MARINE PLANTS: PRODUCTION AND UTILIZATION

René Perez
Institut Français de Recherches pour L'Exploitation de la Mer (IFREMER), Nantes Seaweed production and biotechnology Laboratory,France

Keywords : Marine plant, seaweed, aquaculture, costal zone, polysaccharids, alginic acid, carrageenans, agars

Contents

Summary

Cultivated marine plants are usually intended for human consumption, whereas the biomass from wild aquatic populations is generally used for the extraction of phycocolloids, which serve as thickeners or gelling agents in aqueous solutions. Alginic acid extracted from species known as alginophyts is the best known thickener in the presence of monovalent ions and forms hard, irreversible gels in the presence of bivalent ions. Carrageenophyts yield carrageenans which form a pleasant-tasting gel with milk. During extraction, agarophytes release agars, which spontaneously form gels for use in the food industry, bacteriology, and advanced biotechnologies.

1. Foreword

The notion has come down from the nineteenth century that certain plant species, known as algae or phycophyts, living together (sometimes in close relations) in the aquatic environment are part of the same group, despite differences in shape, colour, biology, methods of reproduction, and metabolism. However, this notion is now considered untrue. The definition according to which algae are regarded as “lower” plants without vascularization or differentiated organs, as compared to land plants, has been invalidated by advances in our knowledge. Recent scientific progress in the fields of molecular biology, cytology, genetics, microbiochemistry, bacteriology, the study of the ocean depths, etc. have led to the notion of a chlorophyllic world composed of five groups or phyla which are fundamentally different and not interrelated. Each phylum is characterized by a pigment which gives a particular colour to the cell: blue for Cyanobionts, red for Rhodobionts, green for Chlorobionts, brown for Chrysobionts, and reddish-brown for Dinobionts.

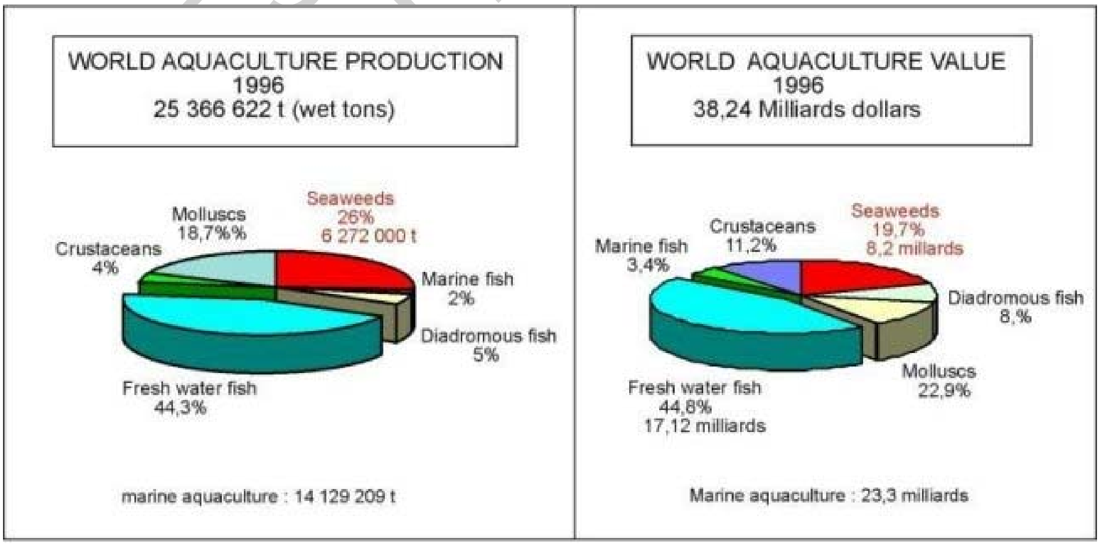

Figure 1. Seaweeds among world aquaculture. In 1996, the quantities of seaweed obtained by cultivation represented 25% of total production (wet weight) and 20% of total value.

Four of these groups have remained exclusively aquatic. The exception is green plants or Chlorobionts, which includes both aquatic and land representatives. The mixture of colors in the aquatic environment is not indicative of the homogeneity of the plant world, but of a fierce competition for space among the five groups, which are fundamentally alien to each other. The common points are simply fortuitous convergences due to the necessity of adapting to a water environment. Thus, the notion of alga no longer corresponds to any scientific definition, and many biologists object to the usage of this term. Accordingly, the term "marine plants" will be used here.

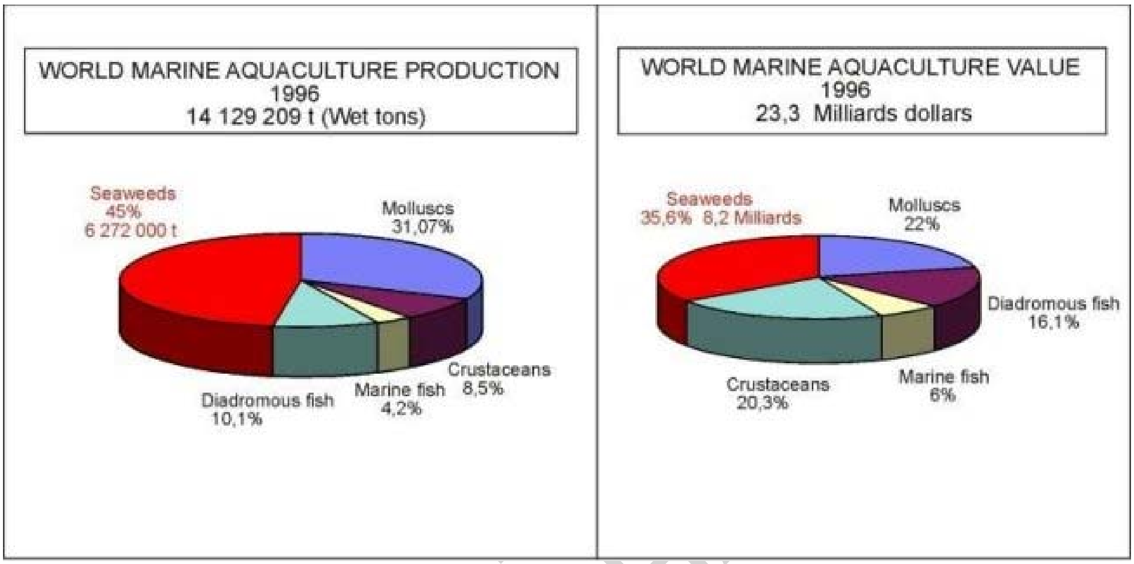

Figure 2. Seaweeds among world marine aquaculture. In 1996, harvests of seaweeds produced 50% of total wet weight and 35% of total value. The cultivation of seaweeds is leading marine aquaculture.

In 1996, world production of marine plants reached 8 017 458 tons (wet weight) for cultivated and naturally growing species combined. Since 1980, the proportion has been greater for cultivated rather than collected natural plants and is continuing (Figure 1) to increase, now representing 6 272 000 tons (80% of total tonnage).

In terms of world aquaculture, estimated at 25 366 600 tons for a turnover of $43 billion, marine plants rank second in tonnage (26%) and turnover (19.9% or $8.2 billion dollars) to freshwater fish (Figure 2).

The 8 107 458 tons harvested in 1996 supplied four main markets (Figure 3): direct food consumption, production of phycocolloids, agriculture-enriching agents and the parapharmacy-cosmetic sector.

The largest part (68.7% or 5 453 731 tons) concerned direct food consumption, essentially in Southeast Asia (mainly in China, Japan and Korea, but also in the Philippines and Thailand). More than 1 600 00 tons (20%) were used for the extraction of original substances, alginates, carrageenans, and agars (designated as phycocolloids).

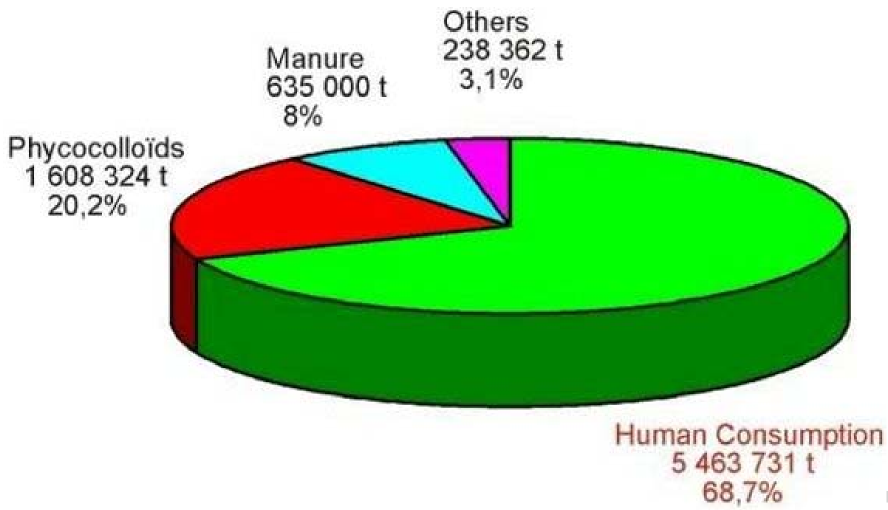

Figure 3. Main uses of seaweeds. The uses of sea vegetables for human consumption is most developed, but only from cultivated seaweeds. Phycocolloids are especially obtained from wild seaweeds, except for the agarophyt *Gracilaria* and some carraghenophyts (*Kappaphycus* and *Eucheuma).*

Enriching agents are derived from marine plants with calcified walls (500 000 tons of *Lithothamnium calcareum).* One hundred and fifty thousand tons of phycocolloid plants (*Macrocystis*, *Laminaria hyperborea*, *Ascophyllum*, *Fucus* and *Ulva*) are also used whole or ground into powder after drying in order to improve soil texture.

Less than 250 000 tons (3%) of aquatic plants are used in seawater therapy, parapharmacy, cosmetics and agrochemistry. This market is tending to develop in Europe and North America, but is practically non-existent elsewhere.

Demand was initially satisfied by the collection of naturally growing plants. However, around 1950 this source proved inadequate both for quantity and quality, and cultivation began to develop. This form of aquaculture, which is carried out mainly in countries where marine plants are consumed and product quality is primordial for sapidity and salubrity, allows the desired quality to be obtained relative to commercial standards. All the food species sold internationally, *i.e. Laminaria japonica* (known commercially as Kombu), *Porphyra yezoensis* (Nori) and *Undaria pinnatifida* (Wakame) are now produced in this way.

This chapter concerns the harvesting of natural populations, particularly marine plants containing phycocolloids, which represent 20% (1 600 000 tons) of total production. However, it is noteworthy that some red species such as *Kappaphycus alvarezii* and *Eucheuma denticulatum* (for extraction of carrageenans) and *Gracilaria* (for production of agars) have been cultivated intensively (more than 500 000 tons) in the Philippines and Indonesia since 1975.

Phycocolloids (alginic acid, carrageenans and agars) extracted from marine plants represent 39% of the colloids produced in the world today (Figure 4). This percentage has been increasing since the epidemic of spongiform encephalopathy (mad cow disease) made the production of gelatin from bovine and ovine races suspect.

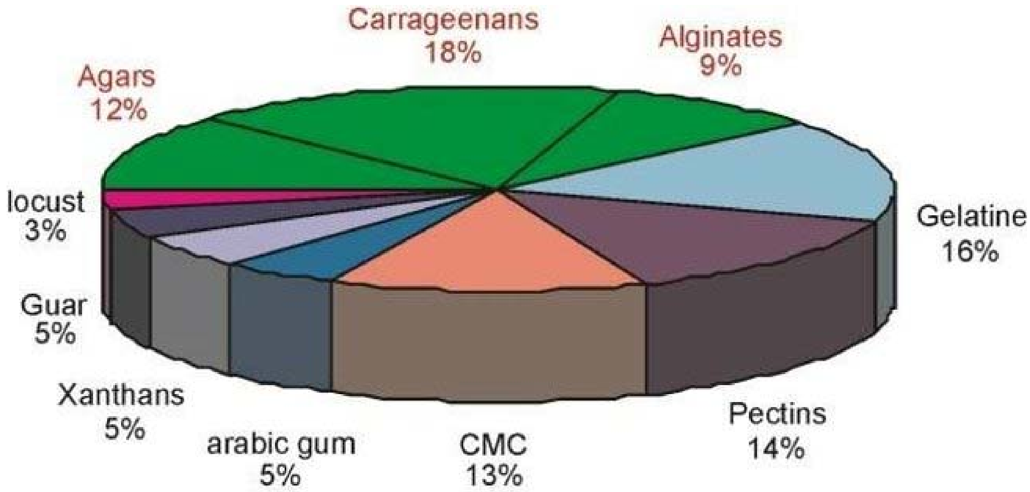

Figure 4. Phycocolloids among other commercial colloids. In 1996, phycocolloids increase to 30% of the total commercial colloids used in the world. This ratio will gradualy reach 45% at the expense of gelatin.

2. Alginophyts and Alginic Acid

Alginophyts are brown plants (phylum of Chrysobionts) containing alginic acid, which is a mucilage released in water by H^+ ions (as in the case of any acid). Within the plant, it is found only in the cell wall.

2.1. Structure of Alginic Acid (Figure 5)

Like other phycocolloids, alginic acid is a polymer, which means that its molecule is composed of similar elements (monomers) linked together. The monomer in this case is mannose in the form of mannuronic acid or guluronic acid.

Within the molecule, 1 500 to 2000 monomers are associated in a linear chain. As the number of these monomers increases, the degree of polymerization (DP) becomes greater and product quality (viscosity or aptitude to form gels) improves.

The active part of the molecule, i.e. that producing the acid, is the COOH radical, which constitutes the side chain of each monomer.

Once extracted, alginic acid can be used directly (code E 400) since its hydrophilic property allows storage of 140 times its own volume of water. However, its salts (alginates) are most often used.

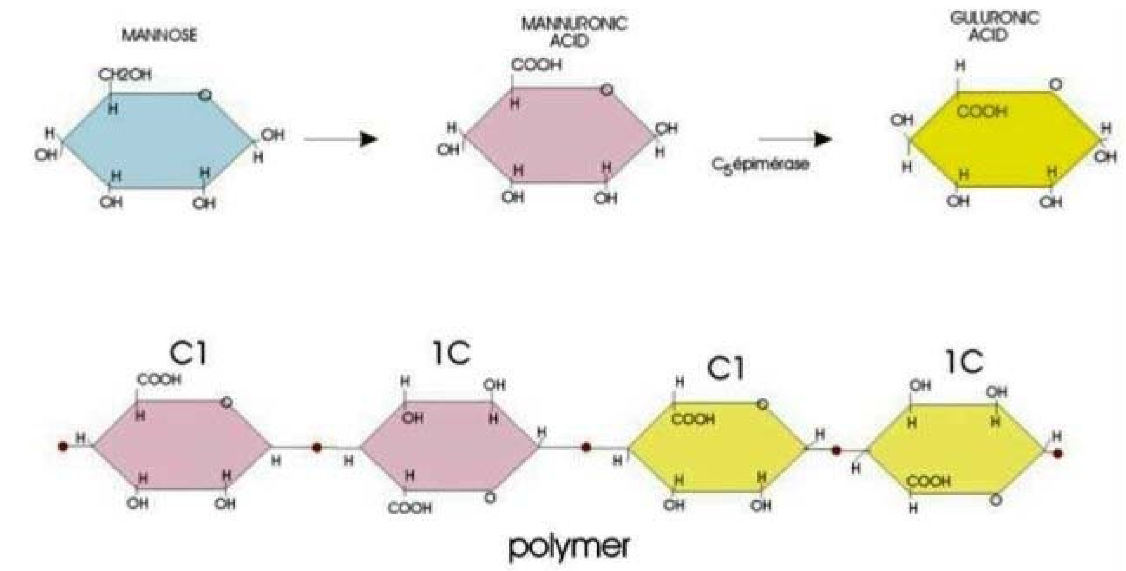

Figure 5. Alginic acid structure. The molecular chain of alginic acid contains 1200 to 2000 monomers that are either mannuronic acids or guluronic acids. The qualities of this colloid depend on the number and position of these monomers.

2.2 Properties of Alginic Acid

Alginic acid as thickener. When dissolved in the form of salts composed of Na^+, NH_4^+, K^+ monovalent ions, of propylene-glycol alginate (the only alginate tolerating acid media) or triethanolamine alginate, it is the strongest thickener known. In solution, alginate salt adds no taste, odor, or colour and thus does not modify the solution in which it is incorporated, except for the viscosity (texture).

Alginic acid as gelling agent. In the presence of bivalent or trivalent salts (calcium, iron, copper, beryllium, strontium, etc.), cold alginic acid forms hard, irreversible gels resistant to high temperatures (400°C). The latter property is important only when the M/G between the number of mannuronic acids (M) and guluronic acids (G) in the molecule is less than 0.7, which is the case for alginic acid extracted from the stipes of *Laminaria hyperborea* and certain *Sargassum* of northeast India.

-
-
-

Bibliography

Arasaki T., Arasaki S. (1983). *Vegetables From the Sea*, 196 pp. Tokyo: Japan Publications Inc. [This book points out the cultivation methods for seaweeds used in human consumption.]

Booth E. (1975). Seaweeds in industry. *Chemical Oceanography* **4** (eds. Riley J. P. and Skirrow G.), pp. 219-268. New York: Academic Press. [Extracts from seaweeds in the food industries are analyzed.]

Boudouresque C. F., Gomez A., Ribera M. A. (1993). Une approche moderne du monde vegetal, 122 pp. Luminy: GIS Posidonies Publishers. [This paper gives a new and modern view on the chlorophyll plant classification]

Glicksman M. (1987). Utilization of seaweed hydrocolloids in food industry. *Hydrobiologia,* **151/152**, 31–47. A. Besse Editor. Kluwer Academic Publishers, Dordrecht, The Netherlands. [The uses of marine plant extracts, such as alginic acid, agars, carrageenans, are explained in some food preparations.]

MacHugh D. J. (1987). Production and Utilization of Products from Commercial Seaweeds. FAO workshop on production and utilization of seaweeds, Qingdao, People's Republic of China publisher, 51–97. [The paper points the seaweeds that give polysaccharid gums used in food, in textile industry, in the paper industry.]

Perez R. (1997). Ces Algues Qui Nous Entourent, 265 pp. IFREMER Publisher (Institut Français de Recherches pour l'Exploitation de la Mer, France). [A thesis looks at the differents methods used for harvesting red and brown seaweeds in the world, the differents utilizations of the marine plants and the effects of seaweeds on our daily life. A new view for the chlorophyll plant classification is explained.]

Stanley N. F. (1987). Production, Properties and Uses of Carrageenans. Production and Utilization of Products from Commercial Seaweeds (ed. MacHugh D. J), Rome: FAO. [Description of red seaweeds used for extraction of carrageenans and carrageenans used in dairy industries.]

Tokuda H., Ohno M., Ogawa K. (1987). The Resources and Cultivation of Seaweeds. *Monographs on Aquaculture Science, Vol. 10*, 254 pp. Tokyo: Midorishobu [Quantities of marine plants harvested in the world or obtained by cultivation in the Southeast Asian Countries.]

Trono G. C. Jr., Ganzon-Fortes E. T. (1988). *Philippino Seaweeds*, 330 pp. Manilla: National Bookstore Inc. [Cultivation of some seaweeds along the Philippine Islands on *Eucheuma denticulatum* and *Kappaphycus alvarezii* v. Tanbalan.]

Tseng C. K. (1984). *Modern Seaweeds of China*. 316 pp. Publisher:Beijing: Science Press. [Tseng describes the development of *Laminaria japonica* cultivation in China and the increase of this activity from 1977 to 1984. He explains how the seaweed production becomes the first of the world with 4 000 000 t of fresh plants by a method of "forced" culture.)

Yaphe W. (1984). Properties of *Gracilaria* agars. *Hydrobiologia*, **116/117**, pp. 171–186. A. Besse Editor. Kluwer Academic Publishers, Dordrecht, The Netherlands. [A new comment about the composition of agars from some wild *Gracilaria* populations.]

Biographical Sketch

Rene Perez, graduated in 1963 from Montpellier University, France, with his D. Sc. Biology and Oceanography, has finished during 1970 his Ph.D Natural Science in Caen University, France. He received the tittle of Doctor for his thesis on exploitation, cultivation and uses of marine seaweeds. He was Chief of the seaweed laboratory of I.S.T.P.M (Institut Scientifique et Technique des Pêches Maritimes, France) from 1965 to 1981, and chief of the Aquaculture plant laboratory of IFREMER (Institut Français de Recherches pour l'Exploitation de la Mer, France) from 1982 and 1990. He is now in charge of the biology, physiology and cultivation of macro-seaweeds used for extraction or human consumption in the laboratory "Production and Biotechnology of Algae" (IFREMER).

He is the author of two books, *La Culture des Algues dans le Monde*, published by IFREMER in 1990, and *Ces Algues Qui Nous Entourent*, published by IFREMER in 1997.