cysts.

There are around 70,000 species of microalgae including the smallest free-living eukaryotic organism known to date.

There are countless fascinating facts about microalgae. For instance, Ostreococcus tauri is the smallest free-living eukaryotic organism known to date, and Braarudosphaera bigelowii is the first eukaryote capable of autonomously fixing atmospheric nitrogen, a recent breakthrough in biology.

The discovery of the relationship between carbon and nitrogen assimilation in microalgae was a groundbreaking piece of work of yours – please can you talk us through the significance of this work and its wider implications? And secondly, what did this work mean for you as a scientist? How did it influence your career?

In my research with microalgae, I had the opportunity to understand how nitrogenous nutrients (fertilizers) enter plant cells through the participation of transport proteins, and how they are internally transformed by the action of specific enzymes. It was also intriguing to understand how the nitrogen assimilating pathway interacted with those concerning carbon and phosphorous assimilation. We learnt how carbon dioxide fixation and nitrate reduction converge to generate organic nitrogen compounds, and finally were able to find the biochemical basis of the dependence of nitrogen assimilation on that of carbon, a regulatory interaction that already occur at the level of the entry of nitrate into the cell.

Aside from their high scientific value to successfully address basic problems, it was also exciting to realize that microalgae combine typical properties of higher plants—such as simple nutritional requirements and efficient oxygenic photosynthesis—with biotechnological attributes characteristic of microbial cells, such as active growth in liquid media and the ability to accumulate and/or secrete certain bioactive compounds of commercial interest. This unique combination enables the use of these photosynthetic microorganisms for applied purposes and represents the basis of Microalgae Biotechnology, which aims to develop commercial products and processes, with an impact on a variety of sectors. I have actually dedicated most of my research to Microalgae Biotechnology, first in the academic sector and then in the business world, at AlgaEnergy.

> "Given the immense biodiversity in the world of microalgae, there is still much progress to be made."

Microalgae have a number of applications. Could you give us a brief tour of how microalgae are used in industry, and in particular how they are being used in agriculture?

The potential of microalgae for practical uses is certainly huge. Besides their use as feed for aquatic and terrestrial animals, the recognized nutritional value of algal biomass has promoted its use as a high-protein supplement in human nutrition and as nutraceuticals. Many different organic compounds can be generated by microalgae and mass-produced outdoors. They include a diversity of carotenoids, phycobiliprotein pigments, polyunsaturated fatty acids, polysaccharides, proteins and a vast array of bioactive compounds. Food, feed, pharmaceutical, cosmetic, and chemical industries benefit from microalgae and derivatives thereof. On the other hand, microalgae can be used for reclamation of wastewater and other bioremediation processes, such as arresting the accumulation of carbon dioxide in the environment. Whereas some products and processes have reached the market, others are still at early stages of research and development. Work is also devoted recently to the consideration of microalgae in the development of new materials, including bioplastics and nanomaterials. Their application in the health sector is highly promising, with a surge of publications and patents in this sector.

Anyhow, perhaps the greatest impact is already taking place in the agri-food sector, with agriculture being especially benefited.

You were involved in the foundation of AlgaEnergy in 2007. What advice do you have for scientists entering business?

I encourage to do it hand by hand with a qualified entrepreneur. Don't try to do it by yourself! One can be an excellent scientist but would most probably fail if entering business without a skilled marketing counterpart. I was very fortunate to interact with AlgaEnergy's founder Augusto Rodríguez-Villa, a real businessman with ample experience, who convinced me to accompany him in raising a biotech company based on microalgae, thus combining our experiences as to better address such a challenge. And that complementarity proved essential for the development of the company.

And finally, where do you see the potential for microalgae in agribiologicals? Are there any developments that particularly excite you?

Microalgae and derivatives thereof have immense potential for agriculture in several areas.

Given the immense biodiversity in the world of microalgae, there is still much progress to be made in differentiating products for the agricultural sector by incorporating new species and processes. At AlgaEnergy, research has always been valued as a strategic element for the company's development, an essential factor for its competitiveness. Currently, a four-year strategic research and innovation plan is underway, aimed at generating novel bioproducts that will make it possible to reduce the use of fertilizers and pesticides. In terms of processes, we are committed to promoting those that are "bio" in nature and supporting a circular economy, reducing potential environmental impacts.

The vast diversity of microalgae offers a collection of different effects that can be achieved depending on the specific strain or combination of strains. The bioprocesses generating the agribiologicals are also open to modifications as to optimize the quality and properties of the products. There's a wide range of possibilities, not only for biostimulants but also for biofertilizers, or even for biocontrol agents to replace chemical pesticides.