Seaweeds… Not So Yucky! They are Part of Our Everyday Lives!

by Thierry Chopin

Only in English do the large (macroscopic), benthic (attached to the bottom) marine algae have this bad connotation (the weeds of the sea!). They are algues marines in French, algas marinas in Spanish, Meeres Algen in German, and the Chinese, who have a long tradition of using them, call them 海藻 (haizao) or the colorful/beautiful plants of the sea.

Did you know that you start your day with seaweeds in your orange juice (a microscopic mesh of carrageenans, extracted from red seaweeds, keeps the pulp in suspension) and you go to bed with seaweeds (your toothpaste would be a liquid without alginates, extracted from brown seaweeds)? Did you also know that every second molecule of oxygen we inhale was produced by an alga (micro- or macroscopic), and every second molecule of carbon dioxide we exhale will be re-used by an alga? Coral reefs would not have been formed without the help of seaweeds and it would be more appropriate to call them coralgal reefs; and a lot of these beautiful tropical white "sandy" beaches are, in fact, fine debris of dead calcified green seaweeds.

Even in the case of radioactive contamination seaweeds come to the rescue. People living near nuclear plants (including around Point Lepreau) are provided with pills of potassium iodide (KI), which are, in fact, a powder of kelps. The principle is that KI saturates the thyroid before radioactive iodine does it. It is a "simple" competition for the fixation of iodine in a key gland for humans. People from Hiroshima and Nagasaki suffered thyroid problems (including cancers) and kelp pills were used. They were also given to people around Chernobyl and Fukushima after these disasters. Recently, the Fukushima accident triggered a rush on kelp pills all over the world.

Unfortunately, seaweeds are often seen as rather unpleasant organisms: they are very slimy and slippery and can make swimming or walking along the shore an unpleasant experience to remember! To put it humorously, seaweeds do not have the popular appeal of "emotional species": only a few have common names, they are not easy to identify, they do not produce flowers, they do not sing like birds, and they are not as cute as furry mammals!

Dr. Thierry Chopin, well-known seaweed expert, and Scientific Director of the Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN). (Photo credit: Hemmings House Pictures)

Giving a simple definition of what seaweeds are is not that simple because this heterogeneous group is only a fraction of an even less natural assemblage, the "algae". Since the Greeks and the Romans, algae – as a misunderstood, unappreciated and underused group of organisms – have been lumped together in a very artificial manner. Algae are not a closely related group but a diverse group of organisms sharing only a few characteristics: they are doing photosynthesis and provide oxygen; they do not make flowers; and their anatomy is relatively simple (no roots, stems, leaves, conductive tissues, and simple reproductive structures). We now realize, especially with the progress in molecular techniques, that this "mixed bag" is completely unnatural, with no real cohesion and with species spread over most kingdoms of organisms.

We should not be using the term "marine plants" any longer to describe seaweeds. If green and red seaweeds are still considered plants, brown seaweeds now belong to the Chromista kingdom. In fact, the well-known green seaweed, sea lettuce, is closer, at the molecular level, to a spruce tree than to the well-known red seaweed, nori, even if their morphology is very similar (a green blade versus a red blade) and they are found close to one another on the shore. I always get a reaction from traditional botanists when I tell them that trees are in fact algae that colonized land! Evolutionarily speaking, that is correct!

Seaweeds in a tide pool along the coast of southwest New Brunswick: the two brown seaweeds we are already cultivating [the kelps *Saccharina latissima* (simple blades) and *Alaria esculenta* (blades with a central midrib)] and two potential candidates for further IMTA development [the red seaweed *Palmaria palmata* (dulse) and the green seaweed *Ulva lactuca* (sea lettuce)]. (Photo credit: Thierry Chopin)

A line of the cultivated kelp, *Alaria esculenta*, in Back Bay, New Brunswick. (Photo credit: Thierry Chopin)

There are approximately 10,500 known species of seaweeds. Around 500 of them have been used for human food and medicinal purposes for centuries. There are, however, only approximately 220 species of seaweeds cultivated worldwide. You will be surprised to learn that the largest group of organisms being cultured at sea is seaweeds, the aquaculture of which represents 46% of the total world mariculture (aquaculture in the marine environment), while fish aquaculture, of which we hear so much, represents only 9%. The reason for this is that 99.8% of the 15.8 million tons of cultivated seaweeds (worth US$7.4 billion) come from China, Indonesia, the Philippines, Korea and Japan, hence our ignorance in the western world. But, yes, in other parts of the world, aquaculture is not necessarily equal to salmon aquaculture! Most of the world seaweed supply (93.8%) is through cultivation.

The seaweed industry is in full mutation. Its best known sector in the western world is that of the phycocolloids – the gelling, thickening, emulsifying, binding, stabilizing, clarifying and protecting agents known as carrageenans, agars and alginates – used in the food, brewing, textile, pharmaceutical, biotechnology, coating, drilling, etc. industries. Why is your ice cream smooth and not full of big ice crystals? It contains carrageenans! The cocoa powder of your chocolate dairy drink is not all at the bottom of the bottle and you believe the product is fresh (has not stayed on the shelf long): the microscopic carrageenan mesh did it again! Green olives with pimento strips inserted in the pit hole? Sorry, a carrageenan paste with a colorant and 2 drops of artificial pimento flavor! Yes, some breweries have a clarifying step for your beer that involves the red seaweed, Irish moss, mostly coming from Prince Edward Island. Fine printing on textile/silk is only possible if the material has been soaked in a carrageenan or alginate solution which will then keep the dye in place. For fast relief of heartburn, you can take alginate tablets or liquids, which block acid reflux from your stomach. All these DNA analyses, on the CSI television series, used to identify who did the crime: banding patterns on agar gels! Why is the gyprock in your garage flame-retardant CSA certified? It is coated with alginates. Wonder why the water does not go through the paper goblets of your water fountain at work? They are coated with carrageenans. Underground drilling is quite tough on bits; they need to be cooled down with alginate mud.

The phycocolloid sector, however, now represents only a minor part (11% of the tonnage and value) of the entire seaweed-derived industry. The use of seaweeds as sea-vegetables for direct human consumption has become much more significant (76% of the tonnage and 88% of the value). Four genera, *Laminaria/Saccharina* (or kombu, for dashi broth), *Porphyra* (or nori, for sushi) and *Undaria* (or wakame, for miso soup) dominate the edible seaweed market. New products and applications of seaweeds are emerging: on one hand a wide range of bio-based, high-valued food and feed products/ingredients/supplements, biopolymers, fine and bulk chemicals, soil additives, agrichemicals, biostimulants, pharmaceuticals, cosmetics and cosmeceuticals, nutraceuticals, functional foods, antioxidants, bio-oils, botanicals, pigments, colorants, aromatics, bioactive compounds, antiviral agents, and, on the other hand, lower-valued commodity energy carrying molecules such as biofuels, biodiesels, biogases, bioalcohols, biomaterials and heat/power generation.

In the last two decades, there has been a renewed interest in the mariculture of seaweeds, not only for the valuable biomass they represent, but also for the biomitigative services they provide as one of the extractive components of Integrated Multi-Trophic Aquaculture (IMTA). IMTA is the farming, in proximity, of several species at different trophic levels, and with complementary ecosystem functions. For example, it combines the cultivation of fed species (finfish) with inorganic extractive species (seaweeds) and organic extractive species (shellfish and other invertebrates). This ecologically engineered ecosystem management approach provides environmental sustainability (biomitigative services for improved ecosystem health), economic stability (product diversification, risk reduction and job creation in coastal communities) and societal acceptability (better management practices, improved regulatory governance and appreciation of differentiated and safe products). That is what we have been developing in the Bay of Fundy since 2001, and with Cooke Aquaculture Inc. since 2005.

The biomitigative services of seaweeds are often not recognized by the rest of the aquaculture world and society in general. Seaweeds should be considered as candidates for nutrient/carbon trading credits (NTC and CTC) within the broader context of ecosystem services. Considering the average composition of seaweeds, and the value of NTC and CTC – which should be around US$10-30 per kg for nitrogen, US$4 per kg for phosphorus and US$30 per tonne for carbon – the biomitigative services of cultivated seaweeds are worth at least US$592.5 million to US$1.698 billion, or as much as 23% of their present commercial value. This should be recognized and accounted for to establish the true value of IMTA (the same should be done with the organic extractors). This would create economic incentives to encourage aquaculturists to further develop and implement IMTA systems to increase the overall sustainability, profitability and resilience of aquaculture farms and their societal acceptability by the general public.

The kelps we are growing at the IMTA sites are also used in salmon feeding trials run by Alan Donkin, from Northeast Nutrition. This is part of the diversification strategy to reduce fishmeal in fish feed formulations. Seaweeds can also be a source of proteins and they do not trigger competition with staple foods from terrestrial plants, causing price increases (as seen a few years ago with the first generation biofuel suggestions such as corn, soya, etc.). This also reduces the need of deforestation for more farm land, irrigation and fertilizers (the fish provides the nutrients in an IMTA setting). If partial substitution with seaweeds proves promising, then it will represent a very fitting loop within the IMTA strategy of Cooke Aquaculture Inc.

We now have an opportunity to reposition the roles, applications and values seaweeds have in coastal ecosystems, the economy and our society, and demonstrate how relevant they can be in many of our everyday activities and in solving global issues (we could also talk about the role of seaweeds in energy generation and biofuel production). A long-term responsible and gradual implementation strategy should be adopted. It will be up to us to bring aquaculture to a new ERA of ecosystem responsible aquaculture, based on the concept of marine agronomy, implemented at the level of each farm, or bay, so that extractive aquaculture becomes as much a part of the routine daily operation as fish farming.

IMTA kelp (*Saccharina latissima*) wrapped salmon-avocado tartare, sesame "cran-apple" vinaigrette, citrus-soy glaze, cilantro and chives… one of the delicious dishes prepared by Chris Aerni, Chef and owner of the Rossmount Inn in St. Andrews. (Photo credit: Thierry Chopin)

An aisle in a supermarket in Japan dedicated entirely to seaweed products. (Photo credit: Thierry Chopin)