The value of seaweed

TEAGASC researchers are developing zero waste industry processes to generate high-value-added products from seaweed.

Biorefinery concept

Depletion of natural resources and climate change, together with increased food needs for a growing global population, are priority economic and environmental issues. These sustainability issues are currently being addressed by the food and feed industries, which are modifying their current practices to develop novel bio-based and more sustainable processes and products, and using natural resources such as seaweed as a source of multiple chemicals and fuel production. Biorefineries, which are facilities that integrate biomass conversion processes and equipment to produce fuels, energy, and value-added chemicals from biomass, are increasingly being employed. Biorefineries exploit natural resources for the production of energy while improving the efficiency of industrial processes, reducing energy consumption, and increasing the production of multiple high-value-added products from raw materials. Following this production system, the waste of one process is sequentially used as an input for another process, with the aim of achieving zero waste production and generating additional benefits from both economic and environmental perspectives (Balina *et al.*, 2017).

Potential of seaweed

The use of seaweed or macroalgae offers huge opportunities for the development and exploitation of biomass through adoption of a biorefinery model. Seaweed are aquatic organisms that live attached to any hard surface on coastal areas and can be classified into three main groups, primarily on the basis of colour: red seaweed or Rhodophyta (over 7,200 species); brown macroalgae or Phaeophyta (about 2,000 species); and, green algae or Chlorophyta (>1,800 species). Moreover, seaweed from different groups can also be differentiated on the basis of structural and biochemical composition, including special types of pigments, polysaccharides, and other bioactive compounds (Garcia-Vaquero *et al.*, 2017). Due to the varied composition of seaweed, this biomass has traditionally been used for multiple agricultural applications, including soil fertilisers and animal feed. The use of seaweed for food applications started over 2,000 years ago, when the Japanese included macroalgae in their daily diet, and over the years the popularity and use of seaweed as an additive in a wide spectrum of foods such as confectionery, canned fish products, snacks and beverages has increased. Moreover, the potential of seaweed to generate energy and store carbon resources has also been exploited by industry to generate biofuel, biogas, biodiesel and bioethanol. Seaweed biomass is easily available for use by the biorefinery industry and the collection of invasive species to produce energy in different coastal areas may reduce the negative environmental impact of these damaging algae. In addition, following the

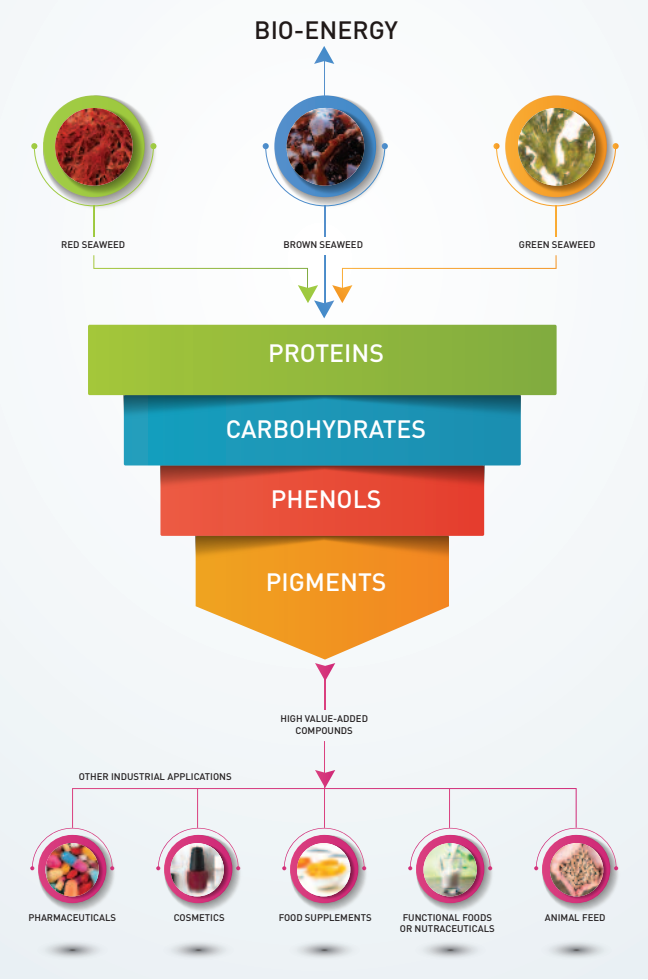

FIGURE 1: Schematic outlining the use of seaweed in a biorefinery model to produce energy and multiple high-value-added compounds.

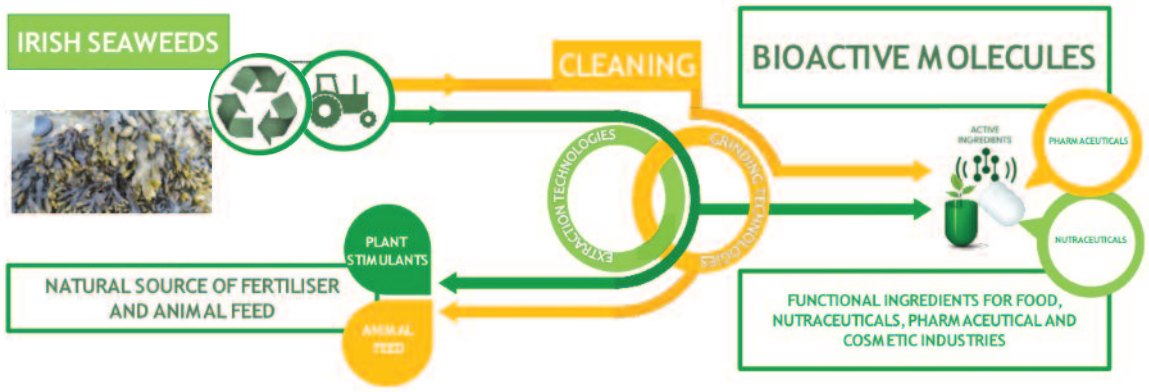

FIGURE 2: Teagasc research is improving the efficiency of industrial processes to produce high-value compounds from seaweed.

biorefinery concept, the biomass will be converted into energy, and intermediate products will also be utilised and transformed into high-value-added products, achieving higher economic benefits than when focusing on attaining a single compound or product. Following the production of energy, the seaweed biomass still contains valuable compounds such as polysaccharides, phenolic compounds, proteins and other small molecules, with multiple biological properties including antioxidant, anti-cancer, anti-tumour and immunomodulatory activities. These are useful in a wide variety of industrial applications such as pharmaceuticals, cosmetics and nutraceuticals (**Figure 1**). For example, phenolic compounds such as phlorotannins have powerful anti-inflammatory, anti-diabetic, antioxidant and anti-bacterial properties. Polysaccharides from seaweed have been shown to be a promising source of biologically active compounds for multiple biomedical applications. Fucoidans from brown macroalgae possess antiviral, anti-inflammatory, anti-angiogenic, anti-cancer and anti-hyperglycaemic effects, while other carbohydrates such as alginates and carrageenans are used for their physical properties. Alginates are currently used in the textile, paper and biomedical industries, while carrageenans are frequently employed in the meat and dairy sector due to their gelling, thickening and stabilising properties.

This wide variety of benefits, high-value molecules and potential applications has recently focused the attention of consumers and industries (pharmaceutical, cosmetic and nutraceutical), which are producing an increased range of products containing seaweed or seaweed compounds, such as health supplements, cosmetics and functional foods (Garcia-Vaquero *et al.*, 2017; Hayes *et al.*, 2015).

Current state of seaweed biorefinery

Researchers at Teagasc are improving the efficiency of the industrial processes to produce high-value compounds from seaweed, by utilising wastes and seaweed by-products (**Figure 2**). Within the SFI Bioeconomy Research Centre 'BEACON' project, Teagasc researchers are currently exploring the use of novel and more efficient technologies, including ultrasound and microwave technology, to obtain carbohydrates or phycocolloids (i.e., alginates), while sequentially exploiting the remaining biomass to recover other bioactive compounds (i.e., proteins, pigments and polyphenols) and transforming the remaining waste into biofuel or biofertilisers. This exploitation model aims to achieve a sustainable and zero waste phycocolloid industry and more efficient industrial extraction processes.

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