Clean and green

TEAGASC is collaborating in international research into how disruptive technologies can be used to extract hydrocolloids from Irish seaweeds.

Hydrocolloids from seaweeds

Hydrocolloids (e.g., agar and alginate) are substances that form gels or provide viscous dispersion in water, and are found in the cell wall of seaweeds. Seaweeds are known for a range of food applications and for their multiple biological properties, including antibacterial, antioxidative, anti-inflammatory, antitumour and antiviral. From an industrial application point of view, hydrocolloids exhibit the ability to be employed as gelling, stabilising, thickening and emulsifying agents, or for water-holding purposes. Among all the polysaccharides present in seaweeds, agar and alginate are two of the most commercialised compounds. Red seaweed species (i.e., *Gelidium sesquipedale*, *Gelidium amansii*) are commonly used for agar extraction since sulfated galactans (e.g., agar and carrageenan) are the most abundant compounds in the cell walls. The most common brown seaweed species for alginate extraction commonly found in Ireland is *Ascophyllum nodosum*, whereas other species include *Durvillaea*, *Ecklonia*, *Laminaria*, *Lessonia*, *Macrocystis* and *Sargassum*. Alginate and agar extracted from seaweeds have also been used to form biodegradable polymer films, which are food safe, recyclable and suitable for biological use. Nevertheless, this application is still under research and relies on the efficiency of methods of extraction of these biomaterials from seaweeds.

Extraction approaches

Conventional extraction processes of agar and alginate are time consuming and are not sustainable due to high usage of chemical solvents (**Figure 1**). During the extraction processes, the harsh conditions created disrupt the matrices of the seaweed cell wall in order to free the targeted chemical compounds into the extraction medium. Non-environmentally friendly wastes are also generated during the purification processes. Therefore, there is an increasing interest in more efficient and greener extraction approaches for hydrocolloids. Researchers at Teagasc, in collaboration with other European research bodies (IATA-CSIC, Spain; Hohenheim University, Germany; RISE, Sweden; and, Nofima, Norway) are investigating the application of novel extraction technologies to produce agar and alginates for the agri-food sector as a part of the BIOCARB-4-Food project (www.biocarb4food.eu).

Novel extraction technologies

Novel extraction techniques (e.g., ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE) and enzyme-assisted extraction (EAE)) are based on different mechanisms to affect the solubility of the desired compounds or to modify the seaweed cell wall in order to shorten extraction time and enhance yields. UAE is based on the acoustic cavitation phenomena. It can disrupt the cell wall totally or partially by collapsing bubbles that hit the surface of the seaweed particles. MAE is based on microwave radiation that heats up the inner water of the cell walls, giving a rise in the intracellular pressure to break down the cell wall internally and then

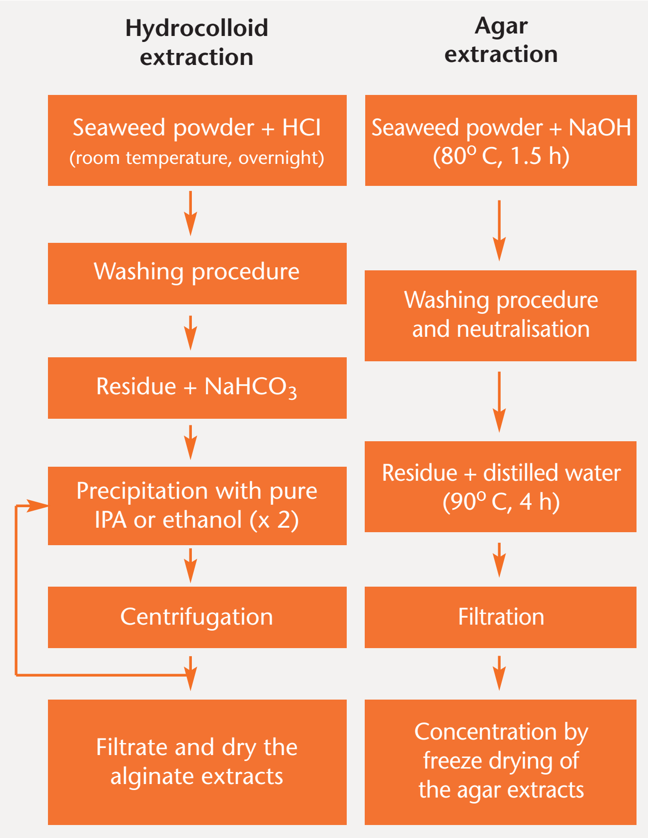

FIGURE 1: Schematics of conventional alginate and agar extraction.

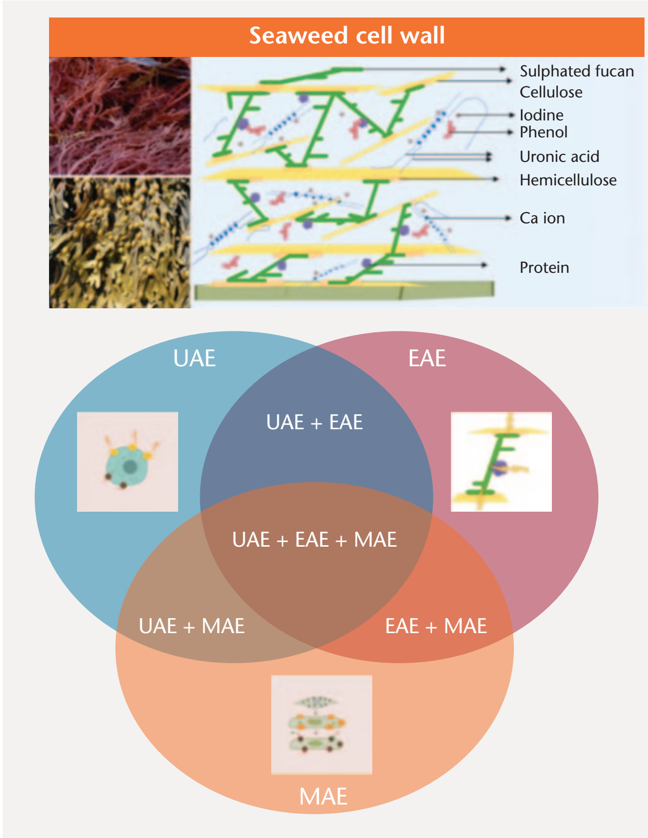

FIGURE 2: The combined novel techniques for hydrocolloid extraction.

release the inner compounds of the cell wall. EAE consists of the addition of enzymes such as carbohydrase (e.g., cellulase, pectinase, β-glucosidase, xylanase, β-glucanase, etc.) to hydrolyse the cellulose and hemicellulose structures in the cell wall and therefore modify the nature of the cell wall. EAE is also a green technique using enzymatic hydrolysis processes to replace the role of organic solvents used in extraction.

The most common lab-scale set-up for UAE is using ultrasonic probes (20 kHz and 500 W), where the transducer is directly in contact with the medium. A temperature control system is frequently employed to avoid thermal degradation of some valuable compounds (e.g., polyphenols, vitamins, proteins and fatty acids). However, for some heat-dependable extractions of agar and alginate, synergism of heat generated from MAE and the acoustic function of an ultrasound system can cause cavitation on the cell wall, which works more effectively than just relying on one individual technique.

Microwave at 2.5 GHz with a power of 400-2,000 W is used to fasten the heat treatment and to accelerate mass transfer during extraction. Both UAE and MAE can also be employed for the purpose of pre-treatment to degrade the cell wall polysaccharides and to release some active compounds such as phlorotannins, which have been found to form complexes with proteins. Thus, protease-assisted extraction (e.g., alcalase, neutrase, papain) can also take place to disrupt the cell wall structure. EAE is carried out under controlled temperature (~ 50° C) while UAE is supposed to couple the process to reduce extraction time and maximise yield. At the end of an EAE process, MAE can be involved to increase the temperature up to ca. 90° C in order to ease up all enzymatic functions. In this way, the potential of these extraction techniques for hydrocolloids can be exploited and it is possible to upscale these techniques, enabling their usage for large-scale industrial production (**Figure 2**).

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