

Editorial

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The Arabian Gulf as a promising spot for algal culture: the current knowledge and the future prospects

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Blue economy refers to the sustainable utilization of aquatic resources to enhance human well-being while minimizing environmental risks and ensuring efficient exploitation of biological resources, such as algae. Algae are the primary producers in the food chain and occupy the lowest trophic level in the aquatic food web. They harness solar energy through photosynthesis and directly contribute to aquatic food security. Through photosynthesis, marine algae reduce the carbon dioxide concentration and help mitigate global warming as well as bio-remediate marine habitats. Moreover, algal biomass possess numerous valuable properties that serve many applications. For instance, algal biomass can be used in the production of algal bioplastics, biofertilisers and biofuel (El Semaary *et al.*, 2018; El Semaary, 2021; 2022). They have been found to increase the growth parameters and improve the water and nutrient uptake. They also enhance plant resistance to salinity and pathogens (Zhang *et al.*, 2024). Additionally, the mucilaginous or gelatinous nature of the algal cell wall and sheath can enhance soil texture and improve water-holding capacity (Hoque *et al.*, 2025). Algae are efficient bioaccumulators of pollutants present in the contaminated environment.

Marine algae have a distinctive chemical composition: 40–50% of their dry weight consists of carbohydrates and polysaccharides (hydrocolloids) such as agars, carrageenans and alginates, which are widely used in food and other industries. They are also rich in proteins and amino acids (including lysine and leucine), water and fat-soluble vitamins (A, B₁₂, C, and E), lipids, minerals (potassium, calcium, iron, magnesium, iodine), and high levels of antioxidants (Wu *et al.*, 2023; Lomartire and Gonçalves, 2023). Algal pigments include chlorophylls, carotenoids, and phycobiliproteins; the concentrations of these compounds vary seasonally and geographically. These valuable substances have significant economic importance and are used across industries including pharmaceuticals, cosmetics, food, and energy (biodiesel, bioethanol, biogas). Large-scale biomass facilities can be established to generate energy from massive algal production (Amalapidman *et al.*, 2025). Algae are also widely used in aquaculture—both directly as feed for farmed aquatic animals and as biological agents that improve water quality.

The Arabian Gulf offers considerable potential for scalable algal cultivation and commercialization of algal-derived products, making it a strategically promising region for developing algal-based agriculture, aquaculture, and bioproduct industries because of its warm, highly sunlit water, extensive coastline, established aquaculture and industrial infrastructure, and growing blue-economy initiatives.

According to Zhang *et al.* (2022), the primary method of cultivating algae is inshore shallow water aquaculture, which is conducted in the marine region near the land at a depth of 5 to 50 m. It takes advantage of moderate seawater velocity and wind degree, and ample nutrients. These conditions typically mimic those of the Arabian Gulf. Indeed, the Arabian Gulf is a semi-enclosed water body with limited water renewal; the calm coastal water is well suited for mariculture. Cultivation of marine macroalgae typically targets three major groups—brown algae (Phaeophyta), red algae (Rhodophyta), and green algae (Chlorophyta)—which supply raw materials for a wide range of industries. Commercial viability and pricing in the seaweed industry depend on multiple factors, such as harvest cost, labor availability, the equipment required for drying and processing, and transport logistics. By 2011, the

global production was estimated at 17.4 million tonnes (wet weight), underpinning a dynamic international industry largely concentrated ($\approx 98.8\%$) in Asian countries, with China being the world's largest producer.

Very few studies have comprehensively documented algal biodiversity in the Arabian Gulf, and the full extent of regional diversity—particularly in the Eastern Province—remains incompletely known. Interest in the region's algal flora dates back several decades, with early Aramco-funded screening surveys conducted to produce inventories of algal taxa (Basson 1979a, 1979b; Basson 1992). Later Aramco-supported study on the marine biology of the Arabian Gulf was carried out by Sheppard and Borowitzka (2001), which attributes to the regional dominance of brown algae for enduring the extreme environmental conditions of Gulf, which allows them to outcompete other algal groups for nutrients and light in the littoral (photic) zone.

El Semaary et al. (2018) collected brown alga *Hormophysacuneiformis*, for biodiesel production, from the AlUquair region where it showed massive accumulation. The spectrometric analyses of fatty acid composition showed that the biodiesel obtained had lesser number of unsaturated fatty acids as compared to the number of saturated fatty acids present, which indicates the stability of biodiesel produced. Thereby, the use of algal biomass for the production of biofuel is feasible. Algal biomass produced through mariculture in the Arabian Gulf can be processed into value-added biofertilizers to enhance local agricultural productivity. The aqueous extracts of *Hormophysa cuneiformis* have been tested as liquid bio-fertilizer (El Semaary et al., 2018). Many brown algae also contain antimicrobial compounds that can reduce the occurrence of soil-borne diseases, and improve water uptake (Ismail and El-Shafay, 2015). These findings indicate that scaled algal cultivation and on-site processing in the Arabian Gulf, followed by controlled extraction and standardized formulation of liquid biofertilizers, can provide locally produced, sustainable inputs for saline-affected and resource-constrained agricultural systems. To harness this potential, targeted species screening, pilot mariculture farms, and simple extraction/quality-control workflows should be prioritized in Gulf coastal development plans.

The search for an eco-friendly, biodegradable alternatives to conventional plastics have attributed marine macroalgae as a promising feedstock. Locally produced *Ulva* biomass from Arabian Gulf mariculture can be converted with relatively simple, low-tech processing into tensile bio-composites with measurable biodegradability. Scaling this approach in Gulf coastal facilities - combining targeted species selection, routine drying/grinding operations, and on-site formulation - can provide a regional pathway for producing sustainable bioplastics from abundant algal biomass (El-Semaary, 2022).

My interest in Algalogy has propelled me to explore algae in three different continents. My research focus mainly on food security and environmental sustainability and eco-friendly applications of algae that mitigate global warming and reduce harmful effects of climate change including using algae in biofuel production, bioremediation, biocontrol, biofertilisers, biogenic nanoparticles production, bioplastics that are decomposable and fertilise soil. Recently, I've been awarded a U.S. patent (US 11,930,824 B1, 2024) for reporting the use of extracts from brown algae (notably *Cystoseira* spp.) as an insect-repellent bioproduct. The patent describes a polysolvent extraction workflow that concentrates the active repellent fractions and outlines formulation approaches suitable for foliar application or seed treatment; some formulations are also reported to have fertilizing co-benefits. This invention is directly relevant to the Arabian Gulf because *Cystoseira* and related brown algae occur in the regional littoral zones, revealing the fact that the Gulf-sourced biomass can be developed into commercially viable repellent products. To translate the patent into practical Gulf-based production, priorities include sustainable mariculture or controlled cultivation of target species, scale-up of the extraction and formulation process, field trials to verify efficacy and environmental safety against target pests, and alignment with regional regulatory and commercialization pathways. The Kingdom of Saudi Arabia has the potential to promote this industry and establish factories that exploits all algal assets. The Eastern Province is an ideal place to start this project with its long coastal line along the Gulf and its weather conditions. If initiated, this patent would pave a clear pathway for value-added algal bio-products that leverage local marine resources while supporting coastal blue-economy objectives. Efforts should be directed towards establishing algal mariculture in the Arabian Gulf for their numerous applications and ecological advantages.

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