Marine phycoculture and its impact on the seaweed colloid industry

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Introduction

It is not a long time since the suggestion was put to an International Seaweed Symposium (VI ISS, 1968) that the problems of supply of raw materials to the seaweed colloid industry would really be overcome only when commercial cultivation of seaweeds became a reality. Today we have come a long way towards that reality. This paper reviews how we have arrived at this point and how it has affected the production of seaweed colloids. The discussion is limited to the production of carrageenan, agar and alginate and the seaweeds associated with these colloids.

Carrageenophytes and carrageenan

The supply of seaweeds for carrageenan manufacture was dominated, until the early 1970's, by *Chondrus crispus* and *Gigartina stellata,* which are found in commercial quantities on the Atlantic coasts of Europe and North America; there was also a large supply of wild *Eucheuma* species from Indonesia. However, as phycoculture of *Eucheuma* developed in the 1970's, this picture changed and today *Eucheuma* cultivated in the Philippines represents about half of the world's supply. Substantial quantities of wild *Chondrus* and *Gigartina* are still collected in Nova Scotia and Prince Edward Island (ITC 1981). Chile exports large quantities of *Iridaea,* mostly to the USA and France. Indonesian exports have declined because the cultivated *Eucheuma* from the Philippines is cleaner and of better quality than the wild material collected in Indonesia.

Carrageenan itself can be separated into three main components (λ, κ and ι), each of which has different properties, especially in regard to the formation of gels, which is one of the most important applications. *Chondrus* and *Gigartina* contain mixtures of these three components (but mainly λ and κ). On the other hand, there is one species of *Eucheuma* which contains principally κ- and a different *Eucheuma* species which contains mainly ι-carrageenan. Obviously *Eucheuma* provides advantages to the processor who wants to make either pure κ- or pure ι-carrageenan. At present the phycoculture of κ-type *Eucheuma* is well developed but the ι-type behaves erratically and is proving more difficult to grow in reproducible quantities.

The market for carrageenan seaweeds has followed a boom-and-bust cycle for many years. This is particularly detrimental to those engaged in phycoculture. For example, in the Philippines, when prices are high, growers/collectors are encouraged to grow more, leading to overproduction and a price slump. They then become disheartened and move to other subsistence activities so that in time the supply decreases, prices rise, more farmers plant again and the cycle continues. Some form of growers/collectors' cooperative which exercises control over the quality of the seaweed, production rates, and price would benefit both buyers and sellers.

Other countries such as Indonesia (Trono *et al.* 1980) and Malaysia (Trono & Ganzon-Fortes 1981) are showing an active interest in *Eucheuma* farming. Such expansion should be approached with caution, because an oversupply could quickly develop. However there may be room for other suppliers, if not more total sales, simply because carrageenan producers may prefer to be less dependent on the stability of supply from any single country.

In North America a considerable investment has gone into efforts to develop vegetative propagation of *Chondrus crispus*. However the methods are both capital- and energy-intensive, and the costs exceed those for the cultivation of *Eucheuma* (Hansen *et al.* 1981).

The phycoculture of *Eucheuma* has led to the manufacture of a new type of carrageenan, less refined, containing more insoluble matter, but much cheaper and still suitable for some current applications. The traditional product is made by dissolving the carrageenan out of the seaweed, filtering off the unwanted residue, then precipitating the carrageenan from the extract, followed by separating and drying it. There are many physical separation difficulties in this process. The new product, called semirefined carrageenan, results from a process which operates on the opposite principle in that most of the matter other than carrageenan in the seaweed is dissolved and removed, leaving a solid residue of carrageenan and cellulose which is dried and milled. Since the carrageenan is never dissolved, there are no separation problems, so the process is faster, easier and cheaper. The new product sells for about 50% of the price of the traditional material but has in it some insoluble cellulose so that it will not form perfectly clear gels. However there are many applications where this is acceptable and because of the lower cost, new applications for this type of carrageenan may be found.

At present about 90% of the world's supply of refined carrageenan comes from five processors in Denmark, France and USA. Because the new, less refined carrageenan can be produced on a smaller scale with a comparatively small capital outlay, more processors may appear. Their pressure for sales, with a much cheaper product, may lead to an expansion of carrageenan into products for which it was previously too expensive.

Agarophytes and agar

The supply of seaweeds for agar is met by a large number of countries and detailed figures have been made available (ITC 1981). The supply is dominated by the Republic of Korea, Japan, Spain and Chile but, because it is relatively easy to manufacture agar, many developing countries are able to collect and process their own supplies of seaweed. Species of *Gelidium* and *Gracilaria* are the principal commercial sources. The former genus gives agar of higher gel strength and commands a higher price. *Gracilaria,* once not favored because of the poor gel strength of its agar, is now treated with alkali; this increases the gel strength but at the cost of a lower yield of agar. Most of the world's production is based on *Gracilaria.*

There is a demand for good-quality agar seaweeds but, because the main source is still natural seaweeds, there can be wide fluctuations in price depending on the source and condition of the seaweeds. The phycoculture of *Gracilaria* species is well established in Taiwan (Yang 1982) where it is combined with pond culture of milkfish. About 12 000 t per annum are produced but a high percentage of this is used for feeding abalone. Labor costs are low, capital outlay not very high and both costs are shared between the fish and the algal culture. Phycoculture of *Gracilaria* has also been reported in coastal villages of southern India (Ramnad District) using a longline rope method in inshore waters, and in Guangdong Province of China (Tseng 1982), but neither is carried out on a large scale.

Other countries are experimenting with the phycoculture of *Gracilaria*. Some developing countries in the warmer latitudes are in various stages of development, from initial research to field trials; these include the Philippines, Sri Lanka, Vietnam, Indonesia and Malaysia (Doty 1977; Trono & Ganzon-Fortes 1981); Chile has also run trials in some northern areas. The methods employed, like those in Taiwan, are labor- rather than capital-intensive. In North America, much research and development have gone into the use of enclosed systems for *Gracilaria* culture and this is well summarized by Hansen *et al.* (1981). The systems have generally been capital-intensive, and as yet no commercial production has resulted. The demand for agarophytes continues to be high, as evidenced by the way they have maintained their high price and the fact that countries like Chile and Korea can process some of their seaweed but have little problem in selling the remainder. The average price of these seaweeds is higher than those for other colloid-bearing seaweeds.

Agar production is dominated (65%) by Japan, Republic of Korea, and Spain; the remaining 35% is spread over about 12 countries (ITC 1981). The Japanese output comes from 170 producers, mostly operating on a small scale, which illustrates how the small-scale operation is typical in this industry. The demand for agar is good, as shown by rising prices since 1974. A stable supply of seaweed from phycoculture would make a large contribution to stabilizing the price of agar, which at present is really too high; it is pricing itself out of several markets. About 50% is used in Asian countries where the strip form is very popular for use in foods. Developing countries produce 40% of the world's agar and the comparison with their contribution to alginate (2.5%) and carrageenan (0.9%) supplies is a reflection of the easier technology and lower capital investment involved in agar manufacture. They are therefore likely to take advantage of their low labor costs and set up successful phycoculture of *Gracilaria* along the lines of the Taiwanese pond culture or the longline method as tried in India and mainland China.

Alginophytes and algin

The supply of seaweeds for alginate production comes mainly from countries in cold-water regions, water temperatures of about 20 °C or less being most suitable for alginophytes. Large quantities of *Macrocystis* are harvested off the west coast of North America; *Laminaria* and *Ascophyllum* are collected in Ireland, the United Kingdom and Norway; *Durvillea* is collected and exported from Australia and Chile; *Sargassum* is collected in some warm-water countries such as India and the Philippines but the viscosity of the alginate is usually fairly low.

The culture of *Macrocystis* has been the subject of many studies (Neushul 1982) but to date its principal use has been in the restoration of natural kelp beds. However China has established the phycoculture of *Laminaria japonica* on a very large scale, nearly 19 000 ha of rope rafts in 1980, with a production of over a million tonnes of wet seaweed. Japan and the Republic of Korea have established the phycoculture of brown seaweeds, principally *Laminaria* and *Undaria*, but the products go mainly to their food markets which offer a much higher price than the seaweed colloid industry can afford.

Two major producers supply 80% of the world's alginate and both use wild seaweed. There is not much international trade in brown seaweeds because the major processors usually ensure supplies by buying direct from the source. Since one processor accounts for approximately two-thirds of the total alginate production, the demand for raw material is not as competitive as for agar seaweeds, nor even as for carrageenan seaweeds. So the alginate industry has so far been little affected by developments in phycoculture, simply because the countries with successful phycoculture channel their product mainly into food rather than alginate production. China has the capacity for expanding its phycoculture with little difficulty if it can find markets for its products, principally *Laminaria japonica;* an alternative is to expand its alginate industry.

Conclusion

The carrageenan industry is utilizing the *Eucheuma* phycoculture in the Philippines but there is little stability in either the supply or the economic return to the growers. Other countries in the Asia-Pacific region are likely to embark on phycoculture. Success is most likely to come to those who can organize their marketing. Meanwhile, development is continuing in North America on *Chondrus crispus* culture. A new type of semirefined carrageenan has appeared as a result of the *Eucheuma* phycoculture and this may increase the scope of the carrageenan market.

There is good demand for agar seaweeds but phycoculture methods, although available, have not yet been adopted on a wide scale so that the colloid industry is still dependent on natural seaweeds. However, several Asian countries are involved in developing phycoculture of agarophytes.

In brown seaweeds, phycoculture is well established in some countries but most of the output goes into food, a more profitable market. The major producers of alginate rely on their traditional supplies of natural seaweeds. China appears to be the only country utilizing phycoculture as the basis for an alginate industry.

References

Doty, M. S., 1977. Seaweed resources and their culture in the South China Sea region. S. China Sea Fish. Dev. Coordinating Progm., Manila, 19 pp.

Hansen, J. E., J. E. Packard & W. T. Doyle, 1981. Mariculture of red seaweeds. Rep. T-CSGCP-002. Calif. Sea Grant Coll. Progm, La Jolla, 42 pp.

ITC, 1981. Pilot survey of the world seaweed industry and trade. Int. Trade Centre UNCTAD/GATT, Geneva, 111 pp.

Neushul, M., 1982. Propagation, cultivation and harvest of the giant kelp, Macrocystis. In R. T. Tsuda & Y. M. Chiang (eds), Cultivation and utilization of economic algae. Guam Mar. Lab. Mangilao: 95–103.

Trono, G. C. & E. T. Ganzon-Fortes, 1981. Report on the training course on *Gracilaria* algae. S. China Sea Fish. Dev. Coordinating Progm. Manila, 187 pp.

Trono, G. C., H. R. Rabanal & I. Santika, 1980. Report on seaweed farming in Indonesia. S. China Sea Fish. Dev. Coordinating Progm. Manila, 56 pp.

Tseng C. K., 1982. Commercial cultivation. In C. S. Lobban & M. J. Wynne (eds), The Biology of Seaweeds. Blackwell Scientific Publications, Oxford: 680–725.

Yang S. S., 1982. Seasonal variation of the quality of agar-agar produced in Taiwan. In R. T. Tsuda & Y. M. Chiang (eds), Cultivation and utilization of economic algae. Univ. Guam Mar. Lab., Mangilao: 65–80.