Institute on Science for Global Policy

Accelerating Algae Into Our Food System**

Jill Kauffman Johnson, M.P.P., Vice-Chair, Algae Biomass Organization, Preston, Minnesota; Rebecca White, Ph.D., Board Member, Algae Foundation, Preston, Minnesota; and Stephen Mayfield, Ph.D., Director, Food & Fuel for the 21st Century, and the California Center for Algae Biotechnology, University of California San Diego, La Jolla, California

Summary: Algae have tremendous potential to deliver nutrient-dense food to address global challenges in food production and health. Algae produce high-quality proteins, carbohydrates, and oils in an efficient and scalable manner. Production systems for algae often have low environmental impact reducing the use of potable water, arable land, and fossil-based energy. Algae have been in our food system for centuries with a few varieties popularized in the last few decades including seaweed, spirulina, chlorella, astaxanthin, and omega 3 fatty acids (DHA & EPA). Although algae offer enormous potential for food production, additional development and infrastructure buildout is required to scale and enable economic production of algae-based food products. Governments around the world acknowledge the potential of algae and are actively investing in further development of algae for food and feed. For example, as part of the 2018 Farm Bill, the U.S. Department of Agriculture (USDA) was directed to classify algae as a crop for the first time. Now is the time to invest in a new Green Revolution that can deliver nutritious and sustainable food solutions.

Current realities: According to the United Nations Food and Agriculture Organization, the world's population is expected to grow by 2 billion people to reach 9.3 billion people in 2050. This population increase and the expected dietary changes associated with global income growth indicate that by 2050, about 60 percent more food will be needed globally to meet demand. An underlying principle in addressing this challenge is "improving the efficiency in the use of resources." In other words, how can we produce more nutritious food using fewer resources, while maintaining the health of our soils, conserving potable water, and protecting the biodiversity and resilience of our ecosystems?

Both macroalgae and microalgae have the potential to deliver global, game-changing food solutions, and provide an expansion of food resources. Algae are the most efficient organism on the planet for turning sunlight, carbon dioxide, and/or carbohydrates into nutritious biomass. Algae are naturally high in protein and healthy oils, offering an opportunity to bring new food and ingredients into the marketplace.

Globally, macroalgae (seaweeds) represent one of the world's largest crops by volume. They are typically grown in coastal areas using two production systems: (i) open pond; and (ii) offshore longline. Open pond systems are located on land and pipe seawater into containment structures that are several feet deep. Depending on location and species, ponds can be harvested continuously throughout the year. Production in ponds requires a small amount of fertilizer, plus electricity for pumps, filters, and aeration. Offshore longline cultivation involves an extensive cultivation model featuring moored longline arrays deployed within maritime concessions. The lines are seeded with strings saturated with seaweed spore, maintained through the grow-out period and then harvested. Offshore production tends to be a seasonal cycle, but multicropping different species can help improve yields.

Microalgae are naturally photosynthetic organisms but can be grown with or without light, and with systems that vary in complexity—from open ponds to highly controlled fermentation systems.

There are three basic productions systems for microalgae: (i) open pond, (ii) photobioreactors, and (iii) fermentation. Open ponds are primarily circular "river-like" systems driven by paddle wheels, often less than 2 feet deep, and can be several acres per pond. These systems have successfully produced numerous marketable commercial products. Photobioreactors are

mainly clear plastic or glass tubular enclosed systems where algae are pumped through the tubes for gas exchange and light exposure. This system produces higher biomass yields than ponds. Fermentation systems involve growing algae "in the dark" using a reduced carbon source, such a sugar or acetate, usually in stainless steel tanks under highly controlled and sterile conditions. These systems have the highest yields (i.e., up to 50 to 100 times that of open ponds) and are already operating at scale in several locations with numerous products on the market.

Thousands of varieties of microalgae exist and can be improved in several ways to make them more productive and/or change the nutrient quality or density. Natural algae are collected in the wild, or from an algae collection, and may be adapted by classical mutagenesis and/or breeding. For some algae varieties, genetic engineering techniques are applied to natural algae to achieve targeted improvements. Gene-edited algae are potentially on the horizon, but no products using this technology are currently on the market.

Scientifically credible approaches and challenges: Algae have a demonstrated ability to produce high-quality proteins, minerals, vitamins, and fats in an efficient and scalable manner, with the potential to reduce the use of potable water, arable land, and fossil-based energy. Algae are at the base of the food chain and often require fewer resources than other organisms to produce proteins and other food ingredients. In many cases, algae food production is climate resilient, and not subject to seasonality or geography. In the case of growing seaweed, it requires no fresh water or arable land and absorbs carbon dioxide helping to reduce acidification in the oceans.

In addition to providing high-quality nutrition, the health benefits of numerous algae varieties have been well-documented. A number of algae-based products can contribute to anti-inflammatory, cardiovascular, brain, and eye health benefits. Unique bioactive compounds are also found in seaweeds that may have broad-spectrum health benefits, including prevention of various cancers, metabolic, cardiovascular, digestive, and neurological diseases. Many varieties of algae have the potential to reduce consumer sodium and saturated fat intake and serve as a natural food preservative. The potential of algae to provide a significant food resource now and in the future, is significant.

There are a number of challenges for the algae sector as companies seek to scale up production and introduce algae products into the U.S. market:

- *Cost:* Continuous improvement in production costs are needed to enable broader incorporation of algae in food products.
- *Functionality and Taste:* Cooperative development with food manufacturers is needed to continuously improve the functionality and taste for food formulation.
- *Market Acceptance*: Consumer education and marketing investment is needed to familiarize and inspire consumers regarding algae-based foods.
- *Innovative Technology:* New technologies are needed to scale production, as well as to make improvements in algae varieties.
- *Regulatory Engagement:* More funding is needed for the Food and Drug Administration (FDA) to increase new food-ingredient reviews and speed to market, verify nutritional and health claims, and improve consumer confidence in the processes for ensuring food safety.
- *Investment:* Diverse funding is needed to scale-up operations; for R&D support for cultivation, processing, and product development; and to improve market penetration of new food products.

Evidence-based options and real-world opportunities: The policy as well as public and private sector recommendations outlined here focus on developing products that are nutritious, cost competitive, and delicious. There are several key elements required for the

global development of algae-based food and much of this effort needs to be implemented with the support and guidance from the U.S. Algae Interagency Working Group, which includes members from the FDA, USDA, Department of Commerce, Environmental Protection Agency, Department of Energy, and National Science Foundation:

- Accelerate development of algae production at scale. As part of the 2018 Farm Bill, the USDA was directed to classify algae as a crop for the first time**.** This decision opens the way for algae to be regulated and supported alongside other crops such as wheat, corn, and soy. For example, the USDA can provide Crop Assistance and Crop Insurance programs to help decrease the risk of investments in algae production and other significant infrastructure investments needed to produce algae at scale. The USDA also needs to contribute its unique federal role to develop an Algae Agriculture Research Program to help fund technology research and development needed to scale production as well as establish standard reference strains and genome sequencing for algae. These types of efforts are similar to the support provided for crops.
- Accelerate adoption of algae ingredients and products by food manufacturers. Through a public-private effort (i.e., USDA, National Institutes of Health, State Department, philanthropic foundations and companies), the USDA needs to establish a Center of Excellence that will support the development of commercial algae products that meet consumer needs for flavor, texture, nutrition, color, consistency, functionality, and safety. This Center could provide a platform to facilitate collaborations for product testing, regulatory guidance, development of analytical standards and methods, and resources to accelerate adoption of algae into foods. In addition, these efforts could also expand publicly available data and information on algae for food applications. This public-private effort could provide the support and a framework to accelerate incorporation of algae in commercial food applications as well as emergency food rations.
- Create greater demand by consumers. Like the efforts of the National Dairy Council and other government-supported commodity marketing efforts, a clear and compelling communications effort needs to be launched about the benefits of algae ingredients and products. This effort should address the demand side to educate about the nutritious, delicious, and sustainable attributes of algae. Accelerating adoption by consumers is critical for the growth of the industry and to address some of the largest health crises we face (i.e., obesity and cardiovascular disease).

The development and production of algae food products are rapidly expanding and can meet many of the health and environmental challenges associated with food consumption and production today. Algae will play an important role in addressing food security and health challenges globally.

References:

Building a common vision for sustainable food and agriculture, UN FAO, Rome, 2014. http://www.fao.org/3/a-i3940e.pdf%20

*** A position paper prepared for presentation at the conference on Innovative Foods and Ingredients convened by the Institute on Science for Global Policy (ISGP), with support from the U.S. Food and Drug Administration, on June 23-27, 2019, in Minneapolis, Minnesota, United States.*