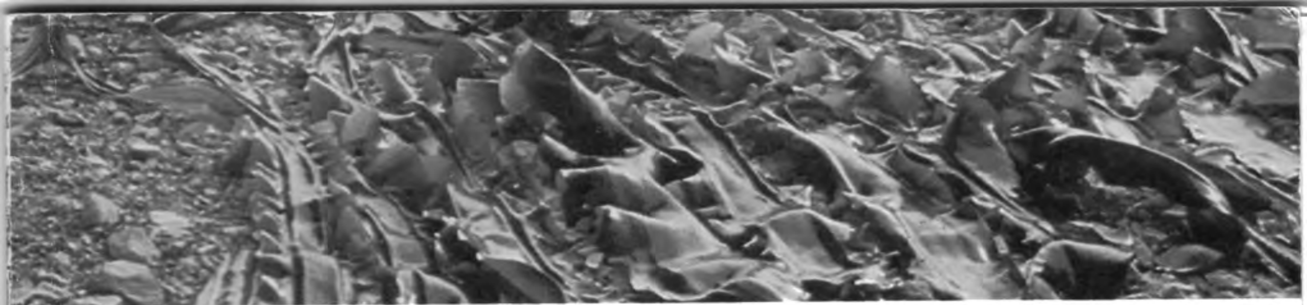

ADB/FAO INFOFISH

MARKET REPORT Vol 6

SEAWEED

ADB/FAO INFOFISH Market Studies

VOLUME 6

THE WORLD SEAWEED INDUSTRY AND TRADE: DEVELOPING ASIAN PRODUCERS AND PROSPECTS FOR GREATER PARTICIPATION

by

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INFOFISH is a cooperative project of Governments in the Asian/Pacific region and the Food and Agriculture Organisation of the United Nations (FAO) to provide marketing information and technical advise to the fishing industries in the region. It is hosted by the Government of Malaysia and located in Kuala Lumpur, 01-02, P O Box 899.

PREFACE

This volume forms part of a series of fishery commodity studies and country market profiles prepared jointly by the Asian Development Bank and FAO. The full series comprise the following titles:

Vol. 1 Highlights and Conclusions

Vol. 2 The international market for tuna

Vol. 3 The international market for shrimp

Vol. 4 The international market for cephalopods

Vol. 5 The world market for fishmeal and the Asian/ Pacific region

Vol. 6 The world seaweed industry and trade

Vol. 7 Dried fish markets in Asia

Vol. 8 High valued finfish markets in Hong Kong, Singapore and Japan

Vol. 9 Fishery sector profiles and briefs for selected countries

The study represents an expanded up-date of a similar report published in 1977 and entitled 'DEVELOPMENT POTENTIAL OF SELECTED FISHERY PRODUCTS IN THE REGIONAL MEMBER COUNTRIES OF THE ASIAN DEVELOPMENT BANK'. The first report was accomplished through the cooperative efforts of the Asian Development Bank and the Food and Agriculture Organization of the United Nations (FAO), and was coordinated by the FAO/UNDP South China Sea Fisheries Development and Coordinating Programme in Manila. The present study is a joint effort of the above programmes. INFOFISH, FAO's Marketing Information and Advisory Services for Fish Products in the Asian Pacific Region, operative since July 1981, also assisted in this programme.

The study was carried out under the ADB/FAO Cooperative arrangement, which provides a vehicle for cooperative activities on a cost-sharing basis. The studies and related appendixes were prepared by FAO staff members and individual consultants. The coordination of the study was carried out by Mr. B. Lanier of FAO Headquarters, Dr. W. Krone of INFOFISH, Mr. A. Woodland of the South China Sea Programme, and Dr. R.C. May, Senior Aquaculturist of ADB.

The main objectives of the study are to analyze the present market situation and projected future absorptive capacity of domestic markets for fishery products in developing member countries of the Bank, and also to examine export market prospects for selected fishery products important to the countries. Present and projected market needs are compared with present and potential production and export volumes; supply, demand and prices for key fishery products are forecasted for 1990. These efforts are foreseen as assisting the Bank and its member countries in planning future investments in fish production and marketing facilities in the region.

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1. Seaweed weights refer to *dried* weight unless otherwise stated.
2. "Ton" denotes *metric* ton unless otherwise noted.
3. Key technical terms cited in the "INDEX TO TECHNICAL TERMS" are printed in **bold type face** at appropriate points in the report text to facilitate reference.

SUMMARY AND CONCLUSIONS

Due in large part to its complexity – biological, technical and commercial, the world seaweed industry remains the least-known among the world's marine-based industries. This is in spite of the fact that the industry contributes in some way to almost every aspect of modern life. Seaweed products find use as fertilizer, animal feed, and as food for direct human consumption. The most dynamic sector of the industry – and the focus of this report – utilizes selected seaweed species to manufacture a formidable array of seaweed colloids which, in turn, find use in a truly remarkable variety of commercial applications, from air freshners and textiles to pharmaceuticals and processed foods.

Marine seaweeds occur in an incredible variety of life-forms, but are generally classified into four main groups, largely on the basis of pigmentation: red, brown, green and blue-green seaweeds. This report focuses on red and brown seaweeds, which account for the majority of seaweeds of commercial importance. Over 650 000 tons (dry weight) of seaweed were harvested during 1980 for use in the manufacture of seaweed colloids (about 270 000 tons), and for use as food for direct human consumption (about 385 000 tons — almost exclusively in Asia). But of the thousands of species of seaweeds that grow in marine waters, relatively few are of commercial value, and end-product usage dictates very strictly which species may be utilized as well as their relative values.

While the seaweed industry has traditionally relied on the exploitation of naturally growing, or wild, seaweeds to fill its raw material requirements, the accelerating pace of advances in seaweed culture techniques in concert with the expanding demand for seaweed products and the rising costs of operation in industrialized countries (where most of the seaweed processing industry is located) have created forces with the potential to alter the global distribution of the seaweed industry. This is particularly true for the seaweed colloid industry.

Various red and brown seaweeds are utilized to manufacture four seaweed colloids: agar, alginate, carrageenan and furcellaran. A colloid is a non-crystalline substance with very large molecules, which dissolves to give viscous or sticky solutions. Seaweed colloids are used to thicken (increase the viscosity) of aqueous solutions, to form gels, to form water-soluble, oil-repellant films, and to stabilize some products. Their use, based on these properties, cover a wide range of products in a variety of industries. Utilization of seaweed colloids is increasing, the growing popularity of prepared, pre-packaged and "instant" foods being an important element in this increase.

Exacting technical requirements for the manufacture of seaweed colloids – especially carrageenan and alginates, involving production technologies which are closely guarded by the world's few manufacturers, and the requisite expertise and costs associated with the effective marketing of these colloids, make for barriers of significant consequence to developing producers wishing to enter the trade.

Agar and seaweeds for agar

International trade in agar and in seaweed for agar manufacture is active and expanding. Both are expected to continue expanding because, primarily, of the increasing demand – from both developed and developing countries – for bacteriological agar, and for agar strip for foods in Asian countries. The current high price of agar is limiting its use in Asian foods, and is allowing some competitive colloids, like carrageenan, to replace it in other uses, such as the canning of meats. Increased production of agar-bearing seaweeds, particularly those yielding bacteriological agar, would no doubt facilitate the expansion of the agar industry as a whole if it resulted in some moderation of agar seaweed price levels.

Many of the developing Asian nations discussed in this report could certainly participate in the future expansion of production of agar-bearing seaweed and of the agar itself. India has already developed a process for agar manufacture, using wild (naturally growing) *Gelidium* and cultured *Gracilaria*. Indian agar production currently does not meet the domestic demand. Expanded production is dependent on additional supplies of seaweed; research is now in progress on the mariculture of *Gelidiella*, a seaweed which gives a higher quality agar (greater gel strength) than *Gracilaria*. The mariculture of *Gracilaria*, already established in Taiwan and India, is under study in the Philippines, Malaysia, Indonesia and Sri Lanka. Field trials have begun in the Philippines, Malaysia is negotiating arrangements to begin small-scale trials, and Indonesia has surveyed areas for suitable sites. Sri Lanka ran pilot trials in 1975, but have not proceeded further.

In that the present production of agar-bearing seaweeds in the two main producing areas among developing Asian nations — India and Taiwan – are now fully utilized, market potential for additional volumes of such seaweeds from mariculture operations in other countries in the region is judged to be very encouraging. If some of the countries considered here do undertake the mariculture of *Gracilaria*, however, it would be logical to link such efforts to the manufacture of agar, rather than simply export dried seaweed. In this way value-added benefits would accrue to the national economy (ies) involved, and present imports could be supplanted by a domestic product, with potential for the generation of export income from any surplus supplies. The production technology for agar manufacture is not overly complex or inaccessible, and the development of the requisite technology is not outside the resources of any of the countries discussed in this report. Agar manufacturing has the advantage of being feasible on both small or a large scale, with the corresponding capital outlay. Development work on a process for agar extraction could commence at the same time as mariculture trials are begun, using the species selected for mariculture.

Carrageenan and seaweeds for carrageenan

The supply and demand for kappa-carrageenan seaweeds is in reasonable balance at present, with the usual minor periodic fluctuations. Nearly half of the world supply now comes from mariculture of *Eucheuma cottonii* in the Philippines. Unfortunately, however, the marketing network in that nation is poorly organized, so that detrimental cyclical variations of good/poor quality, excess/insufficient output, and high/low prices are a problem. The demand for iota-carrageenan, produced from *Eucheuma spinosum*, is increasing steadily, and there is a need for an improved supplies of this seaweed (better quality and more constant production). The mariculture of *E. spinosum* has not been as successful as that for *E. cottonii*; to date the growth pattern of *E. spinosum* in culture operations has been somewhat erratic.

While there is potential for developing Asian nations to produce and enter the market for carrageenan-bearing seaweeds, caution should be exercised. At present market demand for *Eucheuma spinosum*, which yields iota-carrageenan, is stronger than that for *E. cottonii*, yielding kappa-carrageenan. Any significant increase in supplies of the latter species through mariculture could quickly lead to an over-supply situation. Indonesia is experimenting with the production of *Eucheuma*, especially *E. spinosum*, and is negotiating with UNDP, for assistance. In Sabah, Malaysia there is interest in developing *Eucheuma* culture in the Balabac Straits at the northern extremity of the country; some initial trials have been made. Any developing Asian nation wishing to develop mariculture of either type of *Eucheuma* would be wise to ensure a market for the output by simultaneously establishing itself in the production of either semi-refined or refined carrageenan.

The market for the normal grade ("refined") of carrageenan is growing slowly, about five percent per annum. Utilized in many prepared, pre-packaged foods in developed countries, its use has been affected by the current world recession. However, in the last two to three years a new type of carrageenan ("semi-refined") has been produced in the Philippines. This product contains some insoluble material, and thus will not yield clear gels, but its price is about 50 percent of that for refined carrageenan, and it may be used in many applications where gel clarity is not important. Semi-refined carrageenan also has the advantage of being easier to manufacture than refined carrageenan. It is feasible for an entrepreneur to develop the processing technology on an experimental scale for a modest capital outlay, and then gradually increase the scale of operation. This is in contrast to the production of refined carrageenan, which involves a much more complex process. But before committing any funds to the establishment of a plant for the manufacture of semi-refined carrageenan, any investor should carefully examine the status of the market for this product. If new applications for semi-refined carrageenan are found, the market could well be expanding; otherwise, any new production might simply replace refined carrageenan in established uses, resulting in a much more limited sales potential. But because of the lower price for semi-refined carrageenan, it is very possible that the rate of market expansion for carrageenan will accelerate as new applications for the new, lower-priced semi-refined product are found.

While it may be feasible to develop independently the processing technology for refined carrageenan on a small scale, expansion would present many problems which can be both time consuming and costly. The marketing of refined carrageenan is also considerably more difficult and expensive. Investors interested in entering the refined carrageenan trade may find it safer and faster to enter into a joint-venture with an established producer. Joint-ventures with producers in France, Spain or Portugal, in particular, may be feasible; it would be necessary, however, to identify a potential foreign partner who wishes to expand his manufacturing capabilities, and who is thus willing to commit the required capital investment to do so. Any entrepreneur who embarked independently on producing and selling refined carrageenan should be prepared to wait two to three years for any appreciable return on investment; it would be advisable in this case to scale up production, and hence sales, in small, gradual steps.

Alginate and seaweeds for alginate

International trade — in the traditional sense — in seaweeds for alginate production has never been great because most alginate producers arrange their own collection of seaweed and only enter the market when they have a shortfall from these normal sources. At present the supply is adequate to meet the demand. If anything, there is a slight oversupply because of the levelling-off of alginate sales associated with the world economic recession. The bulk of demand for alginates comes from the textile and food industries. Sales to the textile industry are currently down, while those to the food industry are rising marginally, so that overall the position is fairly static and will probably remain so until the current world recession eases.

Under these conditions, real potential for developing Asian producers and exporters can only exist where a domestic market for both the seaweed and the resulting alginate exists. There is a possibility of increased usage of alginate in India by the textile printing industry, but the source of alginate — *Sargassum* species — yields a poor quality alginate for this use. The importation of better species could help the problem but the government prohibits seaweed imports. The Philippines is interested in alginate production from *Sargassum* but has little domestic market for it. The Republic of Korea has suitable seaweeds, and actually imports alginate in appreciable quantities, but the industry and government successfully pursue a policy of garnering the more substantial returns available from selling the seaweeds for food purposes.

Seaweed for direct human consumption

The primary consuming countries for edible seaweeds are Japan, the Republic of Korea and China, thus the bulk of international trade in edible seaweeds is between these nations. There is some minor trade with other countries where nationals of the former ones have settled (e.g. the Japanese community in the United States). The trade is mostly in dried brown seaweeds, some salted, wet brown seaweeds, and the red seaweed *Porphyra*. With the exception of the Republic of Korea, there is little potential for developing Asian producing nations to enter this market because their marine environments are too warm to allow the growth of the seaweeds in demand. The Republic of Korea does have suitable water and is already heavily involved in the mariculture of edible seaweeds.

There is, however, potential for selected developing Asian producers to expand production and augment domestic market supplies for fresh, edible seaweeds such *Caulerpa*, *Ulva*, *Gracilaria* and *Eucheuma*. In the Philippines, for example, *Caulerpa* has been cultured in ponds in the Visayas for some years, and pilot trials on a different species are being conducted near Manila. The product is in high demand as a salad vegetable.

Seaweed for fertilizer and animal feed

Seaweed meal, made from dried and ground brown seaweed — particularly *Ascophyllum* species — has traditionally been utilized for these purposes. The large suppliers were formerly European countries, but the rising price of oil has caused artificial drying to become too expensive, and their production has fallen. There is potential for developing Asian producers to enter this market; most, because of their climate, could arrange natural drying of the seaweed and offer a cheaper product. The main brown seaweeds available in the region are *Sargassum* species, which have not been used widely for these purposes. Some trials, as fertilizers and animal feed additives, may be necessary to establish their usefulness to the market.

Liquid extracts of brown seaweeds have been found in recent years to be effective fertilizers, suitable for use by market gardeners, orchardists, etc. This is another product with potential for both domestic use and for export by developing Asian producers. For such countries, this product has the advantage of very low technological requirements and a small capital outlay.

Seaweed as a feed for aquatic animals is a use which has been developed in Taiwan. The same principle could be applied in other developing Asian areas where aquaculture is an important industry, such as the Philippines, Indonesia and Thailand, among others. In Taiwan, *Gracilaria* has been grown in ponds with milkfish and with shrimp, although the latter give a lower economic return. The milkfish graze on epiphytes on the *Gracilaria*, and eventually on the *Gracilaria* itself if they are left in the pond for long enough. Producing such a dual crop is quite profitable. More recently *Gracilaria* from mariculture has been used as a feed for abalone in Taiwan.

I. INTRODUCTION

The seaweed industry, despite a history dating back thousands of years and a contribution in some way to almost every aspect of modern life, remains today among the more remote and least understood of the world's marine-based industries. This is largely a product of its characteristics, which are daunting in their complexity — biological, technical and commercial. The variations in seaweed species, in their respective ecologies and availability, and in their chemical properties, define a resource and biological base of the industry which is of no mean complexity. The technical and commercial complexity of the industry is exemplified by its most dynamic sector, which utilizes closely guarded technologies to extract a formidable array of seaweed colloids, or gums, from various species of red and brown seaweeds. Seaweed colloids, in turn, find use in a truly remarkable variety of commercial applications. Add to this complexity the dearth of industry data and the not unexpected secretiveness of the few major commercial enterprises which dominate the highly competitive markets for seaweed colloids, and it is not difficult to understand why the industry is little known outside a relatively small number of scientists, biologists and industrialists.

The use of seaweeds for food and as medicines was recorded in China thousands of years ago. Today, seaweed and seaweed products remain widely used food items in certain Asian countries. In the western world, seaweeds were traditionally valued principally for their properties as animal feed and fertilizers and, during the eighteenth and nineteenth centuries, as a source of soda, iodine and other chemicals. While traditional uses of seaweed — as food and, to a lesser extent, as fertilizer and animal feed supplements — remain important in certain countries, it is as raw materials for the manufacture of colloids that seaweeds are now chiefly valued by the world trade.

Indeed, the predominant development in the industry over the last four decades has been the accelerating growth in the output and use of seaweed colloids, notably agar, alginate and carrageenan. Most knowledgeable observers agree that the diverse and growing demand for seaweed colloids will continue to be the prevailing factor influencing the further exploitation of the world's seaweed resources — seaweed culture efforts, and the future development of the global industry. For this reason, and because of constraints enforced by financial limitations, this study focuses on the colloid manufacturing sector of the seaweed industry. The other important sectors of the industry — the seaweed foods, fertilizer and animal feed trades — are also covered in this report, but in less detail, and are the subject of recommendations for further examination where appropriate and promising. Similarly, seaweed species and biology, and seaweed culture, harvesting and product manufacturing technologies are covered in a general, non-technical fashion in this report; those interested in obtaining more detailed information on these subjects should consult the publications listed in the References Section III of this report. however, provides considerable detail on present status and development prospects of the seaweed industry in eight selected developing Asian nations.

II. THE WORLD SEAWEED INDUSTRY

A. The raw materials: seaweed species groups and their exploitation

Marine seaweeds, or algae, are among the most primitive members of the plant kingdom. They occur in an incredible variety of life-forms, from uni-cellular species to giant kelp which may extend in length up to 40 meters. The microscopic forms are seldom utilized, although a species consisting of free-floating threads a quarter of a millimetre long are eaten in Chad and Mexico. Most of the species exploited in quantity take the form of cartilageous feathers, or are strong, giant sea plants, like the brown seaweeds classified as kelp and rockweed. The latter has a differentiated plant body which consists of a root-like "hold fast", a stem-like "stipe" and the leaf-like "blade" or "frond". Seaweeds are generally classified into four main groups, largely on the basis of pigmentation: red algae (botanical class: *Rhodophyceae*), brown algae (*Phaeophyceae*), green algae (*Chlorophyceae*) and blue-green algae (*Cyanophyceae*). Green and blue-green algae, while present in salt water, are more commonly associated with freshwater and on land (for example, on tree trunks, in soil, etc.). Red and brown algae, on the other hand, are found almost exclusively in marine environments.

Brown seaweeds are the most familiar, conspicuous, largest and most abundant of the seaweeds, but in number and diversity are exceeded by the group of **red seaweeds** of which there are some 4 000 different species. The former are particularly abundant in cold northern waters and — most species of commercial interest grow best in waters below 20 degrees celsius, usually at or below the intertidal zone — few species are found in tropical regions. Red seaweeds are usually smaller than brown seaweeds and grow in deeper waters, from just above the low tide level down to five to ten meters. They are more widespread than brown seaweeds as some species grow in cold water and some in temperate to tropical waters. Marine **green seaweeds** grow in a wide variety of ecologies and can be found in warm to cold water, and from marine to brackishwaters. The present study will concern itself mainly with the red and brown seaweeds, which account for the majority of the seaweeds of commercial importance.

The world seaweed industry centres around the three main uses to which seaweeds are put. These are: (i) as raw material for the manufacture of the seaweed colloids agar, alginate, carrageenan and furcellaran; (ii) as food for direct human consumption; and (iii) as raw material for the production of animal feed and fertilizer. Table 1 broadly summarizes the rather complex picture of seaweed use by end-product versus seaweed genera, and the present level of global exploitation of seaweeds for these uses.

Table 1
Seaweed as raw material: their uses and exploitation

Product	Raw material: seaweed groups/principal genera utilized			Estimated global harvest 1980 (tons dry weight)
Seaweed colloids:				270 000
Agar	**Red seaweeds:**	*Acanthopeltis* *Gelidiella* *Gelidium*	*Gracilaria* *Pterocladia*	36 000
Alginate	**Brown seaweeds:** *Ascophyllum* *Durvillea* *Ecklonia*	 *Fucus* *Laminaria* *Macrocystis*	 *Nereocystis* *Sargassum* *Turbinaria*	190 000*
Carrageenan	**Red seaweeds:** *Chondrus* *Eucheuma*	 *Gigartina* *Hypnea*	 *Iridaea* *Phyllophora*	40 000
Furcellaran	**Red seaweed:**	*Furcellaria*		4 000
Food for direct human consumption	**Red seaweed:** **Brown seaweeds:** **Green seaweeds:**	*Porphyra* *Hizikia* *Laminaria* *Caulerpa* *Enteromorpha*	 *Undaria* *Ulva*	385 000
Fertilizer and animal feed	**Brown seaweeds** such as those listed for alginate, but most commoly: *Ascophyllum*	 *Sargassum*		

*Including about 90 000 tons of dried seaweed used in China in alginate manufacture marketed entirely within the country.
Source: International Trade Centre UNCTAD/GATT and industry sources.

As may be seen, about 650 000 tons of seaweeds were harvested during 1980 for the manufacture of seaweed colloids and for use as food. The geographic distribution of seaweed production and the relative importance of the various seaweed genera as raw material for the several products shown above will be discussed in more detail in the sections dealing with the relevant products.

1. The changing pattern of exploitation and the industry

Traditionally, the seaweed industry has relied on the gathering of wild seaweeds to fill its raw material requirements. But the accelerating pace of advances in seaweed culture techniques, in concert with the expanding demand for seaweed products and the rising costs of operation and of expanding production in industrialized countries (where most of the seaweed processing industry is located), are creating forces with the potential to alter the global distribution of the industry in the foreseeable future. This in particular holds true for the seaweed colloid manufacturing and, to a lesser extent, the seaweed-based fertilizer and animal feed sectors.

The culture of *Porphyra* seaweed in Japan dates back to the seventeenth century. But it was the unavailability of Japanese supplies — virtually the only source — of agar in western industrialized nations during the Second World War, and the resulting urgent, unfilled demand for this product in these nations, which stimulated interest in and intensified scientific investigation of seaweed culture technology. The dividends of this work were forthcoming in 1949 with the discovery of sufficient knowledge to allow the rapid expansion of the mariculture of *Porphyra* in Japan beginning in the 1950s.

Mariculture techniques have since been successfully applied to other seaweed species, the most notable being *Eucheuma cottonii*. The successful establishment of a large mariculture industry in the Philippines based on this seaweed had its genesis in another agar supply crisis in Japan in the late 1950s and 1960s, which also had wider implications for the industry, particularly the seaweed colloid manufacturing sector. The effects of pollution on Japanese *Gelidium* beds, the primary raw material for agar production, lead to a worldwide search for suitable alternative sources of agar seaweeds. This eventually resulted in the collection of seaweeds in hitherto untapped areas around the world. But it also precipitated appreciation of the fact that inadequate seaweed supplies were also hindering the growth of both the alginate and carrageenan sectors of the seaweed colloid manufacturing industry, and that seaweed culture offered the best solution to raw material supply problems. Thus, a new era began in the industry, the results of which already promise to change its structure.

Work on the cultivation of other seaweeds has gained momentum since the first culture trials for *Eucheuma* began in the Philippines in 1967; the mariculture of *Gracilaria*, for example, is now well established in some Asian countries, and the past two decades have seen the mariculture output of *Laminaria* in China reached almost 250 000 tons. The culture of *Laminaria* is of less importance in Japan, but Japanese production of *Undaria* is much larger, and the output of *Porphyra* continued to expand very significantly through the 1970s. *Gelidium*, but more importantly, *Hizikia*, are cultured in the Republic of Korea.

These developments are the result of the growing appreciation within the industry of the advantages of mariculture: the relative ease of harvesting and crop control; the possibility of the cultivation of improved seaweed strains with predictable and better yields; and the avoidance of over-harvesting, which occurs all too frequently in the collection of wild seaweeds, with the consequent fluctuation in seaweed supplies. Indications are that virtually all the commercially important red seaweeds will be produced by mariculture in the next decade. These developments augur well for developing countries in Asia with mariculture potential, in that the cultivation, harvesting and processing of seaweeds are highly labour-intensive activities.

B. The industry: sector analyses

The structure of the world seaweed industry and trade is a reflection of the raw material needs, and the technological and marketing expertise required in its three principal sectors: the seaweed colloid manufacturing sector, the food sector, and the fertilizer and animal feed sector. The current structure, the supply, demand and price picture, and the potential for greater participation by Asian producers in each of these sectors is examined in turn below. The emphasis of this analysis, however, is placed on the seaweed colloid manufacturing sector, presently the most dynamic sector of the industry, and judged to present the best opportunity for greater future participation by developing producers.

1. The seaweed colloid manufacturing sector

Various red and brown seaweeds are utilized in the manufacture of four seaweed colloids: agar, alginate, carrageenan and furcellaran. A **colloid** is a non-crystalline substance with very large molecules, which dissolves to give viscous or stickly solutions. **Seaweed colloids** — also referred to as seaweed gums or as phycocolloids — are water-soluble carbohydrates with large molecular weights, which are used to thicken (increase the viscosity) aqueous solutions, to form gels (jellies) of varying degrees of firmness, to form water-soluble, soil-repellant films, and to stabilize some products, such as ice cream (in which they inhibit the formation of large ice crystals, thereby ensuring a smooth texture). Their uses, based on these properties, cover a wide range of products in a variety of industries. Colloids occur in seaweeds as part of the structural components, together with cellulose, and so form an appreciable proportion of the dry weight of seaweed (20-30 percent).

Agar was first manufactured by the Japanese over 350 years ago. The industry remained a Japanese monopoly until the Second World War; the war and other subsequent developments outlined previously resulted in the spreading of the agar — and also the carrageenan — industry worldwide as new sources of supplies of agar-bearing red seaweeds were developed in Asia, South America and Africa.

Carrageenan was first produced in the United Kingdom in 1948, but significant growth in production and demand is a phenomenon of only the past two decades. A limited number of red seaweed species from temperate waters off the coasts of North America and Europe dominated the raw material supply picture until the early 1970s, but the phenomenal growth of the *Eucheuma* mariculture industry in the Philippines has resulted in that country now supplying nearly 40 percent of the seaweed requirements of the world industry. Furcellaran is chemically similar to carrageenan, but its particular molecular structure produces properties that differ from those of carrageenan. Furcellaran was first produced during 1940-1944 in Denmark. It is produced from a single species of red seaweed found mainly in certain areas of the North Sea, the Baltic Sea and in restricted areas off the coast of Eastern Canada; Denmark, however, remains the sole producer of furcellaran.

Alginates were first produced commercially in the United States in 1929, but as with carrageenan, industry expansion has occurred mainly during the last twenty years. Today, the industry continues to utilize only certain brown seaweeds that grow in temperate waters, chiefly in the North Atlantic, off South Africa, Australia (Tasmania), and the Pacific coast of the Americas.

The total production of seaweeds which entered the international market during 1980 for use in the manufacture of seaweed colloids has been estimated at nearly 175 000 tons, valued in excess of US$60 million. These data, and those shown in Figure 1, exclude about 90 000 tons of seaweed production in China which is utilized for alginate manufacture, due to the fact that only a very small portion of this large output presently enters the world market.

Despite data constraints, Figure 1 shows that Asia is the leading region for supplies of seaweeds for the manufacture of agar, and for carrageenan and furcellaran. However, one country accounts for the great bulk of Asian seaweed supplies utilized for agar (Republic of Korea: 62 percent), and for carrageenan and furcellaran (Philippines: 84 percent). In contrast, Asia accounts for less than five percent of world seaweed supplies for use in alginate production; certain European countries, and the United States and Canada account for over 75 percent of world seaweed supplies for this use.

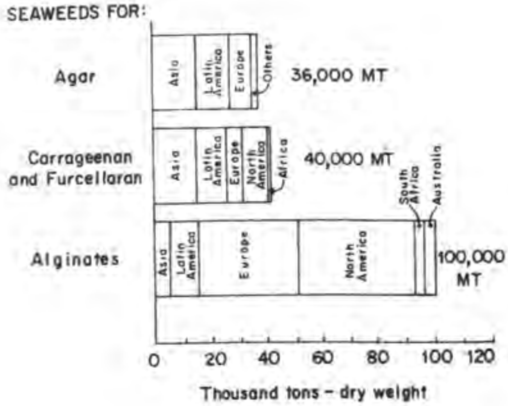

Fig. 1 Estimated world production in 1980 of seaweeds for use in the manufacture of seaweed colloids, by region

Data for above

	Agar	Carrageenan & Furcellaran	Alginates
Asia	18 088	17 900	4 570
Latin America	9 990	5 720	12 800
Europe	6 350	8 400	34 000
North America		7 000	42 000
Others	1 666	150	6 000
Total	36 094	39 170	99 370

Developing countries thus produce nearly 40 percent of the world's seaweed supplies for use in the manufacture of seaweed colloids, fully 70 percent of the seaweeds utilized for agar production, 60 percent of those used in carrageenan (excluding furcellaran) production, and 18 percent of those utilized for the manufacture of alginates. Developing Asian nations account for half of developing countries' contribution to world supplies of seaweeds for colloid manufacture, or 20 percent of total world supplies.

The world supply production picture for seaweeds is in sharp contrast to that for seaweed colloids. The seaweed colloid manufacturing industry remains concentrated in a few nations in the developed world — primarily Denmark, France, Japan, Norway, Spain, the United Kingdom and the United States. Of the more than 41 000 tons of seaweed colloids produced worldwide during 1980, valued at about US$300 million, only about eight percent was manufactured by developing countries; the Republic of Korea is by far the largest producer among these nations. Figure 2 illustrates the absolute and relative levels of output of the four seaweed colloids by region. Asia was the most important producing region for agar, but Japan, followed by the Republic of Korea, accounted for nearly all this output. Europe, led by Spain, accounted for the bulk of remaining production. Asian nations are relatively minor producers of both carrageenan and alginates, although Japan (largely) and India together account for nine percent of the world output of alginates. Several developed nations in Europe and North America produce most of the world output of carrageenan, furcellaran which comprises only 1 000 tons of the European total shown in Figure 2 and alginates. Thus, those developed nations which first manufactured seaweed colloids remain by far the most important producers of these products.

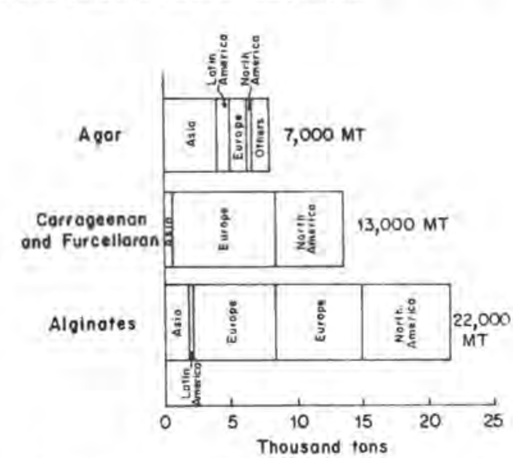

Fig. 2 Estimated world production during 1980 of seaweed colloids, by region

Data for above

	Agar	Carrageenan & Furcellaran	Alginates
Asia	3 574	500	1 950
Latin America	857	0	100
Europe	1 990	7 900	12 825
North America	200	4 500	6 700
Others	440	—	
Total	7 061	12 900	21 575

The disparity between developing and developed nations in seaweed supplies versus seaweed colloid production indicates that there is a flow of dried seaweeds of significant volume from developing countries to developed countries, particularly those utilized for the manufacture of agar and carrageenan. The fragmentary trade data available are discussed in subsequent sections of this report, but the flow is dominated by the movement of dried seaweed from the Philippines, Argentina, Chile and Mexico, to the few large producers in France, Japan, Portugal, Spain, the United Kingdom and the United States. This pattern of trade in dried seaweeds should continue to expand in the future due to the growing importance of seaweed culture. But the emerging trend is for producers of seaweed colloids in industrialized countries to establish new processing facilities in developing nations, near the source of seaweed supplies. The rising domestic costs of manufacture and pollution control, as well as the substantial savings in transport costs, lie behind this trend. As mentioned previously, these forces, and accelerating pace of advances in seaweed culture techniques, point towards a shift in the geographic structure of seaweed colloid manufacturing, paralleling the shift that is underway in seaweed production. This shift will benefit developing countries with mariculture capacity or potential, and is already evident in developments in Chile and the Philippines.

The following sections analyze in some detail the three subsectors of the seaweed colloid industry.

a. The agar trade

1) The colloid

Agar is the dried colloid obtained from the hot water extraction of, principally, the four genera of red seaweeds listed in Table 1. Chemically, agar is a **polysaccharide** (a polymer, or long-chain molecule, with the chains made by joining units of sugar-like molecules), the exact composition of which varies from source to source. It is made up from units of D-galactose joined to 3, 6-anhydro-L-galactose; some of the latter units contain acidic sulphate groups. The average sulphate content of the polysaccharide varies from about two-five percent. Agar is used to form jellies; its gel strength varies according to the species used, so manufacturers often use a mixture of seaweeds. Its extraction is a fairly simple process[1], and in some countries, such as Japan, small batches are made in cottage-type production units. Essentially, the seaweed is boiled with water, the insoluble residue is removed by some means of filtration and the liquid, when cooled, forms a gel. By alternately freezing and thawing the gel several times, the water is removed and a dried 'strip' of agar is produced. Agar is sold in strip form, but also in powder form.

2) End-uses

Agar is used principally in foodstuffs. In this usage, it has a 350-year history in Japan and an over 100-year history in Europe. Its acceptability in food has never been challenged, and the World Health Organization has not specified any limits to daily intake. Because of its gelling properties, agar is widely used to thicken jams and soups. Unlike jelly made from gelatine, agar jellies are stable up to at least 35°C. Agar is also used in the manufacture of sweets, often mixed with gelatine. In the past, agar was widely used in canned meat and petfoods; it is now rarely used for this purpose except in canned tongue products. In Japan, over 60 percent of current total consumption is in foods, notably in a jelly ("tokoroten") which is made from a 1-12 percent aqueous solution of agar. This jelly is cut into thin slices and is flavoured with soy sauce, sugar or vinegar. Because of differing food preferences, uses of agar in food in the Far East vary from those in the West.

Agar's unique application as a culture medium in bacteriology is increasing with the promulgation of national safety legislation, and with the improvement of laboratory facilities in developing countries. Unfortunately, the high-quality agar required can only be made from a limited number of seaweeds, notably *Gelidium* and *Pterocladia*. These seaweeds are in short supply and, as a result, production of bacteriological grade agar may be restricted in the future.

In medicine, agar is often used in the preparation of suppositories. It has long been used as a laxative, particularly as an emulsion with medicinal paraffin. For the latter purpose, it is sold under such names as "Petrolagar". As agarase, it is important in genetic engineering.

The other industrial uses of agar in Europe are negligible. It is used in small quantities to give resilience to gelatine in photographic films. In Japan, it finds some use for textile sizing and in block printing.

Formerly, agar was widely used in the production of canned petfoods and dental impression compounds, but has been virtually supplanted with gelling grade carrageenan in the former use, and with superior alginate-based products in the latter. Restricted supplies and the resulting effect on prices played a significant role in the loss of these markets to other colloids.

3) Supplies

The supply of agar-bearing seaweeds is met by a large number of countries, but a few — the Republic of Korea, Japan, Spain and Chile — dominate the supply picture. Because it is relatively easy to manufacture agar, a significant number of developing countries produce agar utilizing domestic seaweed supplies. Table 2 shows the estimated production in 1980, by country, of seaweeds for agar, as well as agar output levels and the number of manufacturing units, by country. Indonesia, Thailand and the Democratic Peoples Republic of Korea are known to produce and export agar-bearing seaweeds, but data are not available.

The supply of agar has recently been estimated as over 7 000 tons per year. These estimates are higher than those made by the Japanese industry, but are based on extensive

[1]See Appendix 2.