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MANUAL ON MUSSEL FARMING

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Front Cover : Grown up mussels ready for harvest.
Back Cover : 1. Mussel seeds in the intertidal laterite rocks.
2. Seeding of ropes.
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Chapter 1
Introduction

Mussel farming has a long history that dates back to the thirteenth century. Mussels are farmed in many areas of the world with the most common species cultured being the blue mussel, *Mytilus edulis*. The main producers of mussels are countries such as China, Korea, Spain, The Netherlands, Denmark, France and New Zealand. In 1997, 1.1 million tonnes of mussels were produced worldwide, with most production occurring in China (nearly 400,000 tonnes). The Indian mussel industry is relatively small compared with world standards and in 1997, the total Indian production of mussels was 5937 tonnes.

In India, mussel culture is becoming popular in the Malabar area since last six years following the success achieved by CMFRI in rearing green mussel in the backwaters. The simple methods employed for mussel farming was transferred to progressive farmers who took up mussel culture in the backwaters. Soon they found the venture profitable. Demands came from new entrepreneurs for training and mussel farming spread from Kasaragod to Ponnani. From a total of 250 tonnes of mussels harvested in 2000, the total harvest estimated for the year 2002 is 800 tonnes.

Mussel culture in the backwaters of Kerala was first started in Padanna and Cheruvattur Panchayats in Hosdurg Taluk of Kasaragod district. Later it was taken to Elathur in Calicut district and Vallikunnu and Ponnani in Malappuram district. This has happened mainly due to the popularisation efforts by the CMFR Institute. This year the Padanna farmers go for the sixth harvest.

Initially this low cost technology of farming was transferred to five groups with 15 to 21 members at Cheruvattur and Valiyaparamba. Financial assistance was provided by the North Malabar Gramin Bank and Cheruvattur Farmers Co-operative Bank. They provided a loan of Rs.2,60,200/= for the implementation of the project with a subsidy component of 50% subsidy. These groups harvested 67.4 tonnes of mussels during May-June 1997.A portion of the harvested and shucked meat (2000-Kg) was sold to the Integrated Fisheries Project, Cochin at a rate Rs.45 per Kg. The remaining harvest was sold in the domestic market. The groups could realise Rs.3,34,555/= from the harvest with a net profit of Rs.1,04,455/= within a period of 6 months.

Production

The total green mussel production by capture fisheries from Malabar area was 6317 tonnes during 2001. The total production from culture was 400 tonnes. This forms only 6.3 % of the total mussel production from Malabar, which had increased from 4.62 % during 1999.

The yields obtained during 1999 by the groups and the numbers of ropes suspended are given below:

Sl. No.	Place	Total yeild (tonnes)	No. of ropes	Yield/rope (Kg.)
1.	Koyambram	22.75	700	32.5
2.	Kayuthakadu	36.22	900	40.24
3.	Kavunchira	25.2	900	28
4.	Paranthamadu	12.75	300	42.5
5.	Badkekad	18.75	625	30
6.	Ori	13.5	482	28
7.	Thekkekadu	22	760	29
Total		**151.75**	**4667**	**32.89 (Av.)**

During the year 2002, the numbers have dramatically increased and the total production estimated is 750 tonnes. The total production from Malabar is estimated at 800 tonnes. The number of groups and individuals engaged in mussel culture has gone up dramatically and the total number is about 75. An interesting to note that the number of single holding has increased and most of them are male members.

Inputs

In Kasargod, the net operating profit ranged from Rs. 7,646/= in Kayambram to Rs. 16,413/= at Badkekad. The cost analysis of mussel culture at Padanna showed that the major cost was that of Nylon rope (34%), Bamboo (20%) and seed (20%). The other expenditres involved cloth (7%), construction cost (5%), harvesting (4%), seeding (4%) and coir rope (3%).

Constraints

1. Availability of seed

The seeds required for culture is presently collected from traditional fishing areas and these are often causing conflicts between farmers and mussel fishermen. Hence it is essential that additional spat collectors has to be established along the coast to ensure supply of seeds to the farmers.

2. Marketing

The harvesting seasons of cultured mussels is mostly during April - May months and farmers are forced to sell their crop before the onset of monsoon to avoid mass mortality of mussels due to freshwater influx into the backwater system. At present only a few processing plants purchases cultured mussels from the farmers and as a result the local market are flooded with cultured mussels during these months resulting in fall in the prices and thereby affecting the profitability of the operation.

3. Depuration system

The main constraint in the export of cultured mussels is the lack of proper depuration techniques. Depuration plants are needed at regular intervals along the coast so as to depurate the cultured mussels for export processing.

4. Storage facility

If sufficient cold storage facility is provided, cultured mussels can be depurated, shucked and stored not only for export market but also for local market throughout the year. This will increase the profitability of the culture operation.

5. Post harvest technology

Value added products of longer shelf life need to be developed from mussel meat to increase the revenue realization from cultured mussels. Mussel fry, mussel pickle etc. are some of the best examples for value added products. More studies are needed to develop ethnic cuisines with longer shelf life.

6. Siltation of backwaters

Some areas in the backwater system have very high siltation levels especially during rainy season This often results in mortality of mussels in the farms. Hence scientific feasibility studies are required to demarcate potential culture sites.

Prospects

1. Backwater mussel culture is a recent phenomenon along the Malabar coast and opens immense potential for resource and employment generation among coastal communities especially women living below poverty line.

2. Mussel culture is a low investment activity with very good returns. If promoted properly, mussel farming can be used as a tool for women empowerment in the coastal areas and can stimulate healthy socio-economic development in the area.

3. Better post harvest technologies can develop attractive value added products. Since very good export markets are available for mussels, they can be taken up as a challenging opportunity by technicians and scientists.

In the western countries, mussel is considered as poor man's oyster. But in India, mussel can be considered as tool for the upliftment of the poor people living in the coastal areas especially along the Malabar Coast.

Chapter 2
Potential for oyster and mussel culture in Goa

Introduction

Goa is a small maritime state and has a reasonable scope for fisheries production, mainly from marine capture and inland culture resources. It has an equally good potential for production of fisheries processed products for both internal and export markets. More than 90 per cent of the population are fish eaters. Though Goa's coastline of 105 km forms only 1.25 per cent of the country's total of 8192 km, its recorded marine fish landing contribution to the country's total ranges from 2.2 to 3.8 per cent, over the last four years. Similarly, the quantity of fisheries exported from Goa is more than 2.0 per cent of the total fisheries exported by India, contributing about Rs.35.00 crore (0.43%) to country's foreign exchange. However, there is a large scope to increase the production and export through scientific and planned strategy. The per capita fish consumption of Goa is 7.4 kg/day compared to the national average of 5.4 kg, as against the recommended average of 11.0 kg. Present local fish utilization pattern includes 81 percent fresh, 9 percent dried, 5 per cent salted and 5 per cent manured. Due to the state's increasing tourism, fish processing industry and the fact that 90 per cent of the population are fish eaters, Goa has a definite export and internal markets, for fish and shellfish varieties. The fish production of the Goa during the year 2000 is given below :

Fish catch	Goa production (ton)	Indian total (ton)	% of total
Marine	62,113	28,33,848	2.19
Inland	3,509	28,22,701	0.12
Total	65.622	56,56,549	1.16

Water resource of Goa

Rivers

The nine rivers of Goa are Terekhol, Chapora, Baga, Mandovi, Zuari, Sal, Saleri, Talpona and Galjibag of which Mandovi and Zuari are the main ones. The river courses add upto a total distance of 250 km and with its tributaries, canals and creeks form a network of 555 km of riverine system.

Estuaries

The tidal influence and seawater ingress establish long estuarine system in many rivers of Goa. The total estuarine area is 13,157 ha. Excepting June to September, when there is a heavy freshwater discharge into the sea due to monsoon rains, salinity and tidal effects are very much pronounced and they can be felt as interior as 40 km from the river mouth as in the case of Zuari river. In Chapora river, salinity intrusion occurs up to about 20 km. Mondovi has an estuary 5 km wide at the mouth region and 0.5 km upstream. Mandovi estuary is mostly sandy or muddy. Majority of Mandovi riverine network is brackish. Zuari river has the largest estuarine mouth (7 km wide) and mostly rocky substratum.

Based on the salinity gradient, substratum and wave action, the estuaries of Goa can be divided into: 1) Euryhaline zone towards the river mouth with high salinity (30 - 35 ppt), strong wave action and rocky or sandy substratum. 2) Polyhaline zone with moderate salinity (18 - 30 ppt), less wave action, sandy or clayey substratum and mangrove vegetation and 3) Mesohaline zone in the interior region with low salinity (5 - 18 ppt) and silty clay substratum.

Mangrove, brackishwaters and 'Khazan' inundations

Mangoves of Goa are associated mostly with riverine estuaries especially Mandovi, Zuari and the Cumbarjua canal. Several tributaries of

Mandovi, viz. Mapusa, Nanora and Goa have in their network, islands such as Chorao and Diwar and marshy swamps like Pilerne swamps. Many mudflats are also formed on either side of the river canals.

Brakishwater areas of Goa come to about 3500 ha and they are closely associated with estuaries and mangroves. 'Khazan' lands are low-lying paddy fields along the rivers up to the high tide mark. Many of the Khazan lands are the reclaimed beds of Mandovi and Zuari estuaries, protected from the rivers by embankments and water entry is regulated through sluice gates. There are about 18,500 ha of Khazan lands in Goa. In about 12,000 ha, Kharif rice is cultivated during June to October. During the remaining period, they are inundated with saline water, rendering them unsuitable for rice cultivation when only fishery activities can be undertaken.

Molluscan production

About 1000 tonnes of clams, mussels and oysters are harvested annually from the creeks, estuaries and backwaters of Goa. Dense clam beds of *Meretrix casta* occur in estuaries of Goa, especially in Zuari estuary. Meat of clams, mussel and oysters, is available throughout the year and it is in great demand in the markets of Goa. The wedge clam, *Donax cuneata* is abundant in the sandy backwaters especially near Colva and Baga. Of late, there is an abundant settlement of *Perna viridis* in the rocky bottoms of estuaries and backwaters and thereby a rich natural fishery exists during October to January.

About 20,000 fishermen are engaged in marine fishing, who are distributed in 3,380 households situated in 61 villages of the five coastal talukas of the state. Goa has about 50 landing centers. About 25 per cent of the marine catch come from traditional fishing while landings of three talukas namely Marmugao, Salcete and Bardez contribute 75 per cent of the total catch. A sizeable number of fishermen hand pick the clams, oysters and mussel and sell them in the roadside and market. Farm produced oysters and mussels can have three types of markets. Goa being an important tourist destination and having a predominantly fish eating population, the internal market for oysters and mussels will be sizeable. Goa has the logistic advantage of being nearer to cosmopolitan cities like Bombay, Pune and Bangalore and the intake capacity of the live oysters and mussels in these cities, is enormous if properly promoted. If regular availability of sizeable quantities of depurated oysters and mussels are ensured, the export market demand can also be taken advantage of.

Export from Goa constitutes 2.01 per cent of the national fisheries export total. Goa exported around 10,000 ton, valued at Rs.35 crore, over the last three years. Details of the export during 1998 to 2000 are furnished below :

Aspect of export	**1998**	**1999**	**2000**	**% on Indian total**
Quantity (ton)	9,658	8,849	11, 206	2.01
Value (Rs. in crore)	36.55	27.92	34.91	0.43

The above export from Goa can be further enhanced through diversified brackishwater aquaculture production comprising of oyster, mussel, mud crab, etc.

Oyster and mussel culture will give these fishermen a lucrative self-employment opportunity particularly during lean periods. Aquaculture in Goa is predominantly shrimp based. Oysters and mussels being the highest biomass producing species with good export markets and relatively disease free, can be potential candidates for export oriented aquaculture in Goa. As Goa is having many shallow sea incursion, vast areas of estuaries, mangroves and about 100 shrimp farms, oyster and mussel culture can be taken up as an ecofriendly activity without adversely affecting the environment or as biopurifiers in shrimp farms. Success of oyster and mussel culture in estuarine areas, experienced in Kerala, Karnataka and Maharashtra can be emulated in Goa as well.

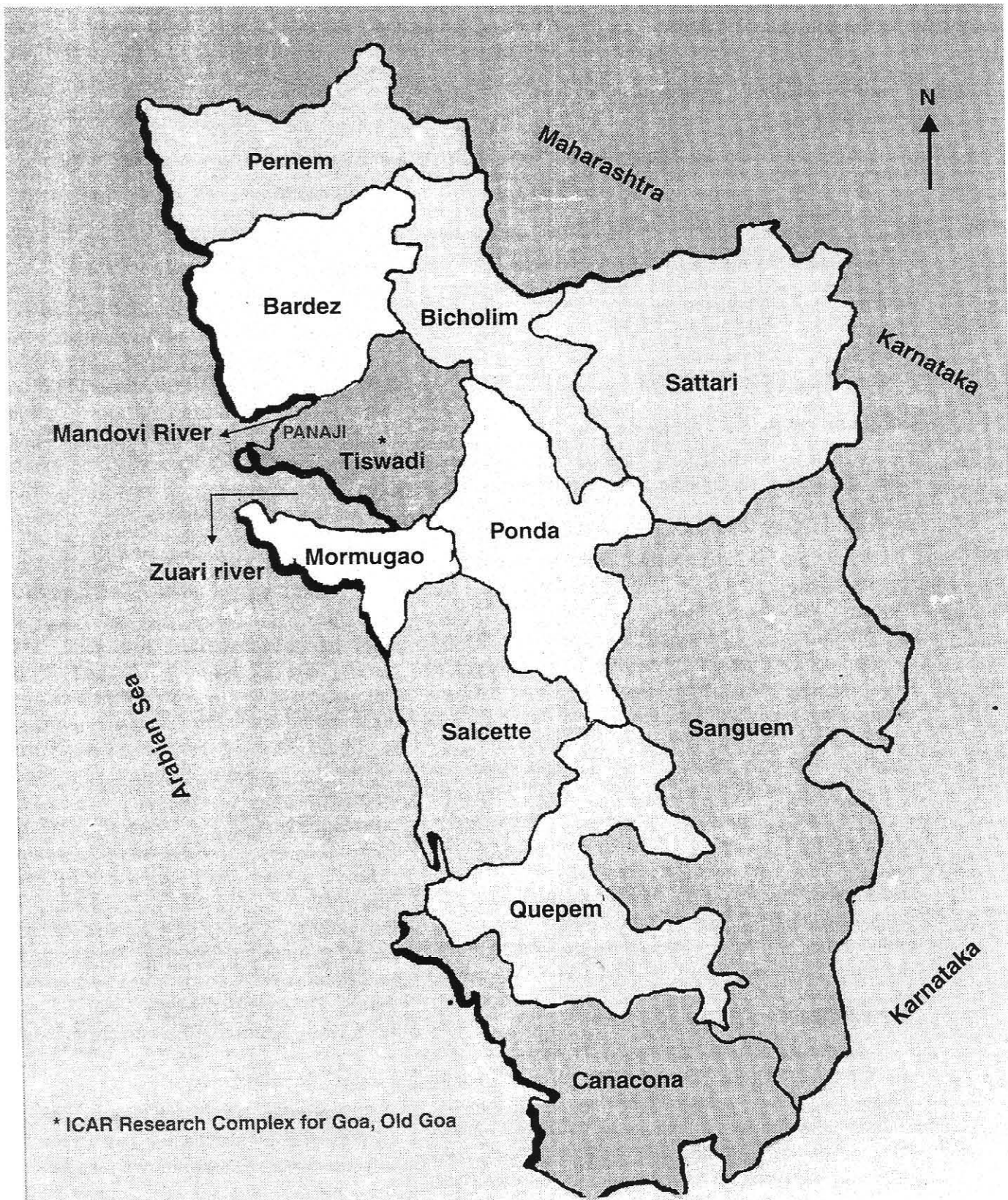


Fig. 1. Map of Goa indicating talukas and neighbouring states

Chapter 3
Biology of green mussel

Perna viridis (Linnaeus, 1758)

Phylum	:	Mollusca
Class	:	Bivalvia
Order	:	Mytiloida
Family	:	Mytiloidae

Common name

Green mussel, Green lipped mussel, Green mussel, Asian green mussel, sea mussel.

Distinguishing features

P. viridis is distinguished from the other two species of *Perna*, *P.indica* and *P. canaliculus*, by few physical features. *Perna viridis* begins its life as a juvenile with a green and blue-green shell that develops brown patches as an adult. Internally, the exhalent siphon and the inner surfaces of the inhalant aperture are outlined with a stripe darker than the variably patterned dark brown mantle This Mytiloid is distinguished from all others of the genus by having 30 instead of 28 diploid chromosomes. The native range of the green mussel is along the Indian coast and throughout the Indo-Pacific. *Perna indica* is distinguished from *P. viridis* and *P. canaliculus* by mantle margins lined with enlarged sensory papillae. Young *P. canaliculus* has light colored zigzag markings on the outer shell and is found only in New Zealand.

Distribution

Perna viridis occurs naturally and is widely distributed along the intertidal coasts of India. The green mussel is also local to Malaysia. *P. viridis* is broadly distributed in the Indo-Pacific where it ranges west from the Persian Gulf and east to New Guinea and Japan and New Guinea for north and south ranges, respectively.

Features

To adjust to the high sediment content in the water the mussel has adopted an efficient way to filter out the sediments using only the finest food particles for energy requirements.

This advantage is gained through the use of labial palps that extend through half of the mantle cavity and capable of producing strong ciliary currents. The ability of the mussel to dispose of the sedimentary particles is directly related to the copious amounts of mucous produced by the mussel. *P. viridis* to have a high organic retention efficiency that may be related to the internal morphology of the bivalve.

Reproduction and growth

Sexes in this species is separate and the fertilization is external. Spawning is closely related to the monsoon seasons and occurs twice a year during March and April and October and November. It is most prevalent during southwest monsoon rainfall. However, green mussels located in Thailand and in the Philippines exhibit continuous breeding throughout the year. Sexual maturity typically occurs at 15-30 mm shell length (corresponding to 2-3 months). The life span of *P.viridis* is typically 2-3 years. Growth rates are influenced by environmental factors such as temperature, food availability and water movements. First year growth rates vary between locations and range from 49.7 mm/yr in Honk Kong to 120 mm/yr in India. Average growth rate per month for *P.viridis* ranges from 2.3 mm reported from Hong Kong to 10.6 mm from Singapore.

Larval development

Spawning is initiated by either sex of the green mussel with each releasing two streams of gametes into the water. Spawning has also been induced by the presence of other spawning individuals in the area and a drop in salinity. Females release about 5 lakh eggs. Seven to eight hours after fertilization the zygote is completely transformed into mobile trochophore larvae. After 16 to 19 hours the veliger larval stage is reached with the larval shell covering the internal body parts and developing

strong ciliated velum. The straight hinge D shaped larvae metamorphoses to pediveliger with a pedal organ, the functional foot and descends to the bottom. The larvae completely metamorphosize in eight to twelve days. In 10-12 days the larvae secrete the initial byssal threads and attaches itself. Changes in organ system takes place and the post larvae with characteristics of adult mussel called spat are formed. The mussel starts looking for a suitable foundation to attach itself to. The larva examines the different surfaces it meets and when it finds a suitable surface, it attaches itself with a few byssus threads. This method of anchoring is secreted from a byssus gland and is used the whole of its life span. The more the mussel is exposed to waves and currents, the more byssus threads it develops. If the mussel should need to move, it cuts off its threads and develops new later. *Perna viridis* has the greatest growth rate of the mussels studied to date. Maximum growth of the green mussel occurs 2m below the surface because of the increased productivity of the water at that depth and a narrow area of temperature and salinity fluctuation.

Feeding

Perna viridis is a ciliary-mucoid filter feeder. This species is an efficient filter feeder, feeding on small zooplankton, phytoplankton and other suspended fine organic material. The four rows of gills serve both as respiratory organs and filter feeding apparatus.

Parasite

An unidentified adult digenetic trematode, of the genus *Gorgoderina*, has been found in this mussel.

Salinity tolerance

The high growth rate of the green mussel is related to high salinity and an abundance of phytoplankton. Mussel has a 50% salinity tolerance between 24 and 80 ppt. The green mussel has a high tolerance for reduced salinities, increased survival during atmospheric exposure, and high survival rates in turbid water. Salinity below 5 ppt is lethal to *Perna viridis* if exposure exceeds 2 days.

Temperature tolerance

The growth is significantly affected by temperature. 50% survival at 10°C and 35°C has been reported.

Chapter 4
Mussel fishery in India

The green mussel *Perna viridis* and brown mussel *Perna indica* are available in India. Green mussel is widely distributed and found extensively around Kollam, Alapuzha, Kozhikode, Kannur and Kasargod in Kerala and in small beds in Chilka lake, Vissakhapatnam, Kakinada, Chennai, Pondicherry, Caddalore, Mangalore, Karwar, Goa, Ratnagiri and in Gulf of Kutch. Brown mussel has a restricted distribution and is found along the southwest coast from Varkala to Kanyakumari and on southeast cost from Kanyakumari to Thiruchendur.

Mussels occur in the intertidal zone attached to rocks and other substratum. Brown mussels are seen upto a depth of 10 m while green mussel are available up to a depth of 15 meters. Mussels are collected during September to May. Method of fishing is simple. During low tide fishermen collect musssels from the subtidal areas using chisel, knife etc. They usually prefer to collect when water is clear and the day is sunny. Bags of coir or nylon netting are tied around their waist to stock the collect mussels. In some places, two or three fishermen set out for mussel fishing in wooden canoes during low tide. About 60 - 160 mm is the size range of the green mussel usually collected.

Production

According to FAO of the United Nations, the average world mussel production from 1991-1997 is about 1.3 million tons. During 1997, China the major producer landed about 400,000 MT, followed by Spain (190,000 tonnes) and Italy (124,400 tonnes). The other mussel producing countries are Netherlands, Denmark and Korea Republic. Unlike other resource, the cultured mussel far exceeds the production from the wild stocks and the recent production enhancement is mainly from mariculture.

In India, the green mussel is mainly landed from Malabar area. Chaliyam/South beach is the biggest landing centre. This is followed by Thalasseri, Moodadi, Kollam and Koduvalli. Seasonal fishery from Caddalore, Malpe, Someshwar and Karwar is done mainly by mussel fishers of Mala bar areas.

Mussel fishery is a part time occupation to some fishermen. A fairly good number of fishermen are engaged full-time in mussel fishing during the peak season. About 520 fishermen are engaged fulltime in the mussel fishery in Trivandrum region and about 270 fishermen are engaged part-time in this occupation. The annual fishery here is around 5000 tonnes. In the Malabar area, most of the mussel pickers hail from Elathur. They migrate to other places during the season wherever the fishery exists. Some of the local fishermen also have started mussel picking. The total number of mussel fishers in Malabar area is 1055. The number of mussel divers in the mussel picking centres is given below.

Mussel fishers in the landing centres of Malabar area.

Area	Number of mussel fishers
Elathur	300
Chaliyam	250
Chombala	100
Thalasseri	80
Thikkodi	75
Koduvalli	55
South Beach	50
Moodadi	50
Thalai	50
Mahe	35
Kollam	10
Total	**1055**

In Chombala and Chaliyam, the mussel pickers use dugout canoes. Only one person uses these boats. At Elathur plank built boats in which 4-5 persons go for mussel picking. They use outboard engines. They are the most professional among the mussel pickers. Mussels are picked with the help of a small chisel. Meshed bags of nylon are tied to the waist for collecting the mussel.

In Elathur area, hand picking during low tide is also observed. This is practiced only for subsistence and for a short period as long as the mussels are present.

Season

Bulk of the landing takes place takes place during October to April with peaks during November and March. During the active monsoon period from June to August, the fishery is suspended as the waters become turbid with low visibility and the sea is also rough. Only handpicking in intertidal areas is done during this period.

Utilisation

Mussel flesh is popularly eaten, even considered a delicious item of food by the people of West Coast. The mussels are mainly consumed in Malabar without depuration. The mussel are mainly cooked or fried. The mussels are sold with shell-on or shucked. The shucked meat is sold in packets of ½ or 1 Kg. Packets. The shell on mussel is sold either by weight or numbers. The cost of shucked meat is about Rs.60 to 70 per Kg. The shell on mussel is sold at Rs 8-10 per Kg and Rs. 60-70 per 100 Nos. depending upon the size.

Mussel fishers landing their catch at Calicut

Mussel market at Elathur, Calicut

Chapter 5
Site selection, seeding and availability of seeds

Site selection

Open sea and estuarine areas free from strong waves action may be selected for sea farming. Clear seawater with high plankton production is ideal for mussels. Moderate water current will bring the required planktonic food and will carry away the waste materials. Silt will adversely affect mussel growth and survival. Site selected should be free from industrial pollution. Salinity range of 30 - 35 ppt is ideal for both green and brown mussel seafarming.

In shallow waters in the sea and estuary, rack and ren method can be adopted but for deeper regions in the sea, the raft method willl be ideal

Seed collection and seeding of ropes

Healthy seeds from the natural beds are to be collected for seeding. The site selected for collection of seed should be free from pollutants. Seed collected from the submerged (sub tidal) areas will be healthier. After removing other organisms and weeds, the seeds may be washed thoroughly in seawater. Ideal size of seed is 20 -25 mm. About 500 to 750 g of seed will be required for seeding on one-meter length of rope. The length of rope is decided by considering the depth where the raft/rack is positioned. While suspending the seeded rope on rack it must be tied in such a way that the upper portion of the rope should not get exposed during low tide.

Nylon rope of 12-14 mm or 15-20 mm coir rope can be used for seeding. Old cotton net, cotton mosquito net or cheap cotton cloth etc. is used for covering the seeds around the rope. Cotton netting of required width and length is spread over it. After placing the rope over the seed, the net is tightly stitched in such a way that the seeds spread uniformly around the rope.

To avoid slipping of the mussels due to growth, a 4 mm nylon rope is wound around the 12-14mm seeded rope with knots at a distance of 25 cm before seeding. Placing split bamboo pegs in the rope at intervals will also serve the purpose. Cotton net around the seed will disintegrate in a week's time. The seed will secrete byssus threads and will attach itself to the rope within this period.

Seed availability and utilisation

A survey of the rich natural beds of green mussels from intertidal to zone up to 15m depth was conducted in the Malabar area. Spat settlement was observed from July onwards. However, the area becomes congenial for spat collection from September onwards. Mussel spat settlement was observed in granite and laterite formations along the entire coast lone. Granite rocks were seen in Mahe. Kottikulam, and Chembarika (Kasargode district) areas. The rest were laterite formations.

Estimated extent of mussel beds from Malappuram to Kasargode district was about 6,200,000 sq m (Table 1). Of the four coastal district, Kozhikode has the highest seed biomass forming 68% of the total seed resource, followed by Kasargode (20.24%) and Kannur (9.8%) districts. However there was no significant seed settlement in Malappuram district.

The total biomass estimated for Malabar area is about 8221 tonnes. In kozhikode district, Moodadi/ Thikkodi area has about 2400,000 sq m of mussel bed contributing about 66% of the mussel seed in Kozhikode. About 42% of the seed in Kannur district is from Thalassery/ Thalai area

In Kasargode, significant resource is found in Chembarika and Kottikulam areas near Bekel .

Maximum spat settlement per unit area was observed in Kottikulam and Chembarika area, where 4.56 and 3.79 kg per sq. m was recorded. In these areas, seeds were observed in intertidal area only. In subtidal area, maximum biomass/sq m was observed in Thikkodi followed by Elathur area. However, the quality of seed of subtidal area is better as the seed in inter tidal area showed stunted growth.

Analysis of spat fall and spat length data shows that monsoon conditions prevailing during the months of July and August triggers spawning. Period starts from late July and continuous up to August end.

Mussel seed settlement along Malabar area indicating major settlement areas

Zone Location area	Estimated extend of mussel bed (sq.m)	Average Mussel biomass per sq m (g)	Estimated biomass in tonnes	Average size of mussel seed (mm)	Number of seed per kg
Kozhikode Chaliyam/South Beach	800,000	820	656	16.19	2284
Elathur/Kollam	750,000	1068	801	17.7	1314
Moodadi/Thikkodi	2,400,000	1547	3712.8	20.66	1010
Chombala	400,000	975	390	18.21	1381
Mahe	200,000	1075	215	17.95	1328
Kannur Thalassery/Thalai	500,000	680	340	17.7	1510
Koduvally	500,000	625	312.5	18.76	1583
Kadalai	250,000	575	143.75	18.34	1788
Kasargode Chembarika	225,000	3786	851.85	17.25	1788
Kottikulam	175,000	4560	798	16.09	2325
Total/Average	**6,200,000**	**1239**	**8220.90**	**17.885**	**1631**

Chapter 6
Culture of mussel

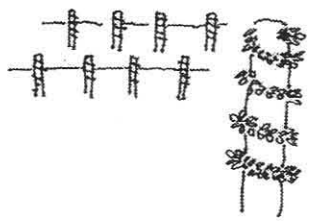
Aquaculture originated in China over 4000 years ago. Egyptian tombs dating from 2500 BC depicted tilapia culture and by 2000 BC Japan was rearing oysters. The first authentic study on aquaculture was written in 475 BC by Fan Li, entitled Yang Yu Treatise on Fish Breeding, which discusses carp spawning in captivity. By the middle ages, Europe had also established farming practices. In Europe and Asia, mussel farming has had a history of using bottom culture methods characterized by letting the mussel attach to sticks, poles, and ropes. The Dutch however, developed a bottom culture method much like land farming principles where mussel seeds are dispersed on the bottom and several years later they are harvested. In Spain mussel farming is practiced based on suspended rope culture techniques from rafts. Mussel farming has two distinct stages: spat collection and grow-out. Suitable measures that take into consideration the specific needs of the mussels during the two stages will result in the optimization of yield and thus better utilization of investment. A mussel farm needs an area that is pollution free as they easily absorb poisons and pollutants. The same area should also have adequate protection against large waves. Even if an area in the outer archipelagos usually means a secure source of nutrients and fewer pollutants.

Culture techniques

Many culture techniques are used for growing mussels worldwide. Some of these are described below:

Bouchot or Intertidal pole culture

In Europe, mussel culture is believed to started in 1235, when an Irish sailor survived a shipwreck on the Atlantic coast of France. He found that the poles he had kept for trapping birds attracted mussel spat settlement. This is became the basis for Bouchot method which is the oldest and the main method utilised in France. In this method, ropes with spat attached are wound around large vertical poles (bouchots) in the intertidal zone. A mesh netting is used to cover the mussels to prevent them being detached and lost. A barrier is placed at the bottom of the pole to prevent predators such as crabs from reaching the mussels. This method of culture requires large tidal ranges, in order to supply the densely packed mussels with food.



Bouchot culture

On-bottom culture

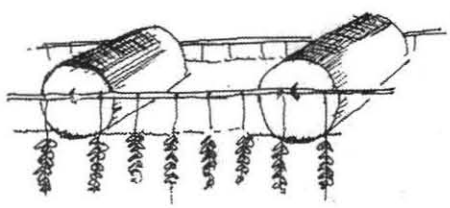
This method is widely used in Netherlands, Denmark and Germany. The culture is based on the principle of transferring seeds from areas of great abundance where growth is poor to culture plots in lower density to obtain better growth and fattening of the mussel. The culture plots must have a firm substratum and less of drifting sand and silt particles. In Netherlands, the seeds are dredged from Waddenzee. The seeds are layed in intertidal areas to produce mussels with thick shells and strong adductor muscle. In the subtidal areas higher meat yield and thinner shells are produced fit for processing industry. The production is about 22 tonnes per acre. The whole process is highly mechanized from collection of seeds to harvesting and marketing.

Long line culture

This method is becoming very successful in open sea mussel farming. A rope is stretched horizontally near the water surface and maintained 1-2 m from the surface with buoys. Mussels are grown on vertical ropes known as 'droppers', which hang from the horizontal rope for a length of 4m. Mussel seeds are collected from natural beds and trans-

planted onto the ropes into a continuous sock-like cotton tube, which is approximately 17.5 cm in width. Small mussels stripped from the collection ropes are inserted. This cotton sock is then wound around the dropper. The mussels grow and attach to the ropes using their byssal threads and the cotton sock slowly disintegrates and falls away. The droppers are placed a minimum of 0.5 m apart and have at least 4 m of free space from the bottom. In deeper waters the gap between the bottom of the line and the sea floor is greater. Anchor ropes extend from each end of the horizontal rope to anchors buried in the mud of the bottom. As the ropes are kept taut, there is no movement around the anchor to disturb the bottom as occurs when boats are anchored.

The density at which mussels can be cultured on long lines could be about 300 per meter, but depends on the food availability, which varies from site to site. Mussels grown on longlines can become smothered by naturally settling juvenile mussels and other fouling organisams . For this reason, most farmers prefer to position their farms away from heavy spat settlement areas to avoid layers of spat attaching to larger mussels.



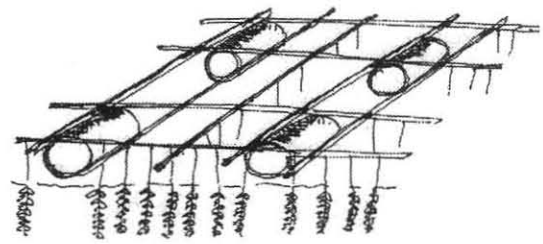
Longline culture

Raft culture

The basic principle of raft culture is simi

lar to long line culture in that the mussels are suspended on droppers but these are suspended

from the raft instead of the long lines. The raft itself is anchored to the seabed removing the need for several anchoring systems. Long line culture however, creates less of a visual impact, and the droppers can be spaced farther apart to maximise the use of the available phytoplankton. Raft culture is more suited to areas of dense phytoplankton and to smaller operations, as there is less scope for mechanical harvesting. This method of culture is used in the Galician Bays in Spain, Saldahna Bay in South Africa but has been abandoned by the New Zealand industry in favour of long lines.



Raft culture

Fixed suspended culture

This is the simplest of the rope-web method used for green mussel cultivation in India and Philippines. The main purpose of the pole is to support the structure. In between these poles, ropes are suspended either vertically or kept horizontally where the depth is a limitation.

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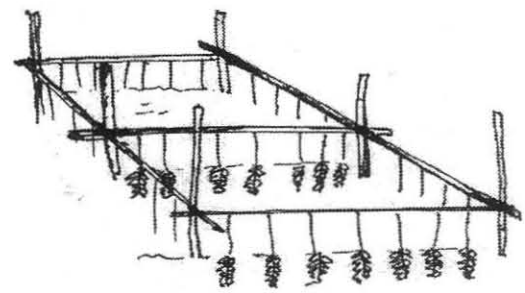
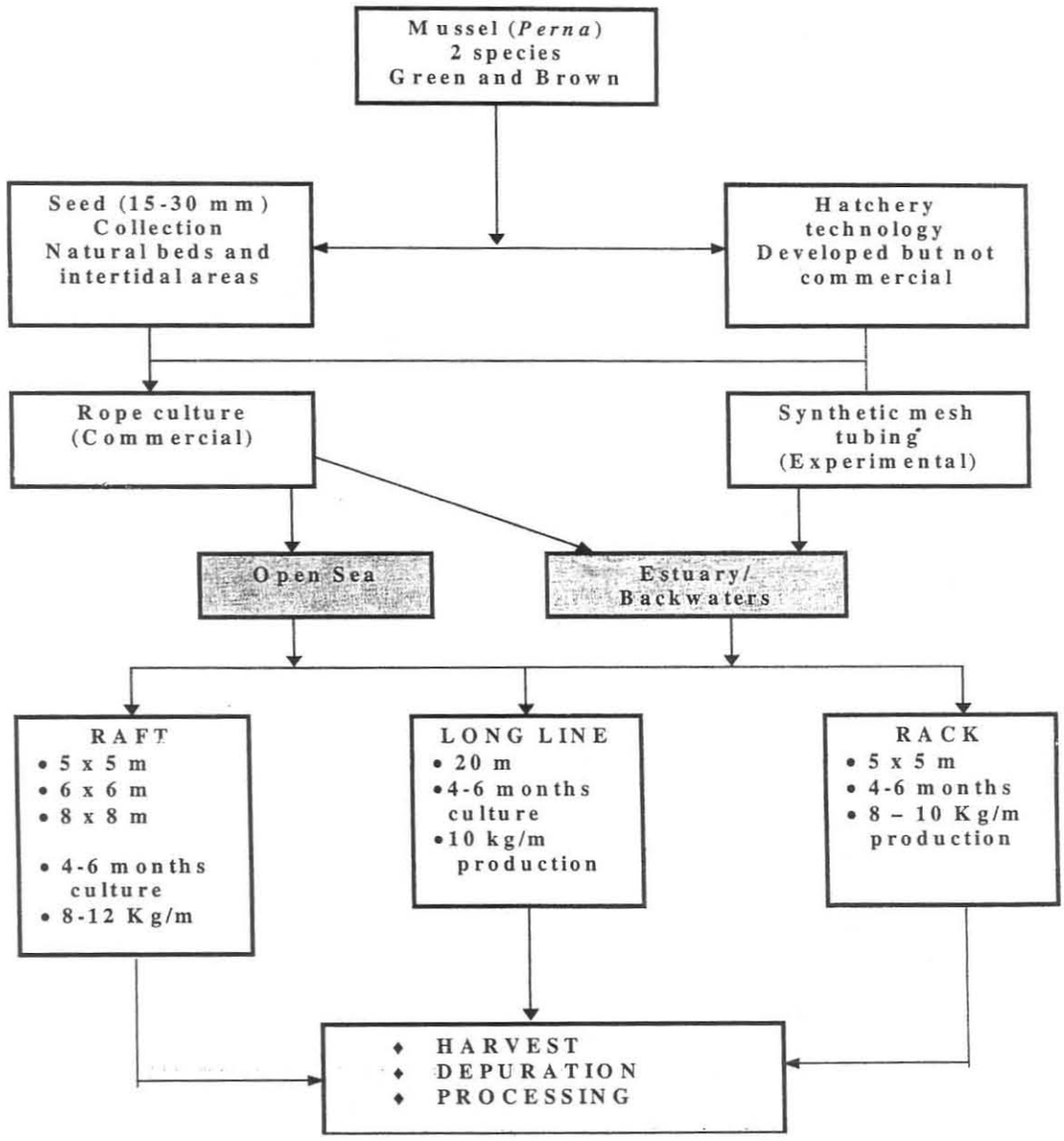


Rack method

Mussel farming protocols followed in India



COST ESTIMATES

Mussel Farming by Raft method in Open Sea

Area of Raft	5 x 5 m (0.0025 ha)
No. of seeded ropes	50 Nos
Length of seeding in each rope	4 m (depth of site more than 5m)
Culture period	Upto 7 months (Nov – May)

EXPENDITURE

Item	Quantity	Rate (Rs.)	Amount (Rs.)
Capital Cost			
Bamboo poles	16 nos	100	1600
Rope for raft construction, 4mm	4 Kg	110	440
Floats (Diesel/FRP drums, 200 l cap.)	5 nos	400	2000
Rope for tying floats, 8mm	1Kg	110	110
Anchors (2 grapnel each 50 Kg,, 2 granite)	4 nos		3100
Anchor rope, 12 mm, 60 m	4.5 Kg	110	495
Seeding rope	20 Kg	110	2200
	Total		**9945**
Recurring cost			
Cotton netting material	50 m	12	600
Nylon rope for stitching	0.5 Kg	110	55
Needles,twines,basin			200
Labour for fabrication of raft	3 mandays	150	450*
Cost of mussel seeds	350 Kg	6	2100
Canoe hiring charges	15 trips	100	1500*
Labour for seeding	8 mandays	150	1200*
Raft mooring charges	3 mandays	150	450*
Labour for harvesting	3 mandays	150	450*
Marketing expense (& shucking carges)			7200
Transportation of poles			350
Transportation of seeds			200
	Total		**14955**
Total financial outlay			**24900**

* Rs. 4050 will go back to the farmer; hence actual recurring cost will be Rs.2845

INCOME GENERATED

Total yield (50 nos x 4m x 10Kg)	2000	12	24000
Income realized			24000
Net income (Rs.24000 – 14955)			**9045**

Chapter 8
Depuration

Introduction

Bivalve farming, especially that of mussels and edible oysters, is becoming popular among mariculture entrepreneurs in Kerala as the shallow waters near the coast or estuaries provide good environmental conditions for bivalve growth. Unfortunately these coastal waters are also the areas often subjected to pollution from different sources.Bivalses being filter feeders can accumulate human pathogenic bacteria and viruses when grown in polluted waters.

The main drawback to increased production is lack of an appropriate price structure and assured market for the produce. The product is exportable if it meets basic quality and sanitation standards. Through export to western markets the farmers can get better price for their produce, thereby, increasing their profit margins. However, European Union markets are very stringent about the quality of bivalve products that they import from Asian markets. To ascertain and maintain the quality of bivalve products depuration is essential. Simple depuration can be achieved by starving the bivalves in clean and filtered seawater/ brackishwater for a certain period of time. More effective depuration can be achieved by using disinfected water in the depuration process.

Even a simple and small depuration unit will be beyond the capabilities of the small-scale farmers, and hence, it is proposed to have depuration plants where bivalve farmers are concentrated, thus enabling the farmers to use it as a common facility for a price to be determined later.

Depuration process

1. Requirements

(a) The basic principle for controlled purifica

tion or depuration of bivalve involves providing clean and purified seawater in tanks, whereby the bivalve filter and pump such water for a period of 24 hours or more if required.

(b) Ideally a depuration plant should be lo

cated near the least polluted source of water in the vicinity of bivalve farms. Also the physical characteristics (salinity, temperature, dissolved oxygen etc.) of the seawater used in the depuration plant should not be radically different from that of the bivalve farming areas. Care should be taken such that the level of dissolved oxygen should not be allowed to drop below 2 mg/l.

(c) Two concrete seawater storage tanks of

the dimension (total capacity 60 m3 x 2) should be constructed at a level above that of the depuration tank to facilitate gravity flow into the depuration tank (see figure). The water to be used will be pumped from a bore well.

(d) The choices for disinfection of seawater

are chlorination, ozonation and UV light irradiation. The latter two are expensive, and hence chlorination (@ 3 ppm) is the method chosen for this project. After chlorinating for 12 h, the water will be dechlorinated using vigorous aeration and / or neutralization with Sodium thiosulphate for 12 h.

(e) Most depuration plants use flow through,

once through or fill and draw principles. It is proposed here to use the batch process (fill and draw), wherein seawater is drawn from the supply treated with predetermined amount of disinfectant to reduce bacterial levels, stored for a time, then pumped to the tank containing bivalves. The process will be repeated once to ensure complete depuration (see flow chart).

(f) Each depuration unit will consist of one

concrete tanks of the size 18 x 1 x 1 m with a gradient of 3% to hold bivalves (see figure). Bivalves will be placed in perforated plastic

trays of standard size. The trays in a single tier will be raised from the tank bottom with the help of concrete blocks. The tank will have drain plugs at the lower end to facilitate cleaning and flushing. Four such depuration units are envisaged.

2. Run duration and capacity

(a) The duration of the run will be 24 h, in

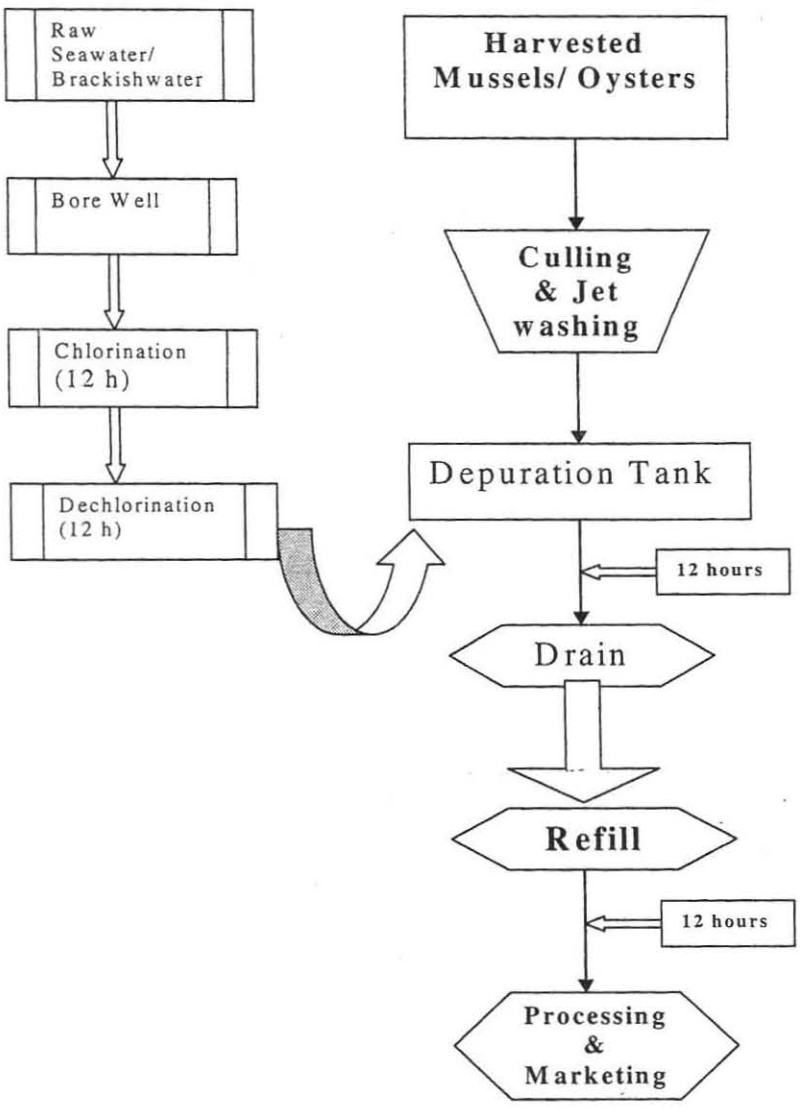
two cycles with one complete flushing for both mussels and oysters (see flow chart). The unit will have the capacity to hold 4 tonnes of mussels and 1 tonne of oysters per run. The water requirement per run will be 120 m3.

What is Depuration?

Bivalves are filter feeders in their feeding habit. During this process they accumulate all suspended biological materials including harmful microorganisms. Before the product reaches the market, these materials have to be removed from their gut. The process of such purification is called depuration.

Hence, depuration is the process of purification of shellfish in which the animals are placed in disinfected recirculating or running seawater and allowed to actively filter feed. The process leads to elimination of bacteria from the bivalve. Disinfections of circulating seawater can be achieved by use of UV radiation, ozone treatment, irradiation etc.

Depuration protocol



Chapter 9
Diversified products from mussel meat

Introduction

Vast changes are being witnessed the world over in production and utilization of seafood. An unprecedented growth in demand is observed for convenience food items like ready-to-cook or ready-to-serve type products processed out of a variety of fish and shellfish. Diversification of products with value-addition seems to be the catchword. So much so, processing of diversified products from fish and shellfish together with their successful marketing in overseas as well as urban domestic markets require upgradation of technology and subsequent value-addition. The conspicuous change in the consumer demands can be due to the increase in expendable income, increase in the number of working-women, awareness of the different types of products and the minimum standards of hygiene and sanitation, increase in the general standard of living and the convenience and speed in kitchen work.

Green Mussel, *Perna viridis* (L), found in abundance along the rocky coastal belt, is an important item of seafood for the people of Malabar Region. During the major harvesting season that spreads over September to May, fishermen engage themselves in collecting the mussels from the wild. Mussel culture by advanced technologies developed by CMFRI has been instrumental in increasing the production of mussels. A number of mussel culture farms have come to exist now. However, cultured mussels constitute only a very negligible part of the total production. Normally, the local population uses mussels in the fresh condition for preparation of different delicacies. Mussels are exported to different countries in the frozen condition. They are also airlifted in the iced condition to the gulf countries where mussels are in great demand.

A number of different products from mussel meat have been developed over the years. Central Institute of Fisheries Technology has been successful in the development of dried and smoked mussel meat, marinated mussel meat, mussel meat pickle, mussel meat chutney powder, canned mussel meat, ready-to-serve fried mussel meat etc. However, it is seen that very few mussel products are readily available to the consumer at the retail market. The latest in the line is the condiment-incorporated, ready-to-eat, fried mussel meat in vacuum packaging for the domestic and export market.

The mussel shells are composed of calcium carbonate. The shells can be commercially exploited to make lime. The mussel meat is highly nutritious and consumed by people of all strata of life.

Proximate composition

Moisture	-	80.00 %
Protein	-	13.00 %
Fat	-	1.50 %
Glycogen	-	3.50 %
Minerals	-	1.50 %

The proximate composition shows the richness of mussel meat as an edible food item. In most of the developed countries, mussels form a delicacy. It is usually consumed in the raw condition in combination with a sauce for seasoning or in the blanched (partially cooked) condition.

Processing and preservation

Sedentary mussels are filter feeders and they feed by filtering the water and taking in the nutrients. This peculiar feeding habit results in the retention of a lot of foreign particles like mud, sand, bacteria etc. in the intestine.

The bacterial profile of the mussel meat is greatly influenced by the quality of the water around the natural beds. If the water is polluted, the condition will be reflected in the quality of the meat. The feeding habits of the organism result in concentrating different types of bacteria in the meat. Microorganisms like Coliforms, including E. coli, and faecal Streptococci are indicators of faecal

pollution. The presence of these types of bacteria in the meat is an indication that pathogenic bacteria like Salmonellae, Vibrio etc. also might be present.

Therefore, the microbiological quality of the mussel meat often becomes one of great public health significance. However, studies have shown that the bacterial load of mussel meat is much lower than that of clams.

Apart from bacterial contamination, it is possible that high residual concentrations of heavy metals and other toxic substances like pesticides also might be encountered in the meat if the mussels have been harvested from grounds surrounded by chemically polluted water bodies.

All these unwanted particles are likely to be harmful to the consumer and hence it is necessary to remove the same before consumption. To ensure the safety of mussel meat, the live mussels have to be depurated first. The process of depuration consists of storing the live mussels in clear and clean seawater for a continuous period of 24 hours, whereby the intestines are flushed out. The mussels can be stored in large containers or tanks, which ensure a circulation of fresh, filtered seawater. No feed or nutrient is given during that period. At this stage, chlorination of the seawater is not of any added advantage since the shells remain closed if there is available chlorine. The mussels, after this treatment (starvation for 24 hours), should be put in water chlorinated to a level of 5ppm available chlorine for 2 hours to remove any further impurities. This depuration process is found to reduce the bacterial load of the mussel meat by 90 %.

There are two methods of removing the meat from the shell. Raw meat can be shucked out with a clean knife from the live shell-on mussels, or the shell-on mussels can be steamed/cooked to open out the shell and the meat taken out. In the latter process, the meat gets cooked and a part of the nutrients is also lost.

Different types of products can be prepared from the mussel meat thus separated. The meat should then be blanched in 5% salt solution for 5 minutes. This consists of boiling the meat and is mainly to enhance the shape and retain the keeping quality of the mussel meat.

Different products from mussel meat

Dried mussel meat

The blanched mussel meat (given as above) is dried in the sun by spreading on a clean surface until a moisture level of 10% is reached. Tunnel drier (electrically operated artificial drier) or solar drier can also be used. The dried product is packed in sealed polythene covers after cooling to room temperature. The product can be stored for 4 - 6 months. The dried mussel meat can be re-hydrated by soaking in water and used for preparation of various curries etc.

Smoked and dried mussel meat

The blanched mussel meat is partially dried in the sun for about one hour (to a moisture level of 40-45%). The partially dried meat is then smoked in a smoke kiln for 30 minutes. Coconut husk and sawdust can be used as fuel for smoking. The smoked mussel is again dried until the moisture level comes down to 10%. The finished product is packed in polythene covers for storage. The product can be stored for 4 months. The smoked mussel meat can be used for preparation of different dishes as in the case of dried mussel meat.

Frozen mussel meat

Mussels are also frozen, individually or as blocks. This is mainly for export to EEC countries. Frozen mussel meat is packed in consumer as well as bulk packs. The mussels are also processed as 'cooked' with the meat in single shell. Frozen fresh meat has a storage life of 40 weeks while iced (upto 8 days) meat when frozen has 15 weeks' storage life.

Canned mussel meat

Some attempts have been made for the canning of mussel meat. The method adopted for canning mussel meat is basically the same as the one employed for other, canned fishery products. The medium used is either 2 % brine or refined groundnut oil. The blanched meat is packed in 8 oz. (200g) round tin containers and hot 2 % brine with 0.2 % citric acid, or refined oil, as the case may be, is added to net weight. The cans are sterilized at 115oC for 45 minutes.

Mussel meat marinade

The marinade can be prepared by keeping the

cleaned, washed and blanched (by boiling the meat in 3 % brine for 5 minutes) mussel meat in a bath of 3 % acetic acid and 3 % salt. The mussels can be preserved in this liquid medium for a period of four months. The acetic acid concentration of the finished bath should not be less than 2.5 %. 1500 ml of the bath will suffice 1000 g of meat. The finished marinade can be stored in airtight glass bottles, preferably, out of direct sunlight.

Citric acid and tartaric acid can be used as replacement for acetic acid, provided, the pH of the medium is maintained at the desired level. Flavoring can be effected by adding different spices like pepper, clove, cardamom, cinnamon etc.

Ready-to-serve mussel meat products

Mussel meat chutney powder

The dried mussel meat is ground along with other ingredients and sieved to get a moderately fine powder. This is then used after mixing with the required quantity of oil.

Recipe

Dried mussel meat	500 g
Black gram dhal	500 g
Red chilly	75 g
Coriander	50 g
Asafoetida	5 g
Refined salt	To taste

The dried mussel meat is roasted in a frying pan without adding oil until it is golden brown in color. All the other ingredients are also roasted separately in the same way. The ingredients, except refined salt, are then ground to a moderately fine powder. Salt is added to taste and mixed thoroughly. Allow to cool, and store in dry, airtight glass bottles or polythene covers.

Mussel meat pickle

Mussels of smaller size are usually used for the preparation of pickles. Bigger ones are cut into two.

Recipe

Mussel meat (blanched & cleaned)	1000 g
Green chilly	50 g
Ginger (skinned & grated)	100 g
Garlic	100 g
Red chilly (powdered)	50 g
Turmeric (powdered)	5 g
Mustard (ground)	25 g
Curry leaves	10 g
Refined salt	100 g
Gingelly oil	300 ml
Vinegar (1.5 % acetic acid)	600 ml

The mussels are fried in gingelly oil till golden brown in color. This is kept aside. Garlic, ginger, green chilly and curry leaves (cut into small pieces) are fried in the oil, drained and kept aside. Red chilly powder, turmeric powder and ground mustard are warmed in the same frying pan. All these ingredients are then mixed thoroughly and allowed to cool. When cold, add refined salt (to taste) and vinegar, and again mixed thoroughly and set aside for two days for maturation.

Washed and dried glass bottles are rinsed with a small quantity of vinegar and the pickle transferred into them. Care must be taken to see that air bubbles are excluded. Add a thin layer of warmed gingelly oil above the pickle and secure with an airtight stopper.

Condiment-incorporated fried mussel meat

This is a very tasty convenience product. It keeps well for a reasonably long duration while retaining the taste and texture. Two permitted food preservatives are used for its preparation. Air and vacuum packing are possible; vacuum packing provides better storage life.

Mussel meat is fried to a golden brown color. Condiments like chilly powder, turmeric powder, salt, pepper powder, and, the preservatives, Calcium propionate and Sorbic acid, are added in the permitted level.

Recipe

Fried mussel meat	1000 g
Red chilly powder	30 g
Turmeric powder	2 g
Pepper powder	2 g
Coriander powder	7.5 g
Refined salt	20 g
Calcium propionate	3 g
Sorbic acid	2 g

The condiments are warmed in a frying pan over a low flame. The mussel meat, which has already been fried and set aside, is added to the warmed condiment mixture and thoroughly mixed. Allow to cool down and pack in polythene covers. The product keeps good for three months. This product is easy to develop, has a good shelf life, can be stored at room temperature and is very convenient for use. Moreover the product does not require any sophisticated method or machinery.

Slightly modified method has since been developed for the preparation of vacuum packed ready-to-eat, fried mussel meat. The shell-on mussels are washed thoroughly in potable water chlorinated to a level of 2 ppm. They are heated in a steam chamber and the meat shucked out. The mussel meat is cleaned by removing the intestinal cavity and washed. The meat is then fried using refined groundnut oil in an electric fryer for 6 minutes. The temperature for frying is maintained between 170 -180 C. The material is cooled and kept aside. The condiments are slightly warmed and mixed thoroughly with the fried mussel meat and kept overnight for equilibration of moisture. The fried meat is then packed in 12 plain polyester laminated with 118 LD-HD co-extruded pouches (size: 12 cm x 15 cm).

The vacuum packed fried product keeps well for 9 months.

The proximate composition (%) of fresh and fried mussel meat

Parameter	Fresh meat	Fried meat
Moisture	76.69	5.25
Fat	2.57	38.86
Protein	12.55	43.20
Ash	2.06	4.60

Diseases / Poisoning

Mussels are said to be harmful when consumed during periods of red tide. This mainly occurs when dinoflagellates bloom, excrete and die off. These algae produce a neurotoxin, which finds its way into the mussels. When human beings consume the contaminated mussel meat, they become affected by paralytic shellfish poisoning.

POST-HARVEST FLOWCHART