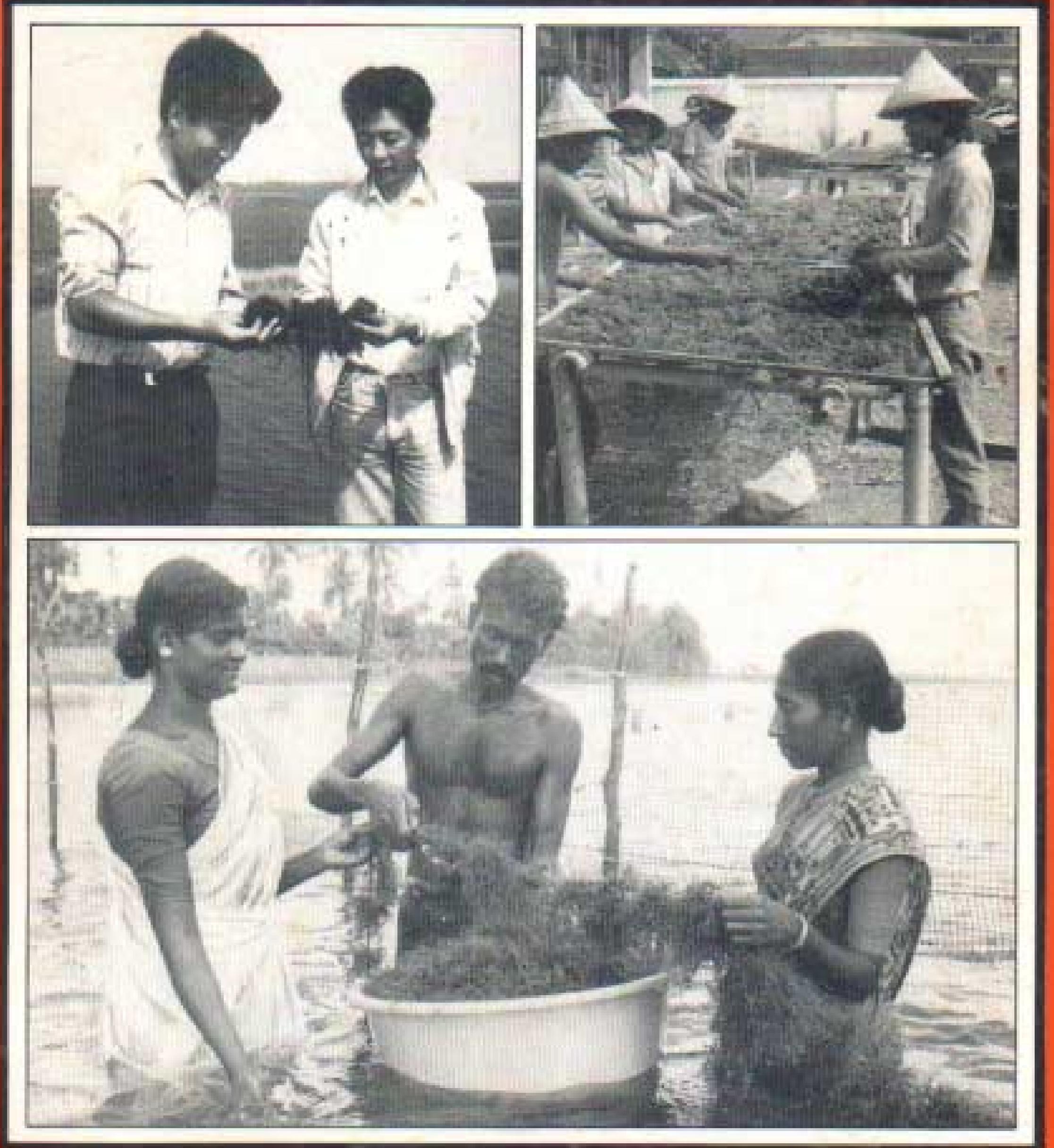
BOBP/REP/45

Report of the seminar on

GRACILARIA PRODUCTION AND UTILIZATION IN THE BAY OF BENGAL REGION

Songkhla, Thailand, 23-27 October 1989



BOBP
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GRACILARIA PRODUCTION AND UTILIZATION IN THE BAY OF BENGAL

Report of a seminar held in
Songkhla, Thailand, 23-27 October 1989

Bay of Bengal Programme for Fisheries Development.
Madras, India, November 1990.
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This report summarizes the proceedings of an international seminar on Gracilaria production and utilization in the Bay of Bengal, held in Songkhla. Thailand. 23-27 October 1989. It also includes 23 papers presented at the seminar by participants from various countries. A bibliography on Gracilaria, which was prepared in connection with the seminar, is being published separately.

The seminar was held to review current status of knowledge on the subject worldwide and to help point future work directions.

The seminar and the report on it were jointly sponsored by two projects of the Bay of Bengal Programme (BOBP)-the Small-Scale Fisherfolk Communities Project and the Post-Harvest Fisheries Project.

The Small-Scale Fisherfolk Communities Project of the Bay of Bengal Programme began in 1987 for a duration of five years. It is funded by SIDA (Swedish International Development Authority) and DANIDA (Danish International Development Authority). Its main aim is to develop, demonstrate and promote technologies and methodologies to improve the conditions of fisherfolk in seven countries bordering the Bay of Bengal-Bangladesh, India, Indonesia, Malaysia, Maldives. Sri Lanka and Thailand. The Post-Harvest Fisheries Project is executed and funded by the ODA (Overseas Development Administration of the United Kingdom).

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INTRODUCTION

The Bay of Bengal Programme began its involvement with Gracilaria farming in 1983 when technical and financial support was provided to the Fisheries Research Institute of the Department of Fisheries, Malaysia. Technical trials based on spore setting and outplanting off Penang Island were promising.

Over the years there has been considerable interest in the agarophytic resources of India, particularly along the Ramanathapuram coast of Tamil Nadu. Research by various institutes'indicated culture potential and in consultation with the Department of Fisheries of the Government of Tamil Nadu, BOBP initiated a pilot project involving two villages in Ramnad district.

Concurrently, a similar project began in Sri Lanka together with the National Aquatic Resource Agency and Sarvodaya Shramadana Sangamaya ; a prominent NGO with wide experience in the country. Various technical problems arose during the implementation of the two pilot projects, but information on current experience with Gracilaria production and marketing in the BOBP region was not readily available. It appeared an opportune moment to gather together as much expertise as could be assembled in one place and assess the "state of the art" in agarophyte culture, processing and marketing, as well as the extent to which natural resources were being managed. Consequently, BOBP in collaboration with the Government of Thailand, convened a regional seminar in Songkhla, Thailand, October 23-27, 1989.

All the BOBP member states sent representatives and in addition, scientists, technicians and business people came from Vietnam, China, Hong Kong, the Philippines, Sweden, the United Kingdom, and the USA. International organizations interested in seaweed production were represented by ICLARM, INFOFISH, NACA and of course, BOBP. Development strategists, scientists, commercial processors and technicians were among the 82 participants.

The seminar was the first regional convocation of the seaweed industry. No international seminar had ever dealt earlier with a particular genus (although there has been some mention of the closely related Polycavernosa).

The topical organization of the seminar reflected an interest in applied aspects of Gracilaria, and included sessions on the status of culture, small-scale processing, marketing, and on the management of natural resources of agarophytes. Twenty-four papers covered these areas of interest, of which seventeen dealt with culture and processing.

This report contains a summary of the seminar proceedings and papers presented at the four sessions - 24 papers in all.

SUMMARY OF SEMINAR PROCEEDINGS

Pond culture of Gracilaria

Almost all cultured Gracilaria derives from ponds: open water systems are still quite experimental in tropical waters. However, open water culture is operating commercially in the temperate waters of China; such systems have also been developed in Chile's cool seas.

Tide level and pond design are particularly important to ensure good flow of seawater. Access to both fresh and seawater enable the farmer to maintain salinity at an optimal level for fast growth. Sites should have protection from strong winds, and muddy sand or sandy soil is preferable. Several issues arose during discussions: Paramount is the high cost of developing new ponds; the soil requirements for pond construction can restrict the spread of the technology. There may be conflicts with mangrove forest conservation if new areas are developed, since such tidal forests are widespread in tropical Asia. Soil acidity could be a very serious problem in ponds established in mangrove forest soils, but reclamation of acid sulphate soils is a lengthy and expensive process.

It is possible to involve small-scale brackishwater pond farmers in Gracilaria culture as demonstrated by private industry in South Sulawesi.

Polyculture of Gracilaria

Gruciluriu may be polycultured with other seaweeds or with fish and prawns. Polyculture of ***Grucilaria*** and Eucheuma has been experimented with in Bali, Indonesia. Trials have employed small-scale open water technology. However, in pond culture, protocols for fertilization regimes for specific soil water types and for maximizing seaweed growth and agar quality are still lacking. The best stocking densities for seaweed, fish and shrimp remain to be worked out, as does the amount of residual stock that should be left after harvesting in order to maximize production. All of the development has been done by trial and error and may be an area for applied research.

Open-water culture : the problem of grazing

Rabbit fish (Siganus spp) are the main grazers and they can literally wipe out large seaweed farms. It appears that juvenile rabbit fish are largely to blame; seaweed farms located in shallow seagrass beds are particularly vulnerable, since this is their natural habitat.

It may be that open-water culture is only possible where natural stocks of the desired species of Gracilaria are found. In practical terms, this may not always be possible. Turbid lagoons may be preferable to more exposed sites. Results of culture trials in Songkhla Lake itself and from earlier BOBP work in Penang seem to bear this out. Fouling by unwanted epiphytes and invertebrates may seriously affect product quality. Open-water culture of Gracilaria has been commercially successful in the Caribbean (St Lucia) but such success stories are rare.

In Malaysia, land based intensive systems have been tested. While of technical interest, there would be little likelihood of such systems being taken up by fisherfolk because of the high capital cost and the level of managerial expertise required.

Selection and seeding methods

Culture systems of whatever nature require seed stock, and a number of questions arose concerning selection and seeding methods. All commercial production in the tropics derive from vegetative propagation rather than spore-setting. Parent plants are used to seed substrates such as stone blocks planted in open temperate waters in China. Similar techniques were tested in Hawaii with limited results but further work with this approach might be warranted in the tropics. Hatchery spore setting in Sri Lanka has been successful on a small scale.

As agar yield and gel strength vary greatly with species and even possibly within species according to variety, strain selection becomes difficult. Until the confusion over the taxonomy of Gracilaria is resolved, selection of strains will remain difficult. If there is a high degree of adaptation to micro-environments, how transferable will the results of strain selection be to new environments? Are the best species being cultured? Given the number of known species of *Gracilaria,* it was noted that only three (G. verrucosa, G. *tenuisripitata* and G. *edulis)* are cultured in Asia.

Seaweeds for human consumption

Seaweeds for direct human consumption are worth more than those destined for industrial use. The nutritional benefits of seaweed consumption were considered as a source of micro-nutrients (vitamins and trace elements). On the industrial side, problems are presented by variations in agar quality and composition as influenced by particular clones, light and nutrient conditions and the interactions of these factors.

The history of agar dates back to seventeenth century Japan. Consumption of seaweed as a fresh vegetable is probably an ancient practice; it is found today in places like Hawaii, Fiji, the Philippines, lndonesia and Malaysia. Home production of agar for puddings, soups and jellies can be found in Sri Lanka. Perhaps production for local consumption has scope for encouragement in some of the BOBP member countries.

World agar production

World agar production is estimated at 7,000 to 10,000 tonnes annually, and about half is from *Gruciluriu.* Japan is the top producer and consumer, but depends heavily upon imported *Gruciluriu* to meet national demand. In the BOBP region, Thailand, Malaysia and Indonesia are major importers of agar. In India, estimated annual production is 75 tonnes, but processing capacity may double if planned units come on line in the next few years.

Small-scale agar production

Small-scale, village level agar extraction has been tried in Thailand, Malaysia and India. In India, an attempt was made to adapt the Thai method to the village situation in Tamil Nadu, India. Inadequate dehydration before sun-drying has been difficult to overcome. In the village setting, the source of heat energy may also present difficulties. Wood is often the only fuel available and is costly.

Economic models can be used to set production targets, and demonstrate what technical problems influence profitability and how. However, there is a paucity of economic data and analysis for various agarophyte production systems now in use or being tested in the region.

Gel strength

International trade in dried *Gruciluriu* is based largely on gel strength; the higher the gel strength, the higher the price paid. Its measurement raised some questions: although the processing industry recognizes a standard method, it is not always used by investigators. Unlike other countries, the Indian industry does not use chemical treatments to upgrade gel strength. It is believed that Indian *Gracilaria* does not respond to such treatment. Local strains may be too high in sulfate or there could be some other environmental influences. Poor post-harvest handling could play a role.

There was disagreement on whether or not village industry could produce an agar of sufficient quality for the market. Several industrialists felt that it cannot and that villagers are better off concentrating on seaweed farming. Adaptive research could address the major problems in the village context — filtration, water removal and sanitation. Perhaps improved technology at this level is available from other countries. Japan has had a village industry for centuries. There are many small-scale agar plants in Taiwan, whose experience can be applied to local conditions in the BOBP countries.

All BOBP countries import agar, particularly the higher grades. The consensus is that world demand is increasing, but there is a lack of detailed information on the trade. A comprehensive study of world demand is needed in order to guide farmers, processors, investors and government policy makers.

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Marketing

Although trade statistics are often questionable, world production is somewhere between 7,000 and 10,000 tonnes annually. Of this, about 3,700 tonnes enter international trade. Dried seaweed (Ceylon moss) has been exported from Sri Lanka since at least the mid-19th century, according to historical data. The present day trade is only a fraction of past production: 5 tonnes compared to 150 tonnes more than 100 years ago! The decline does not appear to be due to the resource base, but rather due to changes in the fishery. Seaweed collection is not competitive with shrimp fishing as a source of livelihood.

In Sri Lanka there is an interesting local market for dried Gracilaria sold in small packets for home production of agar. Porridge flavoured with coconut milk and lemon juice is popular among fishermen in the seaweed-producing areas. It is sold by the glass in small roadside stalls. Home-made jellies are also sold.

Malaysia is one of the region's major consumers of agar and agar products, amounting to M$ 6 million annually. The Malaysian market could have a strong impact on future developments in farming and processing in the region.

Management of *Gracilariu* resource

There is considerable potential for increased production from well managed natural stocks; experiences in Chile are an outstanding example. Production there increased from 80 to 600 tonnes after management measures were introduced.

However, an effective management program depends upon knowledge of the reproduction, growth cycle, growth rates, regeneration capacities, productivity and the influence of environmental factors on biomass production of the stock in question. Unfortunately, very little work has been done on natural stocks of agarophytes in the Bay of Bengal region. Stocks are reported to be over-exploited in the main producing area of India, though firm evidence is lacking because there have been no recent surveys of the resource. Agarophytes have been inventoried at 31 locations in Indonesia, mainly in Java, Sulawesi, and Bali. In Thailand there is a potential harvest of ***Polycavernosa*** (closely related to Gracilaria) from the large number of fish cages in southern Thailand. During the discussions, it was suggested that this might lead to new farming systems utilizing natural spore collection on discarded fish net.

The confused state of taxonomy was a recurring topic for resource management, species must be clearly known before individual stocks can be identified. Comparative studies of species could also be advantageous for culturists as well as resource managers.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

PRESENT STATUS OF GRACILARIA CULTURE

by Gavino C Trono Jr

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ABSTRACT

Species selection for high agar yield and culture site evaluation arc the most crucial factors in seaweed farming for agar production. Seeds can be made available from either vegetative propagules or natural spore recruitment or induced spore-shedding in hatcheries. Gracilaria verrucosa, with high production rates and good gel quality, is preferred in pond culture due to its ability to adapt to a wide range of ecological conditions. Given optimum conditions, harvest of pond cultured ***Gracilaria*** may take place two to three months after seeding. Long line. raft method and substrate improvement are some of the methods applied in field cultivation.

1. Introduction

The increasing demand for agar, agarose and agaropectin is primarily due to the development of new applications of these seaweed products in the food industry, in specialized laboratory methods such as immunodiffusion, diffusion and chromatography techniques, bio-engineering, microbiology and biochemistry. A stable source of raw materials for the manufacture of these seaweed products is essential to meet this increasing demand.

At present, there are two major sources of tropical species of agar-producing seaweeds, namely from gathering natural stocks and from farming/culturing of these species. Production through gathering of natural stocks depends on the availability of harvestable stocks; this is greatly influenced by seasonal changes in the weather (monsoons) which in turn make supply seasonal. In addition, production is highly influenced by the harvest pressure of the previous season. These factors lead to a tendency for production from natural stocks to be unreliable. Production through culturing is more predictable and stable, and targeted outputs are easily attained. Cultivation entails man's intervention in the process of production. It involves a wide range of techniques, from the simple management of natural stocks to the complex propagation of selected clones and genetically bred hatchery seedstocks in capital intensive situations (Neisch 1978).

2. Considerations in the selection of species and sites for culture

The following points are important when considering the selection of species to be used and sites for culture:

a) The species targeted for culture must be fast growing and capable of being propagated utilizing vegetative propagules (cuttings) or spores. Species with large and robust thalli are preferred because they can produce a large amount of biomass within relatively short cropping periods.

b) It must have a high content of good quality agar. These considerations require that the available species be screened. Comparative studies on their productivity should therefore be conducted to determine the species to be selected. Because the properties of agar (gel strength. gelling and melting temperatures, amount of sulfate groups) differ among species, it is essential that the correct name be applied. Thus the taxonomy of the species should be clarified. The names are indices to the type and quality of agar that the Gracilaria contain and are used as the basis for determining prices.

c) The selection of sites is a very important factor to consider in both pond and field culture, because this will ultimately determine the success or failure of the farming venture. In general, sites which support natural stocks of the species to be cultured are good sites. If culture is planned in an area where no stock of the chosen species exists, then one should select sites which have ecological conditions comparable to the site where the stocks are found. This requires the gathering of data on parameters such as salinity ranges, nutrient (i.e. nitrate and phosphate} levels, turbidity, and type of substrate. Other ecological parameters such as degree of exposure to waves, depth of the water and accessibility should also be included in the evaluation of sites.

Natural Gracilaria stocks are generally found in areas which are characterized by calm water. high nutrient levels and shallow areas with sandy-muddy substrates. Sites for field culture should be located in areas which are protected from waves since Gracilaria have fleshy and fragile thalli and are therefore easily removed or broken by wave action. Species which are found in commercial quantities generally grow quite well in slightly brackish and highly fertilized waters, thus protected bays and lagoons are preferred. In tropical areas, *Gracilaria* species with a high potential for culturing are also found on reef, sandy flats, sandy, rocky and wave-exposed areas.

3. Production of Seeds

The term "seeds" as used here refers to both the vegetative propagules (cuttings) and spores which can he utilized as planting materials. The importance of the availability of a local source of seed materials is emphasized. These seedstocks may come from natural stocks or from cultivation. Gracilaria exhibits triphasic alternation of generations consisting of the gametophyte, sporophyte and carposporophyte. The latter, however, is microscopic and is parasitic on the female gametophyte. Thus, the large somatic stage consists of the gametophyte and the sporophyte. The results of studies on the populations of these two generations have shown that the sporophytes are generally more dominant than the gametophytes, i.e. they are usually larger in size and the population makes up the bulk of the biomass. It has also been shown that under pond culture conditions the alga may not develop reproductive stages. These factors are relevant in the selection of the type of "seeds" to be used in culture.

1. *Vegetative propagules (cuttings)*

Healthy stocks are selected for this purpose. They should have thalli which are fleshy and elastic in texture, dark reddish brown in colour, and are robust, well-branched with smooth and shiny surfaces. In addition, they must be clean, i.e. free from dirt and epiphytes. The preparation of the "seeds" varies according to the type of culture used, and these are described in appropriate sections of this paper.

2. *Spores us seeding material*

Two methods are presently used in the production of sporelings from spores: natural spore-recruitment and induced spore-seeding in hatcheries.

2.1 Natural spore recruitment

The use of spores as seeding materials for the production of sporelings for culture requires the availability of natural stocks. In the natural spare recruitment method artificial substrates such as ropes, rocks and netting are used. Ropes and netting are generally preferred because of their ease of handling during both the process of recruitment and cultivation. The use of ropes is a proven technique in the West Indies. The ropes are anchored or tied to wooden stakes among dense populations of Gracilaria. They are left in the area for about two weeks to allow the naturally shed spores to settle on them. The sporelings developing from the spores become visible after three to four weeks, and the seeded ropes are then transferred to the culture sites for outgrowing.

2.2 Hatchery production of sporelings from spores

The production of sporelings from spores requires skill in recognizing fertile materials, and selecting them from available stocks. Recognition of the fertile female materials is quite easy because of the highly recognizeable presence of cystocraps. These fertile structures appear as elevated mammilate "bumps" with dark coloured contents on the surface of the thalli. Cystocarps which

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have already shed their spores are pale in colour. In contrast the recognition of fertile sporophytic thalli is quite difficult because the tetrasporangia are microscopic and do not form apparent recognizeable structures. The use of a stereomicroscope is quite indispensable. Under low magnification, the tetrasporangia appear as dark purplish microscopic spots on the surface of the thalli. The presence of these structures has, however, to be counter-checked by examining sections of the suspected thalli under a compound microscope. The tetrasporangia are of the cruciate type and are embedded in the cortex of the thallis.

The hatchery production of sporelings requires a land-based set-up which may be sited some distance away from the outgrowing area. The set-up was first used in Penang, Malaysia. It is quite similar to those used in the seeding facilities for Porphyra and Laminaria although less sophisticated. It consists of a seeding tank with provision for control of water depth and an adjustable seeding material support structure. This structure consists of a wooden frame strung with monofilament netting material which fits into the seeding tank. It is provided with a mechanism that allows its height from the bottom of the tank to be adjusted.

Various types of substrates, e.g., pieces of gravel, shells or lines can be seeded. These materials are placed at the bottom of the seeding tank. The use of lines as a setting substrate requires an additional structure, i.e. a frame which fits the tank when laid flat on the bottom. The line may be monofilament nylon (90 lbs test as used in Malaysia), nylon braided ropes (ca. 3mm dia) or plastic tying materials. The line is wound evenly around the seeding frame, which is then placed at the bottom of the tank.

Fertile Gracilaria material collected from natural stocks is brought to the seeding facility. The moist materials are placed in containers, such as Styrofoam boxes provided with aeration holes, to avoid stressing which can affect the shedding and/or viability of the spores.

The fertile Gracilaria are then placed on the seeding support structure submerged in water in the seeding tank. The distance of the seeding materials from the seeding substrates (rocks, stones or lines in frames) should be adjusted to ensure the uniform distribution and density of the spores. The seeding materials are left in the tanks for two to three days to allow shedding of spores.

The seeded materials may be left in the tank for another one to three days to allow the spores to germinate and become completely attached to the substrates. The seeded rope is transferred to a holding tank or to a nursery area while waiting for the spores to develop into sporelings.

3. Production and selection of highly productive seedstocks

The utilization of highly productive species/strains with high quality natural product is essential for the successful farming of Gracilaria, or any crop for that matter. In species where it is easy to manipulate the individuals to be improved, hybridization utilizing the gametes may be the normal and logical way of improving the seedstocks. However, in Gracilaria and other species, where the techniques for manipulating the sexual process to produce hybrids are not well known, different methods of selection may be used.

One of these methods is species/strain selection. Different species/strains present in a natural population e.g., different species, various coloured strains, morphologically different thalli are selected. These different species/strains are then multiplied through cloning. Comparative ecophysiological studies are then conducted using these stocks. In situ studies on seasonality and production capacities of the various species/strains relative to changes in ecological factors such as salinity, temperature, nutrients and water movement are important in defining the field conditions which determine the productivity of the various strains, as well as the seasonal aspects of reproductive states and capacities of the various forms.

Physiological studies to determine the range in tolerance of the various species/strains to changes in ecological factors can be determined by manometric techniques using a respirometer, where the various factors can be accurately controlled. The photosynthetic/respiratory responses can be monitored under varying conditions of stress.

Analysis of the content and quality of agar in the various strains is also an indispensable tool for determining the qualities of the various strains or species as a basis for the selection of seedstocks.

4. Methods of culture

1. Pond culture

Although several species of agarophytes belonging to the genera *Gelidium*, *Pterocladia* and *Gracilaria* have been reported to he produced commercially through some form of farming in several countries (such as Japan, China, Republic of Korea, Vietnam, India and the Philippines), it is in Taiwan where the production of *Gracilaria* through pond culture has achieved a high degree of success. Here, an annual average of 12,000 tonnes of dried *Gracilaria* has been produced in recent years (Chiang 1981).

As stated earlier, the genus *Gracilaria* is characterized by the alternation of three somatic generations. Of these, it is the macroscopic, gametophytic and sporophytic stages which are used as planting materials in pond culture. Although the reproductive potential of *Gracilaria* through spores is high, vegetative propagation by cuttings is used in pond culture at present because of the very high regenerative capacity of the plant and the simplicity of the method. However, hatchery-produced seedlings from spores have been demonstrated to be superior in the open field culture of *Gracilaria* (Doty 1986).

Of the several species of *Grucilaria* presently used (e.g. *chordu*, *G. tenuistipitutu*, *G. edulis*, *G. verrucosa*, *G. lichenoides*, *G. compressa* and *G. giga*), *G. verrucosa* is the most popular due to its ability to adapt to a wide range of ecological conditions in ponds, its higher production rates and better gel quality. The culture of *Gracilaria* started in 1962 in southwestern Taiwan. Production in ponds is primarily influenced by three ecological factors, namely salinity, light and temperature. High production is recorded during the warmer months and growth is slow during winter. High light intensity adversely affects growth, and light conditions are controlled by adjusting the water depth in the ponds. Salinity of 15 to 24 ppt appears to be optimal for growth. The increase in salinity during the summer months is controlled by the addition of freshwater, thus farms need to be located near freshwater resources.

1.1 Site selection

Successful pond culture of *Gracilaria* depends greatly on the selection of appropriate sites. The following criteria are recommended for the selection of pond culture sites.

- the site should be located near seawater and freshwater resources;
- the area should be protected from strong winds;
- the pond bottom should be at or near the zero tide level and have a sandy-muddy substrate;
- the pH of the water should be slightly alkaline (i.e. 8.2 to 8.7).

Gracilaria are euryhaline and can grow in brackishwater under a wide range of salinity, although 15 to 24 ppt has been found to be optimal. Rises in salinity during the sunny months due to evaporation losses (reaching values as high as 35 ppt), or falls (to as low as 8 ppt) during the rainy season are detrimental to the crop. The maintenance of optimal salinity in the ponds requires a readily available supply of freshwater and seawater. The ponds should be located in areas protected from strong winds because there is a tendency for *Gracilaria* to accumulate on the leeward side of the pond. The formation of thick heaps of *Gracilaria* in one side of the pond causes shading, which has adverse effects on growth.

Water management is greatly influenced by the tidal changes in relation to the elevation of the pond bottom. Ponds located in areas where the bottom is at, or a little above, the zero tide level are easily managed as water exchange is easy.

1.2 Culture ponds

The average size of ponds for the culture of *Gracilaria* is about one hectare or smaller. Smaller ponds are easier to manage than larger ones because they are less susceptible to the influence of winds. Pond management is also easier when *Gracilaria* is polycultured with shrimp and/or crab. Provision of entrance and exit gates facilitate proper water management.

The depth of the ponds vary from 50 to 80 cm. The bottom is generally of clayish loam, silty loam or sandy loam. It has been observed that in ponds with a sandy bottom, *Gracilaria* easily gets buried due to the effect of wind. This problem, however, could be resolved by increasing the depth of the water during windy periods. In larger ponds, wind-breaks consisting of bamboo slots are installed perpendicular to the direction of the wind to prevent the seaweed being transported to one side of the pond.

1.3 Culture method

The following method is generally followed in the pond culture of *Gracilaria*. The ponds are dried for several days, and then water is introduced. Healthy stocks (see earlier criteria) are selected as planting materials. The planting material is transported from its source to the pond site early in the morning to prevent its exposure to the sun. During long-distance transport it is frequently sprinkled with seawater, and perforated bamboo or plastic pipes are inserted into the bottom of the heap to provide aeration. The plants must be placed in the water of the pond immediately upon arrival. The planting material is then cut into pieces and is broadcast uniformly on the bottom of the pond. In Taiwan, stocking is usually carried out in April at a density of 5,000 to 6,000 kg of chopped *Gracilaria* per hectare.

1.4 Pond management

The water is maintained at a depth of approximately 30 to 40 cm above the algae. However, the depth is increased to 60 to 80 cm during the warm summer months to prevent a significant rise in the water temperature. Water depth is also increased during the cold winter months to avoid temperature drops below 8°C which are lethal to *Gracilaria*.

Frequent exchange of water is necessary to maintain the optimum temperature in the ponds. The water is changed every two to three days, when about 50 to 75% of it is drained and replaced with fresh seawater. The growth of *Gracilaria* is enhanced by adding either organic or inorganic fertilizers. In Taiwan, weekly application of urea at 3 kg per hectare was found sufficient. Fermented pig manure may be applied at 160 to 180 kg per hectare two to three days after changing the water.

1.5 Harvest and post-harvest activities

Under optimum conditions, the crop may be harvested two to three months after seeding. Cropping may be done every 10 to 40 days, either manually or by using scoop nets. The frequency of harvests is dictated primarily by the market price and the season. Approximately 30 to 40% of the biomass is harvested during each cropping. The crop is thoroughly washed in pond water to remove the silt, sand, pieces of shells and other extraneous materials such as snails and other algae. The clean *Gracilaria* is spread uniformly on bamboo screens or plastic sheets for drying. An average wet to dry ratio of 7:1 is generally attained.

Standards set by the Bureau of Standards in Taiwan for the export of dried *Gracilaria* require that the product should not contain more than 1% of mud and sand, not more than 1% shells and not more than 18% other seaweed species. Moisture content should not exceed 20%.

Dried *Gracilaria* is then packed into sacks of 100 kg weight which are either exported or sold to local processing plants. Ten to twelve metric tonnes of dried *Gracilaria* are produced in a hectare of pond.

1.6 Polyculture with shrimp and/or crab

Polyculture with shrimp (*Penaeus monodon*) and/or crab (*Scylla serrata*) is carried out mainly in Ping-tung prefecture in southwestern Taiwan. Stocking material for a hectare of farm consists of 4,000 to 5,000 kg of *Gracilaria*, 5,000 to 10,000 crabs and 10,000 to 20,000 shrimps. Crushed trash fish and snails are generally used as feed for crab. Crabs are harvested after three months, and the shrimp after four to seven months. Survival rates as high as 80% for crabs and 80 to 90% for shrimp have been documented, making this polyculture one of the most profitable aquaculture methods in Taiwan. The net income from polyculture has been shown to be three times that from monoculture.

In the Philippines a group of 40 fish farmers in Iloilo are producing *Gracilaria* in their multi-crop fish farms, using cuttings as seedstocks. Unlike Taiwan, they do not use fertilizer; instead, they allow daily water exchange by tidal flow to ensure adequate nutrient supply for the seaweed. The ease of water management is enhanced by siting the bottom of the ponds at, or slightly above, the zero tide level. Problems with water management are encountered when ponds are located away from both fresh water and sea water sources, and where the level of the bottom of the ponds is way above the zero tide level making water changes a major problem. In such ponds water changes can only be facilitated during extreme high tides, and maintenance of adequate nutrient levels and control of water temperature are difficult. Large size ponds are subject to problems caused by wind generated waves referred to earlier. Provision of wind breakers such as "bamboo blocks" and "net blocks" in the ponds perpendicular to the direction of the prevailing winds (as practiced in Taiwan) has proved effective and led to increased production compared to ponds without them.

The development of blooms of other algae such as filamentous blue greens and greens is a major problem in the Philippines. These algae may totally displace ***Gracilaria,*** or else they become so mixed with ***Gracilaria*** that it is impossible to remove them, resulting in dried materials of very low quality. The problems of blooms of epiphytes and other weeds are being controlled by the introduction of grazers such as Tilapia and milkfish. However, the size and number of these grazers must be controlled otherwise these may consume the ***Gracilaria.***

Pond culture of Gracilaria is also being carried out in Vietnam, Thailand, Indonesia, Hainan and Hawaii.

2. Field culture

Several methods are currently being utilized in the field culture of ***Gracilaria.*** The "seeds" used in these various methods are cuttings or sporelings produced from spores.

2.1 Fixed bottom type of culture

2.1.1 Long line method

In this method, three-strand polyethylene ropes 5-8 mm thick and five metres long are generally used. Other materials such as coir or abaca ropes may also be used. In the West Indies, where the mariculture of sea moss (Gracilaria) is most successful, both sporelings produced from spores and cuttings are utilized as "seeds" in the fixed long line method as well as in the raft method.

The seeding of long lines using cuttings consists of untwisting the rope and inserting bunches of cuttings between the strands of the rope, the seedlings passing twice or three times through the rope. This method ensures that the cuttings are securely held in place. The seeding of the ropes is done in the shade, where the seedlings are placed in basins of sea water to prevent them becoming dehydrated.

The support system for the long lines consists of rows of wooden stakes driven into the ground. The distance between stakes in the row is about one metre, while the distance between rows varies between 4-5 metres or longer. The seeded rope is tied to a stake, stretched tightly and rhe other end tied to the opposite stake in the next row. In the West Indies, two seeded ropes are usually tied to a pair of stakes.

The same technique is supplied for ropes seeded with spores. In Malaysia, unbraided plastic rafia seeded with hatchery produced sporelings was used as long lines. In India, longer ropes are used and additional stakes are provided to prevent the ropes from sagging to the ground. The distance of the seeded ropes from the ground varies depending on the depth and clarity of the water as affected by tidal changes. This'method of field culture is presently being utilized in the West Indies, Myanmar, India, Brazil and Sri Lanka.

2.1.2 Chilean method

The field culture method presently used in Chile is quite simple but has proved very successful. The anchoring system for the seedstocks (cuttings) consists of plastic bags one metre long, 0.1 mm thick and 4 cm in diameter. The plastic bag is filled with sand and the two ends are knotted. Five bunches of seedstock are fixed to the same side of the sand-filled bags by rubber bands.

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The seeded bags are arranged in rows on the substrate and are positioned in such a way that the bag serves as an anchoring weight. The middle of the cuttings are weighted by the bag against the surface of the substrate and their tips freed.

The use of rocks as anchoring units for the cuttings is effective. However the use of both sand-filled bag and rocks as anchoring materials for cuttings was only efficient in sites which are not exposed to strong surges or waves. Evaluation of the efficacy of this system showed that more than 60% of the biomass could be lost due to removal of thalli by strong surges, and rocks were observed to be more easily dislodged from the substrate than the sand filled bags.

2. 1 .3 Improvement of substrates

This method can only be utilized in areas where natural beds are found. The introduction of artificial substrates such as rocks, shells, bamboo or wooden stakes, etc. in the site provides additional favourable substrates for the spores to settle or fragments of thalli to attach. Most of the beds of commercially important species of Gracilaria are found in shallow bays and coveswhere the substrate is generally particulate (sand-muddy). The survival and growth of spores is greatly enhanced by the availability of solid substrates. Studies of the influence of solid substrates on biomass production have shown that production more than doubled in portions of the beds where solid substrates had been introduced.

2.2 Raft method

The raft method is popularly used in West Indies in areas where bamboos are available. The raft generally measures 2 x 4 metres in size. Seeded long lines are tied to the shorter bamboo frame, stretched tightly and fixed to the opposite side of the raft. The distance between ropes varies, but about 12 to 14 lines may be planted to one raft.

In India, coir ropes fabricated into network of 7 cm mesh size was used on a 2 x 2 metre raft. The same method of seeding was utilized.

A variation on this method has been developed in the People's Republic of China. Pieces of rope about 70 cm long seeded with Gracilaria cuttings are hung horizontally on the low fixed raft or vertically along a long line floating raft.

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GRACILARIA CULTURE IN CHINA

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ABSTRACT

Gracilaria verrucosa is the most common species in China and one of the main raw materials for agar production. Experiments showed that spore release is maximum between 8 a.m and 10 a.m, after short desiccation of the mature plant and in seawater with a temperature of 20-25ºC and a salinity of 19-27 ppt.

The spores will grow well above 15ºC, in strong light intensity within 3000 Lux and in salinity range of 23-27 ppt. The *Gracilaria* thalli are tolerant to wide salinity ranges. Outdoor as well as indoor collection of spores are the methods used in rearing of seedlings. Farming is done by means of mud flat or intertidal culture, floating culture or pond culture.

I. Introduction

A number of agarophytes, including *Grarilaria*, *Gelidium* and others, have been used in China as marine vegetables or traditional medicinal herbs for over 1,000 years. However, these seaweeds became an industrially important raw material for processing agar only some decades ago.

Agarophytes in China are mainly represented in three genera of Rhodophyta, *Gracilaria*, *Porphyra* and *Gelidium*. Among more than 30 species of agarophytes, *Gracilaria verrucosa*, *G. tenuistipitata*, *Gelidium amansil* and *Porphyra haitanensis* are the major ones. In addition, other red seaweeds, such as *Pterocladiu* sp., *Gelidiella* sp. and *Ceraminum* sp. are often collected and mixed with the main agarophytes mentioned above and used for producing agar.

China is a major world producer of cultured seaweeds. The total annual production of cultured seaweeds is about 300.000 dry tonnes** Of these, *Laminaria* and *Porphyra* account for 200,000-250,000 tonnes and 20,000 tonnes respectively. *Gracilaria* production is about 5,000 tonnes per annum (Shang, 1976; Chiang, 1981, Yang et al., 1981; Chueh and Chen, 1982; Zheng, 1987). In China, *Laminaria* is a main marine vegetable and raw material for extracting iodine, mannitol and alginate. *Porphyra* is also a popular marine vegetable. But in recent years some phycologists have observed that a considerable quantity of *Porphyra* thalli obtained from the later harvests during the season can be used for processing agar. These later croppings have less edible value.

At present *Gracilaria* and *Porphyra* are the most important raw materials for producing agar. Although *Gelidium* has long been considered as the best raw material for processing agar,it **is** not the ideal cultured species because of its slow growth and low yield. On the other hand, *Gracilaria* is easier to farm. It is expected that a higher output can be obtained in farming conditions. Shang (1976) reported that the average productivity of dry *Gracilariu* in Taiwan ponds was 7-12 t/ha/year. A few years later Chiang (1981, P. 573) observed that 16-43 t/ha/year could be expected. So it is believed that there will be a substantial development of *Gracilaria* culture in China to meet the increasing demand of the agar market.

In the present review I shall first discuss some genera1 ecological characteristics of *Gracilaria* which are especially important to its commercial production, and subsequently review the farming practices developed for the species.

** Weights of seaweed production provided refer to dry weight only

2. Biology of *Gracilaria*

Gracilaria verrucosa is the most common species in China. It grows fast and has a high agar content. Following is a discussion on the influence of the various environmental factors on the release and germination of spores and the growth of thalli of the spores.

2.1 Influence of environmental factors on spore release

Both carpospores and tetraspores are released naturally into seawater after their maturation. Experiments showed that the maximum quantity of spores is released from 8 a.m. to 10 a.m., gradually decreasing thereafter. The minimum quantity is released between 10 p.m. and 6 a.m., after which the next maximum will take place. Besides the diurnal changes in release rhythm, the quantity of spores released also depends on ambient environmental factors. (Zheng, 1987).

2.1.1 Deciccarion

In general, when a mature *Gracilaria* is taken out of seawater and kept in a shady spot for two to four hours (air temperature 15-25ºC), the tetraspores or the carpospores will be released if the plant is dipped in seawater again.

2.1.2 Seawater temperature

Experiments have shown that the highest number of spores are released at 20-25°C. According to field surveys, the reproductive season of *Gracilaria* is between June and August in northern coastal provinces or between March and May in southern China. During these seasons, the natural sea-water temperature is 20-25°C. The experimental results coincided with natural reproductive seasons (Zheng, 1987).

2.1.3 Specific gravity of seawater

When mature plants were kept in seawater of different specific gravities, those in seawater of lower specific gravity would release spores earlier than those kept in water of higher specific gravity. If the plants are put in seawater with an obviously low specific gravity(<1.005), the released spores will swell and even break up due to osmosis caused by the low salinity and most of them will not complete normal germination. In order to obtain good results in the collection of spores, the optimum specific gravity range of 1.015 (19.0-20.2 ppt) to 1.020 (25.5-26.9 ppt) should be observed (Zheng, 1987).

2.2 Influence of environmental factors on germination and growth of the spores

Gracilaria spores just released into seawater measure around 30 um in diameter but this varies with species. Tetraspores are slightly bigger than carpospores. For example, the tetraspores of *G. tenuistipiruta* have a diameter of 24-55 um, and the carpospores 23-40 um. Soon after release, the spores will attach to substrates and start first cleavage of cells. The germination and growth of spores are also influenced by amhiect environmental conditions such as seawater temperature, light intensity and salinity (Zheng, 1987).

2.2.1 Seawater temperature

To examine the germination and the growth of the spores, specimens attached to slides for 12 hours were placed in sterilized seawater enriched with 1 ml of 1 M KNO, and 1 ml of 0.1 M KH_2PO_4 per litre of seawater medium, and incubated with a light intensity of 400 Lux, photoperiod of 10:14 for different periods of time (Zheng, 1989).

The results showed that both tetraspore discs and carpospore discs need a seawater temperature higher than 15°C. Even if all other environmental conditions are suitable for their growth, they would survive but grow very slowly (Zheng, 1987).

2.2.2 Light intensity

Light intensity is one of the most important factors that influence the germination and growth of spores. When the light intensity is stronger, the rate of germination and growth of spores are higher within 3,000 Lux. If the spores attached to slides are kept in a dark place they will die in 20 days.

2.2.3 Specific gravity of seawater

Although Graciluria plants prefer to inhabit estuarine areas, their spores are unable to withstand seawater with low salinity. If the spores attached to substrate are put in seawater with a specific gravity below 1.010, (12.5-13.7 ppt) their cells swell up due to the absorption of water into the cells. The colour of the pigments in the cells becomes pale, and the spores eventually die. Experiments proved that the optimum specific gravity of seawater for germination and growth of spores ranges from 1.018 (23.0-24.2 ppt) to 1.025 (25.5-26.9 ppt) (Zheng, 1987).

2.3 The effect of environmental factors on growth of Gracilaria thalli

The effects of environmental factors on Graciluria thalli are similar to those on their spores, but not entirely the same. For instance, as mentioned above, spores kept in seawater with a specific gravity below 1.010, will break up and die, but the thalli can grow very well in the same conditions. In view of this, ambient environmental factors required by Gracilaria thalli must be studied.

2.3.1 Specific gravity of seawater

Gracilaria are euryhaline seaweeds. Under natural conditions, the specific gravity in which the plant can grow out ranges from 1.005 to 1.026 (5.2-38.1 ppt), Experiments and field surveys have shown that the optimum specific gravity is 1.010-l .020 (11.3-30.1 ppt) where freshwater regularly flows in (Zheng, 1987).

2.3.2 Seawater temperature

Gracilaria are eurythermal plants which can grow at 5-30°C. Optimum temperature varies with species. For example, the optimum temperature for G. verrucosa is 15-25°C. They can be found in northern China during May to August, but in south China only in winter and spring. In summer, the growth of Gracilaria is almost completely stopped in the south until late autumn when the water temperature drops below 25°C and the seaweeds resuscitate.

Field surveys have shown that the optimum seawater tzmperature for G. tenuistipitata, a species mainly distributed in Guangdong and Hainan Island, is identical with G. verrucosa. When the water temperature is 30° C, its diurnal growth rate measures 0.1-0.2 cm/day but as the temperature continues to fall to 28ºC, the growth rate increases to 0.4-4.5 cm/day. When the temperature is from 15-25ºC, growth rate can be higher than 1 cm/day.

2.3.3 Light intensity

The growth of Gracilaria requires a high light intensity. It has been shown that growth rates of seaweeds vary when they are planted at different depths of water (Zheng, 1987).

The study showed that the Gracilaria can grow well in water less than 1 m deep where the seawater transparency is around three metres. If the seaweeds are planted in seawater deeper than three metres, they not only stop growing but start rotting as well.

Dissolved oxygen was measured in seawater collected from different water depths where Gracilaria is located. The results showed that Graciluria exposed to the maximum light intensity also has more intense photosynthetic activity. As the plants are located beneath 3 metres depth, their respiratory intensity exceeds the photosynthetic intensity. This explains the finding that the amount of dissolved oxygen in the seawater of the experimental groups was less than that of the control group in which no Gracilaria were present.

3. Farming

China has **more** than 30 years' history of Gracilaria farming. According to the specific biological characteristics of the seaweeds, different methods of collecting spores and farming thalli have been studied and practised. This includes collecting natural spores, artificial outdoor collection of spores, indoor spore collection, mud flat culture, floating raft culture and pond culture.

3.1 Rearing of seedlings

3.1.1 Outdoor collection of spores

The procedure involves four steps: selection of site. preparation of substrate. collection of parent plants (tetrosporophyte and/or carposporophyte) and collection of spores.

1) Site selection: A suitable site for collection of spores should be an intertidal flat area with a hard bottom and clear seawater with a specific gravity range of 1.010-1.025 (12.5-33.4 ppt). A large spherical dwarf dam 20-30 cm high is made at the selected site to store seawater after ebb tide.

2) Preparation of substrate: Cheap substrates like stones, shells or broken corals can be used. These substrates have a clean surface for easy attachment of spores. If the substrate is stone, each block should weigh about 0.5 kg, the total amount is about 600 tonne stones per ha. For shell, 120 tonnes per ha is sufficient. The substrate is spread on the selected site. In recent years, artificial fibre (e.g. nylon, polyethylene) ropes or nets have been used to collect spores. The texture of these materials is good but the cost is higher. Used or worn fishing nets can be used as cheaper substrates.

3) Collection of parent plants: The parent plants must be fully mature with a dull red-brown colour and without rotted spots. In fully mature plants, the sporangia are easily seen on the entire surface of the plant body.

4) Treatment of parent plants: Parent plants are washed with clean seawater to get rid of mud or other matter and allowed to air dry on bamboo curtains for two to four hours until irregular corrugations appear on the plant surface. At this time, the seaweeds can be spread in a selected site with substrate. The quantity of parent plant required is about 300 kg per ha.

As soon as the parent Gracilaria are planted in seawater, they release a great quantity of spores into the seawater. The spores will settle down on the substrate in one day. Under natural conditions, the germination of spores is very fast. They will turn into dish-shaped thalli in five days.

Another method is to put the desiccated seaweeds into a vat and stir them vigorously with a stick to stimulate release of spores into seawater. About two hours later, the seawater containing a huge quantity of spores can he sprayed into a selected site.

3.1.2 Indoor collection of spores

The main steps followed in indoor collection of spores are similar to those in outdoor collection. The only difference is that the spores attached to the substrate will be kept in indoor tanks for rearing until they grow into young plants.

3.2 Culture methods

3.2.1 Mud flat or intertidal culture

The main feature of this culture method is that the spore collection and farm sites are usually the same. In southern China, in late autumn or early winter, young Gracilaria can grow up to S-6 cm long as they enter a period of faster growth rate. At this stage, the substrate to which young Gracilaria are attached are kept in lines on the bottom, which serve as a walkway, at an interval of 30-40 cm. Routine management practice involves removal of miscellaneous seaweeds, collection of herbivorous gastropods and so on. Women and children often do this. In a normal season, 1,500 kg (dry) of Gracilaria can be harvested.

3.2.2 Floating culture

The method has been adapted from kelp farming. In a suitable season, such as January in southern China or May in the northern part, young seaweeds collected from other fields or reared in indoor tanks are pulled up from the substrate and inserted into “seedling ropes”, which are made of palm thread or artificial fibre. In each 20 metre rope, 200 pieces of seaweed can be inserted at 10 cm intervals. The seedling ropes are then fixed to a floating raft. Three months later, the seaweeds will **reach** a length of over one metre and can be harvested giving yields as high as 3000 kg (dry) per ha.

3.2.3 Pond culture

Pond culture of seaweeds has been adopted by Taiwan's phycologists and farmers since the 1960s. Before 1962 agarophtyes were very scarce in Taiwan, and had to be imported. Phycologists and farmers tried to rear Gracilaria in ponds with milkfish. Unexpectedly good results were obtained and many farms began to change the main cash crop from milkfish to Gracilaria. At present, Taiwan produces 12,000 tonnes fresh weight of Gracilaria annually from 300 ha of ponds (Chiang, 1981).

The stock seaweeds are cut into pieces and spread in the fish pond at a density of 5-6 tonnes of fresh thalli per ha. Chemical fertilizer or pig manure is applied regularly. Every 30-45 days, most parts of the seaweeds can be harvested leaving the rest of the body in the ponds as stock. The harvesting period lasts six months from June to November in the northern region.

This method is also being used in the southeast region where the lesser inputs and higher production make it an attractive proposition.

4. General Comments

Although satisfactory results have been obtained by several Gracilaria culture facilities, there have not been the great advances in production to match those achieved in Laminaria or Porphyra farming. The main reason for this is a lack of balance between production cost and market price. Indeed the lower market price is inhibiting the development of Gracilaria farming.

In recent years, Gracilaria farming has become popular because of the increasing demand from the agar processing industry. A main production zone of Gruciluria has grown up in Southern China (including Guangdong, Guangxi and Fujian provinces) where seawater is warmer and rich in nutrients suitable for growing Gracilaria plants. Liu (1987) reported that there are four species (G. verrucosa, G. tenuistipitata, G. gigas and G. bursa-postoris) which are suitable for farming. His experiments and investigations have shown that it is possible to obtain an average yield of two to three tonnes per ha. He suggested that the acreage under farming of Gracilaria can be expanded to 6700 ha in Guangdong Province to produce 15,000 tonnes (dry) of high quality Gracilaria. Technical progress and advances in Gracilaria farming will further reduce the production cost and improve product quality. The following suggestions are made to improve the culture, production and utilization of this agarophyte:

(1) High priority should be given to selecting species with faster growth rates and higher contents of good quality agar.

(2) Adequate measures should be taken to protect natural stocks of Gracilaria to prevent over-exploitation of natural stock.

(3) Polyculture of finfish and shellfish with Gracilaria offers several advantages. For example, the autophyte seaweeds can improve the quality of water contaminated by cultured animals; Gracilaria is a superior fodder for abalone which has a higher price in the world market. Gracilaria farming can supply feed to abalone farms, while abalone farming would also help to promote agarophyte farming.

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SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

EUCHEUMA AND *GRACILARIA LICHENOIDES*: A CO-FARMING POSSIBILITY

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ABSTRACT

Gracilaria lichenoides was observed to be growing well among Eucheuma on farms in Bali, Indonesia, without adversely affecting its growth or that of the Eucheuma. This observation led to the conclusion that co-farming of Eucheuma and G. lichenoides can benefit the Eucheuma farmer through additional income from the sale of Gracilaria. However, more studies should be done on the ways and means of co-farming Eucheuma and Gracilaria lichenoides, and also on establishing G. lichenoides as an important member of the agarophyte family.

Introduction

Studies on the biology and agronomy of Eucheuma were conducted at Geger Beach, Nusa Dua, Bali, Indonesia from June, 1986 to October, 1989. The experimental site is also the farm of about 50 families who are cultivating Eucheuma coftonii and Eucheuma spinosum. During the experimental period, Gracilaria lichenoides was observed growing among the Eucheuma plants on stakes, ropes, lines and rafts.

Since we were not interested in the culture of G. lichenoides, these seaweeds were considered as pests and were usually removed from near or around the Eucheuma during farm maintenance operations.

Recently (September-October, 1989), we became interested in the G. lichenoides because we observed that the farmers were also gathering these plants and selling them to the local traders who, in turn, wash the dried Gracilaria in fresh water and after re-drying sell them at the market at Denpasar, Bali.

Preliminary cultivation studies on G. lichenoides

Wild G. lichenoides were collected from the stakes, ropes, and rafts where they were growing. They were divided into uniform fifty gram cuttings and then tied with nylon nettings. The propagules (cuttings) were cultured in the same way as Eucheuma, by tying them to the lines attached to a raft (floating culture system) at intervals of 20,25, and 30 cm. along the line. The plants were harvested six weeks after planting just like the Eucheuma.

The fresh harvest weight of G. lichenoides six weeks after planting is given in Table 1.

Table 1 Distance of Planting (cm.)

Propagule No	20	25	30
1	200	205	150
2	210	210	190
3	220	150	220
4	220	240	250
5	17.5	255	240
6	245	230	245
7	200	250	250
8	230	300	270
9	210	225	260
MEAN	212	229	230

The growth ratio (harvest weight/propagule weight, H/P) was computed by dividing the mean harvest weight by 50 grams which was the weight of the initial propagule. The results are given in Table 2.

Table 2

Distance of Planting	H/P ratio
20	212/50 = 4.24
25	229/50 = 4.58
30	230/50 = 4.60

The data show that the ***Gracilaria*** can tolerate closer planting, and suggest that they can be planted alternately between ***Eucheuma*** plants.

The percent dry matter yield (% DMY) was determined by drying 2070 grams of fresh G. ***lichen-oides;*** this produced a commercially dry weight of 180 grams. Hence, the percent dry matter yield (% DMY) = 180/2070 x 100 = 8.69%.

The wet-to-dry ratio was therefore:

100/8.69 = 11.5

The result of this preliminary study showed that there is a potential for growing the ***Eucheuma*** and ***G. lichenoides*** together. The potential yield for a one-hectare farm of ***Eucheuma*** and ***G. lichenoides*** is shown in Table 3.

Table 3

Species	Weight of Propagules	H/P ratio	Net fresh Harvest	% DMY	Dry-Yield per ha per Ha (MT)	Sq. M (KG)
E.cottonii	16	5.0	60	12	7.0	0.70
G. lichenoides	8	4.0	32	8	2.8	0.25

The potential annual income (US $), assuming eight harvests per year has been calculated and is shown in Table 4.

Table 4

Species	Dry Yield/Ha/Yr (Tonnes)	Farm Gate Price (Per tonne)	Gross Income
E. cottonii	56	$350	$19,600
G.lichenoides	20	$450	$ 9,000
TOTAL	76		$28,600

Conclusion

The above data show that there is potential for farming ***G. lichenoides*** together with the ***Eucheuma.*** This can be done by planting the ***Gracilaria*** between the Eucheuma propagules. By doing this, the farmers could increase their incomes by an amount equivalent to about 50% of the yield and value of the ***Eucheuma.***

There are possibly many other ways of co-farming ***Eucheuma*** and G. ***lichenoides.*** Studies on this aspect should be done by interested researchers.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

THE CULTURE OF *GRACILARIA VERRUCOSA* IN TAM GIANG LAGOON, THUA THIEN HUE PROVINCE, S.R. VIETNAM

by Tran Dang Tra

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ABSTRACT

Gracilaria verrucosa is one of the aquatic plants which have been widely researched in the fisheries sector of Vietnam. Because of its wide distribution, fast growth, long annual culture time and capacity for harvesting several times a year, it was chosen as a species for culture in brackishwater coastal areas. Further, its culture is labour-intensive and generates substantial economic benefits.

1. Resource Survey, Biological Characteristics And Experimental Culture Of Gracilaria Verrucosa In Vietnam

Since 1963 Vietnamese scientists, and experts from the German Democratic Republic led by Prof. Dr. W. Brucker, have carried out surveys to determine the genus, species and distribution of seaweeds along the coast from Mong Cai district (Quang Ninh province) to Vinh Linh district (Quang Tri province). Surveys carried out by the Research Institute of Marine Products, Nha Trang Institute of Oceanography, Nha Trang Fisheries University and University of Hue gave additional information for all brackishwater areas along the coast of Vietnam. The results showed that there are 16 species of seaweed along the coast of Vietnam, of which ***Gracilaria verrucosa*** is predominant in terms of its distribution area, biomass and agar content and quality.

Research on biological characteristics, seed production techniques and intensive cultivation of ***G. verrucosa*** has been carried out continuously since 1963. In 1977, the Ministry of Fisheries approved a method for the bottom culture of ***Gracilaria verrucosa*** with a productivity of 10 tonnes/ha/year.

Between 1979 and 1988, some localities applied this method effectively, getting productivity-of 10 tonnes/ha/year, but the technology has yet to become stabilized and applied on a large-scale. However, in small ponds (200-1000 m^2) at the Research Institute of Marine Products at Qui Kim, Hai Phong, productivity averaged 35 tonnes/ha/year.

The overall results showed that ***G. verrucosa*** is distributed widely in brackishwater lagoons in Vietnam, where the bottom is sandy mud, muddy sand or muddy. If the bottom is sandy, the growth is low; if the bottom is muddy the individual size of the organisms is reduced. In general, seaweeds can tolerate salinity from 5 to 35 ppt, and a water temperature of 38°C to 40°C. For G. ***verrucosa,*** salinity from 10 to 22 ppt, temperature from 20°C to 25°C, pH from 7.5 to 8.5 and water depth from 40 to 80 cm are the ideal conditions. Experiments on pulse fertilization showed that a compound of fertilizers consisting of 3 mg/l $(NH_4)_2SO_4$ + 3 mg/l $NaNO_3$ + 0.6 mg/l $Na_2H_2PO_4$ was the most effective.

Pulse seed fertilization should last for only 4 hours, and be carried out in light rather than dark conditions. To limit the influence of foreign seaweeds on ***Gracilaria verrucosa,*** we should:

- improve pond conditions by ploughing the bottom and adding lime and organic fertilizer (0.2-0.5 kg/m^2);
- culture seaweed at an initial density of 500 g/m^2;
- intensify water supply/drainage for culture ponds.

Though the potential is great, the production of cultured seaweed in Vietnam is still low. Even in the best year to date (1987), production was only around 700 tonnes (dry weight), one third of which was harvested in natural habitats. The area available for seaweed culture in the whole

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country in the next decade will be about 2000 ha of which Thua Thien Hue province nas the largest area upto 770 ha in the Tam Giang lagoon system.

2. Topographical and ecological conditions at Thuan An seaweed farm in the Tam Giang lagoon system

The Tam Giang lagoon in Thua Thien Hue province is a continuous system of large bodies of water. Outside, the lagoon is surrounded by a long line of sand stretching from the mouth of the Tu Hien river to the estuary of the O Lau river, connected with the sea by the two estuaries of Thuan An and Tu Hien in the East. Inside the lagoon is the mainland of Phu Loc, Huong Phu and Huong Dien districts and Hue City. The total lagoon system is over 60 km in length. Due to the gently sloping bank the inshore part of the lagoon is shallow. In the dry season, the average water level is less than one metre. The depth in the middle of the lagoon is about 2 m but in some places up to 4-5 metres. The'speed of the river current is about 4.5 km/hr in the dry season, but in the rainy season it can reach 20 km/hr. The bottom structure is different: along the coast it is often sandy or muddy sand, in the middle of the lagoon it is often muddy or sandy mud. At the mouths of rivers one finds crude sand and hard terrain. The tide is semi-solar and irregular, and its amplitude is low (about 0.5-0.8 metres).

Thuan An seaweed culture lagoon is 2 km west of Thuan An estuary and is surrounded by dykes with gates and canals for regulating water.

In,1977-78, 10 ha of experimental ponds comprising eight small 0.5 ha ponds and one large (6 ha) pond were constructed.

In 1983-84, three additional ponds of 11 ha, 22 ha and 17 ha were constructed.

Another 50 ha were added in 1985-86, of which 20 ha were transferred to Phu Tan agricultural cooperative (Hue city). The remaining 30 ha were divided into 2 ponds of 15 ha each. The system of seaweed culture ponds in the Chuong lagoon (total area more than 300 ha) belong to Huong Phu and Hue City territory.

There are two kinds of pond bottom, which are present in roughly equal proportions. Shallow bottoms are sandy or muddy sand while deep bottoms are muddy or sandy mud. In shallow bottom areas Halidube tridentata grow densely and in the deep bottom areas Chara zeylanica and Najas indica grow fast, especially when salinity is low. Depending on the season, there are about 25 species of seaweeds detrimental to Gracilaria verrucosa, mainly blue and green algae (Cyanophyta and Chlorophyta).

The lowest mean water temperature is in January (20.9°C) and the highest is in July (30.6°C). In the temperate months from February to April, the mean temperatures are 21.5°C, 24°C, and 26°C respectively.

Salinity varies with the seasons. In the rainy season from September/October to December/January, the salinity drops to below 5 ppt. In February, salinity begins to increase, and reaches its maximum of 32-35 ppt in July and August.

Mineral content (N and P) in the ponds varies depending on the time of fertilization and the level of development of the seaweed in the ponds. The highest concentration is usually in November and the lowest in April and August. In general, the Tam Giang brackishwater lagoon has average low mineral content.

Surveys on other climatic factors in the region show that average annual rainfall is about 1900-3200 mm and distributed unequally, falling mainly in the period from September to November.

The sun shines about 1700-1900 hours in a year. This is favourable for harvesting and drying seaweed, but seaweed grows slowly in the shallow ponds (under 30 cm deep) during the hot months.

3. Seaweed Culture Techniques

The main crop is grown in spring/summer (January to May), and a sub-crop is grown in summer/autumn (July to September). Seedstock preservation is carried out during winter (October to

December). The condition of the pond bottom is improved by submerged ploughing using a ploughing machine or a buffalo-drawn plough.

Seeding — using transplant seed from seedstock preserved during the winter or seed collected from natural habitats during the same period — is usually carried out in January/February. However, seeding may be carried out one month earlier or later depending on the arrival of warmer weather. Seeding is carried out a density of 200-500g/m^2

Additional manure is added only to the shallow bottom areas at about 2-5 tonnes/ha. Before planting, seedlings whether removed to a new place or gathered from nature are treated by pulse fertilization with inorganic fertilizers (N and P at a ratio N:P = 2:1) at 3-5 kg/tonne of seed.

All water gates are closed in the rainy season to prevent a sudden drop in salinity. In the hot season, the gates are opened and closed daily (depending on the tide level) to allow more circulation of water in the ponds. During monthly periods of low tide, it is necessary to open inlet gates. During this period water should be drained only at night. Whenever foreign seaweeds develop and fully cover the G. verrucosa, harvesting should be combined with removing them so that G. verrucosa growth is not restricted.

Harvesting starts about 1.5-2 months after seeding and continues everywhere in the region up to the beginning of the rainy season. Time of harvest is also decided by the results of laboratory determinations of agar content and quality confirmed by field technicians. The amount of seaweed left after each harvest is 300-400 g/m^2. Seaweed is harvested by scoop net or by hand, then washed in the field and dried on dike embankments. It is transported to a freshwater area for washing and drying for a second time. Finally, it is pressed, packed and transported to the market.

4. Results

1. ***Production of Gracilaria Verrucosa cultured at Thuan An farm during 1985-1988***

Table 1: Yield and productivity of Gracilaria *Verrucosa, 1985-88*

Area (HA) and Yield (tonnes)								
Pond	1985		1986		1987		1988	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield
P1	10	138.58	10	272.15	10	92.15	10	231.00
P2	14	64.38	11	155.52	11	116.64	11	238.00
P3	22	101.52	22	324.00	22	125.72	22	420.00
P4	2	29.28	17	84.24	17	116.64	17	238.00
P5					10	180.00	15	266.00
P6							15	231.00
TOTAL	45	333.76	60	835.91	70	631.15	90	1624.00
Productivity (t/ha)		7.41		13.93		9.02		18.04

In 1985 productivity was low (7.41 tonnes/ha) because the summer-autumn weather persisted for a long time and there was an extended period of high salinity. After June, seaweed production was only 5-10% of that in the same period in previous years. In October, seaweed biomass in the whole lagoon reached 700-800g/m^2. After just two days of harvest which yielded 9.9 tonnes, a big storm blew away all the seaweed. After the storm 98 tonne (wet weight) were harvested from outside the lagoon and this was kept as seedstock for the following year.

Productivity in 1986 was much higher than in 1987. The reason was that the weather was temperate and Binh Tri Thien province had a bumper crop of seaweed. In contrast, hot weather came early in 1987 and lasted until the end of summer (salinity in July 1987 was over 35 ppt). The flood also came early. In August salinity dropped to 124 ppt, then to 5 ppt from September until the following January. Although seaweed was harvested in September and October 1987 during the period of April to September of that year seaweed density was low and the quantity harvested was smaller in comparison to the same period in previous years (though it was higher than in 1985).

The 1988 spring-summer crop achieved record productivity. Although harvesting ended in September, the annual average production was over 18 tonnes/ha, thanks to improvements in production management which encouraged the workers and helped increase yield of G. verrucosa to a much higher level than in the years before.

2. Monthly Production Of Gracilaria Verrucosa, 1985-88

Table 2: Monthlv seaweed harvest (Tonnes. Wet Weight): 1985-88

Month	1985	1986	1987	1988
2	14.00	28.00	51.00	165.30
3	46.30	79.70	107.80	260.50
4	146.40	127.20	110.70	203.80
5	68.00	110.20	103.70	328.30
6	16.60	74. 10	35.90	195.40
7	4.10	203.80	97.70	270.40
8	14.40	123.80	39.50	154.30
9	13.00	88.50	57.30	46.00
10	9.90		27.7	
	333.70	835.90	631.30	1624.00

It can be seen from Table 2 that the seaweed yield reached peaks every year; first in April-May and then in July-August.

In the rainy season (October to January) G. verrucosa grew in the lagoon, but its quality was often low. Because it was affected by the bad weather, it was not harvested but kept as seedstock for the following year.

3. Results of Gracilariu Verrucosa cultured at Thuan An Farm

In order to decide the time and location for harvesting, laboratory technicians at the seaweed centre collect samples from all areas every 10-15 days and test the content and quality of the agar.

Results gathered over several years show that the samples collected in December have a very low agar content'and some samples yielded no agar at all. In samples collected in January, the agar content increases to 15.2-17.2% with a gel strength of 120-125 g/cm^2 (determined at 1.5% concentration and normal temperature). From the middle of February, the agar content reaches 18-23.2%, after which it stabilizes in all areas at between 19.8 and 25.6% with a gel strength of over 200 g/cm^2.

These results coincide with those achieved at the Product Quality Control Branch of Da Nang City, and are now highly trusted by importers.

Several conclusions can be drawn from these investigations. Ponds in the range 5-10 ha are most suitable for management and operation, and give very stable productivity. Ponds with a deep, sandy mud, or muddy sand bottom often give higher yield and better agar quality. However, ponds with a sandy or muddy sand bottom may have dense growths of Halodube tridentuta. If the bottom of the ponds is ploughed and manured every year, productivity could reach over 10 tonnes/ha/year. Regular harvesting plus removal of foreign seaweeds can increase the productivity of G. verrucosa.

In suitable ecological and environmental conditions, G. verrucosa grows fast and can increase its biomass 5 to 10 times within 30-35 days without additional manure. This happens in Thuan An seaweed culture lagoon from March to May, so we have concentrated investment for the material and technical base during that period with the aim of increasing seaweed yield. Annual productivity and yield depend greatly on the quantity and quality of seedlings at the beginning of the crop. Nowadays, all the seedlings required for 90 ha production are supplied by preserving seedstock in the culture ponds during winter. However, if natural seedstock appears at the beginning of the Spring-Summer crop, it should be collected for the purpose of providing additional initial seeding for the culture ponds.

5. Economic effkiency of *Gracilaria Verrucosa* culture

a. The intial investment:

- Gates	V N D	1,800,000
- Drying yard-storehouse		170,000
- Accommodation and office		500,000
- Transport vehicles		530.000
	TOTAL	3,000,000

b. Production costs of raw material
(with productivity of 1 ton/ha/year)
(VND/ton; VND/ha)

- Ploughing the ponds	VND	50,000
- Fertilizers (all kinds)		50,000
- Labour for seeding and controlling foreign seaweed		40,000
- Labour for harvesting and packing		250,000
- Guarding and direct management		250,000
- Indirect management		97,200
- Fuel		100,000
- Depreciation of real assets		300,000
- Tax		200.000

c. Income

- Main product (dried seaweed)	V N D	2,000,000
- By product (Shrimp)		80.000
	TOTAL	2,080,000

d. Profit

e. Ratio of profit and initial investment:

$$\frac{743,000}{3,000,000} = 24.7\%$$

f. Ratio of profit and operating cost:

$$\frac{743,000}{1,337,000} = 55.6\%$$

The initial investment will be virtually paid back after four years of operation. The annual profit rate of the input is 55.6% (a good average standard for production enterprises in Vietnam).

***6.* Prospects for *Gracilaria Verrucosa* culture in Tam Giang Laggon, Thua Thien Hue province, S.R. Vietnam**

The total area of lagoon (about 20,000 ha) in the province means that natural seaweed resources are abundant. The experience gained in the last ten years has led to a high economic efficiency being achieved, even though semi-intensive cultivation is still being used.

Gracilaria culture in Thua Thien Hue province has attracted the attention of both local and central government authorities. The inhabitants living around the lagoon want to participate and are keen to adapt to this new kind of activity. Therefore, the seaweed culture area of this region will be further expanded, and with proper investment about 770 ha of the lagoon can be used for intensive culture.

Culturing, combined with the exploitation and protection of natural seaweed resources in this area, can help achieve the target of 1,000 tonnes of dried Gracilaria ***verrucosa*** in Thua Thien Hue province without any special difficulties.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

FUNDAMENTALS OF AGAROPHYTE CULTURE IN THAILAND

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ABSTRACT

Gracilaria sp. and Polycavernosa were cultured experimentally using four different methods: (a) field monoculture with insertion line technique (b) monoculture in pond (c) polyculture with seafish in sea cages and (d) polyculture with grouper fish in cages.

The best results were obtained from field monoculture with insertion lines and seaweed monoculture in ponds. Insertion lines increased from 1 kg to 20 kg in one month, while pond monoculture grew from 10 kg to 60 kg in 3 months.

Introduction

Before farming of agarophyte seaweeds can be undertaken on a commercial scale, it is necessary to establish the ecological parameters necessary for optimum production. This paper reports a study undertaken to determine these parameters for conditions prevailing in Thailand..

There are two genera of agarophytes with potential for commercial exploitation in Thailand. These are Gracilaria and the closely related Polycavernosa. Abbott (1987) has reported four species from each genus being present in Thailand. These are Gracilaria tenuistipitata, G. firma, G. irregularis, G. salicornia, Polycavernosa fisherii, P. changii, P. fasfigiata and P. percurrens.

Ecology of natural habitats

A study of the natural habitats of the agarophytes in Songkhla lake and Pattani lagoon was undertaken. The water temperature ranged from 20-35°C, with the optimum being 30°C. Salinity ranged from 10-35 ppt with an optimum of 25 ppt. The pH of the water ranged from 6-8, with the optimum being 7 (i.e. neutral). Agarophytes grow best in brackishwater. l-1.5 metres deep over a sandy/muddy bottom. Ideally conditions should be calm with little wind to generate waves which may lead to the seaweed aggregating on the leeward side of the lake.

Farming trials

Experiments have been carried out to assess four potential methods of culturing agarophyte seaweeds. At Ko Yo Island in Songkhla province, seaweed was monocultured using the insertion line technique. The seaweed cuttings were inserted into 50 metre lengths of 3.5 mm rope, and left to grow for one month.

At Da To village in Pattani province, the seaweed was monocultured in a 7 x 10 metre pond under 1 metre of water above a sandy/muddy bottom and left to grow for three months.

The other two experiments involved polyculture with fish in sea-cages. At Ko Yo Island in Songkhla province, the seaweed was placed in a 4 x 6 x 2 metre cage containing 300-350 sea fish and left to grow for one month. At Kantang in Trang province, the seaweed was placed in a 5 x 6 x 2 metre cage containing 300-350 grouper fish and left to grow for one month.

At the end of the growing period, the seaweed was harvested, cleaned with seawater and set out in the sun to dry (this usually took 2-3 days). Wet and dry yields were determined, and drying ratios calculated.

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Results

Successful growth was achieved in all four experiments. The seaweed monocultured in insertion lines grew from an initial 1 kg to 20 kg after one month. The seaweed monocultured in a pond grew from an initial 10 kg to 60 kg after three months, i.e. an average growth rate of 20 kg/month. The seaweed polycultured with sea fish increased its weight from 10 kg to 20 kg in one month, and that polycultured with grouper fish increased its weight by 1620 kg in one month.

The drying ratios calculated were 7: 1 for Gracilaria and 10:1 for Polycavernosa.

Quality and price

To obtain the maximum price, dried seaweed should meet certain quality characteristics. It should be black in colour, be free of impurities such as shells, rocks and mud and have a moisture content of about 20 per cent. Dry seaweed meeting these standards should fetch a price of US $800 per tonne.

Reference

ABBOTT, I.A. (1987). Some species of Gracilaria and Polycavernosa from Thailand. Unpublished manuscript.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

SOME ASPECTS OF THE GROWTH OF *GRACILARIA TENUZSTZPZTATA IN POND* CULTURE

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ABSTRACT

The effect of temperature, salinity, nitrogen, culture density and depth on the growth of *Gracilaria tenuistipitata* were investigated between April 1985 and March 1986 in outdoor ponds in Guangxi Province, South China. The mean annual growth rate was 2.4% per day. Under favourable temperatures of 20-30°C, daily growth rate may reach as high as 3.3%. Salinity had an obvious effect on growth and photosynthesis, and growth peaked at 21 ppt, with a broad plateau between 7-27 ppt. Growth experiments showed that a total nitrogen (NH,- N plus NO,- N) concentration of 4 µm is sufficient to enable the plant to maintain a daily growth rate of 2.7%. The best growth of the plant was obtained at a culture density of 0.5-l kg/m^2 and a culture depth of 30 cm in the pond.

Introduction

Studies on *Gracifaria* are of special interest because of its increasing market value as a source of agar (ADB-FAO 1983), its importance in diet (Cordero 1984) and its significance as food in the cultivation of abalone (Chiang 1981). Recently, the demand for agar has steadily increased, while the supply of *Gracifaria* from natural populations has not. Consequently, cultivation of *Gracilaria* has begun to supplement harvests from natural populations (Mathieson 1975). The commercial beds of *Gracilaria* in China are so limited that the supply is unstable and cannot meet the ever-increasing demands (Tseng 1980). There are two varieties of *Gracilaria tenuistipitata* found along the coast of South China, *G.* tenuistipitata and *G. tenuistipitata* var. liui. Of these, the latter is mainly distributed in the north coast of Hainan Island and is far better than the former, because it grows faster and is adaptable to brackish seawater. *G. tenuistipitata* var. liui is, therefore, one of the most common species under pond cultivation in Guangxi and Hainan Provinces. The cultivation area once reached 1500 hectares, producing some 2000 tonnes dry weight and played an important role in agarophyte cultivation in China. Unfortunately, the growth rate sometimes fluctuated greatly. In serious cases, most of the plants in the ponds died for no obvious reason within a few days. The purpose of the work reported below was to determine the relationship between the main environmental factors and the growth rate and to find ways of overcoming the unusual deaths in order to stabilize and increase production.

Materials and methods

The effect of temperature, salinity, culture, density, depth and total nitrogen content of the ambient seawater on the growth of *G. tenuistipitata* var. liui were studied concurrently in outdoor ponds (l-1.5 m deep) in Guangxi Province, South China and in the laboratory in Qingdao from April 1985 to March 1986. Vegetative fragments of *G. tenuistipitata* var. liui were collected from the outskirts of Haikou city, Hainan Island. Pond culture experiments were carried out at Baihutou station near Beihai City, Guangxi Province, South China as follows:

1. *Temperature:* Triplicate samples of *Gracilaria* fragments 5-10 cm long weighing 500 g were cultured in a rectangular net cage in a depth of 0.5-1 metre. Measurements of weight were taken

every 15 days. growth rates were calculated and temperature monitored throughout the experimental period.

2. Salinity: *Gracilaria* were cultured in two ponds with different salinities using net cages similar to those used in the temperature experiments. The salinity of pond A was 30-34 ppt, and that of pond B was 24 ppt. Total nitrogen content of the two ponds was maintained at the same level by adding nitrogen fertilizer to pond A. Outdoor tank culture experiments and measurement of the effect of salinity on photosynthetic rate were conducted concurrently at Baihutou station and Qingdao Laboratory.

3. Nitrogen: Nitrogen nutrition experiments were conducted in three ponds in which the total nitrogen contents were different. Water samples were analyzed for ammonium-nitrogen (Gao. Zhang er al. 1980) and nitrate-nitrogen (Shi, Dai et al. 1980) periodically. Growth in fresh weight was also measured.

4. Culture, Depth And Density: Triplicates of 20 g of vegetative fragments were cultured in net cages at 30, 60 and 90 cam deptns respectively in a pond and increments in weight measured. At the same time. photosynthetic rates were measured by using the white-black bottle method. Culture density experiments were set up in two ecologically similar sites, each site covering an area of 30 m^2. The culture densities were 150 g/m^2 and 450 g/m^2 respectively. In each of the five plots selected at each site, a 0.04 m^2 net cage was used to culture Gracilaria at the same density. Fresh weight was measured every 15 days.

Results and discussion

1. Temperature

G. tenuistipitata grew in the experimental field all year round. The mean daily growth rate was 2.4% which meant that the weight was doubled each month. March to May and September to November were the months of maximum growth, with a mean daily growth rate of 3.3%. Growth during the remainder of the year was only 1.5%. In the course of the experiment, temperature ranged from 1.5-32°C. Minimum growth rates were recorded at both the lowest temperature (15°C) and the highest temperature (32°C). Optimum growth, which was over 2%, was achieved in the temperature range 20-30°C and this was considered to be the most favourable temperature for growth.

2. Salinity

After one month of experimentation the best growth of *Gracilaria* was obtained in pond B at a salinity of 24 ppt. The weight of G. tenuistipitata in pond B was 1.3 times higher than that in pond A. This demonstrates that salinity is an especially important factor influencing the growth of this alga. Results obtained from tank culture shown in Table 1 indicate that growth peaked at 21 ppt, with a broad plateau between 7 and 27 ppt. Decolorization of apical segments occurred at 3 ppt salinity within two days, and necrosis appeared after four days. At higher salinities, for example at 34 ppt, segments grew branches that were slender and soft, whereas at 47 ppt segments became discoloured after two weeks.

Table 1: Growth in weight as a function of salinity

Salinity (‰)	Fresh weight (g)	
	1 week	2 weeks
3	–	
7	26.3	29.5
14	27.1	33.2
21	29.1	35.2
27	26.2	32.0
34	25.0	28.1
40	24.2	26.6
47	23.7	26.0

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Maximum photosynthetic rate was obtained at 21 ppt and was not markedly affected when the salinity was reduced to 14 ppt or increased to 27 ppt. Under different light intensities, the photosynthetic rates of the alga cultured at 21 ppt salinity were higher than those at 7 ppt and 40 ppt. These data indicate that 21 ppt is the optimum salinity for growth, and confirm the fact that this species is euryhaline and grows well in estuaries where salinity is low and nitrogen content is high.

3. *Nitrogen*

Fresh weight was measured after one month of experiment and the results are given in Table 2.

Table 2: Effect of total nitrogen concentration on growth rate

NO,- N + NH^{4}- N (µm)	Mean daily growth rate (%)
2.97	1.5
3.99	2.7
4.36	3.1

It is apparent that mean daily growth rate increased with the increase of N concentration up to 4.3 µm. Although the growth of *G.* tenuistipitata did not saturate within the concentrations used in this experiment, a high growth rate of 3.1% was attained. It is therefore suggested that in order to support a high growth rate in pond culture a nitrogen level of about 4 µm is desirable.

4. *Culture depth and density*

The pond used for the culture depth experiment was l-I.5 m deep with two openings for the exchange of water. The depth of pond water was usually kept at l-l.2 m. Tables 3 and 4 show that growth and photosynthetic rates increased significantly with decreasing cultivation depth up to 30 cm.

Table 3: Relationship between growth rate and culture depth

	30 cm		60 cm		90 cm	
Culture time (days)	Fresh wt (g)	Daily increment (%)	Fresh wt (g)	Daily increment (%)	Fresh wt (g)	Daily increment (%)
8	26.1	3.3	25.2	2.9	24.9	2.6
15	30.6	2.3	29.6	2.3	25.1	0.1

Table 4: Effect of culture depth on photosynthetic rate

Depth (cm)	30	60	90
Light intensity (pE.m? sec^{1})	250	208	156
Photosynthesis rate (mgO$_2$.gdw$_1$ hr,)	5.21	4.28	3.25

This coincides with Lapointe's (1981) result that G. *foliifera* did not saturate within the light intensity used in his experiment at maximum levels of natural irradiance. The possible reason for the high photosynthetic efficiency of *Gracilarin* (Lapointe and Ryther 1978) is its ability to utilize maximum levels of natural light.

Data in Table 5 show that growth rates of the two culture density treatments were similar, but increments in weight were very different within 30 days. Thereafter, differences between treatments were apparent.

Table 5: Effect of culture density on growth rate

Culture time (days)	A. Culture density 150g/m^2 Fresh wt (g/m^2)	Increment (fw.g/m^2)	Daily growth rate (%)	B. Culture density 450g/m^2 Fresh wt (g/m^2)	Increment (fw.g/m^2)	Daily growth rate (%)
15	270	120	3.9	787	337	3.7
30	372	102	2.1	1000	213	1.8
45	500	128	2.0	1292	292	I.4

Growth rate of treatment B decreased as the density increased to more than 1000 g/m^2, but the increment per unit area was still higher than that of treatment A, because of the high biomass. The experiment indicated that higher culture density in every case increased seaweed production. It is therefore suggested that a density of 500-1000 g/m^2 is suitable for this kind of pond culture.

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THE DEVELOPMENT OF COMMERCIAL-SCALE *GRACILARIA* FARMING IN SULAWESI, INDONESIA

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ABSTRACT

Gracilaria verrucosa was located in 1986 in coastal areas of south Sulawesi, Indonesia. A local company started venturing into Gracilaria culturing and encouraged farmers to take up seaweed culture in abandoned shrimp ponds. The same company exported 60-80 tonnes of Gracilaria per month in 1989. A plan for constructing a processing plant able to consume 50-100 tonnes of raw material per month is under way.

Introduction

Prawn fever started in Indonesia in early 1980. South Sulawesi, with its large area of brackish-water ponds, was no exception. Seventy thousand hectares have been developed out of a potential 150,000.

When we started our company in 1986 and looked at supply and demand, we had our doubts about prawn farming. After all, if every one was going into prawn production, over supply and price declines were only a matter of time. Thus, we began to look at other resources and decided to go into Gracilaria farming.

Another consideration was that Gracilaria can be grown together with prawns, In fact, we found Gracilaria growing naturally in abandoned prawn ponds: further confirmation that the two could be cultured together.

Our company charter mandates a social function. Consequently, we wanted to involve low-income people of the province in seaweed farming.

Prawn prices have dropped in recent years, encouraging farmers to look to seaweed as an alternative source of income requiring little additional investment. Many shrimp farmers are heavily mortgaged and short of capital.

2. Gracilaria development in south Sulawesi

As of 1986, there was no Gracilaria culture in south Sulawesi. Nevertheless, 1,400 tonnes of seaweed harvested from wild stocks were exported during the same year. This consisted mostly of Eucheuma spinosum. There were also orders for Gracilaria from Japan.

We decided to culture Gracilaria, but at the time we did not know much about culture technology. We found difficulty locating seed stock and began with material from Chile, originating from export quality parent stock. But finally, after surveying the coast of south Sulawesi, we located good material near Ujung Pandang at Tanjung Bunga. This Gracilaria produced agar similar to that of the Chilean species. We also found similar seed stock in the Janeponto district. Eventually, we found that the species was Gracilaria verrucosa. Concurrently, in 1986, the University of Hasanuddin, at Ujung Pandang, the Regional Planning and Development Bureau of south Sulawesi and the Fisheries Department of south Sulawesi began investigating Gracilaria and we are now working together to develop pond culture of Gracilaria.

We set up our first pilot project in a 10 ha pond area at Tanjung Bunga. Our company provided

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seed stock, gave training seminars and paid for maintenance and operation costs. The pond owner only observed our activities at the beginning. Once we developed the technology, the owner took over and we purchased the seaweed from him. After harvesting Gracilaria in September 1986, we decided to transplant seed stock to Takalar. Unfortunately, the rainy season began in the area the following December and affected seaweed growth. But since it was the dry season along the coast of the Gulf of Bone to the west, we decided to take some of the Gracilaria from our initial site to Sinjai. Our activities at the original site were reduced to maintenance of the existing stocks and transplantation to new ponds. When we started seaweed farming, we were interested in locating seedstock, and were not really aware of the weather pattern in south Sulawesi. Now we know how to use this unique climatic pattern to maintain year-round production.

In addition to the challenge posed by climate, the company encountered problems in finding farmers willing to take up seaweed culture. In 1986 prawns fetched good prices, but some farmers unable to succeed with prawn culture were interested. However, they had doubts about marketing-who would buy their production? So we began work with these farmers, providing free seed stock and distributing brochures on farming methods. They still remained sceptical, but our persistance has paid off and farmers who seriously took up Gracilaria farming in their defunct shrimp ponds are gradually improving their living standards.

3. Export development

Eight months after the company started distributing seed stock, we harvested 110 tonnes wet weight. Ten tonnes were set aside as seed stock and the remainder converted to 10 tonnes of dried seaweed.

After Japanese buyers accepted our product we sent off our first export shipment. Three months later, the company exported 10 tonnes of dry Gracilaria.

In April 1988, we exported another 20 tonnes. Luckily for us, Gracilaria farming is picking up in several areas with some farmers developing new ponds for seaweed culture.

Now we have another problem-traders trying to muscle into our business and manipulate the price. But our good relationship with our farmers has protected us from such speculators, who are to be found in any business.

4. Our stable period

In the beginning we were dependent on farmers whose production output was variable. In order to stabilise production, we decided to develop our own ponds. This would enable the company to develop the best culture technology and operate to its own standards.

In December 1988, we rented a pond of 6.8 ha from a farmer. Although not too large an area, it enabled us to produce more seed stock for distribution to interested farmers.

By the beginning of 1989, our business started to show good prospects and we decided to buy a 20 ha pond in Takalar Regency. We can now harvest 20 tonnes of dried Gracilaria every two months which translates into 10 tonnes dry weight every month. Production has now stabilized.

A new factor entered the scene in March 1989, when prawn prices on the world market started falling. Now, farmers are getting more interested in Gracilaria because they are looking for alternative crops. Many farmers are asking us how to grow seaweed and are even willing to buy seed stock. Trade in seedlings of Gracilaria is building up, which reduces our costs since we have to supply less seed stock to get the farmers started. Increased availability of seed stock means production will increase.

Since the middle of 1989, we have been able to export 60-80 tonnes of Gracilaria per month. We are now developing a seeding strategy to enable year-round stable production.

5. Further development

Because Gracilaria farming is taking off in south Sulawesi, the company will develop new sites in southeast Sulawesi and some sites further east. In southeast Sulawesi we are constructing ponds on a 200 ha site. Full development of the site will allow us to harvest SO tonnes of dry Gracilaria per month.

Culture methods will differ from those in south Sulawesi because we are working in new ponds. Acidic soil has forced us to wash out pyrites by cyclically pumping water out of the pond and refilling.

Based on our past success and bright prospects, the company will construct an agar processing plant in the region. It will consume 50-100 tonnes of raw material per month, hence our expansion into pond culture. Locating the plant in the production area will reduce transport costs and expand market outlets for the farmers.

6. Conclusions

Gracilaria farming in Sulawesi has a bright future. Involving local farmers reduces the company's costs, and while the company is developing new farm sites we will continue to involve them. But to stimulate further interest on the 'part of farmers, farm gate prices will have to be raised. We expect overseas buyers to raise their prices instead of having a situation similar to that of the falling price of prawns. We would also like to co-operate with international organizations to do more research. Raw material can be semi-refined in processing plants.

7. Acknowledgement

We want to thank the following organizations for contributing to our success: Regional Planning and Development Bureau of South Sulawesi; Department of Fisheries of South Sulawesi; University of Hasanuddin at Ujung Pandang; UNDP (through Mr Leroy Hollenbeck); Bank Rakyat, Indonesia; Ministry of State for Research and Technology (through Mr Jana Anggadiredja); and FMC Corporation - Marine Colloids Division.

SEMINAR PAPERS : SESSION I
STATUS OF THE CULTURE OF TROPICAL AGAROPHYTES

PRELIMINARY OBSERVATIONS ON THE CULTURE OF *GRACILARIA EDULZS* USING SPORE-SETTING TECHNIQUES

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ABSTRACT

While very little work has been done in Sri Lanka on vegetative culturing of Gracilaria edulis, practically no work has been done on culturing Gracilaria by using spores. This paper presents preliminary results obtained during the culture of Gracilaria, using carpospores of the plant. Of the different substrata tested for spore setting, synthetic rafia cleaned in freshwater was the most successful. The plant's growth rate showed a positive correlation with low salinity.

Introduction

The growing interest in the development of the seaweed resource is primarily due to the recognition of its economic importance as a source of food, as **raw** material for the manufacture of commercial products such as agar, alginates and carrageenan and as an additional source of livelihood for communities that inhabit the coastal areas.

Grucilaria reproduces both vegetatively and by sporulating. Whilst some work has been done on culturing Gracilaria sp in Sri Lanka from vegetative fragments (Sivapalan 1975; Sivapalan and Theivendirajah 1985). until now no work has been attempted in Sri Lanka on culturing Gracilaria by sporulating.

A joint NARA/BOBP project at Kalpitiya has been attempting to culture Gracilaria using spore setting techniques. These techniques were earlier tested in a similar BOBP Project in Malaysia (BOBP, 1987). Trials began in August 1988 and some of the preliminary results are presented here.

Methodology

An experimental hatchery was set up at Etalai, adjoining the Puttalam lagoon. Two cement tanks were fed from the Puttalam lagoon using a pump and a filtering mechanism. Water was pumped up to a level of 20 cm from the bottom of each tank. During each spore setting, 6 kg of female Gracilaria (Carposporophyte) collected from the lagoon were cut into pieces and sprinkled over a net floating inside the cement tanks. Twelve frames (40 x 80 cm) made out of polyvinyl chloride pipes were set at the bottom of each tank. Synthetic rafia, synthetic rafia cleaned with fresh water, monofilament lines and coir ropes were tested as substrate lines for spore setting on the frames.

The frames were made out of each type of substrate lines, and all of them were kept in the tanks for three nights. One of the tanks was given extra light for four hours each night. Glass slides were kept on the frames of both tanks to examine whether there were any spore settlements. These slides were examined every day under a microscope. Frames with spore settlement were removed from the tanks, and were submerged in the lagoon and allowed to grow. Growth of the plants after successful spore settlement was monitored by counting the number of plants on the frames and measuring their length randomly. Frames with high growth of Grucilaria were harvested (cropped) after six months. After harvesting, the length of the plants was measured regularly to monitor further growth.

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The salinity, temperature and pH were monitored. A hand-held refractometer and HACH salt water test kit were used to measure salinity (in parts per thousand) and pH respectively. Other environmental parameters **such** as nutrients NO_2^-, NO_3^-, NO_4^+ were monitored once a fort-night.

Results

A total of 24 frames (12 from each tank) were placed in the lagoon after successful spore settlement. During the first three months there were no indications of growth in the plants on the frames. Twenty frames were observed **to have** *Gracilaria* plants after three months. Some of the frames were found to have fallen to the bottom of the lagoon and were covered with mud. There were no plants on these frames. Plants on some of the frames which were in deeper water showed stunted growth.

A comparison of the performance of the frames in the two tanks is presented in Table 1. A larger number of plants were observed on the frames kept in the tank supplied with normal light hours.

Table l : Average number of plants in each type of frame

		Average number of plants/frame			
Tank No	Treatment	Rafia	Cleaned rafia	Coir	Monofilament
A	extra light hours (6-10 p.m.)	5	10	2	8
B	normal light hours	67	150	25	20

Of the different types of substrate lines tested, rafia frames cleaned with fresh water were the most successful, averaging 150 plants per frame with a maximum of 235 plants in one frame.

The growth of plants was also best on this substrate (Table 2). Coir ropes showed some plant growth but also had extensive sediments attached to it. These were also found to be of low durability. Growth of plants on other materials tested was very low.

Table 2: Average length of the plants (cm) in each type of frame after 3 months

	Average length of the plants (cm)			
Tank No	Rafia	Cleaned rafia	Coir ropes	Monofilament ropes
A	4	5	3	4
B	12	30	5	6

Monthly variations of pH, nutrients and salinity were also shown throughout the culture period (Table III). After the initial harvest, the plants attained an average length of 30 cm in four months, a growth rate of 0.25 cm per day.

Table 3: Average monthly values of pH and salinity throughout the culture period

Month	Salinity ppt	PH
August 1988	44	8.3
September	45	8.5
October	41	a.3
November	41	8.5
December	40	8.5
January 1989	40	8.6
February	39	8.4
March	40	8.4
April	41	8.5
Mav	42	8.5

Discussion

These preliminary investigations show that spore-setting techniques could be considered as a feasible method for culturing *Gracilaria* species. Low light-intensity and sedimentation may have affected the growth of plants on frames that were at the bottom and in deeper waters.

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The fewer number of plants observed on the frames placed in the tank subjected to extra light hours confirms the observation of Rao (1976). Spore emission from Gracilaria edulis is highest during the night, and the reduction of dark hours may have caused the reduced emission of spores in the tank provided with extra light hours.

Even though the frames were transferred to the lagoon in August, small plants were not visible on them until late October. This could be due to one of two factors; either the growth of germinated spores was very slow, or natural spore setting could have taken place. However, controls introduced in subsequent trials ruled out natural spore-setting. Since there were no drastic fluctuations in other factors such as pH and nutrient values, changes in salinity may have affected growth of the plants. In August 1988, a salinity level of 44 ppt was recorded (Table III). In October, it decreased to 41 ppt, and this lower salinity could have influenced the germination of spores and the growth of the plants.

Of the substrates tested for setting, rafia cleaned in freshwater was the most successful. The number of plants observed on rafia cleaned in fresh water was double that found on untreated rafia. It is not certain whether there was a difference in the intensity of spore settlement between the two.

Correlation of Gracilaria growth with salinity indicates that the plants grow best in a salinity of less than 40 ppt. Plant growth was drastically affected above a salinity of 45 ppt. There was very little variation in the other environmental parameters such as pH, nutrients and temperature during this culture period. Therefore, the effects of changes in these parameters on the growth of seaweed could not be ascertained.

In this study, Gracilaria edulis attained a growth of 30 cm in four months, averaging 0.25 cm per day. A previous study in Jaffna lagoon (Sivapalan and Theivendirajah 1985) attained a growth of 12 cm from 2 cm fragments in 8 weeks, a growth rate of 0.18.

Several spore setting experiments were carried out subsequently, but very few plants were observed growing. This may be due to the low percentage of female plants in the seed material, and also to the high salinities in the lagoon water caused by the prevailing drought.

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SEMINAR PAPERS : SESSION II

SMALL-SCALE AGAROPHYTE PROCESSING

ASPECTS ON *GRACILARIA*

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ABSTRACT

Various aspects of Gracilaria are presented and discussed in this paper. While Gracilaria culture is often viewed in terms of industrial use and economic benefit. one must not forget to look at their health value for human consumption. This applies also to other species of seaweed. As regards the agar content and gel strength in Gracilaria observations show that these characteristics are related to differences in habitat and environmental factors.

* * *

In southern Chile I once met a producer who proudly-claimed that his agar was the best in the world. Why was his product different? He gave two possible reasons. His Gracilaria raw material was taken for processing on the very day of the harvest without any drying and it was collected on rocky tidal flats on a fairly open coast with rough sea, while most other Gracilaria beds were found in estuaries, lagoons or sheltered bays. In the literature we will find a number of other explanations for differences in quality.

With regard to the economy of Gracilaria production I made a surprising observation : On Isla Santa Maria far out in the Pacific, fishermen and hoys in wet suits collected considerable quantities of Gracilaria in the surf of an exposed sandy beach. In the sheltered Rio Maullin estuary, on the other hand, another natural growth was collected from small boats with eight-footed "spider" drags. Here the average harvest for a day's man-effort was ten times as high as in the Santa Maria Island — and the price was a tenth! Could it really be that the agar content and quality was so inferior as the price indicated? Or is the cold truth that the price of the raw material is set by the buyers at the lowest possible level where they can find people willing to work ? That the price is determined not by value with regard to quality and quantity, but by harvest per man-effort and minimum living cost for a family?

Talking of economy, we get valuable principal information in an estimate of world seaweed production (Anon, 1985). For anybody teaching phycology it can be used to test the students in the art of reading a tahle. Here it follows with my own breakdown and additional calculations:

Estimate of world seaweed oroduction

Location	10^3tonnes net weight		Value U S $ Million		Value per Tonne US$	
Japan	654 }		563.0 }		861 }	
China	700 }	= 69%	130.0 }	= 96.5%	186 }	467
Korea (Republic)	224 }		45.0 }		201 }	
USA	126 }		1.9 }		15 }	
USSR	100 }		5.8 }		58 }	
UK	24 }	= 31%	0.4 }	= 3.5%	17 }	33
Others	572 }		18.9 }		33 }	

TOTAL WORLD PRODUCTION 2400 x 10^3 tonnes, 765 x 10^6 US $

Far eastern seaweed landings are worth 14 times as much per tonne as those of the rest of the world. An analysis will touch upon all thinkable aspects of the seaweed economy; here I will stop — seaweed production for human consumption is worth more than production for industry. Any advice for developing countries should include this basic fact.

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World statistics refer to fresh weight at harvest; the value for the fishermen. They should not be confused with export values of dried seaweed which may at the time have been about US $ 800/tonne. Of course industrial end products will be sold at hundreds or even thousands of times more than the raw material, but processing proceeds will not reach the fishermen.

Import and export figures are not all. We are happy to live in a time when life quality is also included in our demands, in this case health aspects. Around the Bay of Bengal there are still areas with protein deficiencies, keratomalacia (Vit.A), beriberi (thiamine), pellagra (niacin). ariboflavinoses (B_2) and scurvy (C).

Gracilaria is famous for its high protein content. Some of the species are known for their quantities of, among others, provitamin A, thiamine and niacin. However, if seaweeds should go where they are needed, they should all be sent to areas afflicted with severe endemic goitre (the Himalayas and other highlands). (Michanek, 1979, 1981). Coastal populations never suffer from goitre. and vitamin deficiencies are few.

The health impact of seaweed as a food additive does not rest with its content of proteins, vitamins, minerals and trace elements. There is increasing literature on the capacity of phycocolloids to bind heavy metals and thus to decrease our body burdens of lead, cadmium, mercury. arsenic and even radioactive strontium. If ongoing research shows that we can rinse lead out of our bodies by regular intake of seaweeds, there will be an immense increase in the demand, in particular for the populations living and dying in the traffic exhausts of our cities. For this purpose agar and carrageenan are not so good as alginic acid. This may open a new use for resources of Sagassum, Turbinaria, Cystoseira and Cystophyllum.

In the extensive literature on Gracilaria, many papers deal with the question I started with: quality of agar. Let me cite a sampling of recent papers with aspects worth discussing by cultivators.

From molecule chemistry we first learn that much sulphatc gives low gel strength., Second. we learn that a high curling intensity of the molecule chain gives a high gel strength and that this curling of rhe chains increases with increasing amount of 3,6- anhydrogalactose (Yaphe and Ducksworth, 1972).

For the cultivator this means that in tidal areas a Gracilaria growth which is exposed during long periods will produce galactans heavily charged with sulphates, as this radical plays a role in resistance against exposure. In subtidal specimens of the same transect. sulphates show partial absence and the molecules have a high portion of 3,6-anhydrogalactose (Bodard, et al., 1984).

Our third observation could be that 3,6-anhydrogalactose and consequently gel strength has a negative correlation to chlorophyll content - or in plain words. quality is not so good during sunshine periods (Liu, et al., 1981).

The genera Gelidium and Gracilaria are low in sulphate, while Chondrus, Gigartina and Porphyra are high (Bodard, Christiaen and Verdus, 1983). Within Gracilaria the species G. sjoestedtii has lower sulphate content and higher gel strength than G. tikvahiae, G. rextorii and G. verrucosa (Craigie et al., '1984). In a certain species different clones may have very great differences in agar composition and qualities. Strains with thin thalli have a more efficient uptake of nutrients than strains with thicker fronds (Lignell and Pedersen, 1989). Even different parts of the thallus show considerable variation (Craigie and Wen, 1984).

A fourth aspect is that, in general, gel strength is higher in agar from plants grown in nitrogen-rich water and under good light conditions, while the yield of agar is higher from plants grown under poor conditions (Craigie et al., 1984, Lignell, 1988). This may be explained by the fact that plants in nitrogen-rich water grow faster than those in nutrient-poor water and therefore have a larger portion of young tissue. In young tissue the proportion of small cortical cells to large medullary cells is high (Craigie and Wen, 1984).

Chemical observation number five is that gel strength of agar deteriorates markedly with increasing content of 4-0-methyl-L- galactose, which simply means that aged tissue is inferior to young tissue (Craigie and Wen, 1984, Cote and Hanisak. 1986, Lahaye and Yaphe, 1988).

From laboratory culture experiences we could note that Gracilaria is extremely sensitive to low concentrations of nitrogen (Edelstein et al. 1976).

Wang et al. (1984) observed that local plants doubled the fresh weight of their thalli in considerably less time than transplants.

What are the problems of seaweed culture? In one of the discussions at the Symposium of Useful Algae, which we know from the volume "Pacific Seaweed Aquaculture"(Abbot,Foster, and Eklund Eds. 1980), a participant stated that

* Problem no. 1 is grazing and overculture.
* Problem no. 2 is weeds and epiphytes.

The problem of epiphytes, when there is no grazing, was studied by Brawley and Fei (1978).

At the 13th International Seaweed Symposium in Vancouver last August there was a workshop on Engineering Aspects of Algal Cultivation, where various participants noted that:

* each time a culture system is scaled up, new problems arise
* production limits are probably set by the ability to agitate (circulate), rather than by self-shading.
* a given system can be made more economic by reducing the cost of production rather than by increasing productivity. *(Applied* Phycology, September 1989).

For the farmer there are many problems which we see nothing of in the literature, e.g.:

* Is an upgrading of living material through nitrogen starving feasible?
* For a sea farmer, is the way to gain more only to produce more or would it pay better to sit down and do a lot of hand-rinsing of epiphytes, other species and plastic fragments or to rinse a clay-rich harvest from a muddy bottom in clean water of the open sea?
* How much is lost in quality if there is a transport delay between harvest and processing?
* Does the buyer ask for quantities only, while the factory primarily asks for quality?

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SEMINAR PAPERS : SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

AGAROPHYTE HANDLING AND PROCESSING WITH SPECIAL EMPHASIS ON *GRACILARIA*

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ABSTRACT

This paper reviews the technologies of agar extraction from agarophytes, with special emphasis on ***Gracilaria.*** The normal sequence of steps in handling and processing agarophytes are described as dehydration, pressing, evaluation, removal of undesired products, pre-treatment prior to extraction and the control of molecular weight during extraction. While small-scale cottage industry can feed the local market, it does not generally produce agar that meets international quality standards. Home industries may be developed for local demand. There is a lack of marketing information in the Bay of Bengal region.

1. Introduction

Gracilaria spp. are agarophytes or agar-yielding red seaweeds belonging to the class Rhodophyceae. They give rise to a hydrophilic colloid. agar, which on processing is insoluble in cold water but soluble in hot water. Other agar-producing seaweeds are ***Gelidiella, Gelidium,*** and ***Pterocladia.***

"Agar-agar" is the original Malay word for a food gel obtained from seaweed. Chemically, agar consists of neutral agarose and charged agaropectin. Agarose is a long-chain polymer of neutral galactose and its derivatives, while the charged agaropectin chain has some sulphated substitutes. A higher charged agaropectin chain leads to increased viscosity but reduced gel strength. Reducing sulphate content helps increase gel strength. According to Chandrkrachang and Chinadit (1988). the most important properties in determining the quality of agar are gel strength, gelling and melting temperature, sulphate and metoxyl content. clarity of the solution, and ash content.

Apart from seaweed powder and dried seaweed from which agar is extracted, other product forms are strip-agar, agar flakes, and agar powder. High-grade agar is white, while light yellow is acceptable for lower grades.

2. Handling and Processing

Armisen and Galatas (1987) provided an excellent review of the handling and processing methodology for agarophytes. This paper while drawing on their work, attempts to summarise the technologies used.

Preservation of seaweeds between the time of harvest and processing is very important to minimise spoilage, facilitate long distance transportation and extended periods of storage before processing. Before preservation, the seaweed is washed in sea or fresh water to remove adhering sand, mud, snails, barnacles or other foreign material.

Factors to be considered in agar processing:

The extract from the agarophyte has to contain the maximum possible quantity of agar from within the seaweed. In addition, the agar obtained should also have the best physico-chemical properties to satisfy the standards expected of the end-product. The normal sequence of steps in handling and processing agarophytes are dehydration, pressing, evaluation, removal of undesired products, pre-treatment prior to extraction and the control of molecular weight during extraction. There is a need to work with large volumes of dilute extracts. and to consider the economics of dehydrating.

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2.1 *Dehydration*

Immediately after harvest, the seaweed is dried to a moisture content of less than 20%. Seaweed may be air-dried in the open, preferably off the ground, to keep it clean or dried artificially. Bamboo slats, plastic sheets on the ground, or concrete surfaces are used. Sun-drying also bleaches the seaweed. The seaweed must be sufficiently dry to prevent anaerobic fermentation resulting in spoilage or even carbonisation of the bales during storage.

The yield achieved for Gracilaria under experimental conditions in New Zealand is 40 tonnes of dried seaweed from 240-280 tonnes wet raw material. One tonne of the same dried Gracilaria yields 250-300 kg of agar (Hollings, 1985). In Taiwan, the drying ratio obtained is a similar 1:7 (Chen. 1978).

Preservation of Gracilaria by dehydration is difficult as enzymatic hydrolysis of the agar occurs even at relatively low moisture content. This rate is, however, variable depending on the species and its origin. Gracilaria harvested in Sri Lanka, India, Venezuela, Brazil and other warm waters has an agarose less resistant to enzymatic hydrolysis than the more stable Chilean Gracilaria. Agar in Gracilaria, which can undergo hydrolysis because of endogenous enzymes or the growth of Bacillus cereus, is less stable than that of Gelidium (Armisen & Galatas, 1987).

2.2 Pressing

The **second** step is pressing the weed in bales of about 60-100 kg with a hydraulic press, in order to reduce the volume and consequently transportation and/or storage costs.

The seaweed may then be packed into sacks, either for export or sale locally. Alternatively, it may be ground into powder or subjected to agar extraction at the small-scale processor level.

2.3 Evaluation

Because of variations in harvesting and processing methods, chemical properties and product utilisation, it is not possible to consider seaweed and, therefore, the seaweed industry, as a homogeneous entity. Agarophytes from different growing areas should be evaluated for their agar-yielding properties before processing, so that their potential can be assessed.

In principle, evaluation of agar properties involves combining some preliminary treatments with different extraction methods. An important consideration is sampling from a large growing area and the proper treatment of dirt-free samples until they are ready to be processed. A sample size of about 400-500 g of dried seaweed should be used. Provided good results have been obtained, a pilot laboratory which follows closely the actual operations that would take place on an industrial scale should be set up.

Next, aliquots of seaweed representing a homogeneous composition should be taken, and tested for moisture determination, pure seaweed determination, and extraction of agar. Moisture determination is caried out in a drying oven at 65°C.

With Gruciluriu, a sulphate alkaline hydrolysis pre-treatment is usually carried out to change the L-galactose 6-sulphate into 3, 6-anhydro-l-galactose. This is usually done by diffusion with sodium hydroxide solution (0.1M) for one hour at a temperature of 80-97°C taking care not to extract the agar. The agar extraction which follows is carried out while stirring **the** slurry at neutral pH without pressure (95–100°C), for a period that varies depending on the type of Gracilaria. This can take several hours.

A manufacturer of good quality agar should be able to spot variations in yields in a laboratory trial before embarking on an industrial-scale production with a new batch of seaweed. The properties of seaweed from different areas vary greatly. This has resulted in the failure of many processing factories attempting to process batches of seaweed from different sources.

2.4 Removalof undesired products

In order to obtain the purest possible extract, seaweeds are generally hand selected and washed prior to alkaline treatment to eliminate a large quantity of foreign substances.

2.5 Pre-treatment

A variety of pre-treatments are available. Treatment differs depending on source, growth stage, environmental conditions and species.

Pre-treatment should achieve maximum desulphation, while avoiding yield loss through agar dissolving in the solution. The disadvantage is that long-chain polymers may break (as discussed in the following section on "molecular weight control") leading to a reduction of gel strength.

An alternative technique to pre-treatment is *strong alkali post-treatment* at relatively low temperatures soon *after* agar extraction. Ry this means, relatively low-grade crude agar is refined to produce high-grade agar. Alkali post-treatment of traditionally extracted low-grade agar from *Gracifaria* has yielded a two-to-three-fold increase in gel strength, from 300-400 g/cm^2 to 700--1000 g/cm^2 (Chandrkrachang & Chinadit, 1988).

Shengyao et *al.,* 1988, studied the effects of alkali treatment on agars from Chinese *Gracifaria* species using a *cold concentrated alkali pre-treatment* in which *Gracilaria* is treated with 32% NaOH at room temperature for five days. Agars extracted with sodium hexametaphosphate *after* cold concentrated alkali treatment were much better than those extracted with water or any other alkali treatment. The gelling and melting temperatures of agar treated by alkali increased while the viscosity decreased.

The 3, 6-anhydro-1-galactose content of agar isolated from alkali-treated *Gracilaria* was higher than that without alkali treatment, and the reverse relation was observed about the sulphate and galactose content. The increase in gel strength lay in the degree of the sulphate reduction and the 3, 6-anhydro-l-galactose increased.

In another study on pre-treatment by Minghe, 1986, *Gracilaria* was *pre-treated with dilute alkali* prior to extraction at a temperature of 78-80°C for three hours. The yield and gel strength of the agar produced this way were higher than that of agar produced with the usual concentration of sodium hydroxide solution.

2.6 Molecular weight control

Within the seaweed, agar is insoluble in both warm and cold water. Extraction has to take place within certain pH, temperature, and redox conditions. This results in some hydrolysis taking place, thereby increasing its solubility.

During this fractionation, it is necessary to minimise molecular weight reduction. Since all agar extraction works on the principle that agar dissolves in hot but not cold water, excessive molecular weight reduction would cause loss in yields for low-temperature water soluble agar. On the other hand, all molecules that have weights at the higher extreme will not be extracted and will remain in the seaweed.

Thus, a manufacturer has to develop a means of obtaining maximum yield of particle size in the mid-range. This translates mto a high gel strength with more uniformity in particle size and reduced losses at the extremes. It is difficult to modify the percentage of molecular weights dissolving below 20°C but the extraction of molecular weights dissolving above 125°C can be increased by raising the water temperature under pressure whenever the seaweed permits.

To further strengthen the agar product the acid concentration should be adjusted at pH 2-2.5, and for increasing productivity pH 4.0 – 5.0 was best. A pH of 3.5 is ideal, resulting in an agar yield of 21.6% and 650 g/cm2 gel strength (Longchang, *et al.,* 1986).

2.7 Dehydration of dilute extracts

Agar extracts of 0.8-I .5% are considered to be the optimal concentration for subsequent dehydration. The more the agar extracted, the larger the quantity of water required. Generally factories working with *Gracifaria* have a higher water consumption than those using other raw materials. Water consumption also increases when better quality agar is required.

Working with a 1% solution, 99 litres of water have to be eliminated to produce 1 kg of agar. *Evaporation* or *precipitation* is recommended where freezing/thawing is not practicable.

Freezing and thawing the extract is employed both at industrial and cold country household level. Industrial freezing should be slow, to maximise both the growth of ice crystals and the separation of agar. This is usually followed by draining with a water-extracting centrifuge.

This freezing-thawing method. known as syneresis, followed by washing the gel matrix, also helps to purify the gel. Sulphated galactan portions of agar, salts, pigments and other organic compounds are soluble in the thaw water, and are partially removed from the insoluble agarose by filtration.

Factories which use syneresis usually have high water consumption. Some **Gracilaria** agars form soft gels which on washing disintegrate into fine particles. Similarly, low-temperature soluble agarose is lost when washing some agars. Thus, washing the gel matrix after the freeze-thaw cycle can only be performed with high gel strength agars or when alkaline pre-treatment is employed (Yaphe, 1984).

3. Small-Scale Agar Manufacture

Small-scale agar manufacturers with basic technology do not generally produce agar that meets international quality standards. There is little or no scientific control over processing, bacteriological contamination is usually too high, and prices offered too low. Consumption is usually local.

Seaweed is washed and then boiled for agar extraction in water and, possibly, sulphuric acid for about four hours. Washing facilities differ from factory to factory.

To obtain a clear agar solution after extraction. some processors adopt pressure filters, or use high speed centrifugal machines; others depend on sedimentation. After filtration, the hot extract is poured into wooden boxes to gel. The gel is removed from the'boxes, sliced into strips, spread on mats and exposed to freezing cold weather to dry.

In order to produce agar strips, some use air-freezing rooms; others make use of brine tanks in small ice-making plants to freeze the agar gel strips inside ice moulds.

The processing of agar sheets is simpler than that of other products. it may be made in large or small plants. To produce agar powder from dried Gracilaria, the processing technology is similar until the freezing stage. The frozen blocks of agar are then crushed, and the pieces washed to remove impurities. When the crushed pieces are melted, the agar is bleached and washed again before dehydration by low speed centrifuge. It is then dried to a moisture content of 20%. The pieces of dried agar are again crushed mechanically into powder and packed in polythene in quantities ranging from 100 g to 10 kg (Chen, 1978).

A simple cottage industry agar manufacturing process is common in the Philippines. Seaweeds (Gracilaria verrucosa, G. eucheumoides, Gelidium sp. and Eucheuma sp.) are washed with fresh water, sun-dried, and then re-soaked for 5-10 minutes. They are dried again until yellow, and then bleached in dilute vinegar until the colour turns olive green. They are then further dried until they become light brown.

Extraction is done by boiling in vinegar or even sulphuric acid with constant stirring. It is strained in cheese-cloth while still hot and cooled to gel at room temperature. Once set, the agar is cut into bars or strips, sprinkled with salt and ice, and frozen. It is then thawed and dried at room temperature or under the sun, after which it is ready for the local market (Guzman & Guiang, 1987).

4. Comment

It appears that the seaweed industry in the Bay of Bengal region suffers from a lack of marketing information and a need to improve technical know-how on processing. The establishment of processing facilities within the region would help stabilise the industry. The large exports of dried agar-yielding seaweeds, and the exports of high-valued agar products from importing countries such as Japan, should further encourage agar processing. Home industries should be developed with an eye towards product development, and also to suit the local demand.

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SEMINAR PAPERS : SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

PRODUCTION OF AGAR FROM SEAWEED WITH SPECIAL REFERENCE TO INDIA

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ABSTRACT

Agar production in India is about 75 tonnes annually, and takes place mostly in Tamil Nadu. Species from the genera ***Gelidium, Gelidiella*** and ***Graciluria*** are utilized for agar production. Two grades of agar are manufactured in India: food grade and IP grade (Indian Pharmacopoeia standards). The common processing is as follows: acid treatment, hot water extraction, freeze-thaw cycle, bleaching and sun-drying. Plant capacity ranges from 2 to 60 **kg** agar per day.

World production

Marine algae provide a rich and diverse source of raw material for the production of seaweed gums, polysaccharides that find wide application in the food, pharmaceutical and industrial sectors. The three most important polysaccharides, in terms of volume and value, are sodium alginate (and its derivatives), carrageenan and agar. A recent estimate (Anon. 1988) has put annual world production of agar at between 7,000 and 10,000 tonnes. The production of carrageenan and alginates, by comparison, **is** approximately two and three times as great, respectively.

Seaweed gums: Annual world production (tonnes)

Agar	7,000-10,000
Carrageenan	12,000-15,000
Alginates	22,000-25,000

According to Armisen and Galatas (1987), of around 7,000 tonnes of agar produced in 1984, approximately half came from ***Gracilaria,*** the remainder coming mainly from ***Gelidium.*** The breakdown by country was as follows:

Agar: World production, 1984 (tonnes)

Japan	2,440	Taiwan	275
Spain	890	Argentina	200
Chile	820	Indonesia	150
S. Korea	600	China	140
Morocco	550	Others	300
Portugal	320	TOTAL	6,685

Indian production

Observations in India and discussions with all but a few producers, indicate that current agar production is about 75 tonnes annually. If the expansion of output planned by several companies is realised, and the commissioning of other factories now under construction also comes about, total production could almost double within the next few years to around 140 tonnes per annum.

Collection of seaweed destined for agar production, as also that of Sargassum and Turbinaria for production of alginates, is confined at present to the southern part of the Tamil Nadu coastline, between Cape Comorin in the south and the peninsula that stretches out towards Sri Lanka and forms the Gulf of Mannar.

Species of the genera Gracilaria. Gelidium and Gelidiella are utilised for agar production*.

* The terms Gelidium αvδ Gelidiella are often used interchangeably within the Indian agar industry. In practice. of the two general it is probable that Gelidiella is the main one utilized.

Indian agar: species of seaweed used

Gracilaria	*Gelidium*	*Gelidiella*
G. edulis[1]	*Gelidium spp.*	*G. acerosa*
G. verrucosa[2]		
G. crassa		
G. corticata		
G. multipartita[3]		

Notes: (1) Syn. *G. lichenoides*
(2) Syn. *G. confervoides*
(3) Syn. G. foliifera

Of the Gracilaria species, *G.* edulis, collected from the waters off the mainland coast and those surrounding the off-shore islands, is the principal agarophyte. G. *verrucosa,* found in less salty estuarine areas, is used by a few agar producers. The other ***Gracilaria*** species are collected more by accident than design and do not form any significant part of the raw material utilised.

After landing the seaweed, the collector sells his haul to an agent who then dries it and sells it to the processor. A small agent may subsequently sell it to a larger one. Seaweed prices paid both by the agent to the collector and by the processor to the agent reflect the higher quality of the agar obtained from ***Gelidium*** and ***Gelidiella*** compared to that from ***Gracilaria.***

Indian agar: seaweed prices

Seaweed	Price paid (Rs./tonne)	
	Agent to collector(')	Processor to agent(2)
Gelidium/Gelidiella	1800	5,000-8,000
Gracilaria	600	2,500-3,500

Notes: (1) Wet weight
(2) Dry weight

Unlike ***Gracilaria*** from other sources, Indian material appears not to respond to alkali treatment as a means of increasing gel strength. Agar derived from Indian ***Gracilaria*** typically has a gel strength in the range 100-150 g/cm2, while that from ***Gelidium*** or ***Gelidiella*** is around 300 g/cm2.

Two types or grades of agar are manufactured in India: food grade, which is usually produced in mat form, and IP grade, which conforms to Indian pharmacopoeia standards and is usually sold in powdered form. For food use, paleness of colour is invariably considered more important than gel strength, and ***Gracilariu*** alone (which is cheaper and easier to bleach than ***Gelidium*** or Gelidiella) or a mixture of ***Grucilaria*** with ***Gelidium*** is commonly employed as the raw material. In a few cases, or where high gel strength is required, ***Gelidium*** alone is used to produce food grade agar, often in the form of shreds or so-called 'individuals' (strands of larger dimensions than shreds). IP grade agar is produced wholly or mainly from ***Gelidium*** or Gelidiella.

Prices of the agar also, of course, reflect the raw material used and, for IP grade, the more stringent processing requirements. Within the Muslim community, demand for agar, and therefore also its price, is high during the Ramzan season.

Indian agar: prices for agar obtained by producer

Grade	Type	Price (Rs./kg)
Food	Mat	140-160
		180-210 [1]
		200-300 [2]
	Shreds/'Individuals'	270-280
IP	Powder	300-400 [3]

Notes: (1) During Ramzan season
(2) Prices quoted by a few producers
(3) One producer quoted Rs.600/kg

The factories that produce the agar are located for the most part in Tamil Nadu, in close proximity to their raw material source. A few, however, are more distant from the seaweed belt, in Kerala and Andhra Pradesh.

The term 'factory' is used in the broadest sense to cover everything from the smallest family unit producing 2 kg of agar per day to the larger units producing 60 kg. Recently constructed factories plan to produce up to 100 kg/day.

Indian agar:production levels

Scale	Production	
	kg/day	tonnes/year
Large	up to 60	up to 25
Medium	10-40	2-10
Small	2-4	0.5-1

Almost without exception in India, the same basic method of processing is followed by all producers: acid treatment of the cleaned seaweed followed by hot water extraction; primary dewatering and purification of the agar by means of a freeze-thaw cycle; bleaching; and sun drying. Some adjustment is made according to whether *Gracilaria* or *Gelidiella* is being processed or whether it is *G. edulis* or *G. verrucosa*.

Initial handling and cleaning of the seaweed involves laying it out in the sun to dry and to bleach, removing epiphytes and other foreign matter by hand, and washing or soaking the weed several times in water. The seaweed may or may not be dried in between washes.

Acid treatment, to soften the weed in preparation for extraction, is accomplished by immersing it in cement tanks containing dilute hydrochloric acid for periods from 10 to 30 minutes, depending upon the species of seaweed.

After washing the seaweed free of acid, it is boiled in water at normal pressure without the addition of chemicals. Small units may employ direct heat by wood fire to boil the water; otherwise it is done by the use of steam. The extraction vessel may be fabricated of wood, aluminium or stainless steel. The length of time needed to extract 'the agar is dependent on the quality and nature of the raw material, but is usually somewhere between 1.5 and 3 hours. *Gelidiella* requires a somewhat longer time than *Gracilaria.* Yields of agar are around 10%.

After filtering, the extract is run into aluminium trays and allowed to gel. The trays are then transferred to a freezer, where they are kept, usually for 20 to 24 hours but sometimes longer. After removal from the freezer and thawing/draining, the crude agar gel is washed and then bleached by immersing briefly in hypochlorite solution. After washing again, the gel is laid out on mesh screens in the sun to dry. For IP grade agar, particular care is taken during handling and drying to avoid contamination by specks of dirt and other foreign matter. The sun-dried agar may be further dried in a hot-air drier.

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SEMINAR PAPERS: SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

PROSPECTS OF AGAR INDUSTRY IN INDIA

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ABSTRACT

This paper summarizes the status of previous and present work on utilization of agarophytes for agar extraction in India. Present national agar production does not meet demand. Standards are given for food and pharmaceutical grades. Physical properties of 1.5% agar are tabulated for ***Gelidiella acerosa, Gracilaria edulis*** and G. verrucosa. Yields range from 12 to 55% and gel strength varies between IS and 300 g/cm^2 depending on species.

* * *

Utilisation of seaweeds in India for the extraction of soda ash, alginate and iodine started during the II World War. Although the importance of seaweeds was realised during this period, the production of agar did not start until the 1960's. The export of seaweeds continued until 1975 when, in order to meet the requirements of the local agar industry, the Government of India banned the export of seaweeds. However. it should be noted that the local industry does not produce sufficient agar to satisfy the ever increasing domestic demand. Consequently, India imports a large quantity of agar.

The important agarophytes of India are ***Gelidiella acerosa, Gracilaria edulis, Gracilaria crassa, Gracilaria corticata*** and ***Gracilaria folifera.*** The seaweeds used for commercial extraction of agar are ***Gelidiella acerosa, Gracilaria edulis*** and G. crassa..

Gracilaria edulis is widely exploited for industrial utilisation in India. Collection is possible throughout the year around the islands in the Gulf of Mannar, Tamil Nadu. The, ***Gracilaria*** collected invariably contains various other plants. Fresh seaweed is sold at the rate of Rs.0.50/kg. When dried, the yield is 15% of the fresh material Commercial dried material is 60% pure, with a moisture content of 22%.

Since ***1983, Gracilaria*** crassa has been collected from Pampan, Vedalai and Kilakarai, Tamil Nadu. G. crassa grows in shallow areas attached to pebbles and stones; collection is done by hand picking. Only negligible quantities are harvested, and then only when there is no collection of G. ***edulis.*** It fetches a price of Rs. 1,000 per tonne (dry weight).

Agar is a complex mixture of polysaccharides obtained from certain species of red algae. It is mainly a mixture of two polysaccharides, agarose and agaropectin. Humm (1951) and Yaphe (1959) have defined agar as a gel-forming substance soluble in hot water and requiring a 1% solution to set as a gel on cooling.

The yield of agar and its gel strength vary from species to species and also on the method of extraction. Processing conditions play a significant role in the quality of the end product.

In India, Bose ***et al*** (1943) soaked dried seaweeds in water for 18 hours prior to treatment with acetic acid. Chakiaborty (1945) did the same, but used the process of freezing and thawing for purifying the agar gel, and used activated carbon to decolourise the gel. Karunakar ***et al (1948).*** and Joseph and Mahadevan (1948) purified the gel by soaking it in water of low salt content for 96 hours and finally washing under pressure. After freezing, the gel was dried with acetone. Thivy (19.51) soaked the seaweeds for 24 hours prior to extraction. Kappanna & Rao (1963) studied the method of Thivy, and found that soaking and extraction under pressure reduced the quality of agar gel. Srinivasan and Santhanaraj (1965) washed the seaweeds in sea water and then in fresh water several times, and dried them in the sun until they were completely bleached. Extraction was carried out by boiling the seaweeds at pH 6 and the extract was finally filtered and frozen.

A cottage industry method for agar extraction from ***Gracilaria edulis*** was worked out by Thivy (1958). Umamaheswara Rao (1970) has given a comprehensive account of aspects of Indian seaweeds and their utilisation. Much work has been reported on the chemistry of Indian seaweeds (Pillai, 1955a. 1955b). A comparative study was made by Chennubhotla et al (1977) on the yield and physical properties of agar from different agarophytes. The results are given in Table 1.

Table 1: Physical properties of 1.5% agar in water

Species	Yield %	Gel strength (g/cm^2)	Setting temp °C	Melting temp °C
Gelidiclla acerosa	40	125	46	73
Gracilaria edulis	55	63	48	65
G. verrucosa	23	41	40	55

Various authors have reported the yield and physical properties of agar obtained from Gelidiella and Gracilaria species (Table 2).

Table 2

Agarophyte	Yield %	Gel strength (g/cm^2)	Setting Temp °C	Melting Temp. °C
Gelidiella acerosa	45	300	40	92
Gracilaria lichenoides	33	120	45	84
G crassa	23	140	48	84
G. corticata	38	20	44	68
G. folifera	12	15	40	

* Gel strength of 1 5% concentration agar in water at 28 ± 2°C

In 1970, the Bureau of Indian Standards laid down specifications for food grade agar, an extract of which is given in Table 3.

Table 3: Specification for food grade agar

Characteristics	Requirements
Colour	White or pale yellow
Odour	Odourless
Taste	Mucilaginous
Solubitity	Soluble in boiling water
Moisture, after drying at 105°C for 5 hours	20.0%
Total ash by weight, maximum	6.5%
Acid insoluble ash by weight, maximum	0.1%
Insoluble matter by weight, maximum	1.0%
Arsenic (as As) maximum	3.0 mg/kg
Lead (as Pb), maximum	1.0 mg/kg

The use of agar as a water-soluble thickening, emulsifying and gelling agent has become established worldwide in industries ranging from foods, pharmaceuticals, cosmetics, paper, textiles, petroleum, and to the new industry called biotechnology (Glicksman, 1986). In India, agar is used as a medium for tissue culture of ornamental and other plants. It is also used in bacteriological laboratories as culture media. It is used as a stiffening agent in a number of food products, as a sizing material, as mucilage, and in clarifying beverages. It is employed in canning meats, in laxative preparations, as a constituent in medical pills and capsules, in dental impression moulds, and as a lubricant for drawing tungsten in electric bulbs. It is also incorporated into the formulation of silk worm food.

Much remains to be done on the technological aspects of commercial production of phycocolloids from seaweeds. India has a vast seaweed resource which at present is not fully utilised. Concerted efforts, on a national level, are needed for the proper utilisation of available resources. Agar extraction can also be done on a small industrial scale, providing employment opportunities to a number of people. Fresh water availability and sufficiently low night temperature to freeze the agar blocks suggest places like the Nilgiris and other high ranges as ideal locations for such factories. This will, however, involve transportation of raw materials from the coast. Alternatively, freezing facilities will have to be provided in coastal areas. The relative economics of these two possibilities remains to be studied.

As the food and bio-technology industries gain momentum in India, the prospects. for producing various grades of agar from seaweeds are bright. A detailed study on the technology of production is essential in order to make production economical and to make the technical knowhow available to new entrepreneurs entering the field. An in-depth study to locate new raw material sources is also required. India needs a large number of viable small industries to provide subsidiary employment for the local fisherfolk.

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SEMINAR PAPERS: SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

AGAR PRODUCTION ADAPTED TO RURAL AREAS

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ABSTRACT

A programme has been set up to stimulate seaweed production and processing in Thailand. In this connection, the Biopolymer Research Institute has developed a simplified method of agar extraction from many types of ***Gracilaria*** and ***Polycavernosa*** species available in the coastline of Thailand. By utilizing ordinary kitchen utensils in agar processing, it has been possible for the Institute to transfer this simple technology to rural villages in coastal areas. Two processes are proposed: the first is to produce crude agar strips and local agar desserts'; the second is a two-tier system under which crude agar strips are either used for orchid tissue culture or further refined in a processing plant. Increased interest in seaweed collection, culture and processing by rural folk may lead to expanded production and the setting up of modern processing plants to produce high quality agar.

Introduction

Agar-bearing seaweeds, agarophytes, are naturally abundant along more than 2,600 kilometres of Thailand's coastline. Production of natural stock is rather seasonal along the Gulf of Thailand and less so along the Andaman Sea coast. The cage culture of marine fish has become a well-established industry, and agarophytes are appearing as fouling organisms attached to the net cages. These potentially valuable resources remain unexploited in most areas. However, Thailand exports raw seaweeds to developed countries and imports processed agar in increasing quantities every year. As a result, Thailand faces a trade deficit in agar. To reduce the country's dependence on agar imports, the Royal Thai Government recently started a vigorous drive to produce and process seaweed. It focussed on stimulating private investment in seaweed processing for the local manufacture and marketing of agar, while at the same time creating employment for the impoverished coastal population. Within the framework of the programme, the Biopolymer Research Unit (BRU) was established and equipped to work on the identification of seaweeds and the analysis and process development of phycocolloids in Thailand. As a result of long-term fundamental research, the BRU has developed a simplified method of agar extraction from many types of ***Gracilaria*** and ***Polycavernosa*** species in Thailand. This simple technique is suitable for introducing small-scale crude agar production to rural areas. These can be used locally in food and tissue culture. The crude agar produced in rural areas can be collected and further refined with more sophisticated techniques in a central process&g plant to produce high-grade agar for different applications. This appropriate technology can be transferred to the rural people to make them aware of the wealthy seaweed resource on their doorstep.

Materials and methods

Agar-bearing seaweeds were collected from different locations in Thailand and identified by Dr I Abbot of the Department of Botany, University of Hawaii. Some former members of the genus ***Gracilaria*** have been moved to the genus ***Polycavernosa.*** The natural stock of seaweeds collected from Songkhla Bay were identified as ***Polycavernosa fishery.*** The agarophytes growing attached to the net of marine fish cages along the canal of Trung were ***Polycavernosa*** changii while the samples collected from pond culture in Pattani were identified ***as Gracilaria tenuistipitata.***

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The collected seaweeds were placed on a clean surface and sun-dried for 2-3 days. Dry agar-bearing seaweeds are rather dark in colour and can be kept for a long time before extraction. The procedure starts **with** cleaning the seaweed by washing with fresh water 2-3 times and then soaking for 2-3 hours. The cleaner the seaweeds, the cleaner will be the agar produced. After cleaning it is dried in the sun; the colour becomes paler, usually yellowish or light-brown. Before extraction, the dry and **clean** seaweeds are soaked in water in a ratio of 1:20 by weight for 2-3 hours until full hydration is reached. When the seaweed is completely swollen, the mixture is gently boiled in a water bath for 45 minutes. The seaweed is then ground using a traditional stone mortar or an electrical blender. The slurry **is** boiled gently for another half an hour. It is then poured into a simple hand-operated press which is lined with a two layered cloth bag, and which has been preheated by rinsing with hot water. This simple press is a traditional local design used for extracting oil from coconut. After pouring the seaweed slurry into the press, the cloth bag is firmly tied and pressure is quickly applied. The filtrate flows into the tray, and the residue in the bag can be used as fertiliser. At this stage, desserts can be made by adding syrup and flavours. The filtrate **is** left to cool to allow the agar gel to set. The agar gel is put into a freezer for two days. The tray is then thawed at room temperature and the liquid is removed. The agar residue is sun-dried and stored for further use. If no freezer is available, the agar gel is put into a thick cloth bag and gently squeezed, either in the press or **by** putting a heavy stone on top of the bag overnight. The damp agar residue is then sun-dried and stored. A summary flow chart of this simple agar extraction is shown in Figure 1.

Figure 1: A simple method of agar extraction

dried seaweed
↓
wash and clean
↓
sun-drying
↓
decolourised seaweed
↓
bleached seaweed
↓
grinding and boiling
↓
filtering by pressing
↓
agar fitrate

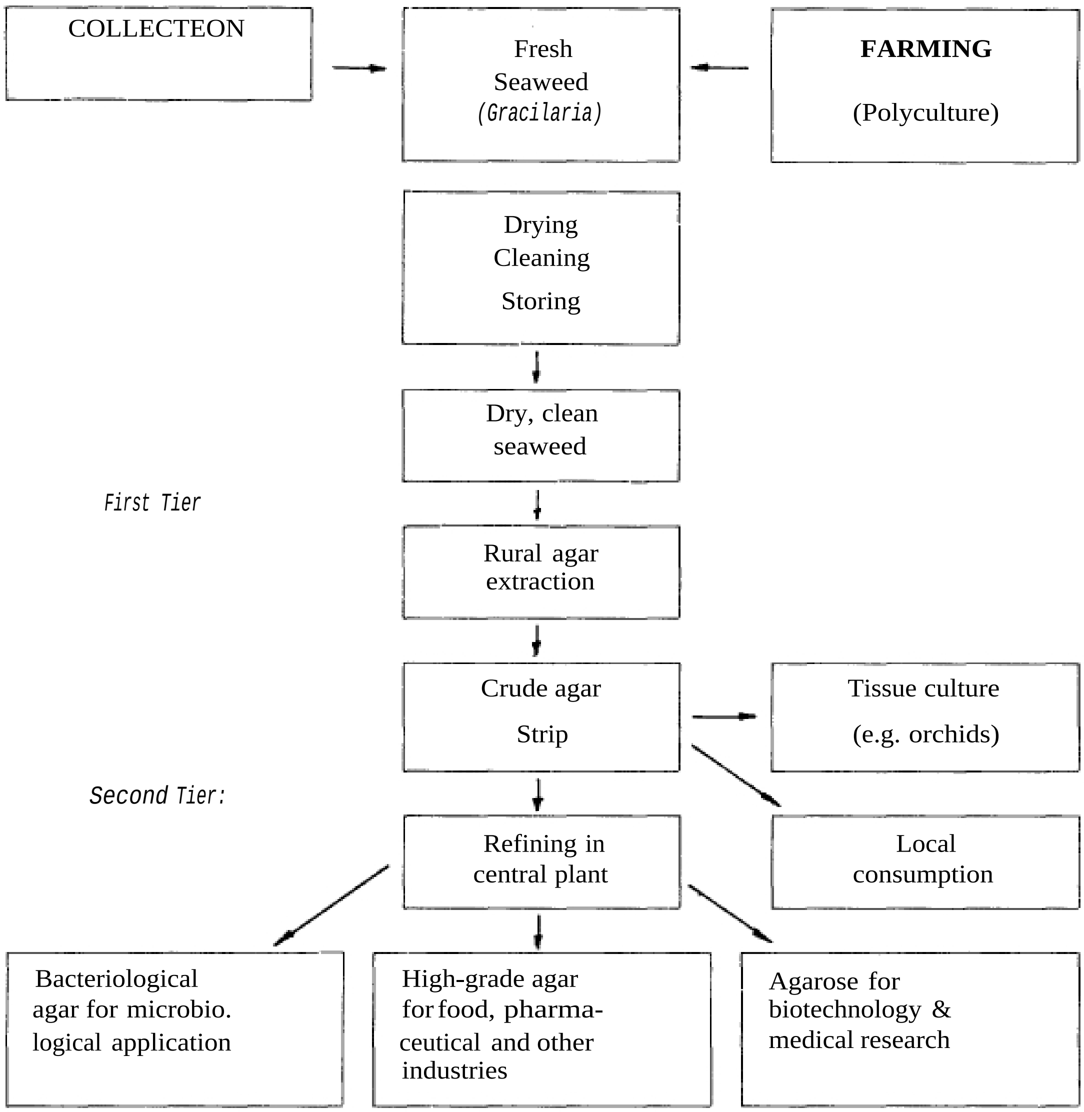
↓	↓
cooling	syrup and flavour
↓	↓
dewatering	cooling
↓	↓
sun-drying	agar dessert
↓	
crude agar strip	

A mobile team of BRU staff arranged the transfer of this simple technology to the rural villages of Songkhla, Satul and Trung provinces during April 1989. Ordinary kitchen tools--cooking pot, blender, gas stove and coconut press there-were put into a compact package which could be adapted for mobile training facilities in three different rural areas during a 5-day operation. More than 100 local villagers participated in the seaweed production and processing training programme. Extension aids comprising video tapes, slides, leaflets and booklets were distributed.

Results and recommendations.

The crude agar extracted by this simple method is rather soft, but it can be used for local food. If a stronger gel is needed, more agar can be added. The mobile training programme appeared to be a great success and beneficial to the local population who responded well. Requests for more training were received from leaders of local communities. The crude agar produced in the rural areas can be used locally, or else collected for further refining to produce high-grade agar. The scheme of such a two-tiered production system is shown in Figure 2.

Figure 2: Proposed two-tiered agar production scheme



The planned production of crude agar in the rural areas will allow some of the benefits of seaweed processing to be channelled to the usually impoverished coastal population. By raising their interest in seaweed collection, culture and processing, the raw material requirements of a central commercial agar reprocessing plant will be established.

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SEMINAR PAPERS: SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

EXTRACTION OF AGAR FROM *GRACILARIA EDULIS* AS A VILLAGE LEVEL TECHNOLOGY – PRELIMINARY RESULTS

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ABSTRACT

A simple method of agar extraction, which has been developed in Thailand, may be suitable for adaptation as a village level technology in fishing villages in Tamil Nadu, India. Preliminary results from trials using the'modified method indicated an agar yield of 12.0 - 24.5% depending on the heating time and the method of heating. Suggestions for further research are discussed.

Introduction

Seaweed collection is an important source of income in fishing villages along the coast of Ramanathapuram district in Tamil Nadu, India. Agarophytes such as Gracilaria spp. and Gelidiella spp. are collected through most of the year by men and women. The seaweed is sold ashore for a few rupees per kilogramme to local agents who, in turn, dry the seaweed before selling it to processing factories for agar extraction. Agar is sold within India and is used mainly in the food industry.

The BOBP's Post-Harvest Fisheries Project is looking into the possibility of agar production being adapted as a village level technology.

By selling agar instead of seaweed, the villagers may be able to increase their income. A simple method of agar extraction has been developed by the Biopolymer Research Unit of the Srinakarinvirot University in Bangkok, Thailand (Chandrkrachang & Chinadit, 1988). This method produces a crude agar which could be upgraded and used in the domestic food manufacturing industry in India. With a few adaptations, this small-scale extraction method might be suitable for use in the villages of Tamil Nadu.

Since June 1989, trials to produce agar from Gracilaria edulis have been conducted in a field laboratory. The main purpose has been to determine the maximum agar yield using this extraction method, and to estimate the amount of seaweed which can be processed per day.

This paper describes the agar extraction technology and the modifications in the technology required to adapt it for use in Indian villages. A summary of preliminary results and suggestions for further research are presented.

Materials and Methods

Materials: To conduct agar extraction trials. the following materials were used: clean seaweed; fresh water; tubs to soak and wash the seaweed; a pan (50 1) to boil the seaweed; wooden spoons; a kerosene or wood-fuelled stove; a screw press; two planks and some heavy stones; filter cloths; trays and a platform to dry the agar in the sun.

All materials were purchased locally. The screw press was a larger version of the coconut press used in Thailand.

Method of extraction:

An outline of the agar extraction procedure is given in Figure 1.

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Figure 1: Outline of the agar extraction procedure.

FRESH SEAWEED

↓

cleaning
drying
storage

↓

CLEAN DRY SEAWEED

↓

washing
soaking

↓

SOAKED SEAWEED

↓

heating
filtration

↓

AGAR SOLUTION

↓

setting

↓

AGAR GEL

pressing out water through filter cloth
drying in the sun

↓

DRIED AGAR

Seaweed collected from natural seaweed grounds, or from a seaweed farm, was cleaned and fully dried in the sun, so that it could be stored for some time. Before processing, the seaweed was washed and then soaked in fresh water for several hours until it felt soft. It was then heated in fresh water, the time depending on the amount and variety of seaweed. After heating, the seaweed was filtered through a cloth with the help of the screw press. The filtration had to be done quickly, and the screw press pre-heated with hot water to prevent the agar solution from setting during the process. The agar formed a gel after cooling. To remove the water from the agar, the gel was enclosed in a thick filter cloth and put under pressure either in the screw press or between two planks weighted with heavy stones for larger quantities. This process takes at least half a day, after which the agar needs drying in the sun for several days.

Extraction trials

Trials were conducted with small (100 g/l) and large (lkg/101 and 2kg/20 I) samples of seaweed. The small (100 g) samples of seaweed (ground or un-ground, bleached or unbleached) were heated in one litre of water for 1, 1 .5, 2, or 2.5 hours in a water bath, or heated directly. The larger samples were heated directly for 2, 3 or 4 hours. All trials were conducted with samples from the same batch of seaweed, which was collected from a seaweed farm and fully dried. Water was added if substantial evaporation occurred during heating, and the water temperature was kept at 90 to 95°C. The seaweed residue was heated for a second time in 500 ml water for 20 minutes (100 g samples), in 4.75 1 for 1 hour (lkg samples) or in 10 l of water for 1.5 hours (2kg samples).

In addition to these experiments, samples from the same batch of seaweed were sent for evaluation of agar yield and gel strength to the Biopolymer Research Unit in Thailand, the Central Salt Marine Chemical Research Institute in India and the Central Marine Fisheries Research Institute in India.

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Results

Results of the agar extraction trials using 100 g of seaweed heated in 1 iitre of water are given in Table I. The data have not been analysed statistically, since trials are still continuing. The average agar yield obtained using this extraction method was about 16 per cent. There were no big differences in agar yield between heating the seaweed in a water bath or heating it directly. Grinding the seaweed with an electric mixer half-way through the heating time increased the agar yield by a few per cent. In most trials, the maximum yield was obtained after a heating time of two hours.

Table I: Agar yield (%) from extraction trials using 100g seaweed heated in one litre of water.

	Heating time (hours)			
	1	1.5	2	2.5
Water bath	16.8	14.4	17.6	14.0
	18.0	16.1	19.0	16.8
Water bath mixed	16.5	14.9	20.0	22.9
before heating	14.8	13.5	23.3	24.5
Water bath mixed	15.1	18.6		
during heating	21.3	18.7		
Direct heating	14.3	12.2	17.9	15.3
	16.8	13.8	18.4	17.4

Increasing the quantity of seaweed being pressed did not greatly affect the agar yield (Table II),, but it should be heated for a longer period. The increase in the heating time, from two to four hours, resulted in an increased agar yield of three and four per cent in the trials with 2 kg samples.

Table II: Agar yield (%) from trials using larger quantities of seaweed.

	Heating time (hours)		
	2	3	4
Seaweed/water (kg/l)			
1/10	17.s		17.4
	18.8		
2/20	12.0	14.5	16.4
	14.2	17.4	17.2

Yield (%) and gel strength (g/cm^2) of the agar from the seaweed samples sent to the three institutes are presented in Table III. Considering that all the samples came from the same batch of seaweed, the differences in agar yield and gel strength are remarkably high. The differences can be explained only partly by the use of different methods of analysis.

Table III: Agar yield and gel strength from seaweed samples sent to different institutes.

	CMFRI India	CSMCRI India	BRU Thailand	BOBP India
Agar yield (%)	42	60	25	16
Gel strength (g/cm^2)	24	120	120	-

Discussion

The variation in agar yield within the same trials is most probably caused by two different factors. There will always be some natural difference in agar yield between seaweed plants of the same species caused by the age of the plants and the season of collection. The method of agar extraction and the equipment have purposely been kept simple, hence there may be a consequent reduction in the precision of the experimental technique.

An agar yield of 16 per cent obtained by this simple extraction method is considered to be satisfactory. However, a daily amount of 320 g agar, obtained by processing 2 kg of seaweed, may not give the fisherfolk enough income, and the amount of seaweed processed at any one time should be increased. Larger quantities such as 4 or 5 kg of seaweed were processed, but several problems were encountered.

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The screw press was too small to process these larger quantities of seaweed. A bigger press can be made, but it will be more expensive and probably too heavy to operate by hand.

The present method of applying pressure to the gel in a filter cloth does not remove enough water from the agar. Consequently, it takes too long (more than 6 days) for the large quantities of agar to dry and it starts decaying. The pressure (0.016 kg/cm^2) exerted on the seaweed by the stones is insufficient. According to Okazaki (1971). a pressure of 100 kg/cm^2 is needed to remove 50 per cent of the moisture. This can only be achieved by using a hydraulic press. It may be difficult to construct a cheap and simple press which can remove sufficient water It is possible that a solar heat collector will help to improve the drying process, but it too should be cheap and simple to operate.

This simple agar extraction technology is not yet ready to be introduced into the fishing villages of India. A replacement has to be found for the present screw press to enable larger quantities of seaweed to be processed. The technique for removing water from the gel has to be improved. In addition. a market has to be found for the crude agar. Samples have been sent to commercial agar processing factories in India to find out whether it can be upgraded, and if so at what cost.

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SEMINAR PAPERS: SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

SMALL-SCALE *GRACILARIA* CULTURE AND AGAR PROCESSING — SOME ECONOMIC ISSUES

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ABSTRACT

An economic model has been established for seaweed farming and agar extraction at the village level. The experience gained by the BOBP pilot farms near Mandapam, Tamil Nadu, India, provides the quantitative data. At a production level of 800 kg dry weight of *Gracilaria edulis* per plot, it is concluded that an agar-selling price of Rs.125 per kg is required, assuming a 1.5% yield of agar, for the project to he profitable. If seaweed production falls to 500 kg. an agar price of Rs.150 per kg is needed, together with an agar yield of 16%. The model shows that the project may still be profitable after fencing each plot to prevent grazing by rabbit fish.

Background

During the last two years BOBP has operated small-scale pilot farms for *Gracilaria edulis* near Mandapam on the coast of Tamil Nadu, India. Recently, small-scale extraction of agar has been evaluated. A model for assessing the economic viability of the activities has been established. This paper describes and assesses this model, and then illustrates some of the economic relationships between key technical and economic parameters. It should be stressed that the model is an example, and that there are several alternatives that could be equally or more appropriate.

DESCRIPTION OF THE MODEL

Structure

The economic model is intended to be dynamic. permitting simulation of different scenarios and their impact on the overall profitability of the project. The main profitability criterion utilised is internal rate of return, but to avoid academic discussions on the pros and cons of different criteria, net present value and pay back period have also been included. The model focuses on actual annual cash flows, rather than any accounting-related measurements of returns.

To simulate different scenarios of possible outcomes of the project, a point of departure, here called “base-case”, has been established. This includes the most likely values of all variables involved at the time the model was created. This base-case version is described in Appendix 1.

Assumptions

The model is intended for a 0.1 hectare plot of G, edulis culture. All equipment for culture and drying of the seaweed, as well as extraction of agar, is assumed to be used exclusively for this plot. Because of grazing problems encountered in Mandapam, a major investment in fencing the plot has been included. The option of using natural seaweed stocks for agar production has not been considered, since the natural resources in the area have been severely depleted by harmful harvesting methods. Natural resources are, however, still harvested and sold as wet seaweed. Cultured seaweed, sold directly as seaweed, is obviously not cost competitive with that from natural resources, so this option has not been examined.

The opportunity cost of labour has been fixed at Rs.20 per man day, the salary presently paid to fisherfolk participating in the pilot culture. The amount of labour required for planting and maintaining the seaweed farms has been considered as fixed, i.e. it does not vary with the amount of seaweed produced. The labour utilised to harvest and dry the seaweeds is expected to vary with the amount of seaweed produced. For extracting the agar, it is estimated that one man day will be needed for every 4 kg of dry seaweed processed.

A detailed list of necessary investments is included in Appendix 1.1. The economic lifespan of individual items has been estimated to equal their expected technical lifespan. All replacement investments and future cash flows are expressed in fixed year one rupees

The income statement contains a specification of sales revenue, all operating costs, and the annual depreciation of investments.

The final table of the model, containing the components of net cash flow per year, is the basis for measuring the profitability of the project. Using net present value, the annual net cash flows have been discounted at an annual discount factor of 15% and 25%. The internal rate of return expresses the discount factor at which the net present value of the project is equal to zero. Finally, the pay-back period. though crude, informs the prospective investor how much time it will take to recover his initial investment.

A critical assessment

Among the assumptions with a high level of uncertainty is the projected seaweed production figure. Pilot farms in Mandapam have not been able to produce anywhere near 800 kg dry weight per plot per year. This seems to be due mainly to grazing and to wind conditions in the open sea culture. If these problems can be overcome, however, it is still felt that an annual production of 800 kg dry weight of G. edulis, representing around 2.7 kg wet weight per metre of line per year, is technically feasible.

The technical parameters for agar extraction have been established during four months of practical trials. and consequently should be considered to be fairly reliable. The agar selling price is definitely on the high side. At present, local food grade agar is sold for between Rs.150 and Rs.250 per kg, the price varying because of festive seasons.

It can be argued that the opportunity cost of labour should be adjusted downwards during the lean fishing and seaweed collecting periods. The quantity of labour needed is based on two years of experience, and should therefore be fairly accurate.

The expected lifespans of the various investments are naturally hard to predict, given the long planning horizons involved. Residual values of the assets at the end of the period have not been included, since they can be expected to be very small for the items not fully depreciated.

Interest costs and interest earnings have been omitted from the model. In "base-case", the initial financing required could be repaid within three years, and interest earnings could be generated on the positive cash flows of subsequent years. It could, however, be argued that the positive cash flows from year four onwards would most likely be used to increase standards of living, in which case little or no interest earnings would be generated. There is also a high variability in the cost of financing, depending on the credit source. A subsidised bank loan at 4-5%, per annum would naturally result in a significantly more profitable project than a long term credit from the informal sector at considerably higher interest rates.

In summary, the optimistic predictions on primary seaweed production and agar price are only partly offset by over estimating the opportunity cost of labour, not including residual values, and a probably unnecessarily expensive fencing method.

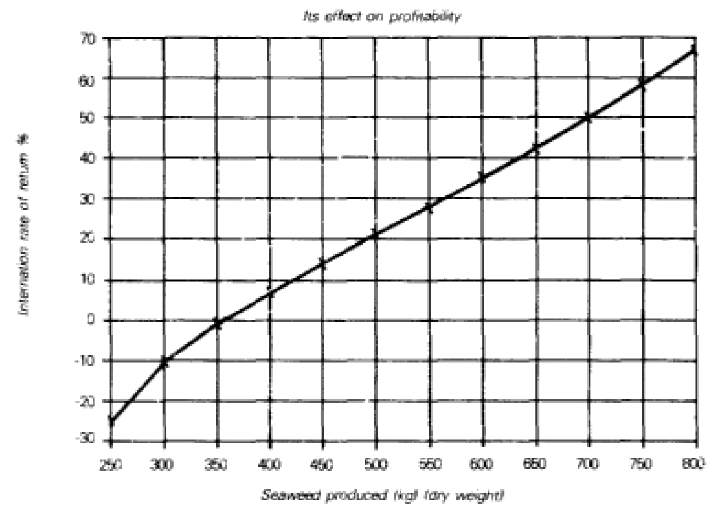
Some economic relationships

The intention of the model has been to assist in quantifying the project in economic terms. It was felt that there was a need to assess the impact of alterations in cost, revenue, and output levels on profitability. The parameters identified as crucial for economic viability were seaweed production level, agar yield, agar selling price and fencing costs.

In the figures presented below, internal rate of return has been used throughout to measure profitability. The project should be considered economically viable when the internal rate of return exceeds the opportunity cost of capital. The opportunity cost of capital equals the return forgone by investing in the project rather than the best alternative project of equivalent risk.

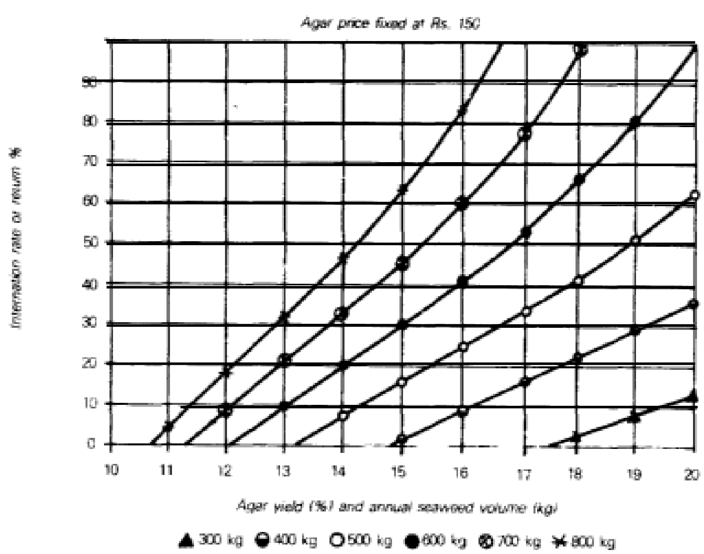
It can be argued that very few alternatives are available to the fisherfolk around Mandapam. But they will definitely require a project return that covers the interest rates offered by banks, plus a healthy risk premium. The local hank deposit rates are around *5%* per annum, and the fisherfolk would probably demand a risk premium of at least 20—25%. This adds up to a required rate of return somewhere in the 25--30% range.

Figure 1 SEAWEED PRODUC11ON VOLUME



Let us start by looking at the effects of different seaweed production volumes on project profitability, keeping all other variables constant at their "base-case" levels. We can see that an annual production of at least *550* kg (dry weight) of G. *edulis* is required to reach a satisfactory level of profitability.

Figure 2 AGAR YIELD & SEAWEED PRODUCTION VOLUME



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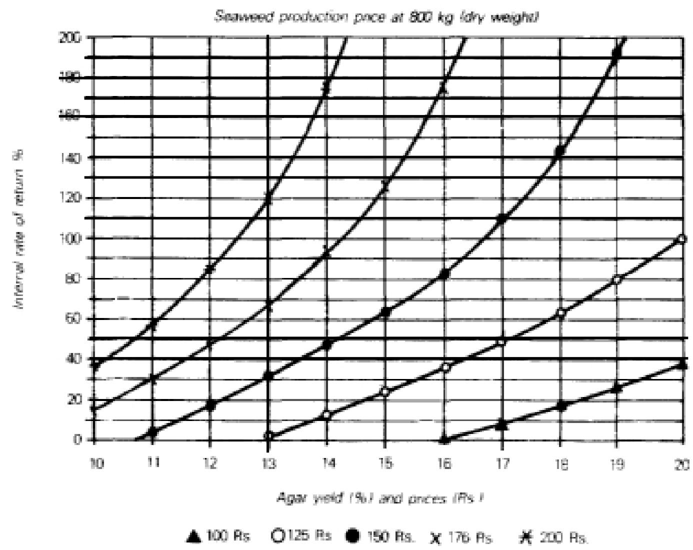
We may then introduce variations in the agar yield, under different seaweed production volumes. In the upper range of seaweed production levels, between 600 kg and 800 kg, there seems to be a trade-off between agar yield and seaweed production, such that a decrease in seaweed production of 100 kg, may roughly be compensated for by a 1% increase in agar yield. This relation holds valid only for agar yields up to around 16%.

It can be observed that, since yields above 17—18% are unlikely, seaweed production levels of 300—400 kg will not be viable.

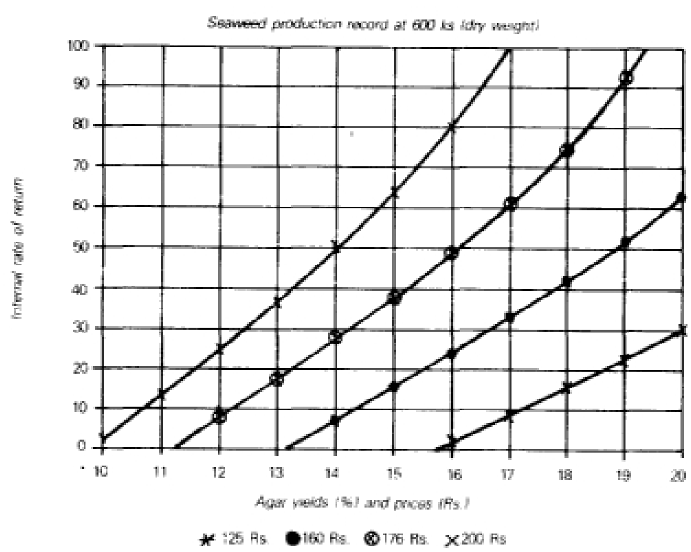
Figure 3 THE IMPACT OF AGAR YIELD & AGAR PRICE



This graph introduces variations in agar prices, keeping agar yields variable, but seaweed production volume fixed at 800 kg (dry weight) per year.

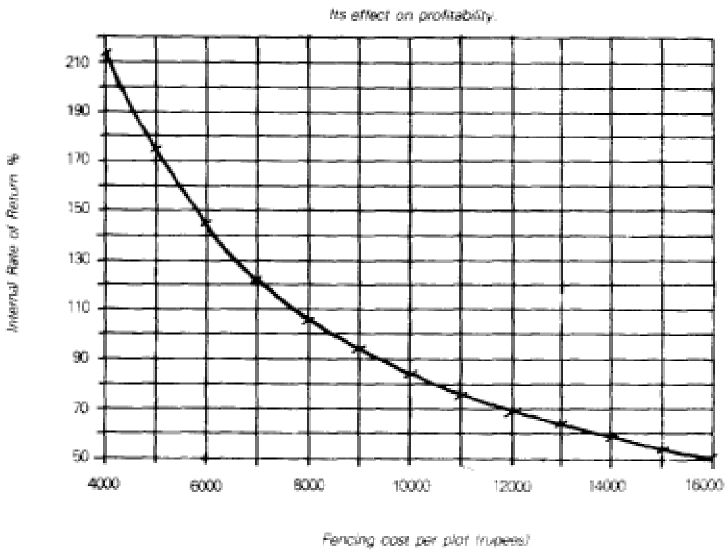
The most valuable information from this graph is that if the agar selling price falls below Rs. 125, it will be very difficult to make the seaweed farm a profitable venture.

Figure 4 THE IMPACT OF AGAR YIELD & AGAR PRICE



If the seaweed production level falls to 500 kg (dry weight) per year, any agar price below Rs. 150 will be too low to be viable, unless drastic technological progress is made, and agar yields above 20% can be achieved.

Figure 5 FENCING COST



This graph illustrates the effect on overall project profitability of changes in the fencing cost. All other variables are kept constant at their “base-case” level. The project will, in its “base-case” version. continue to he profitable even with quite a substantial investment in fencing.

APPENDIX 1.1

Economic analysis of *seaweed and agw prothiction in Mandapam- Tamil Nadu*

This is a model to assess the economic viability of the above activities. Any input data that is high-lighted like this line, can be modified. Please make the directory containing this file the current directory. To access the main menu, just press “Alt” and “M” simultaneously.

Assumptions BASECASE	Year	Year 2-10	
Opportunity cost of labour:	20	20	Rs. per man-day
Seaweed production:	800	800	Kg of dried seaweed/year
Seaweed used for agar production:	800	800	Kg of dried seaweed/year
Seaweed processing capacity:	4	4	Kg of dried seaweed/man-day
Average agar yield:	14.0%	16.0%	Agar produced as % dried seaweed used
Fuel consumption (kerosene = =	0.17	0.17	Fuel units per hour of boiling
Average boiling time:	2	2	Hours
Average boiling volume:	0.25	0.25	Kg of dried seaweed
Fuel cost (kerosene = =	3.5	3.5	Rs. per fuel unit
Cost of filter cloth:	0.25	0.25	Rs. per processed Kg of dried seaweed
Seaweed selling price:	5	5	Rs. per Kg
Agar selling price:	150	150	Rs. per Kg

Lahour requirements

	Rs. per man-day	Man-days per year Year 1	Year 2—10
Vegetative propagation (F)	20	30	10
Outplanting (F)	20	4	4
Maintenance (F)	20	75	75
Harvest(V)	20	15	15
Drying(V)	20	9	9
Agar production (V)	20	200	200
TC		333	313

(F): Fixed labour cost
(V): Variable labour cost

APPENDIX 1.2

Income statement and cash flow

Version: BASECASE

Income statement

	Quantity		Value	
	Year 1	Year 2-10	Year l	Year 2-10
Sales seaweed	**0**	**0**	**0**	**0**
Sales – agar	112	128	16,800	19,200
Labour – seaweed	133	113	2,660	2,260
Labour – agar	200	200	4,000	4,000
Filter-cloth	N.A	N.A	200	200
Fuel	I ,067	1,067	3,733	3,733
Other:	0	0	0	0
Total operating cost			10,593	10,193
Gross margin			6,207	9,007
Depreciation - seaweed			1.800	l , 800
Depreciation - agar			740	740
Income before financial expenses			3.666	6.466

Cash flow	Year 1	Year-3	Year 3	Year4	Years5	Year6	Year7	Year8	Year9	Year 10
Sales (+)	16.800	19,200	19,200	19,200	19,200	19.200	19,200	19,200	19,200	19,200
Investment (-)	18,465	215	891	1,025	991	475	1,701	215	991	l ,025
Operating costs **(–)**	10.593	10,193	10,193	10,193	10,193	10,193	10,193	10,193	10,193	10,193
Net Cash flow (=)	(12,258)	8,792	8,116	7,982	8,016	8.532	7,306	8,792	8.016	7,982

Net Present Value at 25% discount rate: 13,048 Rupees

Net Present Value at 15% discount rate: 23,434 Rupees

Internal Rate of Return: 67:6%

Payback Period

(investments year 2-10 = costs): 2.3 Years

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APPENDIX 1.3

Seaweed culture - an investment summary

Version : BASECASE

Item	Number of units	Unit price (Rs.)	Total investment (Rs.)	Economic lifespan (Years)	Annual depreciation	Annual investment - Seaweed production									
						Year 1	Year2	Year 3	Year4	Year 5	Year6	Year7	Year8	Year 9	Year 10
Seaweed (kgs wet)	225	1.07	240	2	120	240	0	240	0	240	0	240	0	240	0
Stone post	30	21.7	650	10	65	650	0	0	0	0	0	0	0	0	0
HDPE rope 5 mm (M)	300	0.33	loo	2	50	100	0	100	0	100	0	100	0	100	0
HDPE rope 3 mm (M)	3000	0.25	750	3	250	750	0	0	750	0	0	750	0	0	750
Shed			500	10	50	500	0	0	0	0	0	0	0	0	0
Drying frame			200	5	40	200	0	0	0	0	200	0	0	0	0
Fencing	210	58.4	12,254	10	1,225	12.254	0	0	0	0	0	0	0	0	0
Other:			0		0	0	0	0	0	0	0	0	0	0	0
Total			14,694		1.800	14,694	0	340	7.50	340	200	1,090	0	340	750

Agar processing - an investment summary

Version : BASECASE

Item	Number of units	Unit price (Rs.)	Total investment (Rs.)	Economic lifespan (Years)	Annual depreciation	Annual investment - Agar processing									
						Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Coconut presser	1	3,000	3,000	10	300	3,000	0	0	0	0	0	0	0	0	0
Stove	1	100	100	4	25	100	0	0	0	100	0	0	0	100	0
Manual grinder	1	60	60	5	12	60	0	0	0	0	60	0	0	0	0
Pressing planks	4	25	100	2	S0	100	0	100	0	100	0	100	0	100	0
Manual chopper	1	60	60	3	20	60	0	0	60	0	0	60	0	0	60
Aluminium vessels (s)	6	30	180	1	180	180	180	180	180	180	180	180	180	180	180
Aiuminium vessels (I)	1	35	35	1	35	35	35	35	35	35	35	35	35	35	35
Plastic vessels (s)	2	38	76	2	38	76	0	76	0	76	0	76	0	76	0
Plastic vessels (I)	2	80	160	2	80	160	0	160	0	160	0	160	0	160	0
Other 1:			0		0	0	0	0	0	0	0	0	0	0	0
Other 2:			0		0	0	0	0	0	0	0	0	0	0	0
Total			3,771		740	3.771	215	551	27.5	651	275	611	215	6.51	275

A SIMPLE PROCESS FOR EXTRACTING AGAR FROM POLYCAVERNOSA CHANGII

by Ramli Bin Saad

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ABSTRACT

Polycavernoso changii from the Middle Bank of Penang. Malaysia was sun-dried. Extraction of agar was achieved with hot water. After filtration, the extract was set aside to cool and gel. Removal of water from the gel was by syneresis. Final drying was by oven and sun. *P. changii* was found to yield 33-48% agar.

Introduction

Polycavernosa changii is a Gracilaria-like seaweed commonly found in Penang, and other parts of Malaysia. The Fisheries Research Institute studied methods of growing this seaweed and possible commercial-scale culture (Doty, 1977; Faazaz, 1986).

The present study was carried out with the aim of developing a method that can be performed by traditional fisherfolk for extracting agar from this seaweed. There is no agar manufacturing industry in Malaysia at present. All agar is imported. in particular from Korea, China and Japan.

Materials and Methods

The extraction process was based on a report by Coppen (1988) and Trono et *al* (1988). There were four stages, namely harvesting and drying, gel extraction, dewatering of the gel, and chemical treatment.

a. Harvesting and drying

Polycavernosa changii was collected by hand from the Middle Bank of Penang, and sun-dried on netlon attached to an iron rack. It was then soaked in fresh water for 20 minutes for pre-bleaching treatment and then sun-dried again. When it was totally dried, the seaweed was kept in a plastic bag until required for agar extraction.

b. Gel extraction

Extraction was carried out with hot water. A 100 g sample of the dried seaweed was soaked in fresh water for 30 minutes to soften it and to remove impurities. It was then cooked with 2 litres of fresh water in a stainless steel pot for 30 to 60 minutes. The mixture was filtered using double layers of soft cotton cloth and pressed. The extract was collected in an aluminium tray and set aside to cool and gel.

c. Dewatering of the gel

Water was removed from the gel by syneresis, a process by which frozen agar liberates water when it thaws. In the first three experiments, the gel was cut into 1 .5 cm bars and kept in the freezer overnight. In the fourth and fifth experiments, the gel was put into the freezer uncut. In all the experiments, the frozen gel was removed from the freezer the next morning and put in the sun for about three hours to thaw. The gel was then put back in the freezer for another four hours, thawed again for one hour and then kept in the freezer overnight. The next day, the gel was thawed again

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for 3 hours. For the fourth and fifth experiments, the gel was cut into small strips and then dried with the gel from the other three experiments alternately in an oven and in the sun.

d. Chemical treatment

Sodium hypochlorite (2-5% solution) was used to bleach the agar in experiments one. two and three. It was also used to bleach the seaweed before extraction in experiments four and five. Sodium hydroxide was used to treat the seaweed before extraction in experiment three.

Results and discussion

It was observed that the quality of the agar produced was largely dependent on the period of extraction and on the bleaching agent used. When the period of extraction was 60 minutes. the seaweed was crushed and the agar produced was blackish brown in colour. This was largely due to the pigments and particles from crushed seaweed which appeared in the extract through excessive heating. The shorter extraction period. 30 minutes, was found to produce agar that was bright and clear.

Treatment with sodium hypochlorite to clear the dry agar resulted in the agar being crushed and some chlorine residue could also be detected. However, treatment with sodium hypochlorite prior to extraction resulted in agar that was clear and bright. Treatment with sodium hydroxide also resulted in an agar which was clear.

The effect on the gel strength was not measured because the apparatus was not available

In general. pretreatment with sodium hypochlorite and sodium hydroxide decreased the quantity of agar produced. The results are tabulated below.

Experiment No:	Pre-extraction treatment	Cooking duration in 21 fresh water (minutes)	Agar Yield (gm)	Remarks
1.	None	60	45.8	Post bleaching treatment-crushing the agar
2	None	30	47.8	- "-
3	200 ml NaOH (0.1 m) in 2 litres of water for 10 minutes	30	37.5	-"-
4.	5% NaOCL for 30 mins.	30	33.0	No post-bleaching treatment
5	2% NaOCL for 20 mins.	30	34.x	-"-

Further studies will be carried out using different concentrations and durations of soaking in NaOCl, NaOH and other chemicals, to determine the maximum yield of agar with high gel strength that can be produced.

Acknowledgement

I would like to thank the Director of the Fisheries Research Institute, Mr Ong Kah Sin, for his encouragement and constructive criticism on this paper. Lastly, I would like to thank the Director-General of Fisheries, Malaysia, Dato Shahrom bin Hj. Abdul Majid, for permission to present this paper.

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SEMINAR PAPERS: SESSION II
SMALL-SCALE AGAROPHYTE PROCESSING

GRACILARIA CORTZCATA : A POTENTIAL SOURCE FOR BIOACTIVE SUBSTANCES

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ABSTRACT

Crude extracts of ***Gracilaria corticata*** exhibited anti-bacterial activity only against gram + bacteria but after fractionation, samples were active against gram- bacteria and ***Mycobucterium tuberculosis.*** These fractions have been found to be more effective than penicillin, chloramphenicol and sulphadiazine against a number of test organisms.

Introduction

During the last few years, interest has been awakened in marine biodynamic substances. Anti-bacterial potential has been detected in a number of macroscopic marine algae from all over the world. Distribution of these compounds in Rhodophyceae has been reported by Gerber ***et al.*** (1958), Glombitza (1970), Glombitza and Heyser (1971), Glombitza and Stoffelen (1972), Glombitza ***et al.*** (1973), Glombitza ***et*** al. (1974), and Hornsey and Hide (1974). Agar extracted from ***Gelidium*** and ***Gracilaria*** exhibited a marked inhibitory effect on the growth of the influenza B and mumps viruses (Gerber ***et*** al. 1958 and Takemoto and Spicer, 1965). This has been attributed to the agar galactan units (Nigrelli et al. 1967). In the late 1970s a study was undertaken on the antibacterial activity of Indian marine algae. This paper describes a part of that study, in which ***Gracilariu*** *corticutu* was identified as a potential source of bioactive substances.

Materials and methods

G. corticuta, collected from Diu on the coast of Gujarat, was thoroughly washed to remove extraneous matter and epiphytes and then frozen until required.

A method has been standardised for extracting plants using different solvents (organic and aqueous) and temperatures (20°C and 50°C). Staphylococcus aureus, Bacillus meguterium (gram +), Escherichia coli, Proteus vulgaris, Shigella sonnei and Salmonella typhosa para A (gram –) were used as test bacteria. Bioassay was by the agar plate diffusion test. The degree of sensitivity of the test organisms was determined by measuring the zone of growth inhibition.

Four different fractions i.e. fraction A, fraction B, phenols and pigments were prepared from ***G. corticutu*** using the method reported by Parekh (1978). An in vitro comparative study of these fractions was conducted with known antibiotics (supplied by Bharat Laboratories, Bombay) against all the test organisms.

The antitubercular activity of different concentrations of fractions A and B was evaluated at Shri K. J. Mehta T.B. Hospital, Amargadj, Madhya Pradesh.

Results & Discussion

The antibacterial activity of crude extracts of G. corticutu against gram + bacteria is shown in Table I. The diethyl ether, acetone and ethanol extracts exhibited better activity than the chloroform extract. Hot and cold aqueous extracts and ammonium sulphate extract were not effective against any of the test organisms. The heat stability of the active principle was demonstrated, there being no difference in activity by acetone extracts prepared at 20°C and 50°C.

* Paper presented at the seminar by Dr. V.D. Chauhan, CSMCRI.

Table I: Antibacterial activity of crude extracts of G. corticata

Test Organisms	Zone of inhibition (mm) Solvents used for extraction						
	Diethyl ether	Acetone	Alcohol	CHCl3	Hot Water	Cold Water	Ammonia SO, Soln.
B. megaterium	16	15	14	T	-	-	-
S. aureus	13	11	23	-		-	-

- = No activity T = Trace activity

E. coli, P. vulgaris, P. aeruginosa, S. ***sonnei*** and S. ***typhosa para A*** were resistant

Seaweeds are highly susceptible to microbial decomposition as soon as they arc removed from their natural habitat. Attempts have been made to find a suitable method for preserving the plants along with their bioactive properties. Acetone extract prepared from ***G. corticata*** dried at 37°C was almost as active as that from deep frozen undried material. Acetone extract from plants dried at 60°C showed no activity against any of the test organisms.

Marked seasonal fluctuations in quantitative antibiosis have been reported, with the best antibiotic production occurring at the time of most rapid growth and proliferation (Baslow. 1969). In the present study, G. ***corticata*** exhibited antibacterial activity throughout most of the year; there was a period of high activity, between the months of September and January (Table II).

Table II: Seasonal variation in the antibacterial activity of G. corticatu against S. *aureus* and *B. megaterium*

Month of collection	Zone of inhibition (mm)	
	S. ***aureus***	***B. megaterium***
March	T	T
April	T	T
May	8	9
June	10	8
July	10	9
August	10	8
September	12	10
October	12	10
November	15	12
December	12	12
January	12	12

Extracts were prepared in acetone

Crude extracts of G. corticata were not active against gram - bacteria. It may be that the active principle is masked or inhibited in crude extracts. Hence, fractionation into fraction A, fraction B, phenols and pigments was carried out and each was tested separately for its antibacterial activity. Fraction A was active against all the test organisms. whereas fraction B was active against all bacteria except S. ***typhosa*** Para A. Phenols showed activity against both gram + and gram – bacteria.

Water-soluble derivatives of chlorophyll have been reported to have antibacterial activity (Smith, 1964). Pigments extracted from G. ***corticata*** did not show antibacterial activity, thus excluding the possibility that the antibacterial activity of the crude extract was due to pigments (Table III).

Table III: Antibacterial activity of different fractions obtained from G. corticata

Fractions	Zone of inhibition (mm) S. aureus	B. megaterium	E. coli	P. vulgaris	P. aeruginosa	S. sonnei	S. typhosa
Fraction A	12	16	18	10	9	15	12
Fraction B	10	15	14	12	8	7	NT
Phenols	12	13	11	10	T	NT	NT
Pigments		-			-	-	

- = No activity T = Trace activity NT = Not tested

In vitro comparative study of these fractions with commercially available antibiotics indicated that the activity of fractions A and B was greater than that of penicillin, chloramphenicol and sulphadiazine, and comparable to that of tetracycline, streptomycin. kanamycin, garamycin, polymyxin and erythromycin (Table IV).

Table IV: In vitro comparative study of antibiotic activity of G. corticata with known antibiotics

Antibiotic (Conc/disc)	Zone of inhibition (mm)						
	S. aureus	B. megaterium	E. coli	P. vulgaris	P. aeruginosa	S. sonnei	S. typhosa
Penicillin (5 units)		8				-	
Streptomycin (25 µg	25	15	9	18	21	T	23
Tetracycline (10 µg)	20	15	10		T	20	11
Erythromycin (10 µg)	14	16	11	11	T	T	10
Chloramphenicol (50 µg)	13		-	-	-	-	-
Sulphadiazine (200 µg)	13		-	-		-	
Kanamycin (30 µg)	25	17	19	21	10	T	21
Garamycin (10 µg)	28	23	18	18	22	T	28
Polymyxin (250 µg)	18	17	16	15	18	T	15
Fraction A (50 µg)	12	20	20	13	T	13	12
Fraction B (50 mg)	12	15	17	12	T	21	15

- = No activity T = Trace activity

Antimycobacterial activity of seaweeds has been reported by Burkholder (1960). Sarganin and Chonalgin, isolated from brown and red algae, also showed inhibitory activity against Mycobacterium ***smegmatis*** (Martinez-Nadal et al. 1966). In the present study, fractions A and B of G. corticata were tested against isolates of Mycobacterium tuberculosis for antitubercular activity. The results revealed the complete inhibition of growth of strains 111, 129, 167, 207,442, 361A, and 362A in culture of 64 µg/ml of L.J. medium, indicating high effectiveness towards mycobacteria.

From the studies, it is concluded that ***G.*** corticata can be explored as a good source of biomedicals.

Acknowledgement

The author is thankful to the Director, CSMCRI, Bhavnagar, for the encouragement and facilities provided.

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SEMINAR PAPERS: SESSION III
MARKETING AND MARKET POTENTIAL FOR AGAROPHYTES AND EXTRACTS IN BOBP REGION

UTILIZATION AND MARKETING OF SEAWEED IN SRI LANKA

by S Subasinghe and A Jayasuriya

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ABSTRACT

Out of nearly 260 species of seaweed growing in the coastal waters of Sri Lanka, only two species are exploited commercially at present: *Gracilaria verrucosa* and *Gracilaria edulis*. Various factors-like non-availability of resource data, deficiencies and difficulties in collection and marketing, and lack of adequate investment or interest from the industrial sector-hamper development of a seaweed production and processing industry. The export of dried *Gracifaria* has been highly variable partly because of the unsettled conditions in the country.

1. General

Sri Lanka has a coastline of approximately 1700 km along which many varieties of marine algae are found. Most of these marine weeds are of limited economic potential, except for a few species of Chlorophyceae, Rhodophyceae and Phaeophyceae. However, only two species of algae are commercially exploited in Sri Lanka at present, namely *Gracilaria verrucosa* and *Gracilaria edulis*. Since the mid-19th century, various studies have been carried out on taxonomical aspects and on the commercial importance of the seaweeds of Sri Lanka (Sigmond, 1841; Harvey, 1853; Svedelius, 1903: Tressler, 1923; Deraniyagala, 1933; Boergesen, 1936).

2. Present status of the seaweed industry

In the 1970s about 50-100 tonnes of dried *Gracilaria* were exported annually from Sri Lanka. The quantity exported in 1972 was around 50 tonnes with an export value of Rs.76,000 (FOB). In 1986, exports increased to 150 tonnes, of which 70 tonnes were from the Kalpitiya area and the balance from Trincomalee. Over the last two years (1987 and 1988) there was no harvesting of Gracilaria in Trincomalee due to the unsettled conditions which prevailed in the area during this period. There are no figures available with the Sri Lanka customs or the Export Development Board for 1987/1988. However, according to one of the main exporters there was a sharp drop in exports in 1987, with only 10 tonnes of dried *Gracilaria* being exported. In 1988 this was further reduced to 5 tonnes. However, it appears that there is a renewed demand by the importer countries, as evidenced by an export order from Japan for 20 tonnes of dried Gracilaria received by a Sri Lankan exporter recently.

During May to November, wild Gracilaria grows well in the Puttalam lagoon. Harvesting is normally carried out during the phase of vegetative growth from May to November. This coincides with the south west monsoon period and also the season for prawn fishing in the lagoon. This coincidence could possibly be a reason for the lack of interest shown by fishermen for harvesting seaweeds during this season.

The shrimp fishery is the main livelihood of people in the Puttalam lagoon area. They fish in the lagoon with drag nets and cast nets during the monsoon season. Their average daily income derived from the shrimp fishery is around 200 to 250 rupees (6-8 US$). A boatload of fresh seaweed weighing'around 200 kg, with a dry weight of around 30 kg can be collected by two people in 5-8 hours. The collectors receive 350 rupees (10-11 US$) for 50 kg of dried seaweed from agents who represent export companies based in Colombo. As a maximum of two operations only are possible in a day, the total income rarely exceeds 700 Rs/day. This income has to be shared with all those who were involved in the collection. A recent NARA socio-economic survey (1988) revealed that only one quarter of those engaged in seaweed harvesting have their own boats. Furthermore, the collectors have to hire boats from outside sources and also have to pay for fuel. Thus, they end up with a very small profit margin from these operations. In comparison, shrimp fishing is more attractive as it gives a better and more reliable income, due to the steady market potential of shrimp.

Sargassum is not exploited on a commercial basis at present. However, there have been several enquiries about the purchase of ***Sargassum*** from importing countries such as Japan. Because of uncertainties in the supply of raw material, exporters are not in a position to undertake orders. It appears also that difficulties in detailed identification of the plant have posed difficulties to these exporters.

3. Marketing network

Seaweed collected by the boats is unloaded on the beach and allowed to sun-dry for 4-5 days. The dried weed is tightly packed in gunny bags and transported by cart to the purchasing centres. Even though some cleaning is done by the collectors during sun drying, further cleaning is carried out at the purchasing centres. Here, the seaweed is sieved to remove particulate matter such as sand and sea shells, and then stacked to await transportation to Colombo. The middleman gets around Rs.10-12 for the dried seaweed. Further cleaning is carried out by the exporters prior to bailing for shipment. 'A bail of dried seaweed weighs approximately 150 kg.

A very small percentage of the dried seaweed is sold locally. Retail packs, weighing 50 to 100 g, are sold at most supermarkets, pharmacies and grocers in Colombo and its suburbs. Packeting of seaweed is carried out by traders who get their supplies from their agents. These agents visit the producer areas periodically and purchase the dried weed direct from the collectors. A retail pack of 100 g is sold at Rs.20-30, with the retailer getting a 15-20% commission. According to most Colombo traders, packeted seaweed is a slow-moving item except during the Islamic festive season, when demand is good. However, according to these traders, over the last few years there has been a growth in seaweed sales and it is used increasingly in local cuisine. They also believe that the local seaweed is superior to the imported, as evidenced by consumer preference for the former.

Seaweed is a popular item of food in producer areas as well. A recent socio-economic survey carried out by the National Aquatic Resources Agency (1988) revealed that 9 out of 10 people living in the Puttalam lagoon area use ***Gracilaria*** for domestic consumption. The most popular preparation is a porridge made by washing the dried seaweed several times and cooking it in water for 15-20 minutes. The thick soup obtained is sieved using a cloth strainer or wire mesh sieve, and coconut cream and lime are added to taste. The villagers believe this porridge to be highly nutritious and it is considered a must during the fasting season. The porridge is sold at kiosks in the Kalpitiya area at Rs.2/glass, and enjoys a very good demand among the local fishermen who rarely miss taking it on their return from the sea around noon time. According to a Kalpitiya boutique owner, the "commercial" recipe for the porridge includes 2 kg seaweed, three limes and 600 g sugar giving 30 glasses of the porridge. Seaweed jelly cube is another common sweetmeat of the area. Seaweed is washed several times until it becomes lighter in colour and is cooked in a little water. Lime and colouring are added to the syrupy mass obtained, which is then allowed to set for about an hour to a jelly like mass. The jelly is then cut into cubes.

4. Limiting factors and constraints

Over the last few decades, interest in the seaweed resources of Sri Lanka has surfaced periodically. There has been no continuing interest in the commercial exploitation of this resource, in spite of the marked growth in seaweed consumption and the seaweed-based industries worldwide. In Sri Lanka, the seaweed industry has always been a subsidiary of the fishing industry, with the collection and processing of seaweed being carried out by the fishermen to supplement their income. Unlike other countries of the region, the industry in Sri Lanka has so far not attracted adequate investment or interest from the industrial sector.

There are nearly 260 species of seaweeds growing in the coastal waters of Sri Lanka, of which nearly 20 species are of commercial interest (Durairatnam, 1961). Of these, only two species of ***Gracilaria*** are of any commercial importance at present. The under-utilization of the country's seaweed resources can be attributed to several limiting factors and constraints.

Non-availabillty of resource data

Information on *Gracilaria* spp is scanty. The lack of resource data has hampered the expansion of the industry, the collectors and exporters depending heavily on the resources from traditional collecting grounds. Exporters have often experienced difficulties in getting adequate supplies of dried seaweed to fulfil export orders. The unsettled conditions prevailing in the North and the East have also deprived exporters of access to the resources of the Trincomalee area, an area which used to provide 50-70 tonnes of dried seaweed annually. This has created a vacuum in the export market, a vacuum which could have been filled if alternative collecting grounds were available. In a heavily export-oriented industry like the seaweed industry, uncertainties in the supply situation could restrict growth. The unavailability of resource data can thus be considered as one of the factors limiting the expansion of the seaweed industry in Sri Lanka.

Deficiencies and difficulties in collection and marketing

Several deficiencies and difficulties in the collection and marketing of the economically important species of seaweeds of Sri Lanka can be identified. *Gracilaria* caters mainly to an export-oriented market, whereas *Surgussum-based* products have a fairly important local market. Imports of alginates, agar-agar, alginic acid substitutes like gelatine and related products in 1987 have been valued at Rs. 29 million.

When considering the past production figures for *Gracilaria* from the Eastern and North-western coasts, the potential production using traditional harvesting practices can be estimated at around 200 tonnes of dried seaweed. However, if other potential sites on the North-western and Northern coasts are considered, there is no doubt that there could be a significant increase in potential production. In the Kalpitiya area, Gracilaria is collected by waders, who often face difficulties due to the presence of poisonous sea snakes, sting rays and sharp edged shells of the razor shell oyster (Pinna). In the Mannar and Trincomalee areas, the collectors depend mainly on the seaweed cast ashore as only a very few beds have been located, and these are found mostly at depths ranging from 10-20 feet.

Production in the Kalpitiya area consists mainly of *Gracilaria* collected from shallow coastal beds. Collection is undertaken in response to demand for the dried seaweed from middlemen who supply the exporters. The collector fishermen cannot, therefore, depend on seaweeds for a regular income because the demand and market price are influenced by the variable export market. It is interesting to note that, at times, even the seaweed cast ashore is not collected by fishermen, because of difficulty in marketing it. Hence, it is important to devise a scheme for purchasing the product, independent of the middlemen, possibly through state intervention, in order to encourage the collector fishermen and to assure them a steady income.

As discussed earlier, most of the *Gracilaria* produced in Sri Lanka is exported in dried form without any further processing. Most countries exporting this seaweed have realised the benefits of exporting processed products rather than the dried seaweed. Export of the unprocessed product has two distinct disadvantages: the high costs of packaging and transport force down the price paid to collectors, and the raw material being processed elsewhere means that the benefits of gainful employment in manufacture are lost to Sri Lanka. A close look at the feasibility of further processing the seaweed locally is necessary, in order to improve the profitability and employment generation capacity of the industry.

Imports of seaweed products and substitutes

During the period 1960-1970, several pilot-scale operations were undertaken to examine the feasibility of extracting alginic acid and agar from local seaweeds. The locally manufactured alginic acid and agar were found to be of international standard. Encouraged by the results of these trials, the Government decided to expand the industry, and action was taken to set up a network of collection centres and processing plants under the management of the District Development Councils. Interest in this direction was catalysed by the introduction by the Government of an import quota system for manufacturers.

A change in Government policy in the mid-1970s meant the removal of the import quota system, and the local market once again became open to imported seaweed products. This acted as a disincentive for investment in the local seaweed processing industry, and to date has resulted in Sri Lanka remaining as an exporter of dried seaweed.

Attempts were also made in the 1970s to popularise the incorporation of dried powdered seaweed (Ulva spp) as a green supplement for poultry feed in place of imported alfalfa preparations. Laboratory studies were encouraging, with seaweed preparations showing promising results. Research and development activities on this subject were abandoned with the influx of cheaper feed material.

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SEMINAR PAPERS: SESSION III
MARKETING AND MARKET POTENTIAL FOR AGAROPHYTES AND EXTRACTS IN BOBP REGION

SEAWEED MARKETING AND AGAR INDUSTRIES IN MALAYSIA

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ABSTRACT

Agar is imported and marketed in Malaysia in four main forms: agar strips, bacteriological agar (powder), agar desserts (jellies) and flavoured powder mixes. The domestic marketing of agar entails a host of different intermediaries, each performing varied functions such as importing, wholesaling, .processing, distributing, merchandising, financing and retailing. Malaysia imported 172 tonnes of agar strips worth M$ 6.55 millions in 1988, which suggest that a large domestic market exists to support the production and processing of seaweed in the country. However, competition from other countries in the region may be a serious constraint for the development of Malaysian seaweed processing and agar production.

1. Introduction

1.1 Objective

The objective of this study was to assess seaweed processing and agar-utilising industries in Malaysia by:

1. Locating all information on the production and marketing of agarophytes, especially *Gracilaria* spp, in Malaysia.

2. Interviewing a representative cross-section of the people concerned with agar production and marketing, including the main processors, dealers and consumers of agar so as to get an idea of the demand for agar in the country.

3. Determining the total volume and value of agar imported into Malaysia by interpreting national trade statistics and by interviewing a sample of importers so as to give an indication of the supply of agar.

1.2 *Methodology*

The study relied on secondary sources and field surveys during which interviews were carried out with importers, processors and dealers involved in the agar trade. Total trade volumes and values of agar imported for the last five years were obtained from the external trade statistics of the Department of Statistics. Preliminary surveys of agar products sold by retailers indicated that the main exporters of agar to Malaysia were Korea, Japan and Singapore. Therefore the export figures of agar from these countries into Malaysia were obtained from the Japanese External Trade Organisation, and the Korean Trade Centre in Kuala Lumpur, and the Singapore Trade Statistics Department in Singapore.

Agar is imported and marketed in Malaysia in four main forms: agar strips, bacteriological agar (powder), agar desserts (jellies) and flavoured powder mixes. Five categories of intermediaries involved with the trade and marketing of the agar were identified: namely importer, wholesaler, distributor/packer, manufacturer and retailer. At least three from each category were interviewed. The surveys were carried out in Kuala Lumpur, Penang and Johore Bahru, which have been identified as the main centres for the trade and import of agar in the country.

2. Current status of the Malaysian seaweed industry

2.1 Seaweed resources of Malaysia

Traditionally, seaweeds have been utilised in Malaysia as food, animal feed and fertiliser and even in traditional medicine (Zaneveld, 1959; Burkill, 1966; Johnson, 1967; McHugh and Lanier, 1983). The documented use of local seaweeds was compiled by Phang (1984). Fourteen species of ***Agardhhiella, Corallopsis, Gelidiopsis, Gelidium, Gracilaria, Grateloupia, Laurencia*** and ***Padina*** were recorded as agar-producers, four species of ***Eucheuma*** as carrageenan-producers, and seven species of ***Colpomenia, Hormophysa, Hydroclathrus, Padina*** and ***Sargassum*** as alginic acid-producers. Recent studies at the University of Malaya have added two more species of agarophytes, namely ***Gracilaria blodgettii*** and ***G. salicornia.***

2.2 Research on agarophytes and their culture in Malaysia

The first study on agar content and quality of seaweeds in Malaysia was on ***Gracilaria*** by Burkill ***et al*** (1968). There was no further contribution to agar research until Doty & Fisher (1987) showed the potential for seaweed farming in Malaysia. The agar content of local species analysed ranged from 44-67% (Doty, ***et al*** 1983, Santos and Doty 1983). As a result of Doty's studies, a one-year pilot project on seaweed culture in Penang was undertaken (1983-84) by the Fisheries Research Institute at Glugor together with Agronomic Research Development and Production Inc., Honolulu, Hawaii. Further trials were reported by Faaaz Abdul Latiff (1986).

2.3 Production of agarophytes and agar in Malaysia

There is no known industrial production of agar in the country. Local fishermen collect species of ***Gracilaria*** and prepare the dessert "agar-agar" for home consumption or for sale. The first seaweed production company in Malaysia was set up in early 1989 based on the ***Gracilaria*** species known as G16. Due to unforeseen circumstances the crop was destroyed and plans for the continuation of the project are unknown. ***Gracilaria*** G16 had an agar yield of 17-19%, with gel strength greater than 610 g/cm^2.

3. The agar trade

In 1980, estimated world production of seaweeds for use in agar manufacture was 36,094 tonnes, of which about 18,088 tonnes was produced by Asian countries (McHugh and Lanier, 1983). Of the total amount produced in Asia, Korea accounted for 11,308 tonnes or 62.5% while Japan produced 4,000 tonnes or 22.1%. The remainder came from the Philippines, Taiwan, India and Sri Lanka. It is estimated that the agar produced by Asian countries, mainly Japan, Korea, and to a lesser extent, Taiwan and India, was 3,574 tonnes. The primary consuming countries for agar are Japan, Korea and China.

3.1 Forms of agar in Malaysia

Agar Strips

These are imported in bulk, mainly from Korea and Japan. The strips are repacked by packers or wholesalers into convenient sizes of 20 g or 35 g and then distributed directly or via retail outlets such as supermarkets and provision shops. The agar strips are bought by consumers for the preparation of jelly desserts, and the business enjoys peak sales during the many festivals in the country. Agar strips and agar powder are also imported,directly for utilisation by the manufacturers of jelly desserts.

Agar desserts/jellies and flavoured powder mixes

There are very few manufacturers of jelly desserts in the country, Socma being the main manufacturer. Some are imported in processed form from Japan, Indonesia and the Philippines. Instant agar powder mixes of various flavours are also sold. These come mainly from Thailand,

and at least one brand is from Taiwan. They are sold in vacuum packs ranging from 10-85 g, or in paper boxes of 90 g.

Bacteriological agar

Most of the bacteriological agar is sold in Kuala Lumpur to universities, research institutes and hospitals. The various brands available include “Difco”, “Merck”. “Oxoid”, “Bitek”, “Eiiken” and “High Media”. They come mainly from the United States of America and United Kingdom. “Eiiken” comes from Japan, while “High Media” is the newest brand from India. The Indian agar is price competitive. One salesman estimates that the total market for bacteriological agar in the country is valued at M$ 2 million per annum.

3.2 Imports

The only official source for import figures is the external trade statistics published by the Malaysian Department of Statistics. One major disadvantage, however. is that statistics on agar imports do not appear separately but are lumped together under “seaweed products” (SITC code 292-981-O) or under “vegetable saps and extracts; pectic substitutes; pectinates and pectates; agar-agar and other mucilages” (SITC code 292-910-00). Hence, imports of agar can only be estimated by examining the statistics available for the two commodity groups.

The value of imported seaweed products increased from 1980 to 1987 as indicated in Table 1. Between 1984 and 1987, however, there was a decline in the value of imports due, perhaps, to the severe recession in the country. The main countries exporting agar to Malaysia are the People’s Republic of China (which accounted for almost 37.0% of the total import value in 1987). Japan (18.1%). Korea (14.6%), Singapore (14.3%) and Taiwan (10.7%).

Table 1: Imports (Volume and c i f value) of seaweed products by country of origin, 1980-1987

Country	1981		1982		1984		1985		1986		1987	
	tonnes	M $	tonnes	M$	tonnes	M $	tonnes	M $	tonnes	M$	tonnes	M$
Australia	0.49	1,464	1.02	6,095	-0.07	252	-----	0.00	0	0.07	173	
China	139.45	202,887	26.34	110.995	37.69	238,804	21.00	184,600	32.17	159,011	31.56	193,163
Hong Kong	2.32	19,047	5.36	10,440	14.43	22,274	18.05	20.250	11.98	16.927	1.21	3.382
Indonesia	5.59	6,740	0.06	188	3.01	9,402	0.20	300	0.18	427	0.03	352
Japan	110.13	65,368	32.72	131,129	25.57	305,628	32.91	219,101	41.66	187,778	12.16	94,454
Korea Rep. of	30.43	93,362	59.16	155.952	21.48	104,919	24.38	117,945	26.78	126.802	20.30	76.246
Norway												
Philippines		·	0.21	2.343	23.79	12.494	53.25	13.462	48.61	21,107	25.01	6,031
Singapore	7.00	100	0.59	2,178	1.57	6.456	0.52	1,735	0.03	197	3.11	74,491
Taiwan	19.67	67.487	14.55	87,757	5.95	34.126	9.20	46,540	18.17	70,674	16.81	56,148
Thailand		·	0.15	245	0.02	113	0.14	413	1.43	1,297	1.30	1,811
U.K.				14	0.01	406	0.03	288	0.12	1,707	0.70	14,707
Others #	0.97	4,474	0.59	1,969	0.23	966	0.34	2,534	0.59	576	0.75	533
TOTAL	315.95	460,929	140.75	509,396	133.82	735,840	160.02	607,168	181.72	586,503	112.71	552,501

Includes Austria, France, Germany, North Korea, Laos, Macau, Norway, New Zealand, Switzerland, U.S.A. and Vietnam.

Imports of vegetable extracts and saps, pectic substances, pectinates and pectates. agar-agar and other mucilages also increased from M$5.58 million (cif value) in 1982 to M$ 13.6 million in 1987 (Table 2). Unfortunately, it is not known what percentage of this total constitutes agar imports. By country of origin, Korea emerges as the most important source, accounting for some M$7.72 million or nearly 57.0% of the total import value in 1987. This is followed by USA (18.9%), Denmark (5.2%) and Japan (4.0%).

A significant proportion (perhaps as high as 90%) of the agar imported for food is in the form of agar strips, while the remaining 10% is in powdered and jelly dessert forms. Imports of agar strips from Korea increased from 73.95 tonnes valued at M$1.83 million in 1982 to 168.74 tonnes valued at M$6.40 million in 1988, thereby registering average annual growth rates in physical and value terms of 21.4% and 41 .0% respectively (Table 3). However, a slight decline in the import of agar strips from Korea was recorded between 1987 and 1988.

Table 2: Imports (Volume and c i f value) of vegetable saps and extracts; pectic substitutes; pectinates and pectates; Agar-agar and other mucilages by country of origiri, 1980-87.

Country	1982		1983		I984		1985		1986		1987	
	tonnes	M $	tonnes	M $	tonnes	M $	tonnes	M $	tohnes	M$	tonnes	M$
Australia	9.6	0.26	1.1	0.10	1.5	0.07	8.3	0.51	10.1	0.07	1.6	0.03
China	14.1	0.09	20.3	0.15	19.7	0.24	44.5	0.12	56.4	0.32	11.4	0.19
Denmark	11.7	0.20	10.4	0.10	14.2	0.25	14.6	0.21	17.2	0.25	37.8	0.71
France	12.6	0.26	1.1.4	0.25	22.9	0.56	12.3	0.27	6.1	0.13	10.4	0.22
Germany, Fed. Rep.	22.6	0.41	37.1	0.43	15.8	0.25	22.0	0.16	7.7	0.08	12.4	0.14
Hong Kong	84.5	0.14	64.4	0.13	6.4	0.04	1.7	0.15	1.5	0.13	3.3	0.16
Indonesia	53.9	0.06	49.6	0.08	50.1	0.05	41.5	0.03	5.1	0.01		
Japan	51.4	0.31	32.3	0.64	160.2	0.36	24.9	0.47	20.1	0.50	23.8	0.54
Korea,Rep.of	458.8	4.532,819.5		6.54	988.4	5.741,614.0		6.40	213.7	5.53	242.2	7.12
Singapore	106.7	0.24	251.2	0.45	38.3	0.27	35.3	0.16	8.2	0.21	42.8	0.48
Taiwan	7.2	0.01	35.7	0.06	15.6	0.10	40.2	0.11	34.7	0.06	9.8	0.10
United Kingdom	38.0	0.24	33.9	0.29	17.9	0.25	25.8	0.26	17.3	0.24	15.3	0.22
U.S.A.	53.7	1.09	71.4	1.38	76.8	2.15	100.2	1.95	72.3	1.47	82.6	2.57
Others #	47.3	0.74	52.6	0.26	106.2	0.38	164.9	1.47	181.6	1.45	63.8	0.52
TOTAL	971.5	5.583,490.9		10.941,534.0		10.712,150.2		12.27	652.0	10.45	557.2	13.60

Includes Austria, Belgium, Brazil, Canada, India, Iran, Ireland, Italy, Netherlands, New Zealand, Pakistan, Philippines, Spain, Switzerland, Turkey and Vietnam.

Table 3: Imports (Vdume and c i f value) of agar strips from Republic of Korea and Japan, 1980-1988

Year	Republic of Korea		Japan	
	Tonnes	M$	Tonnes	M$
1980	n.a.	n.a.	3.50	125,530
1981	n.a.	n.a.	4.37	128,180
1982	73.95	1,826,305	4.10	127,500
1983	107.24	2,530,003	1.25	319,630
1984	n.a.	na.	9.86	287,040
1985	142.84	3,648,045	14.40	367,670
1986	162.11	4,570.683	11:20	282,630
1987	211.32	7,378,233	6.10	252,180
1988	168.74	6,404.368	3.30	144,740

Sources: 1) Korea Trade Centre, Kuala Lumpur.
2) Japan External Trade Organisation, Kuala Lumpur.

By comparison, imports of agar strips from Japan are relatively small and have declined recently from 1985 onwards to reach 3.30 tonnes valued at M$ 144,740 in 1988. The decline in imports from Japan can be explained by the rising value of the Japanese yen, which has forced Malaysia to cut its imports from Japan. This was further aggravated by falling demand for agar resulting from the 1984-86 economic recession.

By virtue of its geographical proximity, a fairly substantial proportion of Malaysia's imports of agar is handled through Singapore. It is understood that the bulk is handled by a few large importers based mainly in Kuala Lumpur, Penang and Johore Bahru. Over the last five years, however, the trade from Singapore experienced a downward trend owing to the soft domestic demand for agar.

Besides agar strips, Malaysia also imports processed agar-based products such as confectionery jellies and jelly desserts from and through Singapore. In 1986,'Malaysia imported about 160.4 tonnes of processed agar products (including jam, fruit jelly, marmalade and nut puree and paste) worth S$ 546,000 (Singapore Trade Statistics, 1986). These products were either imported (mainly from Japan) and then re-exported to Malaysia, or were produced locally by Japanese companies registered in Singapore.

3.3 Marketing and distribution patterns

This section analyses the marketing of agar strips, agar powder and jelly agar in Malaysia. The marketing of agar is undertaken by a host of intermediaries such as importers, wholesalers, packers, agent distributors, processors/manufacturers and retailers. All of these normally perform the three major functions of marketing, merchandising and financing simultaneously. In general, the marketing of agar follows the pattern of a few large importers selling direct to many wholesalers and/or agent distributors, who then service numerous small retailers such as provision shops, supermarkets, hotels and restaurants.

Agar strip and powder

Since practically all of the country's need for agar is imported, the role of importers in the marketing of agar strips is crucial. There are fewer than 20 companies, with various scales of operation, which have a monopoly over the trade. In a sense, therefore, the market structure of agar strips could be characterised as oligopolistic, with a small number of importers controlling a sizeable share of the agar market. More than half of the importers are found in Kuala Lumpur, while the remainder are in the other large cities such as Penang, Johore Bahru and Kuantan. Virtually all the importers also deal in other dried food provisions, and agar strip constitutes only a small proportion (less than 10%) of their total business volume. Three major types of agar importers could be identified, namely importer, importer-repacker and importer-repacker-wholesaler. These three groups could be differentiated by the marketing activities they perform. The distribution channels and functions performed by the intermediaries in the marketing of agar strip is shown in Figure 1. It should be noted that the marketing and distribution of agar powder, another form of raw agar, is essentially similar to that of agar strip. Again, most if not all of the importers/repackers/wholesalers of agar powder are found in large cities and major consumption centres such as Kuala Lumpur, Penang, Johore Bahru, Ipoh and Kuantan.

Like the importers, the wholesalers of agar strip are located mainly in large urban centres, and are involved in wholesaling other food provisions besides agar. They provide a crucial link between importers and retailers. They also perform important facilitating functions such as selling, pricing, financing, grading and merchandising. A gross estimate suggests that more than 95% of the agar handled by wholesalers is sold to distributors/suppliers, manufacturers and large retailers, while only 2-5% went to small retailers and ultimate consumers.

Another marketing intermediary which is becoming increasingly important is the distributor/supplier (Figure 1), otherwise known as the stockist. These provide a link between wholesalers and certain retailers, especially the small retailers scattered throughout the country.

At the retail level, the agar trade seems highly competitive as there are a large number of retailers involved. Agar retailing is generally widespread and agar is sold in most retail outlets; ranging from small village provision shops to large city supermarkets. The retailers provide the final link between sellers and consumers. Agar, however, accounted for a mere 1-2% of the total volume handled by most retailers.

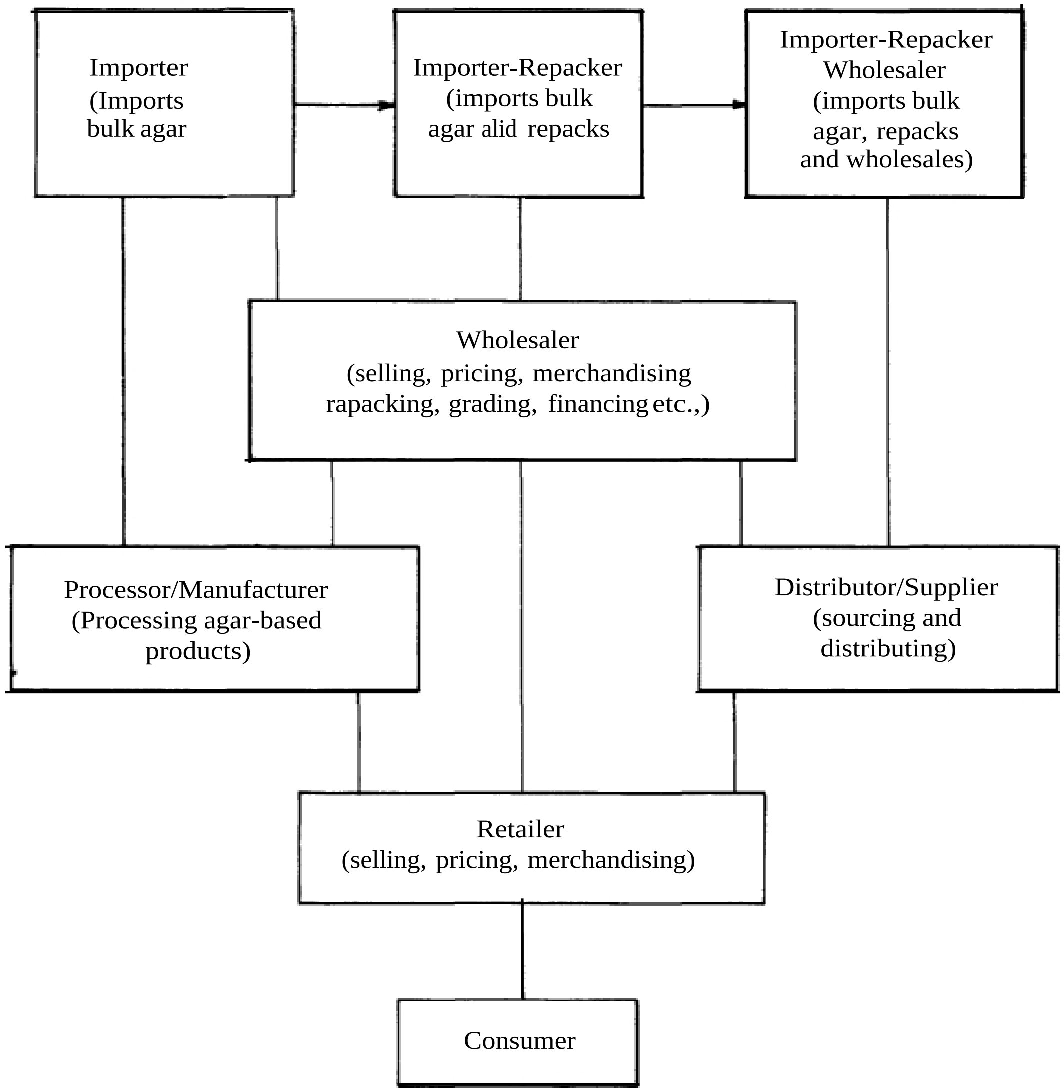
For the majority of agar traders (importers, wholesalers and retailers), agar constitutes only 5-10% of their total business. The actual volume of agar traded varies considerably from one dealer to another, depending on their scale of operation. A gross estimation indicates that the volume traded by each importer/wholesaler in a year, ranged from 3.0-10.0 tonnes valued at M$135,000-$450,000.

As for the retailers, it was found that their trade volume in agar is generally low, hardly exceeding 100 packets (20 g per packet) per month valued at M$ 160-$180. One large supermarket, however, reported that its sale of agar strip averages 600 packets a month, valued at M$ 960-$1000. Sales of agar powder are reported to be much lower, and retailers complained that it is not as saleable as agar strip. As expected, sales of both strip and powder increased by as much as 30-40% during festive seasons such as Hari Raya, Chinese New Year and Christmas.

Processed agar (jelly desserts)

The manufacturing or processing of agar into jelly desserts is a relatively small business in Malaysia. Fewer than 10 companies are involved. Among the big names are Nutritional Products

Figure 1: Marketing Channels for Agar Strip and Agar Powder, Peninsular Malaysia



Sdn. Bhd. (Petaling Jaya) which is a subsidiary of Nestle, Foodpro Sdn. Bhd. (Kuala Lumpur), CPC (Malaysia) Sdn. Bhd. (Kuala Lumpur), Kinos Food Industries Sdn. Bhd. (Johore Bahru), and Fourseason Foodstuff Industries (M) Sdn. Bhd. (Penang). Except for Foodpro Sdn. Bhd., which is a subsidiary of an oil-refining company, the others are primarily food-based companies involved in the manufacturing of other food items.

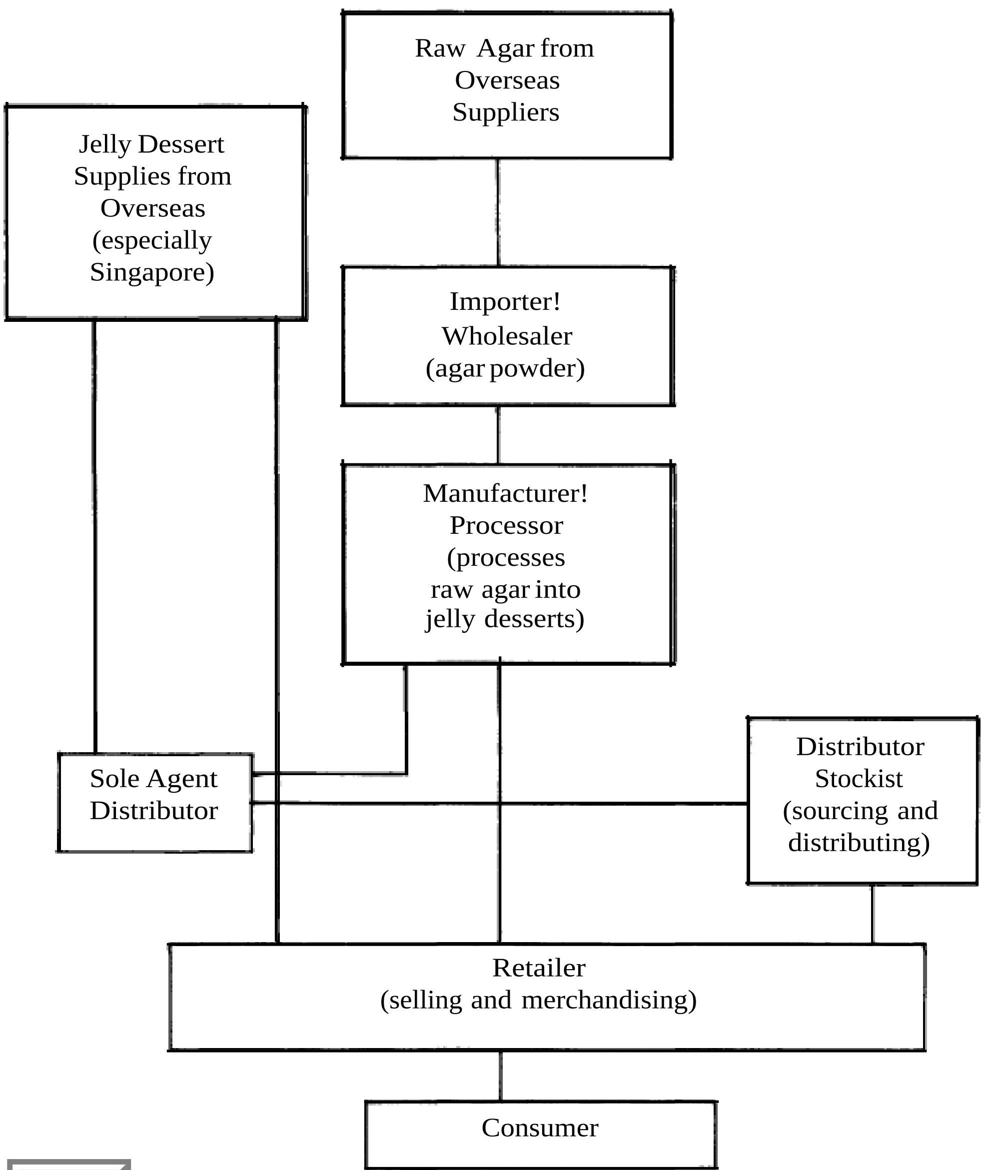
Detailed business information could not easily be extracted from the manufacturers interviewed because of the high degree of secrecy maintained by most companies. However, some basic information on the manufacturing business of one particular company was obtained.

The company started to manufacture jelly around 1986 as part of its diversification programme. It is understood that the dessert accounts for about 20.0% of the company's overall business. The raw material required, agar powder, is imported mainly from Korea. In 1988, the company imported approximately 6.0 tonnes of agar powder worth some M$ 150.000. The company sold about 2.7 million cups of jellies worth about M$ 1.0 million in 1988, an increase of about 10% over the previous year's sale of 2.4 million cups worth M$ 0.9 million.

The marketing pattern for the jelly desserts is somewhat different to that of agar strip or agar powder. A characteristic of the marketing of jelly desserts is the absence of wholesaling (Figure 2). Instead, marketing is usually dominated by sole agent distributors and stockists/suppliers who provide the important link between the manufacturers and retailers. Most manufacturers undertake their own packaging and branding, while some like Foodpro Sdn. Bhd. also do contract packaging for retailers such as the Seven Eleven Company. The retailing of jelly desserts is done mostly by supermarkets, mini-markets and provision shops selling food items. These outlets are dispersed throughout the country.

As with agar strip retailing, jelly desserts constitute only one of the many items sold, and usually account for less than 10% of the total volume.

Figure 2: Marketing Channels for Processed Agar (Jelly Desserts), Peninsular Malaysia



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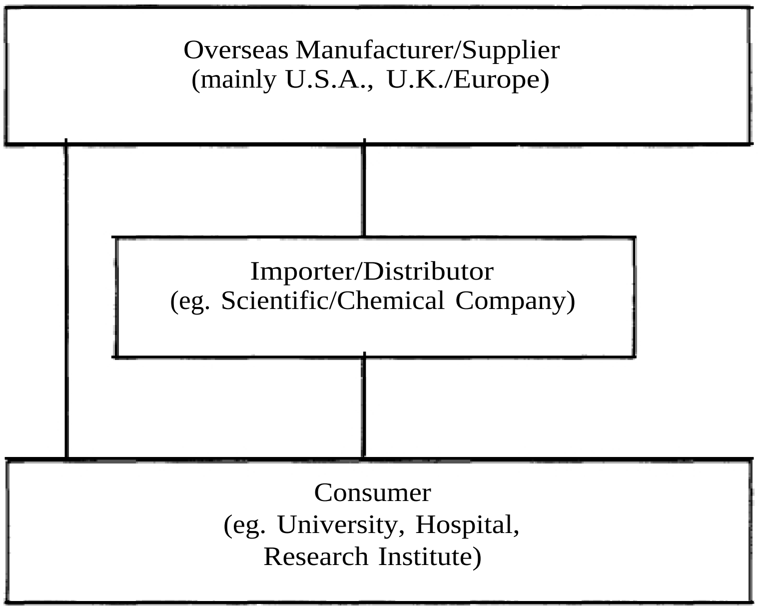
Bacteriological agar

Marketing of bacteriological agar is more simple than that of agar strip or processed agar jellies. Essentially, it revolves around the importer-cum-distributor who imports directly from overseas manufacturers, in particular from the U.S.A., United Kingdom/Europe (Figure 3). Field surveys identified companies selling scientific equipment and supplies as the main businesses involved in the bacteriological agar trade. Importing small quantities at a time, most of them reported that bacteriological agar constitutes only a fraction (1—2%) of their total business.

Figure 3: Marketing Channels for Bacteriological Agar, Peninsular Malaysia



A unique feature of the bacteriological agar trade is that neither wholesaling nor retailing is involved in its marketing and distribution. The product is sold directly by the importer/distributor to the consumers (Figure 3). The main consumers are hospitals, universities and research institutes. In some instances, these institutions import bacteriological agar direct.

3.4 *Demand and prices*

International demand for agar remains strong as evidenced by the continuing high priëes and the ease with which major exporting countries like .China and Korea (McHugh and Lanier, 1983) dispose of the product. The market price of agar seaweed is higher than those for other colloid-bearing seaweeds.

In Malaysia, demand for agar has been dictated primarily by its major utilisation, as food for human consumption. Unlike more essential food items such as rice, fish, meat and vegetables, agar is considered non-essential and is eaten only as a desert. Hence, demand for agar is very income and price elastic, meaning that a slight change in the price of agar and consumers' income would bring about a remarkable change in the demand. Besides price and income, demand for agar is also determined by consumer preference, availability and price of other colloid substitutes (e.g. carrageenans), eating habits and nutritional considerations. One major advantage is agar's acceptability to all religious and cultural groups among multi-racial Malaysian communities. Statistics on the domestic demand for agar and its per capita consumption are not, how-ever, available.

The market price of agar is reflected, to some extent, in its import value (cif). From the statistics available on imports from Korea, it was found that the ex-vessel prices of agar strip have been on the increase over the last five to six years, averaging M$37.95 per kilogram in 1988. This represents a remarkable increase from the 1982 price estimated at M$24.70 per kilogram. On average, the import value of agar strip increased at an annual rate of about 10.0%. The rising prices of imported agar can be construed as reflecting the continuing strong domestic demand.

At wholesale and retail levels, there can be wide fluctuations in the price of agar strips depending on the individual trader's profit margin and the quality of the agar as measured by its gel-strength. Laboratory analyses were undertaken to determine the relationship between gel strength and retail prices (Table 4). As expected, it was found that the higher the gel-strength of the agar strip. the higher its retail price. On average, the high-quality agar strip, originating mainly from Korea, is retailed at M$ 1.80- M$ 1.90 per 20 g packet. In comparison, the retail price for low- quality agar strip, supplied mainly from China, averages M$ 1.20- M$ 1.30 per 20 g packet. The retail price of agar strip of the same quality may differ by as much as 10% from one outlet to another, depending on the individual retailer's profit margin.

Table 4: Gel strength and retail prices of agar strip, Peninsular Malaysia, 1989

Brand	Country Of Origin	Gel Strength (g/cm^2)	Retail Price (20g)
A	Korea	**> 500**	M$ 1.90
B	Korea	**408**	M$ 1.60
C	Korea	185	M$1.55
D	Unknown	**86**	M$l.35

From the few brands of agar powder available in the market, it was estimated that the retail price averaged about M$1.20-M$1 .30 per 10 g packet. Agar powder imported from Japan commands a better price than that packed and distributed locally.

The prices of jelly desserts were more difficult to estimate, as they are sold in different types of containers with different units of measurement. The most common packaging is in packets containing 20 cups of jellies, each individually packed with 19 g content. A packet of agar jellies is usually retailed at M$l.00-M$1.30, with slight variations from one retailer to another. A well-known brand, Square Cut Jelly, is sold at M$0.60 per cup, and the content per cup is 130 g.

In the case of bacteriological agar, it was found that the consumer price varies in the region of M$250-M$450 per kilogram depending on the grade. For example, Bacto-Agar, a supposedly high-grade bacteriological agar is sold at M$ 418 per kilogram, while a lower grade called Bitek-Agar fetches about M$352 per kilogram. The purchase price of bacteriological agar was in the region of M$ 200- M$ 350 per kilogram, depending on the grade. In general, the purchase price had increased by as much as 10-20% since 1986.

3.5 Marketing margins

The marketing margin or price spread for agar in this study is analysed in terms of dollars per kilogram and as percentage of retail price. In an efficient marketing system. the marketing margins can be equated with processing/manufacturing costs, transportation costs, handling charges and the normal profits of market intermediaries.

The data in Table 5 indicate that the marketing margin of a 20 g packet of agar strip is 66.7% of the retail price or M$ 1.20 per 20 g packet. of this, about M$0.80 or 66.7% is accounted for by marketing costs, while the remaining M$0.40 or 33.3% is the profit made by the various marketing intermediaries (wholesalers and retailers). Transportation, handling charges, storage, and packaging constitute the major items of marketing costs.

At the wholesale level, the marketing margin and wholesale price account for 33.3% and 55.5% respectively of the retail price. At the retail level, the marketing margin is 11.1% of the retail price, all of which constitutes gross profit margin to the retailers.

Analysis of the marketing margin indicates that the importer's share of the retail price is M$0.60 per 20 g packet or 33.3%. Based on this information, the importer's share of the retail price appears relatively low. This does not necessarily mean that the marketing system is inefficient.

Table 5: Marketing margins of agar strip per 20g packet, Kuala Lumpur

Trade Level	cost		Price (M$)
Importer			
Net price received by importer			0.60
Transportation	0.25		
Handling charges	0.15		
		0.40(22.2%)	
Wholesaler	1.00		
Inter-market transportation	0.10		
Storage	0.20		
Packaging	0.10		
Profit margin	0.20		
		0.60(33.3%)	
Retailer			1.60
Profit margin	0.20		
		0.20(11.1%)	
Price paid by consumer			1.80
Total marketing margin		1.20(66.7%)	

Note: ***Figures in parentheses indicate percentages of retail price***

For agar powder, the marketing margin was estimated to be M$0.90 per 10 g packet or 69.3% of the retail price of M$ 1.30 (Table 6). Of this, 38.5% was accounted for by the wholesaler, 15.4% by the importer and another 15.4% by the retailer. The importer's share of the retail price was 30.8%.

Table 6: Marketing margin of agar powder per 10 g packet, Kuala Lumpur, 1989

Trade Level	cost		Price (M$)
Importer			
Net price received by importer			0.40
Transportation	0.10		
Handling charges	0.10		
	0.20		(15.4%)
Wholesaler			0.60
Inter-market transportation	0.10		
Storage	0.10		
Packaging	0.10		
Profit margin	0.20		
		0.50(38.5%)	
Retailing			1.10
Profit margin	0.20		
		0.20(15.4%)	
Price paid by consumer			1.30
Total marketing margin		0.90(69.3%)	

Note: ***Figures in parentheses indicate percentages of retail price.***

The marketing margin of one brand of agar jelly is analysed (Table 7). The net price received by the manufacturer is M$0.35 per cup, hence the manufacturer's share of the retail price is 58.3%. This is much higher than the importer's share of retail price for agar strip (33.3%) or agar powder (30.8%). The marketing margin at the manufacturer's level is M$ 0.10 per cup or 16.6% of the retail price, comprising mainly manufacturing costs such as raw material, labour and packaging.

At the sole agent distributor level the marketing margin is M$ 0.10 per cup or 16.6% of the retail price, This percentage seems low compared with the marketing margin at wholesale level for agar strip (33.3%) and for agar powder (38.5%). Such a difference is not surprising, considering that the distributor for agar jellies does not perform activities like storage, and packaging which wholesalers have to undertake for agar strip or agar powder.

Table 7: Marketing margins of processed agar (jelly desserts) per cup, Kuala Lampur, 1989.

Trade Level	cost		Price (M$)
Manufacturer			
Net price received by manufacturer			0.35
Raw materials	0.05		
Labour	0.02		
Handling and packaging	0.03		
		0.10(16.6%)	
Distributor			0.45
Transportation	0.05		
Profit margin	0.05		
		0. 10(16.6%)	
Retailer			0.55
Profit margin	0.05		
		0.05(8.3%)	
Price paid by consumer			0.60
Total marketing margin		0.25(41.6%)	

Note: Figures in parentheses indicate percentages of retail price

The overall marketing margin for agar jellies amounted to M$0.25 per cup or 41.6% of the retail price. Of this, 16.6% was accounted for by manufacturer's margin, 16.6% by distributor's margin and 8.3% by retailer's margin. It is noted that the marketing margin for agar jellies (41.6%) is lower than that of agar strip (66.3%) or agar powder (69.3%).

4. Potential for development and constraints

Malaysia imported nearly 172 tonnes of agar strip worth some M$6.55 million in 1988. This means that a sufficiently large domestic market exists to support the production and processing of seaweed, especially ***Gracilaria,*** in the country. Moreover, if this species could be successfully cultivated in Malaysia, substantial savings in foreign exchange would be attained through import-substitution.

Malaysia is blessed with several natural factors such as an abundance of sunshine and the absence of destructive typhoons. Most of the coastal areas are relatively unpolluted from sources such as silting, agricultural, agro-industrial and human wastes. Aquaculture in general has not been intensively developed, and at present offers no strong competition to seaweed culture. The political stability of the country, together with its well developed infrastructure and good shipping and communication network, pose few problems for the marketing of the product. A substantial domestic market for the processed agar, as well as good regional (ASEAN, Japan and Korea) and possibly international markets (U.S.A.. E.E.C., etc.), is also envisaged. Malaysia has good international links with the Muslim world and agar is the accepted substitute for gelatine in the food, cosmetic and pharmaceutical industries.

Notwithstanding the bright prospects there exist a number of constraints and problems that need to be overcome if a seaweed industry is to be developed. Heading this list is the inadequacy of technical capability and expertise. The technology available for seaweed culture in Malaysia is far from satisfactory and it may take several years of concentrated and well-designed effort to make it successful enough to compete with other seaweed producing countries in the region. A constant supply of consistent quality is important if seaweed produced in Malaysia is to be competitive with that of other producers. Moreover, while Gracilaria cylindrica was shown to produce a good food agar, it cannot be used for more demanding and higher valued uses such as bacteriological agar. The search for high-quality agar producing species must therefore continue. Stock improvement studies should also be conducted.

In addition to technological considerations, the potential development of the seaweed industry in Malaysia may be affected by market and economic constraints. While the domestic market may be able to support a small number of agar-producing enterprises, the full-scale development of the agar industry will very much depend on a reliable regional and international market. Unfortunately, potential producers (particularly those in developing countries like Malaysia) wishing to enter the international seaweed trade would be faced with stiff competition from the more established producers.

5. Conclusion

Almost all of the country's agar is currently imported, mainly from Korea. The bulk is utilised in Malaysia in the form of agar strips used mainly for jelly desserts. The other forms include agar powder and bacteriological agar for scientific purposes.

The domestic marketing of agar entails a host of different intermediaries, each performing varied functions such as importing, wholesaling, processing, distributing, merchandising, financing and retailing. In essence, the marketing of agar follows the general pattern of a few large importers selling to a relatively large number of wholesalers and/or agent distributors and stockists, who then service numerous small retailers and other retail outlets such as supermarkets, restaurants and hotels. Domestic demand remains strong as suggested by the continuing high imports and cif prices of agar. However, demand was adversely affected by the 1984-86 economic recession which had the effect of reducing imports, particularly from Japan. Furthermore, the fall in imports from Japan since 1986 can be attributed to the rising value of the yen. Demand and market potential for agar could not be analysed in detail, owing to the absence of detailed information. However, it is unlikely that demand for agar would increase substantially in the future since agar is a non-essential food item. Demand for food agar, however, is very price and income elastic.

It is timely, perhaps, for Malaysia to develop seaweed production and processing. However, before venturing into seaweed culture and processing on a large scale, there is a need to undertake in-depth market evaluation for different species of seaweeds, both at the domestic and international levels. New markets should be explored so that new seaweed-producing countries like Malaysia would not be too vulnerable to wide price fluctuation and uncertainties. The domestic market should be expanded to reduce over-dependence on the foreign market. There is also a need for more research on new uses for the various species of seaweeds. To ensure a constant supply of raw seaweeds for any processing plant that might be set up, Malaysia could act as a collecting centre for neighbouring countries in the ASEAN region. Once processed, the product could then be sold back to these countries.

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SEMINAR PAPERS: SESSION III
MARKETING AND MARKET POTENTIAL FOR AGAROPI-IYTES AND EXTRACTS IN BOBP REGION

INTERNATIONAL TRADE IN AGAR FOR COUNTRIES IN THE BAY OF BENGAL REGION

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ABSTRACT

Trade statistics from 1980-87 of imported/exported agar from the BOBP countries are presented in this paper. Thailand, Malaysia and Indonesia account for most of the imports in the region. Export of agar is recorded from four BOBP countries. However, re-export and misclassification of items may interfere with sound interpretaion of the statistics.

* * *

It is the intention, here, to look at the international trade in agar, making use of available statistics. Before examining the data it is prudent to sound a cautionary note. Trade statistics are ultimately only as good as the person who completes the customs form or the one who interprets it. Items may be misclassified. So-called 'Danish agar', for example, which appears in European trade statistics, is not agar at all but furcellaran, a carrageenan-type gum obtained from the seaweed ***Furcellaria.*** Figures available for imports of agar into the European Community indicate that 301 tonnes from the Philippines entered the UK in 1986 (Nimeke, 1986), a figure cited recently elsewhere (Anon, 1988), although incorrectly attributed to 1987. This, too, according to sources in the United Kingdom and Philippines (personal communication), is spurious and presumably refers either to carrageenan or the seaweed from which it is obtained.

For some countries, agar is not separated from other commodities. This is the case for Malaysia, for example, where it is included under the heading, 'Vegetable saps and extracts, pectic substances, pectinates, agar and other mucilages'. In such a situation, imports of agar can only be estimated by examining other countries' exports. Even this, however, may not be accurate or reliable. Thus, figures for imports of agar into Indonesia from Japan, when extracted from Indonesian import and Japanese export statistics, respectively, are in poor agreement although both list agar separately (Table 1).

Table 1: Indonesian imports of agar from Japan (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
Indonesian imports from Japan (1)	22	2	67	233	75	18	12	47
Japanese exports to Indonesia (2)	136	122	126	88	32	61	6	1

Source: (1) Indonesia Foreign Trade Statistics
(2) Japan Exports and Imports

Notwithstanding these comments, it is hoped that the trade statistics presented go some way towards representing the true picture with regard to international trade in agar within the BOBP region.

Thailand, Malaysia and Indonesia account for most of the imports of agar within the region (Table 2). Imports into Thailand, valued at Bht 112.9 million in 1987, come mainly from Japan, although there have been increasing amounts from Chile in recent years (Table 3).

Figures for Malaysian imports have been fairly consistent during the present decade, at around 250 tonnes per annum, except for 1983 when a sharp increase to over 500 tonnes was recorded (Table 4). Singapore, it should be noted, is not a producer of agar, but rather, re-exports imported material.

Table 2: Agar imports, BOBP countries (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	681	489	739	1236	689	661	684	699
Of which by:								
Thailand	209	184	230	307	260	234	252	277
Malaysia(1)	303	253	233	574	256	253	259	279
Indonesia	159	43	262	350	163	170	165	140
India(2)	6	6	4	3	6	3	5	NA
Sri Lanka	2	~(3)	7	~	NA	~	~	1
Bangladesh(1)	2	3	3	2	4	1	3	2

Notes : (I) Derived from exports by Japan. S. Korea and Singapore
(2) Year begins 1 April
(3) ~ Indicates < 0.5

Table 3:.Agar imports, Thailand (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	209	184	230	307	260	234	252	277
Of which from:								
Japan	117	90	143	195	150	143	134	126
S. Korea	22	25	19	22	16	20	20	10
Chile	59	60	64	60	58	70	94	134
Taiwan			3	21	2		2	6
China	8	9		8	20			
USA					11			
Others	3		1	1	3	1	2	1

Source: Foreign Trade Statistics of Thailand

Table 4: Agar imports, Malaysia (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	303	253	233	574	256	253	259	279
Of which from :								
Japan	4	4	4	11	10	11	11	6
S. Korea	15	57	74	107	82	146	162	214
Singapore	284	192	155	456	164	96	86	56
Hong Kong								3

Source: Derived from exports by Japan, S.Korea, Singapore, Hong Kong.

Indonesia imports agar from a variety of sources, with Asian and South American countries contributing significant amounts (Table 5). Figures for Hong Kong and Malaysia, like those of Singapore, refer to re-exports. Total imports for 1987 were valued at US $526,000. Imports in 1983, again, appear to have been higher than normal.

Indian demand for agar is met primarily by domestic production (Coppen, 1989) but small amounts of higher grade bacteriological/pharmaceutical agar are imported (Table 6).

Imports of agar into Sri Lanka and Bangladesh are also low, of the order of a few tonnes per annum or less (Tables 7 and 8). There is not much local production either.

Exports of agar are recorded for four BOBP countries, although for Thailand and Malaysia, at least, these probably represent re-exports (Table 9).

The main destination for Thai agar has been the USA (Table 10). For Indonesia, most of the 9 tonnes exported in 1988 went to Singapore (Table 11).

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Table 5: Agar imports, Indonesia (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	159	43	262	350	163	170	165	140
Of which from:								
Japan	22	2	67	233	75	18	12	47
Taiwan		12	170	102	74	106	30	24
Singapore	43	21	19	1			3	
Hong Kong	36	6	1			25	21	
Malaysia			2	12	10	9	12	7
Chile				2		9	43	8
China	58						12	45
W. Germany			1		1	3		1
Spain							31	5
France								2
USA		1	1		3			
Others		1	1				1	1

Source: Indonesia Foreign Trade Statistics

Table 6: Agar imports, India (tonnes)

	1980	1981	1982	1983	1984	1985	1986
TOTAL	5.7	5.8	3.8	2.6	6.0	2.6	4.7
Of which from:							
Japan	0.9	1.9	0.5	1.0	1.5	1.2	2.1
China					2.0	0.4	0.5
France	0.8		1.0	0.9	1.0	1.0	1.6
USA	4.0	0.3		0.7			
Singapore		2.3	1.8				
UK					0.5		0.5
W.Germany		1.0			1.0		
Argentina		1.0					
Thailand			0.4				
Others		0.3	0.1				

Source: Monthly statistics of the Foreign Trade of India
Note: Year begins 1 April

Table 7: Agar imports, Sri Lanka (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	2.5	0.2	6.8	0.1	NA		0.1	1.4
Of which from:								
India	0.3	0. I						
Singapore	2.1		0.1					
UK			6.7					0.4
Switzerland								0.9
USA								0.1
Others	0.1	0.1		0.1				0.1

Source: External Trade Statistics, Sri Lanka
Note: (-) indicates < 0.05

Table 8: Agar imports, Bangladesh (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	1.8	2.5	2.5	2.2	4.4	1.3	3.0	1.9
Of which from:								
Japan		0.7	1.4	0.2	1.0	0.5	0.6	1.4
S. Korea					1.4	0.8	1.4	0.5
Singapore	1.8	1.8	1.1	2.0	2.0		1.0	

Source: Derived from exports by Japan, S.Korea and Singapore

Table 9: Agar Exports, BOBP countries (tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987
TOTAL	2	15	6	15	33	40	24	19
Of which by:								
Thailand			~(3)		1	12	12	11
Malaysia (1)			2	12	10	9	12	7
Indonesia				2		1		1
India (2)	2	15	4	1	22	18		NA
Sri Lanka								
Bangladesh								

Notes: (I) Derived from imports by Indonesia
(2) Year begins 1 April
(3) ~Indicates < 0.5

Table 10: Agar Exports, Thailand (tonnes)

	1983	1984	1985	1986	1987
TOTAL		1.2	11.8	11.7	10.8
Of which to:					
USA			4.8	7.0	3.5
Canada			1.6	0.6	1.1
Australia		0.1	1.6	1.8	2.3
Netherlands			1.1	0.5	
France			1.5		
UK				1.0	
W. Germany					0.7
Burma		1.1			
Japan					1.0
Singapore					0.7
Others			1.2	0.8	1.5

Source: Foreign Trade Statistics of Thailand
Note: (-) indicates < 0.05

Table 11: Agar exports, Indonesia (tonnes)

	1983	1984	1985	1986	1987	1988
TOTAL	2.0		0.5		0.6	9.0
Of which to:						
Japan	2.0					0.5
Hong Kong					0.5	0.4
Singapore						7.8
Saudi Arabia					0.5	0.3
Netherlands					0.1	

Source: Indonesia Foreign Trade Statistics

Indian exports, which occasionally rise to quite significant amounts, are known to originate from indigenous production (Table 12). A number of different countries have purchased Indian agar at one time or another, but none appear to have sustained such imports.

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Table 12: Agar exports, India (tonnes)

	1980	1981	1982	1983	1984	1985
TOTAL	**1.5**	15.1	4.0	1.4	21.8	18.0
Of which to:						
Saudi Arabia					21.8	
Yemen Arab Rep.		5.1	1.9			
United Arab Em.				1.0		
Kuwait	0.2					
Japan						**18.0**
UK			1.3	0.4		
Australia		10.0				
Kenya	1.0					
Mauritius			0.8			
Sri Lanka	0.3					

Source: Monthly Statistics of the Foreign Trade of India
Notes: Year begins 1 April; (~) indicates < 0.05

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SEMINAR PAPERS: SESSION IV
MANAGEMENT OF NATURAL RESOURCES OF AGAROPHYTES

MANAGEMENT OF NATURAL RESOURCES OF TROPICAL AGAROPHYTES

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ABSTRACT

This paper deals with considerations on management and utilization of natural stocks of seaweed for commercial exploitation. Emphasis is laid on intensive biological studies to determine seasonality in biomass production, reproduction, regeneration, recruitment, abundance and distribution. Strict application of a management scheme will help improve the production ecology of a given seaweed bed.

1. Introduction

The production of agar-producing seaweeds comes from three sources, namely gathering of drift materials, direct harvest from natural stocks and cultivation. At present, the bulk of the seaweeds used for agar manufacture still comes from harvested natural stocks. There are no available and accurate data on the contribution of agarophytes produced through culture, but judging from the genera presently produced in different countries, which were imported by Japan in 1984 (Armisen and Galatas 1987). about 50% of the raw seaweeds presently processed into agar still come from natural stocks. The genera presently utilized in the international market for agar production are *Grucilaria, Gelidium, Pterocladia, Gelidiella, Anfheltia* and *Ceramium.*

Approximately 6,683 tonnes of agar were produced by 14 countries in 1984 (Armisen and Galatas 1987). Of this, about 48% was processed from *Gelidium* and *Pterocludia* with the remaining 57% from "other seaweeds" which undoubtedly include genera such as *Gelidiella* and *Gracilaria.* As far as *we* know today, only the genus *Gracilaria* is presently produced in commercial quantities through cultivation. In the first half of the 1980s, Chile, Brazil, Taiwan and Philippines were the main suppliers of cultured *Gracilaria* to Japan. Recently, Vietnam, Indonesia, Thailand, Hawaii and others have applied culture techniques in *Gracilaria* production. At present, however, a large proportion of the *Gracilaria* produced still comes from local stocks. *Gelidium* and *Pterocladia,* utilized mainly for the manufacture of bacteriological agar and agarose, come so far as we are aware, from the gathering of natural stocks. Their commercial production through farming seems to be still a long way from realization. Thus, the production of most of these agarophytes is expected to be dependent on their natural stocks for a long time to come.

2. important considerations in the utilization of natural stocks as a source of biomass

The production of agarophytes from natural stocks is very much influenced both by seasonal factors and by harvest pressures exerted on them during the preceding cropping season. Because their growth cycles are greatly influenced by environmental conditions and by man's exploitive activities, their production is unreliable. They are prone to over-exploitation, and the need to manage and conserve their stocks is of prime importance in order to sustain or further enhance their productivity and prevent over-exploitation.

The design of a sound management scheme for the natural stocks of commercial agarophytes depends primarily on the availability of information on the various aspects of their biology, such as reproduction and growth cycle, growth rates, their regeneration and recruitment capacities, their productivity and the influence of environmental factors on the biomass production potential of the stocks. This information is necessary to formulate guidelines for managing the natural

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stock of the target species. The information can provide answers to questions such as where the species is abundant, how much to harvest per unit area, when to harvest, how many times (cropping intervals) the stocks can be harvested in one season and what kind of harvest method is best for the species. Gathering such information on the species to be managed requires basic skills in field sampling and data gathering. Under management. the production of stocks can be forecast with confidence. This information is most important for quoting in contracts which may be entered into by the farmer, fisherman. or exporter.

It is therefore of prime importance that any plan to exploit natural seaweed stocks be preceded by intensive biological studies to determine their seasonality in biomass production, reproduction, regeneration and recruitment. This information is necessary for determining the best possible time to harvest, and the amount of stocks harvestible, without diminishing their production capacities.

3. Requisites to the rational exploitation of natural stocks

In a "free-for-all" situation, there is always a natural tendency for resource users to over-exploit resources, especially where there is a prevailing demand for the produce. The literature is replete with records of resource losses due to over exploitation. Thus, it is necessary that the commercial exploitation of natural seaweed stocks, or any resource, be preceded by biological studies which shall be the basis for their management.

3. I Inventory and assessmentof stocks

The inventory and assessment of stocks are initial studies which should be done in areas where the exploitation of stocks has not yet started. This will identify the species potentially available for development, where and when these species are abundant, how much biomass is available for harvest and the behaviour and responses of the stocks to certain degrees of exploitation.

The need to know the true identities of the different species is very important because unlike other resources, e.g., fish and crustaceans, the kinds and quality of agar vary from species to species. Thus, it is very important that the taxonomy of the species comprising the stocks is known. In addition, the quality of the hydrocolloid (agar) should be defined, characterized or evaluated as the price of the produce is determined by the quality of its extractable agar. In the world agar market, the name of the species and, in the case of ***Gracilaria,*** information on the source of the dried raw material, .are important because they reflect the differences in the properties of the agars. ***Gracilaria*** from Chile, for instance, fetches a higher price than that from the Philippines because it contains higher quality agar. Thus, the names applied to these produce serve as a basis for their pricing. The price is generally based on the moisture content and the purity and quality (gel strength, melting and gelling temperatures, viscosity and amount of sulfate group) of the agar.

Information on the abundance and distribution of the resource in space and time may be gathered through biomass samplings of the stocks. The application of available methodologies may differ slightly, depending on the behaviour of the resource. However, the transect quadrat method is widely used especially **in** situations where stocks are not homogeneously distributed in space. The size of the bed is first delineated and permanent transects are marked. The orientation of the transects is generally related to certain ecological gradients, such as depth and wave exposure. Biomass samplings are generally done on a monthly basis along the transects; the size of the quadrat varies from 0.25-1.0 m^2. The number of quadrats to be sampled along the transects may also vary, depending on the size and homogeneity of the bed, the time and effort required but most important is the amount and type of data for statistical analysis i.e. the more the samples that are gathered, the more reliable the data **will be.**

The amount of loose (drift) biomass should also be monitored to derive reliable data on the total biomass production of the bed.

Data on biomass production recorded for a period of one year will indicate the annual productivity and seasonality in production of the stocks. Additional data from following years will make the information on the stocks more reliable as a basis for management. In most stock assessment studies where the target species or group of species and their distribution are known, the main concern is the determination of production data.

The size of the bed must be known so that the potential total production of stocks can be determined. This information is vital in determining how much of the stocks should be harvested without unduly diminishing their productivity. Using the production data from the samples, total production of the bed may be projected/calculated by multiplying the biomass data (g/m^2) by the size of the bed. The accuracy of the method is much improved if regular and repeated samplings of the stocks are carried out.

Additional information on production in the area can be gained through interviews with market vendors and seaweed gatherers. Initial interviews may be done in local open markets where seaweeds are sold. Seaweed vendors are a good source of information on the kinds of species, the amounts they sell, the sources of seaweed stocks, suppliers and the approximate number of gatherers. Seaweed gatherers are good sources of primary data on production. They can easily be identified by inquiring from local officials in the area. Data on gathering sites, number of gatherers, the gathering season and output per unit effort may be acquired from this source. An estimate of local production can then be made, and counter-checked with the data on potential biomass production of the beds or collecting area.

The seasonal variation in the reproductive/fertility states of the stocks should also be known. The fertility of the stock may be determined by randomly collecting 50 or more thalli and determining the number which are vegetative and fertile. This is usually expressed as % fertility. This information is relevant in the scheduling of harvesting/cropping periods. The recruitment capacities of stocks is generally influenced by their states of fertility, especially for those species where recruitment is largely dependent'on the production of reproductive cells (spores). Cropping or harvesting should be scheduled some time before or after the peak of fertility of the stocks, in order not to interfere unduly with the recruitment process. This, however, may not be relevant to species where production is based mainly on vegetative means (cuttings, fragments). Some stocks of Gracilaria, for instance, have been reported to be purely vegetative (Rueness et al. 1987). Pond cultured ***Gruciluriu*** have been observed to be purely vegetative the whole year round in Northern Philippines (personal communication). In cases where recruitment is primarily based on vegetative means, a certain amount of the seedstock is retained in the bed for the next season's croppings. This amount may be equivalent to the amount of biomass produced in the bed during its lowest production period.

In addition to these basic biological studies, harvesting experiments should be carried out to determine the production capacities and the effects of different harvest pressures and methods on the regeneration of the stocks. The information on the capability of the stocks to regenerate to their former level of production after trial cropping/harvesting shall be the basis for determining the harvest schedules during the cropping season.

3.2 Development and application of a management scheme for the stocks

The application of a management scheme to natural stocks has been shown to significantly improve the total production of the beds. In Chile, the annual production of Gracilaria in Lenga Cove located in San Vicente Bay increased from 80 tonnes to 600 tonnes after the application of a management programme (Poblete and Inostroza. 1987). It is apparent from their studies that the strict application of a management scheme had improved the production ecology of the bed, resulting in an increase of seven and a half times its normal production.

In general the formulation and application of a management scheme for the natural stock of seaweeds may follow the following steps. Variation from this scheme may be necessary to suit certain biological characteristics of the species concerned. The basic considerations are:

a) Seasonal changes in the annual productivity of the stocks.

Data on changes in the annual productivity of the stocks are derived from the monthly biomass measurements done on the bed. They provide information on the total amount of biomass available for cropping, and the season when cropping/harvesting may be done. In addition, the seasonal variation in the amount of agar contained in the crop is also considered in the scheduling of the harvest. A high quality crop is obtained when harvesting is done during periods where the agar content is high.

b) Determination of the amount of biomass to be left after cropping.

The amount of biomass left after the first cropping is very important in determining the amount of biomass available for the next cropping season. As a "rule of thumb," the minimum amount to be left in the bed to serve *as* "seeds" for the next cropping season should not be less than the lowest biomass recorded during the year. The amount of biomass available for harvest will be the difference between the total amount available in the bed during its peak production period and the minimum biomass during its period of depressed growth.

c) Determination of the harvest schedule.

How often should the harvest be done during the peak production season? The harvest regimes can be determined from information on the regenerative capacity of the stocks, e.g. from the results of studies on different trial harvest pressure. The schedule of subsequent harvests is determined by the period within which the stock can recover its original biomass after the first harvest.

d) Control of the amount of biomass to be harvested.

The amount of biomass to be harvested during each harvest regime should not exceed the amount of biomass available for cropping. It is, therefore, necessary that the number of fishermen should be limited, and that the amount of crop each is allowed to harvest must not exceed his share of the biomass available for cropping during each of the cropping periods.

e) Protection of the recruitment and regeneration processes.

This is a very important consideration because the continuity of the stocks depend on these processes. The approach may differ depending on the biological characteristics of the species. For stocks which depend on the regeneration of biomass through vegetative structures such as holdfasts, cuttings or fragments, and underground thalli, protection may be ensured by the application of harvest methods which cause the minimum harm to these regenerative structures. For stocks whose recruitment and regeneration processes depend both on reproductive cells and vegetative structures, the timing of the harvest so as not to impede or adversely affect recruitment and the use of harvest methods which have minimal destructive effects on the regenerative structures are important considerations. Thus, harvesting should not be done during peak fertility of the stocks.

f) Socio-economic considerations in managing the resources.

The fishermen/seaweed gatherers should be organized into production groups such as cooperatives. Only bonafide members have the right of access to the resource, and the amount each member is allowed to crop is determined by his fair share of the biomass available for cropping. A legal basis for enforcing these regulations can easily be achieved through rules promulgated by the local government, or by the cooperative's established rules/regulations. Peer pressure among the members can also be a strong factor. Management of the co-operative is done by selected members. A portion of the members' earnings is channelled back to the co-operative for management support. Technical assistance should be extended to the cooperative by the government agencies concerned.

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SEMINAR PAPERS: SESSION IV
MANAGEMENT OF NATURAL RESOURCES OF AGAROPHYTES

GRACILARIA RESOURCES OF INDIA WITH PARTICULAR REFERENCE TO THE BAY OF BENGAL

by Prof Krishnamurthy Vasudeva

ABSTRACT

Thirty one species of Gracilaria are found on the Indian coastline of the Bay of Bengal. The estimated biomass of Gracilaria from Indian waters is 1700 tonnes. Studies on the cultivation and harvesting of Gracilaria ***edulis*** have shown that an interval of about six months between harvests will ensure continued good growth of the crop.

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The genus Gracilaria is represented by 32 species in the Indian region. of which 31 are found in different parts of the Bay of Bengal coast. In respect of species diversity and biomass, ***Gruciluriu*** is second only to Surgussum of the Phaeophyta. Another noteworthy feature of ***Gruciluriu*** is the diversity of the species on the Indian coast which is not matched anywhere else in the world. It may, therefore, be stated without hesitation that Gracilaria is the most economically important genus on the Indian (Bay of Bengal) coast.

Two species of ***Gruciluriu, G. corticutu*** and ***G.*** folifera. are found more or less throughout the Indian coasts wherever the shore is rocky. On the other hand, a few economically important species like ***G. edulis, G.*** verrucosa, ***G. fergusonii, G. bursa-pastoris*** and ***G. textorii*** have restricted distribution. G. ***eucheumoides*** is found only in the Nicobar group of Islands in the Bay of Bengal.

Estimates of ***Gruciluriu*** resources on the Indian coasts have been made by several scientists using diverse methods. Table 1 summarizes the results of various estimates of India's Gracilaria resources based on the standing crop at the particular time.

Table 1: Estimates of available *Gracilaria* biomass from Indian waters

Author & year of publication	Locality & Area	Estimated bio-mass in tonnes
Varma & Krishna Rao 1962	Gulf of Mannar 235.25 sq. km	195.30
Krishnamurthy 1969	Drift on the Indian coasts	50.00
Umamaheswara Rao 1968	Pamban 3.58 sq.km	233.15
CSMCRI, Bhavnagar 1978	Tamil Nadu coast 1971-1976	1700.00

Earlier estimates by Koshy & John (1948), Chacko & Malu Pillai (1958), Thivy (1960) and Desai (1967) gave no details of the methods of survey, and were restricted to small stretches of the coast. Varma and Krishna Rao (1962) and Umamaheswara Rao (1968) described the methods they used, although their surveys were confined to small areas in the Gulf of Mannar and Palk Bay sides of Mandapam. Harvest figures, based on landings for Pamban, Periapatnam and Kilakkarai during 1966 to 1968, were given by Umamaheswara Rao (1968).

A study of seaweed drift on the Indian coast was reported by Krishnamurthy ***et al*** (1967) and by Krishnamurthy (1969). These drifts are particularly heavy in some parts of the Indian coast and may be used locally for manure and for bio-gas production. This survey indicated potential areas for more intensive surveys.

The more scientific and, therefore, more reliable survey made by a team of scientists from the Central Salt and Marine Chemicals Research Institute, Bhavnagar, in collaboration with other institutions like the Central Marine Fisheries Research Institute and the Departments of Fisheries of various State Governments, gave data that can be taken as the basis of future estimates. The survey, begun on the Tamil Nadu coast, was followed by a similar survey on the coast of Andhra Pradesh.

The Gracilaria resources of Tamil Nadu and Andhra Pradesh coasts of the Bay of Bengal are shown in Table 2. A perusal of this table shows that the total Gracilaria resources of the east coast of India assessed so far can sustain a production of about 75 tonnes of agar per annum, assuming that all of the Gracilaria can be harvested and utilized. In practice, however, it is neither feasible nor desirable to harvest the entire quantity available. Assuming that 50% of the standing crop can be harvested, it follows that only about 37.5 tonnes of agar can be produced. This is totally inadequate and will not meet Indian demand for agar.

Table 2: Estimates of available biomass of different species of **Gracilaria** from Tamil Nadu and Andhra Pradesh coasts (CSMCRI Surveys)

Species	Quantity in tonnes (Fresh weight)	Quantity in tonnes (Dry weight)
G. edulis	617.46	104.97
G. corticata	284.61	45.54
G. folifera	11.35	1.99
G. textorii	4.80	0.72
G. debilis	1.35	0.11
G. fergusonii	100.40	16.06
G. crassa	1.42	0.12
G. bursa-pastoris (G. compressa)	1.45	0.15
G. verrucosa	412.76	61.91
Other species (23)	474.16	71.12
Total of all species	1909.76	302.69

The agarophyte resources of India have been over-exploited and the biomass of these algae has been diminishing over the years. The estimates considered above are 15 to 20 years old and may not have much significance now. A renewed estimate, adopting a scientific method of survey and annual monitoring of the resources using remote sensing techniques, is essential to keep a watch over these resources.

Experimental work on repeated harvesting of a standing crop of Gelidiella ***acerosa*** (Joshi & Chauhan, 1985) has shown that adopting a sensible harvesting programme can ensure regrowth of the standing crop. Similar studies on ***Grucilaria*** would throw light on methods for conserving these resources. Studies on the repeated harvesting of cultivated ***Grucilaria edulis*** have shown that an interval of about six months between harvests will ensure continued good growth of the crop.

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SEMINAR PAPERS: SESSION IV
MANAGEMENT OF NATURAL RESOURCES OF AGAROPHYTES

GRACILARIA SPP. RESOURCES IN INDONESIA

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ABSTRACT

Commercial seaweed farming began in Indonesia on a small-scale in 1979. The three main species of ***Gracilaria*** in Indonesia are ***G. lichenoides,*** G. ***gigas,*** and ***G. verrucosa.*** This paper presents a study of the quality of ***Gracilaria*** collected from 31 locations.

Introduction

Indonesia's seaweeds of commercial importance are the agarophytes ***Gracilaria spp., Gelidium spp., Gelidiella spp.*** and ***Pterocladia spp.,*** and the carrageenophytes ***Eucheuma spp.*** and ***Hypnea spp.*** Until 1983, almost all of the seaweed products manufactured in Indonesia were derived from the harvesting of wild seaweed stocks. These are neither adequate in volume and reliability, nor competitive in cost. There are also problems with continuity of supply and in controlling the quality and quantity of the products.

Commercial seaweed farming began in Indonesia on a small scale in 1979, using ***Eucheuma*** spinosum. After more intensive study and development, further ***E. spinosum*** farming started in 1983. Farming of ***E. cottonii (E. averizii)*** began in 1984, in cooperation with the Genu-Kopenhagen pectin factory.

Indonesian agarophytes

An intensive study of Indonesian agarophytes was started in 1985. It involved collecting local species and analysing their quality; studying biological and environmental aspects in support of farming experiments; studying farming techniques and methods for experimental farm and farming development; and studying agar processing methods and the development of an agar processing industry.

Variation in the quality of some Indonesian Gracilaria

Indonesia's ***Gracilaria*** comprise three main species, namely ***G. lichenoides,*** G. gigas and G. ***verrucosa.*** The properties of seaweed samples collected during the period 1985-87 are given in the following table.

Variation in the quality of some Indonesian *Gracilaria* **collected between 1985 and 1987**

Location	Yield %	Gel Strength (g/cm)	Gelling point/ Melting point	Dried Product	Harvest Season
Terora, Bali	8.7	170	25/69	8.0	AG-JA
Geger , Bali	9.4	210	29/76	9.5	AG-JA
Paciran (1) East Jawa	18.7	880	41/88	80.0	(FA)
Paciran (2) East Jawa	17.9	960	41/90	140.0	(FA)

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Location	Yield %	Gel Strength (g/cm)	Gelling point/ Melting point (C)	Dried Product (Ton/Yr)	Harvest Season
Sekotong (I) Lombok	19.2	890	40/92	60.0	JL-FB
Sekotong (2) Lombok	19.1	905	42/91	50.0	JL-FB
Lembar Lombok	17.3	825	39/90	SO.0	JL-FB
Lbhn. Haji Lombok	15.4	770	36/87	40.0	SP-FB
Tg. Gontor Sumbawa	16.9	900	39/91	60.0	SP-MR
Lbhn. Lalar Sumbawa	18.2	920	41/90	120.0	SP-FB
Sumbawa Besar, Sumbawa	16.6	740	35/87	40.0	JN-FB
Teluk Saleh Sumbawa	18.4	690	34/87	60.0	JN-FB
Dompu Sumbawa	20.6	720	36/88	50.0	SP-JN
Plbn. Ratu West Jawa	16.9	570	36/88	30.0	JL-DC
Lbhn. Banten West Jawa	17.1	710	34/83	35.0	AG-DC
Malimping West Jawa	16.7	770	41/87	40.0	AG-DC
Pameungpeuk West Jawa	15.4	480	33/81	35.0	OC-MR
Pantai Baron Jogyakarta	14.9	390	32/81	25 .0	NP-AP
Pacitan East Jawa	15.8	440	33/83	15.0	JN-DC
Warambadi Sumba NTT	18.2	660	37/87	25.0	AP --NR
P. Sawu(1) NTT	14.7	520	34/82	20.0	JL-JA
P. Sawu (2) NTT	17.1	690	35/89	45.0	JL-JA
P. Besar Flores	12.3	310	31/82	15.0	SP-JA
Tongga P. Rote NTT	17.4	720	36/89	40.0	JL-JA
Tg. Pila P. Rote NTT	13.3	290	32/86	10.0	AG-JA
Tg. Bunga South Sulawesi	18.1	710	39/89	35.0	(FA & WS)
Sibatua South Sulawesi	17.3	810	40/91	200.0	(FA)
Maros South Sulawesi	14.4	510	35/87	20.0	JL-DC

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Location	Yield %	Gel Strength (g/cm)	Gelling point/ Melting point (C)	Dried Product (Ton/Yr)	Harvest Season
Mamuju South Sulawesi	17.5	965	41/92	-	(FA)
Takalar South Sulawesi	18.7	1090	40/92	60.0	(FA & WS)
Bone South Sulawesi	17.1	790	40/88	50.0	(FA & WS)

Notes: Moisture content of all samples less than 20%

- FA = Farming Area
- WS = Wild stock
- JA = January; FB = February; MR = March; AP = April; MY = May; JN = June; JL = July; AG = August; SP = September; OC = October; NR= November; DC = December

* = Estimated

AN INVESTIGATION OF SOME ENDEMIC AGAROPHYTES IN SOUTHWESTERN THAILAND

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ABSTRACT

Distribution of ***Polycavernosa*** along the coastline of Satul, Trang and Krabi Provinces was investigated. In Krabi Province, the highest occurrences were observed in June and the lowest occurrences in April. In Satul and Trang provinces, the highest occurrences were observed during January-April and the lowest occurrences during August-September. ***Gracilaria*** was found attached to the polyethylene net of fish cages, bottom sand, mud and underwater materials.

Conditions suitable for optimum growth of Polycavernosa were found to be : 29-32° C water temperature. 25-30 ppt salinity and 25-27 cm water depth.

Introduction

Gracilaria are used in the manufacture of various products which include human food, animal fodder, fertilizers and soil conditioners, and as raw materials for the chemical and pharmaceutical industries. The latter two are significant because they have a market worth of over US $300 million annually (HAI., 1986). Thailand exports seaweed (mostly ***Gradaria)*** totalling between 20 and 200 tonnes/year (dry weight), and valued at 4-10 million baht (HAI.. 1986)

At present, eight endemic agarophytes are found in Thailand (Abbott, 1987), four species belonging to the genus ***Gracilaria (C. tenuistipitata*** var liui, ***G. firma, C.*** irregularis and ***C.*** salicornia and four to the genus ***Polycavernosa (P.*** fisheri, ***P. changii, P. fastigiata*** and ***P.*** percurrrens). The major producing areas are the southern region of Songkhla lake and the shallow mudflats in Pattani Bay (Tachanoravong. 1989).

The purpose of this study was to investigate the natural growth of endemic agarophytes in southwestern Thailand (Krabi, Trang and Satul provinces). The results can be used as basic information for natural production management and for future studies of culture techniques.

Method

The investigation was conducted between November 1987 and April 1988 in the coastal areas of Krabi, Trang and Satul provinces. A pre-survey in the three provinces was done in November 1987, in order to study basic information on natural production of ***Gracifaria*** and ***Polycavernosa.***

The investigation was carried out at 11 stations in Krabi province. six stations in Trang province and 10 stations in Satul province. Every survey station was investigated twice during the period of study.

Water and air temperatures were recorded by mercury thermometer, and water salinity was measured by hand refractometer.

The natural growth of seaweed which attached to fin-fish net cages was recorded. The growth period and seasonal fluctuations were observed. The total amount of endemic agarophytes in the fin-fish net cages was weighed. An estimate of production for the harvesting season was made as follows:

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1. The cages with attached Polycavernosa were taken out and weighed by direct balance (wet weight). (The size of fin-fish net cages is around 5 x 5 m and 2 m in depth).
2. The frequency of cleaning the net cages was recorded. The weight of Polycavernosa removed when cleaning the net cages each time was estimated and recorded.
3. Total amount of Polycavernosa which could possibly be harvested in a year was estimated.

Results

During this investigation, only the genus ***Polycuvernosu*** spp. was found. No members of the genus Gracilaria ***were*** found during this period. The species of Polycavernosa ***spp.*** may be ***P.*** changii (Abbott, 1987), but a further study on species classification is recommended. ***Polycuvernosu*** were found on the polyethylene net of fish cages at a depth of 40-70 cm from the water surface.

At the 11 stations surveyed in Krabi province, ***Polycuvernosu*** was found mostly in March, May, June and July. At some stations, ***Polycuvernosu*** were found all the year round. Total amounts of Polycuvernosa found ranged from 20-50 kg/cage per season. It is estimated that a total amount of 22,130 kg may be available for harvesting each year (Table 1). Fish culturists in Krabi province harvest only a few kilograms of Polycuvernasa for selling fresh in the local market.

Table 1: Natural growth of Polycuvernosa sp. on finfish net cages in Krabi province.

St	Period (month)	Salinity (ppt)	***Temp C*** W.	A.	***No.*** cages	Weight kg/cages	Total Wt. kg.
1	7- 12	30	32	38	52	50	2600
2	5- 6	30	32	33	26	35	910
3	s - 6	30	30	32	100	35	3500
4	6	31	29	31	48	35	1680
5	1 –12	30	31	32	16	35	560
6	1 - 12	25	32	38	20	20	400
7	1-12	29	32	34	8	20	160
8	3	24	29	29	70	20	1400
9	1- 12	25	30	31	120	50	6000
10	1-12	25	29	30	140	35	4900
11	I - 12	28	29	32	-	20	20
Total	-	-	-	-	338	355	22130

At the six stations surveyed in Trang province, Polycarvernosa was found mostly in January, February. March and April, although at some stations it was found all the year round. Total amounts of Polycavernosa ranged from 20-35 kg/cage per season. An estimated total of 5,075 kg may be available for harvesting each year (Table 2). There is no local market for ***Polycuvernosu*** in Trang province.

Table 2: Natural growth of Polycavernosa sp. on finfish net cages in Trang province

St	Period (month)	Salinity (ppt)	***Temp C.*** W.	A.	***No.*** cages	Weight kg/cages	Total Wt kg
1	3-- 4	28	29	30	-	20*	20
2	1	27	29	31	16	35	560
3	1 - 12	27	32	33	12	20	240
3	1-12	25	31	30		20”	20
5	1- 12	25	31	30	210	20	4200
6	2	25	31	30	-	35	35
Total	-	-	-	-	238	150	5075

* No finfish net cages, it can be found attached to underwater stone, sand and mud.

At the 10 stations surveyed in Satul province, Polycavernosa was found mostly in March and April. Again, as in Krahi and Trang. it was found at some stations all the year round. Total amounts of Polycavernosa ranged from 20-50 kg/cage per season. An estimated total of 26.545 kg may be available for harvesting each year (Table 3).

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Table 3: Natural growth of polycavernosa **sp. on finfish net cages in Satul province**

St	Period (month)	Salinity (ppt)	***Temp C*** W. A.		***No.*** Cages	Weight kg/cages	Total Wt. kg.
1	3 - 4	30	30	34	-	35*	35
2	4	32	31	32	88	35	3080
3	4	35	29	30	-	20	20
4	4	30	29	34	60	50	3000
5	4	31	30	34	120	20	2400
6	3- 4	28	30	31	70	20	1400
7	1 - 12	25	29	33	70	20	1400
8	3- 4	23	36	38	310	35	10850
9	12- 4	25	34	35	180	20	3600
10	12- 4	22	34	36	38	20	760
Total	-	-	-	-	936	275	26545

* No fin-fish net cages, it can be found attached to underwater stone, sand and mud.

There is no local utilization of Polycavernosa. A few fish culturists in Satul province have been informed about the market potential for this seaweed, but no local market has developed up to the present time.

The physico-chemical properties of the coastal water in fin-fish net cages in southwestern Thailand were investigated the previous year (Tookwinas et al., 1985). Water visibility ranged from 0.39-l .57 cms. Other water properties are shown in Table 4.

Table 4: Average physico-chemical properties of coastal water in finfish net cage and coastal aquaculture ground area in Southwestern Thailand (Tookwinas el al. 1985)

St	Depth m	Visibility m	D.O. mg/L	pH	Salinity %	NH-N mg/L	NO-N mg/L	PO mg/L	Si mg/L
1	1.72	1.03	5.60	8.10	30.10	**0.00096**	0.00294	0.0290	2.77
2	1.32	0.75	6.30	8.10	29.70	0.0016	0.0030	0.0180	2.80
3	5.44	1.43	4.60	7.80	28.90	0.0034	0.0026	0.0045	2.49
4	3.16	1.57	5.32	7.80	30.23	0.0110	0.0026	0.0590	2.02
5	0.88	0.61	5.24	7.99	29.40	0.0032	0.0020	0.0200	3.10
6	1.22	0.74	4.56	7.79	24.06	0.0028	0.0023	0.0172	2.35
7	0.90	0.47	5.53	7.69	24.79	0.0130	0.0004	0.0460	2.46
8	1.26	0.66	4.71	7.58	20.50	0.0180	0.0055	0.0490	2.74
9	1.55	0.80	4.85	7.62	17.19	0.0210	0.0170	0.0250	2.53
10	2.62	0.98	4.88	7.72	25.51	0.0128	0.0028	0.0570	2.505
11	4.20	1.34	4.45	7.51	25.90	0.0146	0.0016	0.0550	2.73
12	1.72	1.06	5.03	7.56	24.06	0.0200	0.0025	0.0703	2.60
13	1.54	0.80	5.21	7.73	28.73	0.0120	0.0030	0.0580	2.78
14	1.04	0.52	5.88	7.90	29.65	0.0380	0.0056	0.0300	1.96
15	1.62	0.75	5.94	8.01	30.05	0.0160	0.0035	0.0440	2.27
16	4.96	1.08	5.19	7.94	25.22	0.0200	0.0025	0.0430	2.10
17	2.53	1.00	5.09	7.77	17.83	0.0120	0.0022	0.0460	2.51
18	1.00	0.47	5.66	7.73	26.75	0.0098	0.0035	0.0540	2.72
19	1.26	0.39	5.57	7.87	27.36	0.0320	0.0088	0.0630	2.43

Conclusions and Recommendations

There is a potential Polycavernosa production of approximately 53.7 tonnes (wet weight) in the three provinces. This is equivalent to a dry weight of about 7.7 tonnes.

At present, there are no agar processing plants in Thailand. Thailand exports dry seaweed to Japan, West Germany, Hongkong and Malaysia at quantities ranging between 20 and 200 tonnes/ year. Agar is imported at quantities ranging between 200 and 300 tonnes/year, at a value of 50 to 100 million baht. Some of the seaweed production is utilized and consumed in Thailand, but the bulk is exported (HAI, 1986).

The export of dry seaweed fluctuates. This may be due to the poor quality of the local product, and irregular supply. These factors discourage fish culturists from cultivating endemic agarophytes in Thailand.

Information from this investigation indicated that the selling price for dry ***Polycavernosa*** is very low. Fish culturists in Krabi province were informed that dry ***Polycavernosa*** could be sold for 15 bahtkg, compared to around 2 baht/kg for the fresh product. This price would not provide an incentive for fish culturists in the area to farm ***Polycavernosa.*** It seems likely that a selling price of more than 30 baht/kg for dry ***Pofycavernosa*** would be required to stimulate interest in ***Poly-*** cavernosa farming.

There have been initial experiments in culturing ***Gracilaria*** and ***Polycavernosa.*** One of these experiments used polyculture in fin-fish net cages. These seaweeds can grow on the polyethylene net and on the bottom of the cages. Production levels ranged between 50 and 100 kg/100m2 /year (Tachanaravong, 1989). Fish culturists would harvest by cutting, leaving around 5 to 10 cm of ***Gracilaria*** and ***Polycavernosa*** shoot. The shoots re-grow to harvesting size in 2-3 months. This method could be adopted by fish culturists in southwestern Thailand, which is the largest area for brackishwater fish cage culture in the country. There appears to be potential for producing large quantities of seaweed in this way.

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