# Bay of Bengal Programme

## Post-Harvest Fisheries

AGAR AND ALGINATE PRODUCTION FROM SEAWEED IN INDIA

BOBP/WP/69

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS

BAY OF BENGAL PROGRAMME BOBP/WP/69
Post-Harvest Fisheries

# Agar and Alginate Production from Seaweed in India

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Although small by world standards, Indian production of agar and alginates — natural gums derived from certain species of seaweed — contributes to the national economy by supplying materials to the market that would otherwise need to be imported. It is also important in providing income opportunities to many fishing communities, particularly the women, who harvest the seaweed from coastal waters.

This paper surveys the Indian seaweed industry and its principal products, agar and sodium alginate. Technical and economic aspects of seaweed collection and processing, and the markets for the products, are examined. Trials undertaken by BOBP to cultivate *Gracilaria* seaweed and to employ it as a source of raw material for village-scale agar production are briefly described.

The work presented is based on information collected during visits made in 1988 and 1989 to harvesting centres along the south-eastern coastline of Tamil Nadu, Kerala, Andhra Pradesh and Gujarat. The seaweed industries are not well documented and the report relies heavily on first-hand information gained through visits and discussions with the seaweed collectors, agents and processors.

The authors would like to thank all these people for their kind assistance during the implementation of this study as well as the Post-Harvest Fisheries Adviser and local consultants involved in the collection of data and the organization of this visit.

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The Bay of Bengal Programme (BOBP) is a multi-agency regional fisheries programme which covers seven countries around the Bay of Bengal — Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka and Thailand. The Programme plays a catalytic and consultative role: it develops, demonstrates and promotes new techniques, technologies or ideas to help improve the conditions of small-scale fisherfolk communities in member-countries.



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## 1. *INTRODUCTION*

In addition to edible and other direct uses, marine algae provide a rich and diverse source of raw material for the manufacture of seaweed gums, a group of natural compounds characterized by their thickening and gelling properties. Such compounds find wide application in the food, pharmaceutical and industrial sectors. The three most important of these compounds, in terms of volume and value, are sodium alginate (and its derivatives), carrageenan and agar. An estimate in 1980[1] put total world production of these three gums at around 40,000 t, valued at US$300 million. This was obtained from 150,000 t (dry weight) of seaweed. A more recent estimate has put annual world production at:

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

Carrageenan is not discussed further in this paper since neither the compound, nor the seaweed from which it is derived, is produced in India. The production of agar and alginates in India, including the technical and economic aspects of the collection of the seaweeds and the processing and marketing of products from them, are the subject of this report.

## 2. *PRODUCTION AND TRADE iN SEA WEED AND SEA WEED GUMS*

### *2.1 World*

World production and trade in seaweed is very large, but the greater part of this is intended for edible use, mainly in Japan, China and South Korea.

Agar is obtained from certain red seaweeds, the most important of which are from the genera *Gracilaria, Gelidium* and *Gelidiella.* Japan is the main consumer and producer of agar; most of the 10,000 t of agar—yielding seaweed (agarophytes) that is estimated to enter international trade each year[2] is imported by Japan. Of this world-wide harvest, 63% comes from Chile, with the Philippines (15%), South Africa (10%) and Brazil (6%) also significant suppliers. In 1984, Japanese production of agar amounted to almost 2,500 t (37% of the total world production of around 6,700 t); other important producers were Spain (13%), Chile (12%), South Korea (9%) and Morocco (8%).

Alginates are obtained from a number of different brown seaweeds and since many of these are cold- or temperate-water types, the main alginate producers (USA, UK, Norway and France) are able to use indigenous sources of weed, such as *Laminaria, Macrocystis* and *Ascophyllum.* An exception is Japan, which relies on imports of weed from Norway. Over a third (8,000-10,000 t) of the world's alginate production is estimated to be used in developing countries, mainly in Asia, and almost all of it is imported by them.

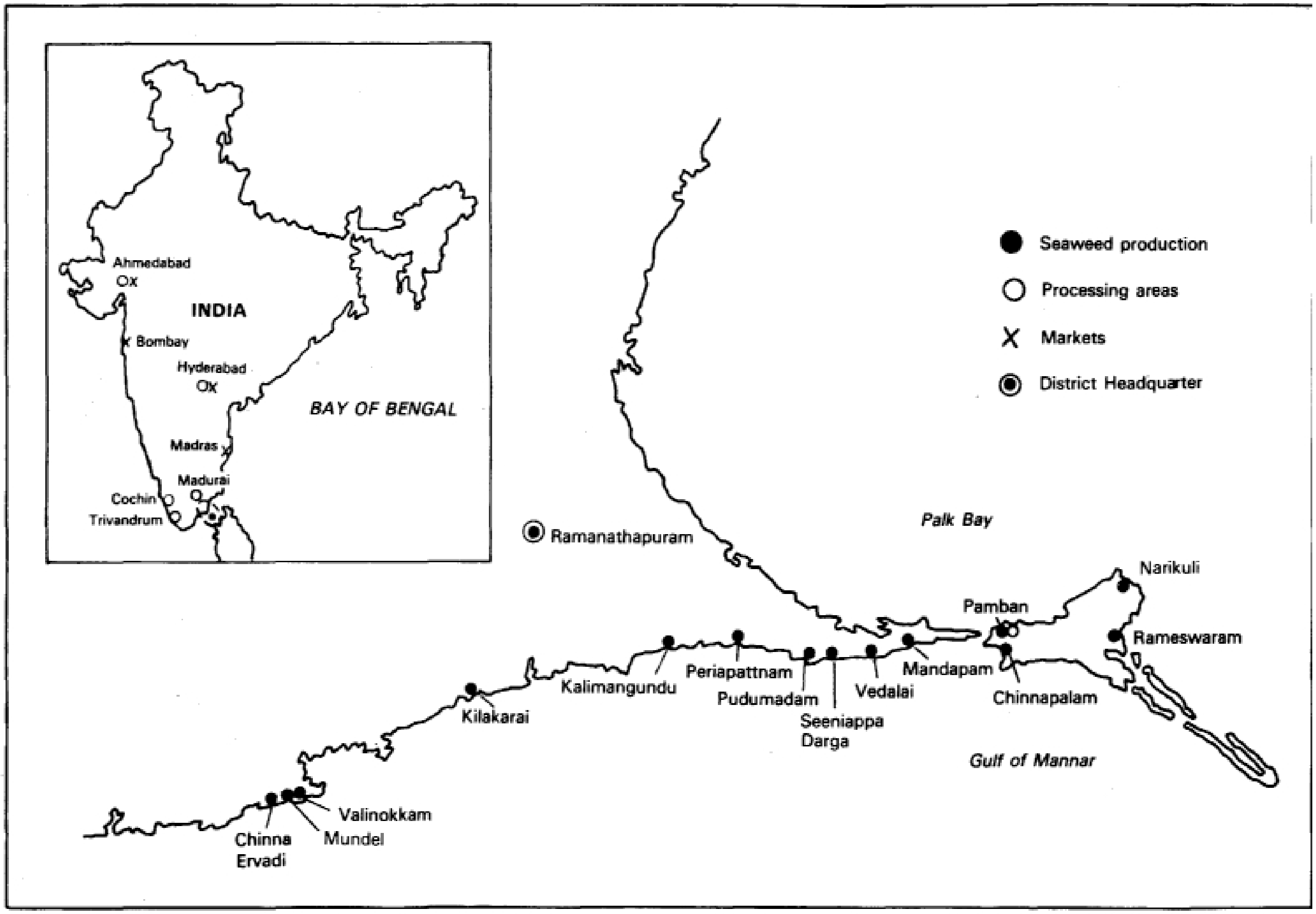
### *2.2 India*

Figures for Indian agar production were not available to the authors cited earlier[1,2] but data gained from the present study through discussions with 16 producers (judged to be something approaching the total number in business in India) indicate that current domestic production is around 75 t/yr (estimated). This would represent 1% of the total world production in 1984. If the expansion of output planned by two of these companies and the commissioning of other new factories now under construction is realized, total production is set to almost double to around 140 t/year within the next few years.

It was not possible to obtain detailed information on alginate production during the present study, but it seems probable that it was of the order of around 300 t in 1989 (though it was as high as 800 t in 1979), again representing about 1% of world production.

1. UNCTAD/GATT, 1981: *Pilot survey of the world seaweed industry and trade.* (International Trade Centre).
2. FAQ, 1988: *Seaweed.* (Globefish Highlights 3, *pp.* 29-33)

Fig. 1  **Production and marketing areas for seaweed. agar and alginates**



By international standards, Indian agar and alginates do not compare favourably in terms of gel strength and viscosity. Although the Indian products are competitive on a cost basis and are not subject to export restrictions, the world market offers little scope for most categories of Indian-produced agar and alginates. But occasional shipments of agar have been made by the larger producers to the USA, UK and Japan; in the course of the fieldwork for this study, one company stated that it had just exported *1.5 t* of food grade agar to Japan.

From 1975 to 1984 there was a ban on the export of seaweed from India. Since then, minor quantities of dried seaweed have been exported in a sporadic and, largely, experimental fashion; 6 *t* of seaweed were exported in 1985. The present export policy of the Government of India (1988-91) permits export 'on merit' of all types of seaweed against the procurement of a licence. Such a licence is usually granted by the Joint Controller of Import and Export after due consideration of each application.

The Government of India allows the import of agar and sodium alginate (dental grade) under Open General Licence[3] to actual industrial users and export trading houses. Other grades of sodium alginate are termed 'limited permissible items' by the Governmeru of India import policy, which requires that additional Jicences permitting import be obtained by actual users and export trading houses. Import of all grades of agar and sodium alginate is, therefore, possible and there is no control or ceiling on the aggregate amount of imports entering the domestic market as each licence is considered on an individual basis. No reliable estimate of the quantity of imported agar exists – current annual imports are thought to be in the range of 6 to 125 *t*. (Official trade statistics have never been greater than 6 tonnes in 1980-1986, but other sources have quoted up to 125 *t*.)[4] No reliable estimate exists for the quantity of alginates imported.

The present import policy of the Government of India (1988-91) restricts the import of seaweed and other algae, fresh or dried, to licence holders who have to apply and fulfil conditions laid down under the Export Control *Act* of 1955 which is administered by the Central Government and the Chief Controller of Imports and Exports or an authorized official.

# 3. *SEAWEED COLLECTION IN INDIA*

## *3.1 Location*

Although processing takes place in several states, commercial harvesting of seaweed, all from natural sources, is limited to the southern portion of the Tamil Nadu coastline, from Kanyakumari (Cape Comorin) in the south, northwards to the peninsula that forms the Gulf of Mannar, a total distance of almost 300 km. Collection is particularly concentrated in that part of the 'seaweed belt' that runs along the coast of Ramanathapuram District and includes the villages of Mundel, Valinokkam, Chinna Ervadi, Kilakarãi, Kalimangundu, Periapattnam, Pudumadam, Seeniappa Darga, Vedalai, Pamban, Chinnapalam and Rameswaram. Here, the seaweed is collected both from the walers off the mainland coast and those surrounding the chain of off-shore islands (Fig. 1).

## *3.2 Species of seaweed utilized*

Agarophytes used in commercial processing are species of the genera *Gracilaria, Gelidium* and *Gelidiella.* Where the gel strength of the agar is not critical, as in food use, *Gracilaria* alone may be utilized. In other cases, and whenever bacteriological/IP grade agar is produced, *Gelidium* or *Gelidiella,* separately or mixed with *Gracilaria,* is utilized. (The terms *Gelidium* and *Gelidiella* are often used interchangeably within the industry although they are recognized as being separate genera.)

There is undoubtedly some variation in the distribution of the different seaweed varieties along the coast, but it is not possible to define this with any precision. *Gracilaria edulis* (syn. G. *lichenoides),* found along the whole of the Tamil Nadu coastline, is the most abundant and commonly used *Gracilaria* species; G. *verrucosa* (syn. G. *confervoides)* occurs in estuarine/brackish water areas, such as are found near Tuticorin, and is utilized by one or two producers. Other *Gracilaria* species found in Indian waters include G. *crassa, G. corticata* and G. *multipartita* (syn. G. *folizfera),* and any one, or more, of these may be present in indeterminate amounts in what is sold as *'Gracikiria'* or *G. edulis.*

3 This was the policy prevailing in mid-1990 when this report was written.

4 Coppen J.J W., 1989: *International trade in agar for countries in the Bay of Bengal Project Region.* From Seminar on *Gracilaria* production and utilization in the Bay of Bengal'. (Oct. 23-27, 1989, Songkhla, Thailand.)

The particular species of *Gelidium* used do not appear to be identified within the industry, either by the seaweed agent or the processor. *Gelidiella* is invariably stated to be *Gelidiella acerosa* and tends to be found in slightly more rocky areas than, for example, *Gracilaria.*

Indian alginate production is derived from *Sargassum* and *Turbinaria* seaweed. Industry sources do not usually name the particular species used, but the species are believed to be predominantly *Sargassum wightii* and *Turbinaria conoides,* with some *S. myriocystum* and *T. ornata.*

### *3.3 Seasonality of collection*

Most seaweeds are generally available from agents throughout the year, although there are a few months when stocks are especially plentiful and others when they are less so. Processors and agents agree that there is a peak in *Gracilaria* collection during January-April. *Gelidium/Gelidiella* are usually described as being non-seasonal, although occasionally the reverse is acknowledged. It is probable that growth of the seaweed varies somewhat according to local conditions and this, together with other factors, such as prevailing weather conditions and the extent to which seaweed collection is a primary or secondary activity within the fishing community, gives rise to the 'seasonality' observed. There may be no collection for a short period around June, when the seas are rough, or in November, during the heavy rains. July-August, when high winds have torn the weeds free from their growth points, is said to be a peak period for *Sargassum* collection.

### **3.4** *Methods employed*

For the people of the coastal villages, fishing is their main income and seaweed collection is an important second source of income; for the women who are otherwise not actively employed in fishing it may be their only income. Priorities are determined by weather conditions and the time of year, social and religious attitudes within the community and, of course, judgement as to which of the two activities is more remunerative at a particular time.

Harvesting of agarophytes is done through in-shore collection during low tide, on the shores of neighbouring islands and by diving from boats when the seaweed is further out. Hand picking of seaweed is normally carried out by women and children equipped with divers' masks and a net bag. Metal scrapers have been in use in some areas in recent years and have made it possible to harvest larger quantities of seaweed with less effort, but the landed seaweed tends to contain a higher proportion of rock and coral fragments which are scraped up along with the weed. In addition, removal of the rootstock prevents regeneration, with the consequent threat to future supplies.

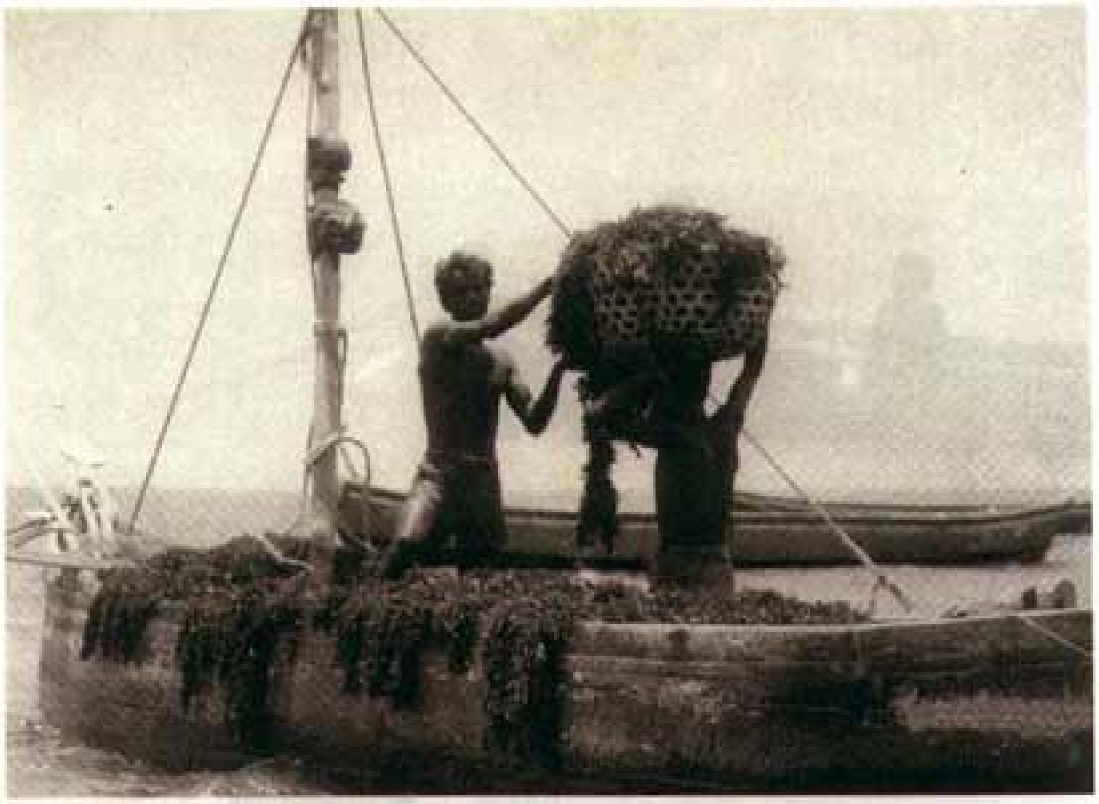
The collection of alginophytes is generally done by men since it involves picking larger quantities of weed. Harvesting *Sargassum* and *Turbinaria* is rather easier than red seaweeds and landings are less likely to contain those unwanted seaweeds which are so difficult to avoid when collecting agarophytes.

### *3.5 The role of the seaweed agent*

A key figure in the seaweed industry is the agent, who acts as middleman between the collector and processor. His role within the village community, however, is more than just a buyer and seller of seaweed. He is usually business-minded and is able to control the quality, quantity and price of seaweed released to the processor, as well as the price offered to the collector. He regularly gives cash loans to the seaweed collectors to cover daily living expenses. Additionally, some agents own stores where the collectors can get credit for goods against the seaweed they gather. The agent is thus able to ensure regular seaweed supplies. However, the collectors take loans from as many sources as possible, causing the agent to complain that though he supports the collector's family he does not receive a greater quantity of seaweed except that which has been adulterated.

During harvesting, seaweed collectors are managed by the main agents with the help of an 'organiser' who supervises the work for a commission. The organiser takes the collectors to the seaweed areas in the agent's, or, when the agent does not possess any, in, hired boats. The agent who owns a boat is entitled to one share of the harvested seaweed, while the rest is divided among the collectors.

*Diving for seaweed off the islands near Mandapam, South India.*



*Seaweed harvested from near the islands off the Mandapani coast being landed at a mainland village.*

*Seaweed spread out to dry on the beach at a village in the Ramanathapuram District, Tamil Nadu, South India.*

Seaweed collectors who can raise the required capital may seek to become agents themselves. Land for storage and drying is generally taken on lease and one or two thatched sheds are constructed for storage of the seaweed. A few agents have even registered for tax purposes, an indication of the volume of business they transact. Most of the small sub-agents supply these agents.

## *3.6 Financial returns*

When the seaweed is landed, the agent inspects it and pays the collectors. They receive a price which the agent says is the ruling market rate. No negotiations are entertained by the agent. Payment is made on the basis of quantity, though this is estimated in a subjective, rather crude fashion: per basket of wet weed for agarophytes and per boat-load for alginophytes, the latter being more abundant, easier to harvest and consumed in greater quantities than the former. Prices quoted by one agent are given below (Table 1):

**Table 1 : Prices for seaweed paid by agent to collector**

| *Seaweed* | *Price paid (Rs. /tonne, wet wt.)* |
|---|---|
| *Gelidiella*[1] | 1800 |
| *Gracilaria*[1] | 600 |
| *Sargassum*[2] | 150 |

***Notes:*** *(1)* 50 baskets = 1 tonne
*(2)* 1 boat-load = 1 tonne

These prices should be regarded as being illustrative rather than necessarily representative, since the assessment of how much one basket or boat-load of seaweed weighs does not appear to be consistent among the different villages. However, prices seem to be remarkably stable, remaining unchanged for several years, according to several agents.

Seaweed collectors confirm that prices have varied little in the past few years, although they remain fairly ignorant about the amount of seaweed sold and the payment owed them. The cause for the uncertainty over money due to them is because of the numerous loans in cash and commodity which are discounted against payments. The agents, on the other hand, claim that prices they receive from processors are falling and this prevents beach prices from rising. Furthermore, they believe that the collectors deliberately adulterate the wet seaweed with other weeds, coral and sand, and this justifies their offer of low prices.

On completion of the transaction, the agent lays the seaweed out on the beach to dry. After one or two days it is transferred to thatched sheds for storage, either in heaps or sacks. Labour is hired by the agent on a daily wage basis for sorting, cleaning (if this is done), drying and packing the seaweed. The agent may employ as many people as are necessary, depending on the volume of seaweed coming in for sorting and drying. Some agents claim to receive as much as 5 t per day during peak season. Sometimes during periods of high demand, an agent may buy partly dried seaweed from a smaller sub-agent for further drying and final sale. Seaweed sales, in any one year, typically comprise of a large proportion of the low value *Sargassum* and *Turbinaria* and a smaller proportion of the higher value agarophytes.

The processor inspects the seaweed and negotiates a price depending on his perception of the purity and dryness of the weed. Again, this assessment is likely to be highly subjective. Most agar producers questioned put the purity of their raw materials at around 50-60% at best; several users of *Gelidiella* considered it, typically, to be 30% pure. However, there is a general resignation on the part of the processor about this state of affairs and the constantly repeated view is that, if they did not buy what was offered them, someone else would. There is little to gain by attempting to enforce quality standards, they state.

For the smallest agar producers, it is the proprietor himself who inspects the seaweed and negotiates the transaction. Larger factories send employees to supervise the packing and dispatch of the seaweed, although this is often more a formality than a means of ensuring better quality. Some firms have a purchase office in the area which may even provide ‘in-house’ labour for preliminary sorting and cleaning of weed. All processors, regardless of size, bear the transport and packing expenses incurred by the agent.

‘Turn-around’ time is often as little as 5-10 days from the time of collection of the seaweed to its sale to the processor, but agents claim that properly dried material can be stored safely for many months. The frequency with which purchases are made varies considerably and depends more on the distance of the processor from his raw material source than on the scale of operation: some processors buy weed every month, some two or three times a year and others just once a year. Some may buy the bulk of their seaweed when it is in plentiful supply and then ‘top up’ with smaller amounts as required.

Prices quoted by processors for the different types of seaweed were fairly consistent and are shown below (Table 2):

**Table 2 : Prices for seaweed paid by processor to agent.**

| *Seaweed* | *Price paid (Rs./tonne, wet wt.)* |
|---|---|
| *Gelidium/Gelidiella* | 5,000— 8,000 |
| *Gracilaria'* | *2,500*— 3,500 |
| *Sargassum/Turbinaria* | 750— 1,000 |

*Notes: (1)* One processor quoted Rs. 3,500 for *G. **edulis*** and Rs. 1,200 for ***C.** verrucosa*

## ***3.7*** *Raw material supplies*

Annual estimates of seaweed harvested between 1978 and 1985 in the principal harvesting centres along the coast of south-east Tamil Nadu are given below (Table 3, Figure 2):

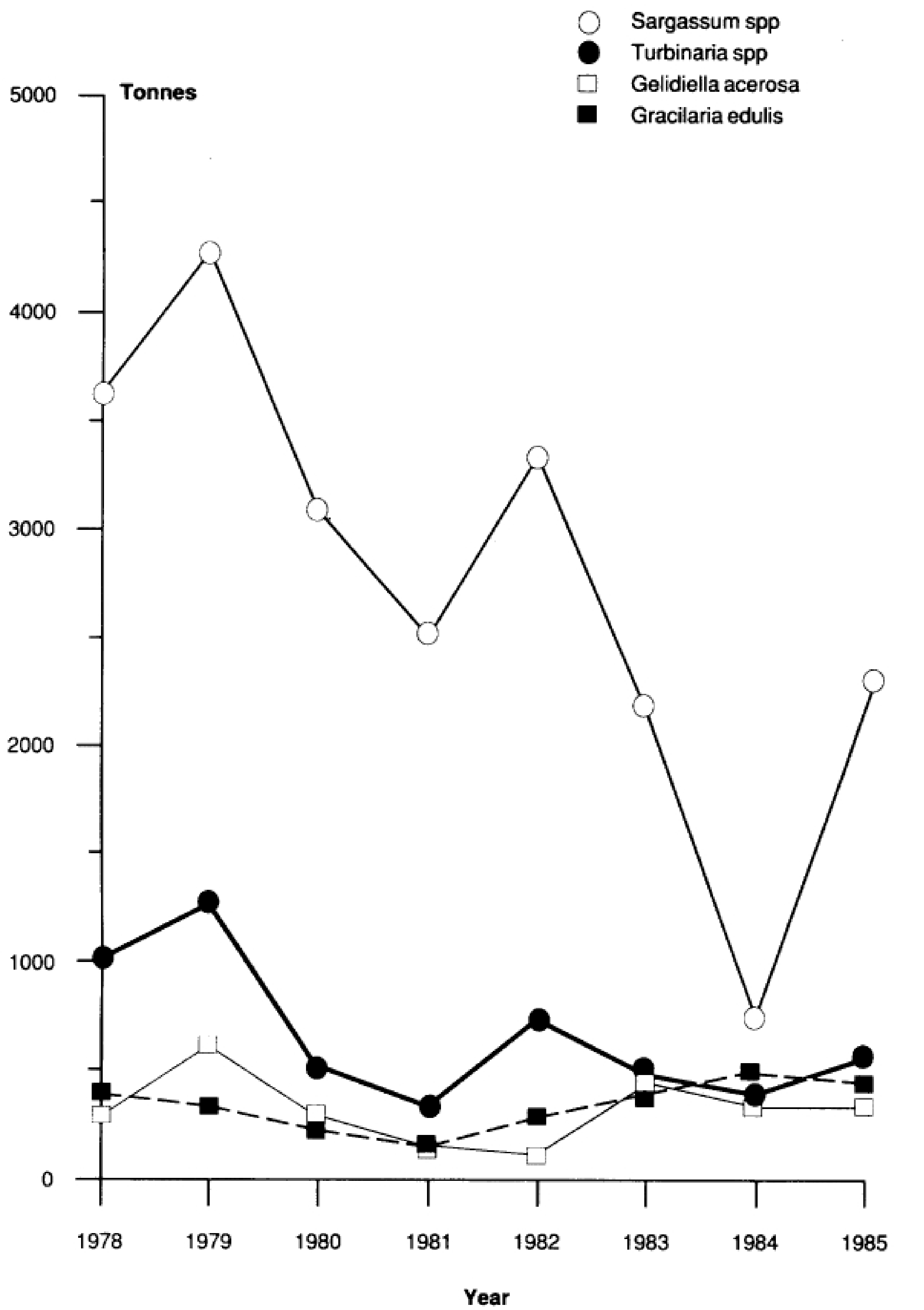
**Table 3 : Total seaweed landings** (dry weight)

| | *Agarophytes* | | *Alginophytes* | | |
|---|---|---|---|---|---|
| *Year* | *Sargassum spp.* | *Turbinaria spp.* | *Gelidlella acerosa* | *Gracilaria edulis* | *Gracilaria crassa* |
| 1978 | 3636 | 1021 | 288 | 395 | |
| 1979 | 4256 | 1281 | 541 | 342 | |
| 1980 | 3090 | 438 | 247 | 213 | |
| 1981 | 2522 | 222 | 131 | 117 | |
| 1982 | 3176 | 704 | 102 | 225 | |
| 1983 | 2070 | 375 | 293 | 291 | 85 |
| 1984 | 780 | 235 | 210 | 320 | 96 |
| 1985 | 2096 | 385 | 189 | 269 | 45 |

***Source:*** Seaweed Research and Utilisation in India5

5 1987 : *Seaweed research and utilisation in India.* (Bulletin 41, CMFRI, Cochin, India).

**Figure 2. Total** Seaweed **Landings**



Landings of *Gelidiella, Sargassum* and *Turbinaria* were at a peak in 1979; in that year, *Gracilaria* landings were slightly less than at the peak (in 1978). Since then, *Gelidiella, Gracilaria* and *Turbinaria* all reached a low in 1981/82, after which they recovered somewhat. *Sargassum* has shown a declining trend since 1979.

The threat to the natural resource posed by the use of metal scrapers during harvesting of agarophytes has already been mentioned. Although more recent data is not available,a number of collectors have expressed the opinion that there has been an increasing scarcity of red seaweeds over the years and that they now have to work harder to collect the same quantities as formerly[6]. With the expansion of agar production capacity that is now taking place in India, this situation is likely to be aggravated further.

Resource management of seaweed appears to have received little attention in India. Government concern has been restricted to controlling trade in seaweed through licencing, with little effort being made to prohibit harmful harvesting practices. The need to conserve the natural resource is recognized by present efforts to develop seaweed farming as an alternative source of good quality, easily accessible raw material for the agar industry (See 6.1).

## *4. PRODUCTION OF A GAR IN INDIA*

### *4.1 Uses and types of agar produced*

The most important attribute of agar is its great gelling power and the wide range of conditions under which it retains this property. Although, as has already been stated, Indian agar has a gel strength lower than that from other sources, it neverthless meets a significant part of the domestic food and pharmaceutical industries' demand.

Agar is used in the preparation of jellies, dairy products such as yoghurts, confectionery of the jelly/marshmallow type, bakery products, including pie fillings and icings, and canned meats. In India, it is widely used in such vegetarian foods and dishes as faluda and blancmange. The Muslim community also traditionally consumes large quantities during the Ramadan season.

Although small amounts of agar may find use as a laxative or excipient, the major application of 'pharmaceutical' grade agar is as a culture medium for the growth of micro-organisms such as bacteria and fungi. In this context, pharmaceutical, or **'IF',** grade agar, sometimes referred to as 'bacteriological' or 'microbiological' grade, is also used by university and other research establishments and laboratories. (The term 'IF grade', used to denote the fact that the agar meets Indian Pharmacopoeia standards, is used hereafter in this report since it is used widely within the Indian agar industry.) Its related use as a medium for plant tissue culture is more recent, but one which is gaining an increasing market. Among the other minor uses of agar is the preparation of casting moulds, especially those used in dentistry.

The chemical fraction largely responsible for the gelling properties of agar is agarose, and it finds specialized use in laboratories carrying out biochemical separations. However, to date, there has been no Indian production of agarose, the small domestic requirement being met by imports.

Agar is produced in several different physical forms, the most common being the mat, or strip, form, which is the simplest to produce. Where there is a particular requirement on the part of the end-user for high gel strength food-grade agar, it is produced in the form of shreds or 'individuals', the latter essentially being strands of larger dimensions than the shreds; both are produced to order, using *Gelidium,* rather than *Gracilaria,* as the raw material. Powdered agar, both IF and food grade, is produced from the mat form by milling.

### *4.2 Quality criteria*

Indian producers consider the colour and gel strength of agar as the most important criteria of its quality. For food use, paleness of colour ('whiteness') is deemed all-important and, so, bleaching

6 Usitalo J., 1986 *Commercialseaweed collection and the agar/alginate industries in Tamil Nadu, India.—Seaweed cultivation as a solution to over-exploitation of a natural resource.* (Swedish National Board of Fisheries, Gothenburg).

of the agar gel during the final stages of processing is universal. Gel strength is less important and, therefore, *Gracikiria,* which is also easier to bleach than *Gelidium* or *Gelidiella,* is mainly used for production of food grade agar. Indian Standard specifications exist for food grade agar (IS *5707,* 1970)[7]. but there is no attempt by the smaller producers to ensure that their product complies with them. In any case, the specifications do not lay down limits or ranges for gel strength or, perhaps more importantly, microbiological load.

Gel strength (and gelling temperature) is more important for IF grade agar and, for this reason, such agar is always produced from *Gelidium/Gelidiella* or a mixture of either with *Gracilaria.* Most processors do not routinely make gel strength measurements, but all of them, large and small alike, are aware of the differences in product quality consequent on the use of different raw materials.

Values of gel strength for agar derived from Indian *Gracilaria* are around 120-150 g/cm$^2$: for *Gelidiu,n* or *Gelidiella,* the figures are in the range 300-350 g/cm$^2$. These compare with values of up to 1000 g/cm$^2$ or more for internationally traded agar. (The reasons for these differences are largely due to the intrinsic limitations of Indian raw materials. Gel strength depends upon the species of seaweed and the particular conditions under which it grows. For Indian species, agar properties are not outstanding.) Neither IP nor Indian Standard specifications lay down limits for minimum gel strength of IP/ microbiological grade agar[8]

## 4.3 Location of the industry

As the nearest commercial and industrial centre to the seaweed belt, Madurai is the natural focus for agar production in India. Other producers in Tamil Nadu are located, for the most part, in towns nearer the southern coast. However, there are a significant number of factories some distance from their raw material source: in Kerala, northern Tamil Nadu and Andhra Pradesh (see Appendix 2 and Figure 1). Production in Kerala may have been attracted by the prospect of cheap hydro-electric power and soft water, although in times of water shortages there is a high risk of imposed electricity quotas and power cuts, with consequent loss of production.

## 4.4 Scales of operation

The Indian agar industry is composed of small, often family-run, enterprises employing as few as three or four people and producing 2—4 kg of agar per day (0.5-1 t/yr), medium size units producing 10—40 kg of agar per day (2—10 t/yr), and larger units. In the case of the latter, some of the new producers hope to reach production targets of up to 100 kg per day (25 t/yr) in the near future.

## 4.5 Processing methods employed

### GENERAL PRINCIPLES

The steps required to obtain agar from seaweed are indicated in Figure 3 and summarized below:

1. Cleaning of seaweed
2. Chemical pre-treatment
3. Extraction of seaweed
4. Filtration and gelation of extract
5. Bleaching and dewatering of gel

In speaking about agarophytes in general terms, it is important to appreciate that what may be optimum conditions for recovery of agar from one source are often not the case from another. This is particularly true for chemical pre-treatment and arises because agar is not a homogeneous material. Being a mixture of polysaccharides, the proportions of which vary from source to source, the conditions for their extraction also differ. Thus, *Gracilaria* requires slightly less severe conditions of processing than *Gelidium* or *Gelidiella,* while *Gracilaria verrucosa,* used by a few producers, needs to be handled differently from *Gracilaria edulis* in certain respects.

7 **1985 15** : 5707—1970. *Indian standard specification for ogar—food grade.* (Pharmacopoeia of India, 3rd edition.)

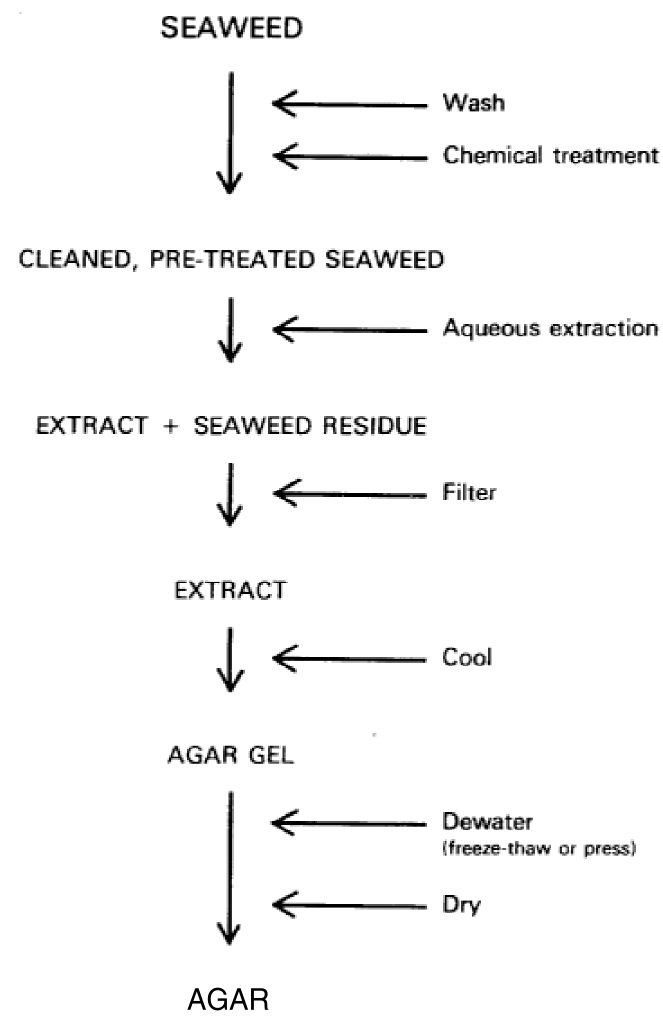
8 1985 : IS : 6850— 1973. *Indian standard specification for agar—microbiological grade.* (Pharmacopoeia of India, 3rd edition, pp A154—A155.)

Furthermore, the quality of the final product is highly dependent on the quality of the raw material, which, in turn, is dependent on a number of factors:

- intrinsic *(e.g.* species of seaweed),
- environmental *(e.g.* temperature and salinity of water during growth of seaweed),
- harvesting *(e.g.* degree of mixing with other weeds), and
- post-harvest *(e.g.* conditions of storage of seaweed prior to processing).

In India, the same basic method of processing is followed, almost without exception, by all producers: acid pre-treatment of the cleaned seaweed followed by hot water extraction, primary dewatering and purification of the agar gel by means of a freeze-thaw cycle, bleaching and, then, sun-drying.

**Figure 3: General processing scheme for production of agar**




CLEANING OF SEAWEED

Agar is insoluble in cold water and the seaweed may safely be washed with water to remove soluble impurities, such as salt, as well as to assist in the separation of foreign matter, such as other weeds, sand, stone and pieces of coral. If it has not already been done, the processor, on receipt of the seaweed, would first lay the weed out in the sun to allow some natural bleaching to take place. It is then washed as many as four or five times, either briefly or given a more thorough soaking overnight, and dried one or more times between washes. Washing is carried out in open cement 'tanks', with or without some form of mechanical agitation, and is accompanied by hand-sorting to remove epiphytes.

## CHEMICAL PRE-TREATMENT

Chemical treatment of agarophytes prior to extraction often produces a better agar in terms of quality or yield than one produced without such treatment. Alkali pre-treatment has been found to be the most useful, particularly for *Gracilaria spp.,* a product of higher gel strength being obtained. Conditions must be optimized to avoid dissolution and degradation of the agar and so minimize accompanying reductions in yield. The chemical rationale of alkali treatment is that increased gel strength results from production of 3, 6-anhydrogalactose units induced by alkaline hydrolysis of galactose-6-sulphate groups within the agar molecule. Having said this, it appears that Indian *Gracilaria* does not respond well to alkali treatment.

Acid pre-treatment, however, has also been recommended or described in the literature and this type of treatment is almost universally employed in India. The purpose of the acid is to soften the weed and prepare it for extraction. Treatment is accomplished by immersing the weed for 10-15 minutes — and never more than 30 minutes — in cement tanks containing the dilute acid, usually hydrochloric. With longer immersion there is the risk of extracting some of the agar; the remaining agar is also said not to gel well. Where *Gracilaria* and *Gelidium/Gelidiella* are used as a mixed raw material, the latter is given a longer acid treatment than the former.

The seaweed is then washed two or three times to free it of acid and transferred to the extraction vessel.

## EXTRACTION

Agar is extracted from seaweed using hot water. Although adjustment of the pH is sometimes beneficial, and the use of certain additives, such as phosphates, is claimed to improve yields or colour, the Indian practice is simply to boil the seaweed in water at normal pressure without the addition of chemicals. In this way, the need for sophisticated equipment is eliminated and production costs are kept to a minimum.

The seaweed is usually added to boiling water in the extraction vessel, which is heated either by live steam introduced through pipes at the bottom of the vessel or, in the case of some of the smaller producers, by direct heat from a wood fire. The vessel may be of aluminium, stainless steel or wood, and is of a size to accomodate anything from 20-30 kg of seaweed (+ water) up to 300 kg and more for the largest producers. The ratio of water:weed varies from around 5:1 to 10:1 and reflects, to some degree, the raw material used.

With only one or two exceptions, the seaweed extracted in India is in whole form, since the possible benefits of greater extraction efficiency brought about by reduction of the weed to a finely divided state are more than offset by the difficulties in filtration and separation of the liquor from the mucilaginous residue. Even where this is not the case, the weed remains unground; rather, it is pulverized by wooden beaters during the initial washing stages and reduced to pieces a few centimetres in length.

After addition of the seaweed, boiling is continued for between 1½ and 3 hours, the exact time being a matter of judgement on the part of the operator in charge of the extraction. He usually removes samples of extract and weed at intervals and tests them with his fingers; good gel formation and the right 'feel' when the weed is pressed between the fingers indicate that extraction is complete. The length of time needed is determined in large measure by the quality and nature of the raw material. *Gelidium* requires somewhat longer than *Gracilaria* for complete extraction. The state of maturity of the seaweed is also important.

Yields of agar are not high, usually in the range 5-10% (based on 30-50% purity of the raw weed), though they may be slightly higher for *Gelidium* than *Gracilaria.* Such yields are an indication, in part, of the generally poor quality of the seaweed available in India.

## FILTRATION AND GELATION OF THE EXTRACT

On completion of the extraction, the hot aqueous extract is allowed to drain through a metal screen at the bottom of the holding vessel. The screen retains the bulk of the seaweed residue and allows the liquid extraction to pass through several layers of filter cloth. These remove finer, particulate matter. The extracted seaweed, sometimes after recovery of a further, small amount of agar by a second extraction, is discarded as waste or given to local people for use as manure.

The clarified liquid is then led into shallow aluminium trays, either directly, *via* a hose or buckets, or after temporary storage in a heated tank. For the production of IP grade agar, where absolute clarity is required, the liquor is further passed through a filter press before discharge into the trays. On setting aside to cool, a firm gel of crude agar soon forms in the trays.

BLEACHING AND DEWATERING OF THE GEL

Removal of water from the gel, though technically simple, is the most demanding part of the process in terms of time and energy requirements. It is possible to remove much of the water by the application of a gradual and increasing pressure on the gel, but although this principle forms the basis of the cottage-scale process for crude agar production currently being developed by BOBP (see Section 7), it has not been widely adopted on an industrial scale.

Instead, in India, as in many other producing countries, the long established method of freezing and thawing the gel is universally used. The freeze-thaw cycle is critical not only to the successful dewatering of the gel but to the attainment of a good quality product as well, the cold thaw water, in which the agar is insoluble, removing low molecular weight polysaccharides, salts and pigments.

Within a few hours of forming a gel (no more than 24 hours, otherwise the gel deteriorates) the trays of agar are placed in a freezer, where they are stored for periods of at least 20—24 hours (and sometimes as long as 72 hours) at temperatures ranging from – 10 to – 20°C. The process of freezing should be slow rather than rapid so that a uniformly frozen gel matrix is obtained. To help achieve this, the agar gel is ‘combed’ with a metal ‘comb’ before placing it in the freezer; this also makes the subsequent washing and drying more efficient an4 gives the finished product its characteristic mat-like appearance. If the agar is to be produced as ‘individuals’ or shreds, the cutting or shredding of the gel is done prior to freezing

After removing the trays from the freezer, the agar is allowed to thaw, then washed with water and bleached, usually by immersion in a shallow cement tank containing hypochlorite solution. Treatment is brief, generally no more than 10— 15 minutes. The agar is washed again several times, before finally being laid put on mesh screens to dry in the sun. Occasionally, to obtain a product of low and more consistent moisture content, the sun-dried agar is further dried in a hot-air drier.

For IP grade agar, deionized water is used for washing and particular care is taken during handling and drying to avoid contamination by specks of dirt and other foreign matter. Agar discolours somewhat on storage, so, if there is no likelihood of immediate sale, bleaching is sometimes omitted at the usual stage and carried out on the dried product only when required . If the agar is to be sold in powdered form, the dried mats of agar are ground and sieved before bagging.

## *4.6 Marketing and prices*

Small and medium size producers of food grade agar, ‘China Grass’, sell their product to wholesalers or dealers in the large cities such as Madras and Bombay. The common mat form is packed in polythene bags and dispatched in sacks to the dealer. He then repackages the product, for retail sale, often under his own brand name. Poorer quality (off-white) mat agar is powdered and sold as ‘instant’ China Grass. Larger producers sell both to wholesalers and direct to end-users.

IF grade is generally sold direct to the end-user, the larger producers supplying several tonnes a year to a customer, generally responding to a tender inquiry.

Occasional consignments of agar are exported by the larger producers, and opportunities exist, for the sale of food grade agar to West Asia. However, on the whole, production is designed for domestic needs and is not of sufficient volume or quality to be attractive to foreign buyers.

Domestic demand for agar is good and none of the producers questioned in the present study complained of difficulties in selling their product. IF grade agar appears to be particularly attractive to new or prospective producers as well as to some of the existing producers of food grade agar, who indicated their intention, or desire, to start producing it.

Ranges of prices obtained by producers for different types of agar are given below (Table 4). Piices for food grade agar are dependent upon colour, gel strength ('individuals'/shreds from *Gelidium* fetch more than Gra'cilaria-based mat) and whether or not it is the Ramadan season. For good quality food grade agar produced in powdered form, prices are slightly higher than for the corresponding mat form.

**Table 4:** Prices for agar **obtained by producer**

| Grade | Type | Price (Rs.1Kg) |
|---|---|---|
| Food | Mat | 140—160 |
| | | 180—210 (Ramadan) |
| | | 200—300[1] |
| | 'Individuals'/shreds | 270—280 |
| **IP** | **Powder** | 300—400[2] |

*Notes:* (I) Prices quoted by a few producers fell into this higher range
(2) One producer quoted Rs. 600/kg

### *4.7 Constraints faced by the industry*

The dissatisfaction of producers with the quality of their raw material has already been mentioned. Most would be willing to pay a higher price for cultured seaweed that is free of epiphytes and other foreign matter.

Small family units face a chronic shortage of capital. Several producers expressed the view that they would like to buy more seaweed than they do, so as to increase production, but they lacked the financial resources. Similarly, when machinery breaks down, they are often unable to meet the cost of repairs at the time of failure.

All factories have to contend with shortages or irregular supplies of electricity and water, although the larger ones, with greater resources and a certain amount of flexibility, suffer less if they are able to anticipate problems and act accordingly. Nevertheless, companies do go bankrupt and, indeed, some of the smallest producers are former employees of such companies who have the necessary experience and enterprise to start up their own businesses. All factories produce below capacity. In addition to enforced stoppages, production is also affected by seasonal factors, particularly for small-scale and food-grade producers. Output is less (or none at all) during the monsoon period, when the agar cannot be dried outdoors, and increases as demand peaks during the Ramadan season.

## 5. *PRODUCTION OF ALGINATES IN INDIA*

### *5.1 Types of alginates produced and their uses*

The word 'alginates' is a generic term, meaning the various derivatives of alginic acid that either occur naturally in certain brown seaweeds (alginophytes), or are produced from the natural derivatives. Alginic acid is present in seaweed mainly as calcium salt, with lesser amounts as magnesium, sodium and potassium salts. The most important commercial derivative *of* alginic acid is the sodium salt, the form in which it is extracted from the seaweed. Other derivatives produced include the potassium, ammonium and calcium salts, propylene glycol alginate and alginic acid itself.

The ability of alginates to increase the viscosity of solutions to which they are added in low concentration enables their use in a wide range of applications in the industrial, food and pharmaceutical industries. Of primary importance in India is their use as a thickening agent in textile printing, where they are added to the paste containing the dye. Other industrial applications include the manufacture of rubber compounds and paper. In the food industry, alginates are used in the manufacture of a multitude of dairy, bakery, meat and other products, which take advantage of their thickening, gelling and stabilising properties.

## 5.2 Quality criteria

The viscosity of alginates can be modified and enhanced by the addition of a ***variety*** of different chemicals, but the viscosity of a one per cent solution of the alginate in ***water*** is a measure of its effectiveness as a thickening agent. As with agar, the properties which make alginates useful products are determined very much by the raw material source from which they are obtained. Cold-water seaweeds, such as *Laminaria, Macrocystis* and *Ascophyllu,n,* enable a wide range of grades of sodium alginate to be produced, which, in broad terms, may be categorized as low (20-50 mPa.s* or cps**), medium (400-500 mPa.s) and high (800-900 mPa.s) viscosity[9]. In India, sodium alginate produced from *Sargassum* and ***Turbinaria*** generally has a viscosity of 20-50 mPa.s (equivalent to around 1,200 mPa.s at 3% concentration). Many grades are produced.

## 5.3 Location of the industry

Madurai and surrounding areas, with proximity to raw material sources, and Ahmedabad, close to the main markets, are the main centres of alginate production in India (see Appendix 2 for list of alginate producers; also see figure 1). A few producers of agar also produce alginates — despite the two operations having quite different equipment and chemical needs.

## 5.4 Scales of operation

The installed capacity of alginate units ranges from 1-3 tonnes per month for the smaller units, up to 50 tonnes or more per month for the larger ones. Although actual production is inevitably less than these limits, it does not usually suffer from shortages or irregular supplies of raw materials, as ***Sargassum*** and ***Turbinaria*** are available in plenty throughout the year (the former being the more abundant).

## 5.5 Processing methods employed

GENERAL PRiNCIPLES

The steps involved in producing sodium alginate from seaweed are shown in Figure 4 and summarized below. Two routes are possible:

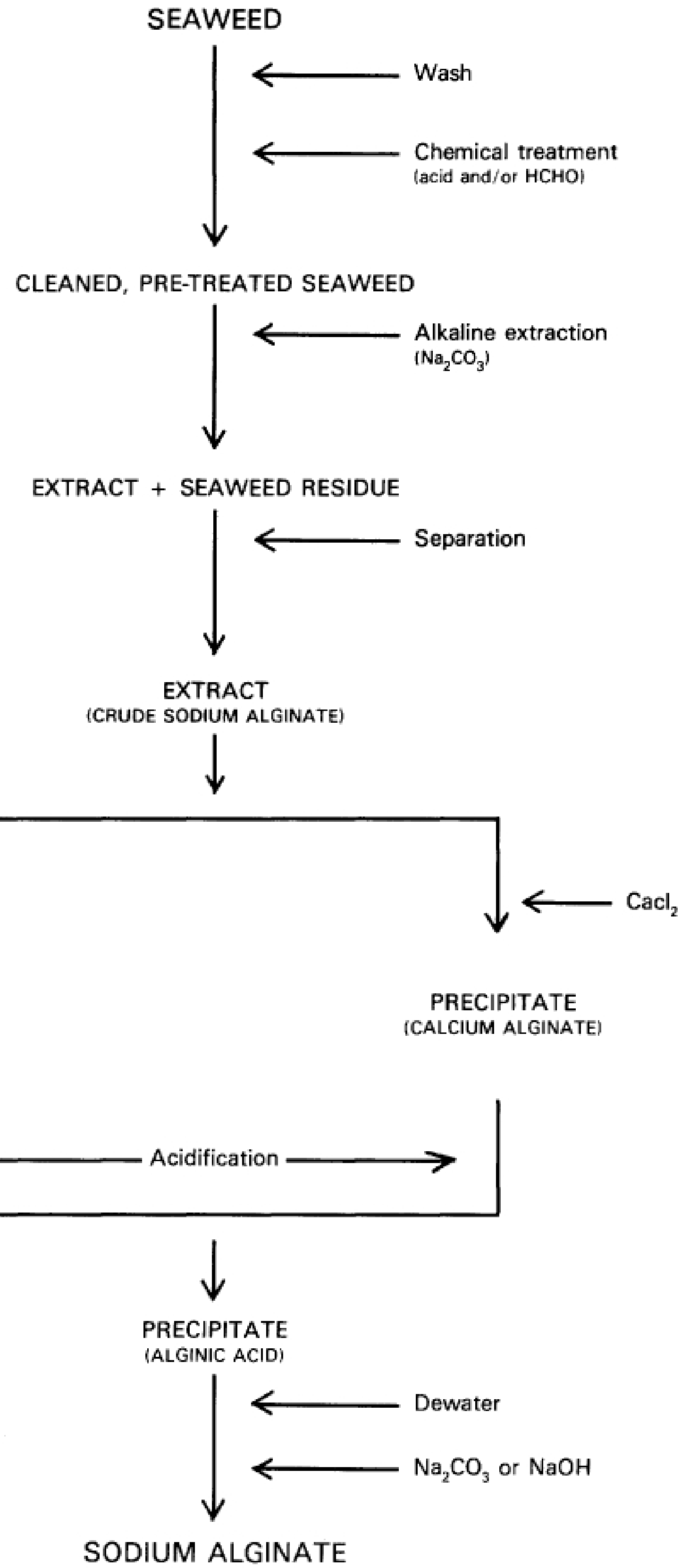
I. Cleaning of seaweed,
2. Chemical pre-treatment,
3. Extraction of seaweed,
4. Separation of extract,
then,
5. Acidification/precipitation of alginic acid, and
6. Production of sodium alginate
OR
5. Addition of calcium chloride/precipitation of calcium alginate,
6. Acidification/conversion to alginic acid, and
7. Production of sodium alginate

As has been stated elsewhere[10], the difficulties of alginate processing arise not from the chemistry involved but from the demanding nature of the physical separations required: slimy residues have to be separated from viscous solutions, and gelatinous precipitates need to be freed of large amounts of liquid contained firmly within their structure. It is for the latter reason that the route involving direct precipitation of alginic acid from the seaweed extract, although shorter than that in which the intermediate calcium alginate is formed, is not necessarily the preferred one — the alginic acid produced is gelatinous and difficult to handle. Calcium alginate, on the other hand, precipitates in a fibrous, easily filterable form which can then be converted into alginic acid, which is also fibrous and readily separated.

9 **mPa.s** = milliPascal. **second;** ss **cps** = **centpoise.**

10 **McHugh, D.J. 1987:** *Production, properties and uses of alginates.* **Production and utilisation of products from** commercial **seaweeds. (FAO Fisheries** Technical **Paper 288, pp 58—115. FAO, Rome.)**

**Figure 4: General processing scheme for production of sodium alginate**



### PREPARATION OF SEAWEED FOR EXTRACTION

Before extraction, it is best to treat the washed seaweed with acid. This not only converts the calcium alginate present in the seaweed into alginic acid, which is more easily extracted by alkali than the calcium salt, but leads eventually to a better quality product since acid-soluble phenolic compounds, whose presence would otherwise cause discoloration and loss of viscosity, have been removed. Any remaining phenolics may be removed by treatment of the seaweed with formaldehyde solution (formalin).

### EXTRACTION

Extraction from the seaweed is carried out using sodium carbonate solution, which removes the alginic acid as soluble sodium salt. The precise conditions depend on the physical state of the seaweed and the type of pre-treatment it underwent. Excessively long extraction times and high temperatures need to be avoided to minimize degradation of the alginate and loss of viscosity. In India, the seaweed is stirred in the alkaline solution in large wooden vats, either at ambient temperatures for up to 12 hours or at 60—70°Cfor 3—4 hours.

After digestion, the thick slurry is allowed to settle and is then diluted with water to make it more manageable in the subsequent separation stage. If the seaweed has been ground prior to extraction, then a filter press is needed to separate the liquor from the solid residue; otherwise, draining through a filter cloth is adequate.

### THE DIRECT PRECIPITATION OF ALGINIC ACID AND CONVERSION TO SODIUM ALGINATE

The extract is acidified, usually with hydrochloric acid — sometimes with sulphuric acid if hydrochloric acid is not available — and the resulting pale brown, fibrous precipitate of alginic acid separated by pressing or centrifuging (or a combination of both). The alginic acid is converted to the sodium salt by dissolving in sodium hydroxide solution. The solid product is obtained by precipitation with alcohol and centrifugation. Drying and milling to the required particle size is the final step.

Tight pH control is necessary to make the process as efficient as possible. Alcohol recovery too, should be efficient to minimize losses and keep production costs down. Small manufacturers use either this method or the indirect route *via* calcium alginate.

### PRODUCTION OF ALGINIC ACID *VIA* CALCIUM ALGINATE

Instead of immediate acidification, the dilute extract is added to 10% calcium chloride solution, thereby separating the fibrous calcium alginate. Alginic acid is then produced by acidification of the solid mat of calcium alginate with hydrochloric acid.

## *5.6 Marketing and prices*

The small-scale units sell textile grade alginate to dealers in Bombay and Ahmedabad. Units in Tamil Nadu supply textile mills in Erode. Larger units supply textile grade to dealers, government agencies and, through agents, textile mills. They also supply food grade alginates, mainly to the ice cream industry. Pharmaceutical and cosmetic grades are supplied too.

Although there may be considerable differences in the quality between alginates produced by the small and large producers, the smaller units are able to survive because the market is dominated by cost-conscious users willing to buy low quality alginates at low prices.

Textile grade sodium alginate sells for around Rs. 70—80/kg. Large units, on the other hand, although they could sell ata price of around Rs. 85/kg, are obliged to add 42% duty and 5% tax pushing up the price to the end-user to Rs. 125/kg. The corresponding price for food grade sodium alginate is Rs. 140/kg.

In addition to these pricing difficulties, large units have to compete with imports, which are only slightly higher priced (Rs. 135—165/kg), yet are much superior in quality (viscosity). The organized sector of the industry has, therefore, to survive in the face of a hostile market.

*One of the* Oracilaria *farms **BOBP helped** to establish in the Ramnad District.*

*Harvesting **the*** Gracilaria *grown in one of the farms **BOBP** set* up *in the **Ramanad** villages.*

## 5.7 *Constraints faced by the industry*

While raw materials are not such a problem, alginate producers, like their counterparts in the agar industry, suffer from periodic shortages of electricity and water which interrupt or stop production. In addition, the use of chemicals is greater and such items as industrial alcohol may be in short supply.

The large scale sector has, as its biggest constraint, a government policy which allows import of sodium alginate by all industrial users against the procurement of a licence. There are, in addition, the levies referred to above on the domestic sales of sodium alginate. These levies make the price of locally produced sodium alginate almost equal to that of the imported product. The result of such handicaps is the under-utilization of capacity.

# 6. *SEA WEED CULTURE AND THE PROSPECTS FOR ITS COMMERCIAL DEVELOPMENT IN INDIA*

## *6.1 Agarophytes*

An obvious solution to the problems of raw material supply and the dissatisfaction with quality expressed by agar producers is to cultivate seaweed. Cultivated seaweed would be of an assured quality. It would also remove the threat to the natural resource that is being posed at present by the methods of harvesting and the increasing demand for agar.

Research into the cultivation of agarophytes has been carried out by Indian government research organizations over a number of years. Both the Central Marine Fisheries Research Institute field station at Mandapam, in the Gulf of Mannar, and the Central Salt and Marine Chemicals Research Institute, Mandapam, have done extensive work on *Gracilaria edulis* and *Gelidiella acerosa* dating to the 1970's. However, although favourable economic indications have been claimed, no one in the industrial sector has, to date, taken up such cultivation as a commercial venture.

In late 1987, after a great deal of preparatory work and the active involvement of men and women from the fishing villages of Vedalai and Chinnapalam, culture trials of *Gracilaria edulis* were set up under BOI3P supervision[11] Although a small amount of seaweed was harvested, these pilot scale attempts to culture G. *edulis* failed, primarily due to grazing by juvenile siganids (rabbit fish).

Almost all agar producers, large and small, indicated during the present study that they would be willing to pay a higher price for cultured seaweed. But they would expect an increase in agar yield from around 10% to at least 13%. Few producers expressed an interest in cultivating seaweed themselves. Only two companies are known to be exploring the possibility of seaweed culture, both involving *Gracilaria verrucosa.* This species, although not widely used as a source of agar in India, has the advantage of growing in brackishwater and is, therefore, not likely to face the same devastating threat grazing posed G. *edulis.*

## 6.2 *Alginophytes*

A little experimental work on *Sargassum* cultivation has been carried out. But as there appears to be no shortages of raw material, there are no compelling reasons, and little interest within the industry, to pursue the development of alginophyte culture.

# 7. *VILLAGE SCALE PRODUCTION OF AGAR*

One of the attractions of the cultivation of seaweed by villagers is that they would then have a ready supply of good quality raw material with which to undertake their own small-scale processing, should a suitable method be available. In India, 'cottage-scale' methods for the extraction of agar have been developed and/described (by CMFRI, for example), but have not been put into practice.

11 Angell C.. 1987: ***Seaweed** farming: New **BOBP** project in Tamil Nadu.* (Bay of Bengal News 26, pp 14-15.)

Recent studies in Thailand[12] have demonstrated that it is possible, on the village scale, to produce crude agar which can then be upgraded and used in the normal way. The crude agar is treated with alkali in the same way that the seaweed itself is often treated prior to extraction.

Although it appears that alkali treatment of Indian-grown *Gracilaria edulis* may not have the same beneficial effects as has been found elsewhere, experiments aimed at producing crude agar along the lines of the methods used in Thailand were recently conducted by BOBP (using seaweed available from the cultuie trials). The method entailed extraction from seaweed with hot water, then dewatering the agar gel by application of pressure (without resort to freezing) and sun-drying.

Unfortunately, despite considerable effort, the process was not capable of producing usable agar economically and work on it has now ceased.

*Some of the agar that was made during the **BOBP** experiments carried out in Mandapa.n.*

12 Chandrkrachang S. and Chinadit U., 1988 : *Seaweed production and processing – a new approach.* (INFOFISH International 4, pp 22—25.)

## Appendix I

## LIST OF AGAR PRODUCERS IN INDIA

*Tamii Nadu*

| | |
|---|---|
| Anu Chemicals | P4/128 Railway Feeder Road<br>Pamban —623 521<br>Ramanathapuram Dist. |
| Balaji Ice Products<br>(formerly Susee Ice Freeze) | Main Street<br>Sundhar Nagar<br>Tirunagar<br>Madurai—625 006 |
| Bismi Agar Industries | 401/1 Gandhiji Road<br>Pudur<br>Ilayangudi<br>Ramanathapuram Dist. |
| Cellulose Products of India Ltd. | Bl/B2 Developed Plots<br>SIDCO Industrial Estate<br>Koothiarkundu PO<br>Madurai – 625 006 |
| Marine By-Products | D-26 Industrial Estate,<br>Kappalur<br>Madurai – 625 006 |
| Microchem | 130-A Balaji Street<br>Alagappan Nagar<br>Madurai —625 003 |
| Nellai Agar-Agar Industries | 16-A Puthu Amman Kovil Street<br>Sinthupoonthurai<br>Tirunelveli —627 001 |
| Omega Marine Chemicals | Austinpatti New Road<br>Austinpatti<br>Madurai – 625 005 |
| Ponselvam Phytochemicals | 81-A Beach Road<br>Tuticorin —628 001 |
| Snap Natural & Alginate Products Ltd | Plot No. I SIPCOT Industrial Complex<br>Ranipet – 632 403 |
| Southern Sea Products | 135/1 Poovanthi Road<br>Madapuram<br>Tirupuvanam PO |
| Sri Subbulakshmi Agar-Agar Industries | 179 Harvey Patti<br>Tirupurangundam PO<br>Madurai—625 005 |
| Srivas Chemicals<br>(formerly Sri & Srivas Industries) | Kondagai Road<br>Keeladi<br>Silaiman—625 201 |

*Kerala*

| | |
|---|---|
| Marine Chemicals<br>(formerly Cochin Agar & Chemicals) | XII/1129 -A Cochin College Road<br>Cochin—682 005 |

| | |
|---|---|
| Ocean Agar & Chemicals | Mini Industrial Estate<br>Nooranad Sanatorium PO<br>Alleppey Dist. |
| Quixcel Biochemicals<br>(formerly Neyyar Agar & Chemicals) | NMC VIII/109<br>Chemparathyvila<br>Vazhuthoor<br>Neyyattinkara —695 121<br>Trivandrum Dist. |
| Seena Agar-Agar | Kollothilpurayidom<br>Power House Road<br>Alleppey – 7 |
| Standard Agar-Agar<br>(formerly Hindustan Agar Co.) | Gujarathi Street<br>Alleppey – 12 |

*Andhra Pradesh*

| | |
|---|---|
| Algae Chemicals (Pvt) Ltd | 48-13-28 Srinagar<br>Vishakhapatnam – 530 016 |
| Halogen Chemicals (Pvt) Ltd | Panatoor Village<br>Pallur Post<br>Chittoor TK —517 135<br>Chittoor Dist. |
| South Sea Chemicals Ltd | 6-3-628/15 Ravindranagar<br>Khairatabad<br>Hyderabad – 500 004 |

## Appendix II

# LIST OF ALGINATE PRODUCERS IN INDIA

*Andhra Pradesh*

| | |
|---|---|
| Hindustan Chemical | Hyderabad |

*Gujarat*

| | |
|---|---|
| Ashahi Chemical Industries Pvt Ltd | 113 GIDC<br>Mehsana—380 051 |
| Bluebird Chemicals | Rajkot<br>Ahmedabad |
| B R Sheth Chemical Industries | 4 Ramakrishna Society<br>(Opp. OM Cinema)<br>Vejalpur Road<br>Ahmedabad—380 051 |
| Cellulose Products of India (P) Ltd | Kathuwada<br>Ramol District<br>Ahmedabad |
| Jag Fashion Textile Mills (P) Ltd | 58 GIDC Industrial Estate<br>Vatwa—382 945<br>Ahmedabad |
| Shailesh Industries | 909-910 Naroda Industrial Estate<br>Phase IV D.T.<br>Ahmedabad |

*Karnataka*

| | |
|---|---|
| Brahmavar Chemicals | Brahmavar<br>5 Kavari District |

*Tamii Nadu*

| | |
|---|---|
| Balaji Chemical Industries | 15 Ammankulam Road<br>Pappanaikan Palayam<br>Coimbatore— 641 037 |
| Marine By-Products | Kappalur<br>Madurai—625 006 |
| Meenakshi Chemicals | Kappalur<br>Madurai – 625 006 |
| Ponselvam Phytochemicals | 81 A Beach Road<br>Tuticorin —628 001 |
| Snap Natural and Alginate Products Ltd | Plot No. 1 SIPCOT Industrial Complex<br>Ranipet – 632 403 |
| Sree Padmavathi Chemicals (P) Ltd | 164 Mills Road<br>P B No 68<br>Rajapalayam —626 117 |
| Sri Ayyappa Chemicals | Alampatty Road<br>Thirumangalam P O<br>Madurai District |

## PUBLICATIONS OF THE BAY OF BENGAL PROGRAMME (BOBP)

The BOBP brings out the following types of publications

Reports (BOBP/REP/...) which describe and analyze completed activities such as seminars, annual meetings of BOBP's Advisory Committee, and subprojects in member-countries for which BOBP inputs have ended.

Working Papers (BOBP/WP/...) which are progress reports that discuss the findings of ongoing BOBP work.

Manuals and Guides (BOBP/MAG/...) which are instructional documents for specific audiences.

Miscellaneous Papers (BOBP/MIS/...) concern work not sponsored by BOBP — but which is relevant to the Programme's objectives.

Information Documents (BOBP/INF/...) which are bibliographies and descriptive documents on the fisheries of member-countries in the region.

Newsletters (Bay of Bengal News) which are issued quarterly and which contain illustrated articles and features in non-technical style on BOBP work and related subjects.

Other publications which include books and other miscellaneous reports.

A list of publications in print follows. A complete list of publications is available on request.

### *Reports (BOBP/REP/...)*

21. *Income-Earning Activities for Women from Fishing Communities in Sri Lanka.* E. Drewes. (Madras, September 1985.)
22. *Report of the Ninth Meeting of the Advisory Committee.* Bangkok, Thailand, February 25-26, 1985. (Madras, May 1985.)
23. *Summary Report of BOBP Fishing Trials and Demersal Resources Studies in Sri Lanka.* (Madras, March 1986.)
24. *Fisherwomen's Activities in Bangladesh : A Participatory Approach to Development.* P. Natpracha, (Madras, May 1986.)
25. *Attempts to Stimulate Development Activities in Fishing Communities in Adirampattinam, India.* P. Natpracha, V. L. C. Pietersz. (Madras, May 1986.)
26. *Report of the Tenth Meeting of the Advisory Committee.* Male, Maldives. 17-18 February 1986. (Madras, April 1986.)
27. *Activating Fisherwomen for Development through Trained Link Workers in Tamil Nadu, India.* E. Drewes. (Madras, May 1986.)
28. *Small-Scale Aquaculture Development Project in South Thailand: Results and Impact.* E. Drewes. (Madras, May 1986.)
29. *Towards Shared Learning: An Approach to Nonformal Adult Education for Marine Fisherfolk of Tamil Nadu, India.* L. S. Saraswathi and P. Natpracha. (Madras, July 1986.)
30. *Summary Report of Fishing Trials with Large-Mesh Driftnets in Bangladesh.* (Madras, May 1986.)
31. *In-Service Training Programme for Marine Fisheries Extension Officers in Orissa, India.* U. Tietze. (Madras, August 1986.)
32. *Bank Credit for Artisanal Marine Fisherfolk of Orissa, India.* U. Tietze. (Madras, May 1987.)
33. *Non-Formal Primary Education for Children of Marine Fisherfolk in Orissa, India.* U. Tietze, Namita Ray. (Madras, December 1987)
34. *The Coastal Setagnet Fishery of Bangladesh — Fishing Trials and Investigations.* S. E. Akerman. (Madras, November 1986.)
35. *Brackish water Shrimp Culture Demonstration in Bangladesh.* M. Karim. (Madras, December 1986)
36. *Hilsa Investigations in Bangladesh.* (Colombo, June 1987.)
37. *High-Opening Bottom Trawling in Tamil Nadu, Gujarat and Orissa, India : A Summary of Effort and Impact.* B. T. Anthony Raja. (Madras, February 1987.)
38. *Report of the Eleventh Meeting of the Advisory Committee,* Bangkok, Thailand, March 26-28, 1987. (Madras, June 1987.)
39. *Investigations on the Mackerel and Scad Resources of the Malacca Straits.* (Colombo, December 1987.)
40. *Tuna in the Andaman Sea.* (Colombo, December 1987.)
41. *Studies of the Tuna Resource in the EEZs of Sri Lanka and Maldives,* (Colombo, May 1988.)
42. *Report of the Twelfth Meeting of the Advisory Committee.* Bhubaneswar, India, January 12-15, 1988. (Madras, April 1988.)
43. *Report of the Thirteenth Meeting of the Advisory Committee.* Penang, Malaysia, January 26-28, 1989. (Madras, March 1989.)
44. *Report of the Fourteenth Meeting of the Advisory Committee.* Medan, Indonesia, January 22-25, 1990. (Madras, April 1990.)
45. *Report of the Seminar on Gracilaria Production and Utilization in the Bay of Bengal Region.* (Madras, November 1990.)

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