Onshore (Land Based) Culture of Pearl Oysters for Pearl Production

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Marine pearls are precious and are the most attractive objects of adoration. Pearls are most revered biological products from time immemorial. Pearls have been extolled as a metaphor of life for virtue, love, wisdom and justice, spirituality and righteousness. The occurrence and use of pearls have a history more ancient and more fascinating than any other precious objects. Pearls occupy a pride of place in one of the most ritually important events in most of the famous temples in India. They are the symbol of bliss. So, much so, humans clamour to wear as big pearls as possible, conquered by the appeal of their universal ornamental value. Pearls and pearl shells have long been highly prized. The shell has been used for a wide range of decorative purposes in many countries. Good quality natural pearls are rare and are therefore extremely valuable. Thus pearl culture and cultured pearls gained popularity. As on today there is no commercial pearl production (either freshwater or marine) in India, and marketed freshwater pearls are from China.

The Chinese were producing pearl images of Buddha by the 12th century by attaching carved images onto the valves of freshwater mussel, like half pearls of today. It is reported that W.Saville-Kent produced the first spherical pearls in 1890 from *Pinctada maxima*. K.Mikimoto had received a patent for the production of half pearls in 1896 and quickly dominated the round pearl culture technology (Gervis and Sims,1992). Thus technology of marine pearl production is more than a century old and well established in different parts of the world, with several local adaptations depending on the local environment. The sea based pearl culture which is a currently practised system uses rafts, rens, long lines, baskets etc. In all these systems the spat produced by hatchery/collected from the sea are reared in suitable density and grown to implantation (seeding) size. They are implanted with suitable beads and further reared for nacre formation and pearls harvested after suitable time depending, on size of the beads. In the entire process, the major input is cleaning process, apart from seeding. The pearl oysters are prone to attacks by heavy fouling borers and predation attack by them, as they lead a sedentary life in the sea and sea farms. The older oysters have the tendency of increased gaping of valves and are prone to attack by crustaceans and fishes. Heavy settlement of foulers and borers requires frequent cleaning, otherwise the situation may lead to slow growth and mortality. Thus the process of cleaning, to avoid foulers and borers apart from vessel maintenance, occupies major recurring expenditure in the sea based oyster culture.

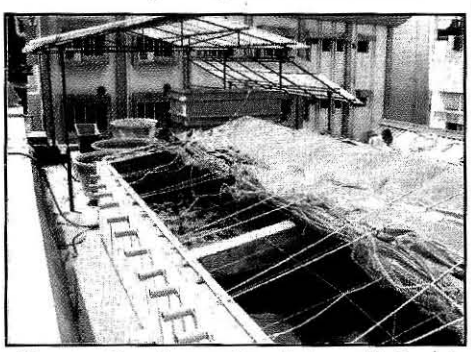

Fig 1: On-shore (land based) Pearl culture tank

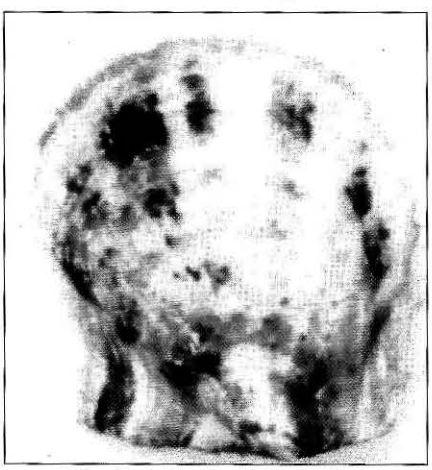

Fig 2: *Pinctada maxima*

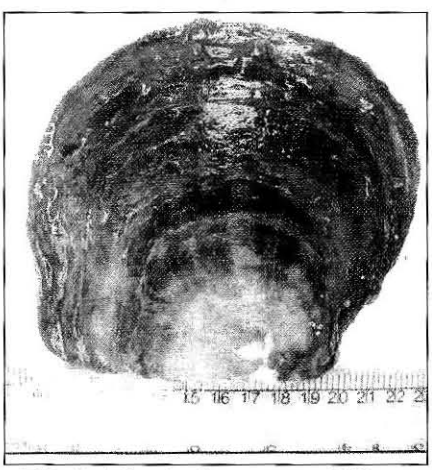

Fig 3: *Pinctada margaritifera*

Pearl Oysters

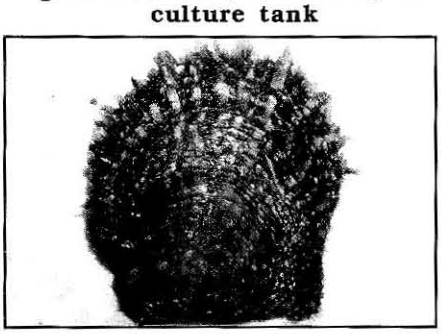

Fig 4: *Pinctada fucata*

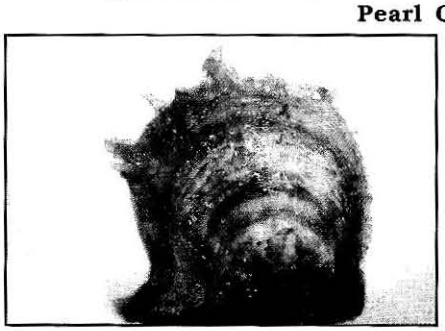

Fig 5: *Pinctada chemnitzi*

Pearl Oysters

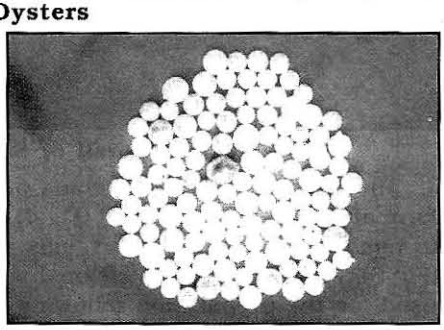

Fig 6: Pearls (6-9 mm) produced under onshore technology

The pearl production event starts with the insertion of suitable bead along with a mantle graft from donor oyster. The mantle tissue starts to spread around the nucleus in a cup shape. After three days, a degenerative process takes place in the inner epidermis and the mesoderm tissue, leaving the outer epidermis to complete the pearl sac by itself. This completely envelopes the nucleus and nacreous layer starts laying from about 6 weeks after implantation.

There are only 3 species of pearl oysters in the world that are capable of producing gem quality pearls. They are *Pinctada maxima*, *Pinctada margaritifera* and *Pinctada fucata* in the order of pearl value and importance in the world trade. In India two species viz. *P.margaritifera* and *P.fucata* are recorded but pearl production was achieved only in *P.fucata*. However, *Pinctada maxima* isolated as spat are being successfully reared in the mariculture lab of Visakhapatnam Regional Centre of CMFRI. India is yet to attain the status of a commercial pearl producing country, in spite of resources. Countries like Japan are endowed with sheltered bays which are highly suitable for placing floating rafts for pearl culture securely through all seasons. Though India is endowed with long coastline, suitable locations for pearl culture in the sea are very limited and hence enough interest is not shown by the entrepreneurs, in pearl culture, as it is seen as a risky sea based activity.

On shore (land based) pearl production technique was developed to overcome many of the problems in the sea based culture relevant to Indian conditions (Syda Rao 2001). It has been further refined, standardised and upgraded.

The technology of onshore (land based) pearl culture developed by CMFRI has been provisionally patented, with priority date 21.4.2001. The salient features of the technology are summarized here.

The Onshore (land based) Technology

For any culture operations Brood stock is very important and a vital component for the successful production of end product. As on today there is no systematic broodstock developmental approach in pearl culture operations as there is no shortage of brooders. These are available from natural source/ beds. The practice followed in all countries is that mature specimens are collected from the sea, either wild or farm grown and they are subjected to spawning in the hatchery. A look at the literature shows that the pearl oysters, irrespective of species have two peaks of maturation, one around April and other around October, in almost all the countries. Thus we are heavily dependent on sea and season for producing pearl oyster spat. To overcome this problem, captive broodstock technique was developed as a part of onshore pearl culture technology (Syda Rao 2003). In this, the pearl oysters are kept in fully mature condition round the year and can be subjected to spawning at any required time as suitable. Several spawnings were successfully induced round the year in the past few years at the facility developed at Visakhapatnam Regional Centre of CMFRI within the prevailing environmental conditions i.e, salinity 16-37ppt, and temperature 18-32° C. After inducing the pearl oyster to spawn, the spat are produced by following the procedure/technique developed and perfected byAlagaraswami *et al.*, (1983). The rate of spat production depends on water quality and environmental conditions. However, the spat production under hatchery conditions is never a constraint/limiting factor, once proper water quality standards are strictly followed. After the settlement of spat and until they reach 5 mm Dorso Ventral Measurement (DVM) they are considered as a hatchery component. The hatchery techniques for all commercially important pearl oyster species are well developed and standardized.

The grow out phase starts from 5 mm. The oyster spat are distributed in outdoor tanks and they get attached to hard substratum/natural stones. Specially designed tanks (cement concrete) are constructed for this purpose. The tanks are constructed in two rows at a height of 120 cm at the edge and 150 cm at the centre. They are provided with proper seawater, freshwater and drainage facility. Also all tanks are provided with aeration facility. The depth of seawater in the tanks is maintained at 1m level, and a minimum of 10% of seawater is exchanged daily in all grow out tanks. The oyster spat are kept on the bottom of tanks attached with suitable substratum or natural stones. The pearl oysters of over three years of age do not attach but just lead sedentary life. The density of pearl oysters vary from 5000 nos/ m^2 (5 mm) to 50 nos/ m^2 (>75mm) depending on size. The pearl oysters are thinned at regular intervals as growth progresses.

The semi filtered sea water is used to replace the water at the rate of 10 % every day. However total replacement of seawater is essential at a frequency of 10 days.

The technique of mass algal (Phytoplankton) culture at negligible cost is also developed as part of onshore pearl production technology. Here the normal protocol of maintaining stock culture and tier system is followed and F_2 medium is used. However at the final feeding stage (10 to 15 t tanks) the techniques of monoculture of algal production are standardized without using any medium. This will facilitate the production of algae at negligible expense, thus minimizing the cost, one of the most critical, recurring component. This will prevent the passing of residual chemicals from algae to pearl oysters. Only slow sand filtered water is used for entire algal production without chlorination or usage of antibiotics.

The pearl oysters are fed with a mixed diet of 3 species viz., *Chaetoceros calcitrans*, *Isochrysis galbana* and *Nanochloropsis salina* at a ratio of 50:30:20 by a specially designed drip method, so that the algal cell concentration in the tanks is continuously and automatically maintained at a rate from 10,000 cells/ml to 80,000 cells/ml, from spat to adult stages. It is a very simple, dynamic and auto system which provides the desired feed at desired densities suitable to the size of the oysters at varying densities. This is the major component in onshore land

based system and has to be dealt with proper attention. Any negligence or tampering with this will be disastrous to pearl oysters.

Normally growth is fast under onshore conditions as compared to sea based culture, due to continuous availability of feed at required levels. The growth range achieved by *P.fucata* at Visakhapatnam Regional Centre's tanks are indicated hereunder. They attain a DVM of about 70 to 80 mm in 15-18 months which makes it possible to implant the oysters with 6-8 mm nuclear beads. A record growth of *P.fucata* of above 100 mm and 100 grams was achieved under onshore system in 36 months. The largest *P.fucata* recorded in India from the natural beds of Gulf of Mannar is 75mm and 80 gm weight in about 72 months, whereas the largest recorded from Gulf of Kutch is 86 mm with an estimated age of about 84 months (Rao and Rao 1975). It is also pertinent to mention here that the growth rate of pearl oysters will never be uniform but about 60-75% of the stock at the end of grow out period are suitable for implantation. The rest are stunted in growth, due to inherent reasons and may not deserve further rearing. In fact, it is suggested to cull out the very slow growing population at regular intervals, to make the system more efficient. As the production of spat is not at all a limiting factor, culling will not affect economics; on the other hand it increases the efficiency.

As the pearl oysters reach suitable size after 360 days, the implantation can be initiated at this stage. Suitable oysters are implanted with 6-8 mm on a daily basis and maintained in separate tanks with suitable identification marks for tanks. As the implantation progresses, the oysters left behind will grow further and become eligible for implantation. The Indian pearl oyster *Pinctada fucata* is being grown to seventh year in the Visakhapatnam Regional Centre's facility. About 25% of oysters can be implanted upto three times. At every successive implantation the size of pearl will increase. Thus the posession of a large proportion of aged population has lot of economic importance in the pearl culture, particularly in land based system. Thus the implantation and harvest is a continuous process throughout the year. If the pearl oysters are in a mature condition, they are induced to spawn one month before implantation. This will ensure better stability of inserted beads. The post implantation period is not much different, except for looking for mortalities. There may be few cases of mortality, during the first 7 to 10 days of implantation. There should be daily check for dead specimens which have to be removed immediately to maintain standard water quality. Mortalities after about 7 to 10 day are negligible.

The bead rejections start after 48 hours and continue till 40 days. It is better to remove the rejected pearl oyster, if identified to separate tanks, so that they can be re implanted after the wound is healed in course of time.

The pearl oysters after implantation are maintained in a similar way till their harvest. After about 3-4 months of implantation period the pearl oysters can be screened for bead retention either by X- ray or scanning. The bead bearing oysters can be segregated while the rest can be re-implanted after their wound is totally healed. By following this simple technique the rate of pearl harvesting can be substantially enhanced.

While harvesting a pearl, it can be removed by scratching the gonad gently without damaging/killing oysters. This enables the replanting of the oysters after 3 or 4 months, thus increasing the yield. The process of seeding and harvesting pearls is a continuous daily process. The entire process is simple and dynamic and requires proper understanding, devotion and discipline to achieve good results. Under normal conditions the pearl production can be upto 30%. Among them good quality pearls may be around 15-20%. The hygienic conditions at the time of implantation and post operative culture are very important for the formation of good quality pearls. As the pearl sac formation will be completed in six weeks (Michil 1968, Masahiko and Suzuki 1995), the hygiene of tanks during that period is also very critical for maintaining of quality standards of pearls.

There are several inherent advantages of onshore system particularly in the Indian context. This system is highly suitable for other species also, particularly *Pinctada maxima*.

As the seawater used in land based culture is semi- filtered the menace of foulers and borers is negligible. The pearl oysters need to be gently brushed once in a month or so which is a very easy process and economic burden is negligible. In the sea the fouling is so heavy that in a matter of days the entire surface of oysters get encrusted, leading to slow growth and mortality. Cleaning costs account for almost 80% of the budget of the pearl culture operations. Since the oysters are in protected tanks, the entry of predatory organisms is totally avoided. It is reported that in Australia the mortality of larger *P.maxima* is regular apparently with a certain frequency, (Stephanic *et al.* 1994). It is grown in depth of above 20-25m, where the feed is low leading to mortalities. Such species may thrive well with least mortalities under onshore conditions. Since it is the most valuable species and highly priced pearls of above 12 mm are produced, onshore system will enhance its high economic viability, by reducing cleaning operation cost, mortality and imparting fast growth. Preliminary experiments indicate that *P.maxima* survival and growth are higher in onshore system.

In the land based system, feed is continuously made available to pearl oysters in required concentration, a pre requisite for bivalves. Consequently growth is faster and mortalities are low. The experience at Visakhapatnam Regional Centre facility for the last four years reveals that the rate of mortality from a spat to implantation size is less than 10%. The rate of mortality in the post implantation period is another 10%. Thus the survival of 80% has become a reality. The rejections are suitably compensated with re-implantations. Thus effectively 40% pearl production can be realized.

In the entire operation of several components of onshore culture, the usage of chemicals and antibiotics

are totally prohibited. At no stage bleaching powder or chemicals are used for any purpose. The chemicals for Guillard's F_2 medium are of fertilizer value and they are also not used at final feeding stage. The faecal matter, a pollutant in tank system, is daily siphoned out from the tanks. Only soap or detergents are used for cleaning of glassware/tanks. Thus the entire set of operations are eco-friendly and this may not cause problem to the system on a long term basis as witnessed in some other pond culture systems. It is reported that in the sea based system, the accumulation of faecal matter at the bottom of the sea in the culture sites caused water quality problems and affected the quality of pearls, as in Japan.

Apart from round pearls, half pearls, Mabé (image) pearls and "Kesi" (tissue) pearls also can be produced at the fag end of their life. Since the oysters have to be killed to extract the former two varieties of pearls, they are only secondary products particularly in marine system.

Diversification under Indian Scenario

In India the research activities are entirely concentrated on *Pinctada fucata*.This can produce pearls only to a maximum size of 10 mm. However in other parts of world more thrust is given to other species in view of pearls of higher value that can be produced from oysters like *P. maxima* and *P.margaritifera*. China is producing marine pearls from all species apart from huge quantities of several varities of freshwater pearls. These dominate the world market.

P.maxima : *Pinctada maxima* (Jameson 1901) are the biggest of all pearl oyster species. It is externally distinguished by its light fawn colour and has no traces of radial markings. The nacre has a clear, rich luster which at the distal border has a golden or silver band of varying width. This gives the species its common name of golden or silver-lip pearl oyster. *P.maxima* has no hinge teeth. The growth processes are slightly convoluted and two or three times wider distally than proximally. It can grow up to 300 mm "diameter" and attains a weight of about 6 kg.It is a protandrous hermaphrodite, maturing as males after first year. Females will appear after 2 years, and 1:1 sex ratio will be reached after 3 years. This species is distributed in the central Indo-Pacific from Myanmar to Solomon Islands. Australia and Indonesia are the leading countries in its culture apart from Myanmar, Thailand, Philippines and Japan. This species produces the most lustrous "golden or silver" south sea pearls from 12 to 20mm, (starting from the age of 2years/120mm) fetching dream value in the international markets. The world production of south sea pearls is very limited. Establishing a pearl farm of *P.maxima* takes more than seven years to reach full production status, certainly most lucrative of all pearl culture activities. In India few specimens of this species are reared in the mariculture facility of CMFRI, Visakhapatnam.

P.margaritifera: *Pinctada margaritifera* (Linnaeus) 1758, commonly called the black-lip pearl oyster is distinguished by black colouration to the outer surface of the shell and non nacreous border. The external shell often shows lighter striations radiating from umbo.The silvery nacre inside the shell becomes black towards the distal rim, hence the name black-lip pearl oyster. The anterior border of the shell extends far in advance of the anterior lobe. It can attain a maximum size of 30 cm "diameter" and weight of about 9kg.The life expectancy of *P.margaritifera* is up to 30 years. This species also tolerates wide salinity range of 18-36 ppt and a temperature of 18-32°C temperature. The distribution of *P.margaritifera* is wide and ranges from the Gulf of California, Mexico to eastern Mediterranean Sea, but has very high abundance in the atoll lagoons of eastern Polynesia from Taumotu Gambier archipelago of French Polynesia to the northern group of the Cook Islands. In India very limited population of *P.margaritifera* is available around Andaman & Nicobar Isalands. In the seas of mainland India it is sporadically reported from both the coasts. Few numbers of this species are being reared in the mariculture facility of Regional Centre of CMFRI, Visakhapatnam under land based system. In south Pacific Islands where it is extensively cultured, an underwater structure called "trestle" culture system is followed to hang the black pearl oysters at the bottom of highly protected shallow waters/ lagoons. In these areas sub-surface long line system is also practised. This species produces (Tahitian) black pearls of 8 to 16mm after attaining 18 months and above age. The spat production techniques are standardized for this species also like other species. Black pearls rank number two in the global pearl production. In India efforts are being made to produce black pearls by CMFRI in A&N Islands.*P.margaritifera* also offers good scope for land based system in India.

P.chemnitzi : *Pinctada chemnitzi* (Philippi 1849) is another important pearl oyster species which is hardy and attains good size, tolerating wide salinity, temperature and turbid conditions. It is distributed in Australia, China and India. Not many studies were conducted in view of limited culture potential related to poor quality of pearls. This species is widely available along both of coasts of India. It is being successfully cultured under onshore conditions in view of its excellent potential for training for implanting larger beads. Few very small pearls produced showed good golden colouration. After one year (70-80mm) under land based system about 25% are eligible for implantation with 5-8 mm beads. Hatchery seed production was successfully accomplished in China by following the same techniques like other species.

Marketing

Marketing is a major component of pearl culture and has some special features unlike other products. In general no two pearls are exact in quality and thus the quality standards are some what subjective, and depend on several other factors including the experience in pearl trading. In general there is no direct marketing of produce from farmer to wholesale market. All marketing is through agents/agencies/middlemen who may share the profit. The price is also highly variable. In India, since

there is no commercial production/ active trading, there is absolutely no information on pricing/marketing of marine pearls. All international marketing is through auctions, in which only authorized agency/ agencies can participate. All pearls are put to auction in assorted condition and no grading or value addition is generally undertaken as such at farmer level, as the value addition is done by marketing agencies. Although the percentage composition of good quality pearls will fetch better market, pearls of all grades are accepted. In general about 30% of pearls harvested are of the best quality and have excellent value(In land based facility it is much more),40% reject pearls are used in pharmaceutical industry and 30% misshaped, and half coated etc are marketed for various pieces of jewelry. The parameters that decide the quality of pearls are: shape, luster, colour, size and surface texture. In the pearl producing countries like Japan, Australia, Indonesia, Myanmar, South Pacific Islands, etc., the farmers have ties up with the agencies for marketing. It may not be appropriate to calculate the economic returns based on the retail market prices; as they might have under gone lot of suitable changes after leaving the farms. Apart from pearls, pearl oyster meat and shells of *Pinctada margaritifera* and of *P.maxima* fetch good price, in international market. In Sudan *P.margaritifera* is cultured solely for shell purpose.

Economics

The economic performance of land based system at Visakhapatnam is worked out by calculating the cost and returns, productivity measures and financial feasibility indicators. These results are based on critical study by the author along with Dr.R.Narayanakumar, an economist in CMFRI, an account of which is being published elsewhere.

The cost of operation or production includes both annual fixed costs and annual variable costs. The annual fixed cost includes depreciation, interest on fixed capital, insurance and taxes and administrative expenses. The annual fixed cost worked out to Rs.44, 05,000. The operating cost (also known as variable costs) was calculated for each operation including the growth phase and seeding phase. The entire operation was for 24 months. The pearl production was expected at the end of 24th month. The cost analysis for an onshore pearl culture of 2.5 ha with waterspread area of 4,000 m^2, taking into consideration the cost of beads, appropriate wages, interest rates, yields over long run and all other costs is given briefly in the following paragraphs.

The operational costs were estimated for a period of 10 years. The average annual operating cost worked out to Rs.32, 03,068. The average annual fixed cost worked out to Rs.44, 50,000 and thus the average total cost of production per annum worked out to Rs.76, 53,068. The gross revenue from the pearl production is estimated based on an annual production of 27,000 gms at a rate of Rs 400/gm. The production is increased from the fourth year onwards at the rate of one per cent till the 8th year where it becomes standardized. Thus, with an annual average gross return of Rs.108,00,000, the annual net profit worked out to Rs.23, 94,108. It is important to note that the actual return from the production process is expected after 24 months i.e., after two years only. Hence the net profit is negative for the first two years.

The ratio analysis indicated that 60 per cent of the earnings on an average take care of the fixed (26%) and operating cost (34%), thus leaving 40 per cent as annual average net profit. The break-even production is estimated at 15,816 pearls per annum and the break-even price is estimated at Rs.283 per gram. These results indicate that if the production or price is below these levels, it is not economically and financially viable to operate the system. However, in this production system, the current level of production and price is well above average levels.

The financial feasibility analysis indicated was worked out by estimating the pay backperiod, rate of return to capital, Net Present Worth (NPW), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) based on certain assumptions. It was found that the pay back period was 7.9 years and the rate of return to capital was 12.60 per cent.

The Net Present Worth was estimated Rs.30, 68,150 at 20 per cent discount rate, which is a good indicator for financial feasibility.

The Benefit-Cost Ratio is 1.11 at 20 per cent discount rate. The Internal Rate of Return is worked out at 29.59 per cent, which is higher than the assumed required rate of return i.e., 20 per cent. In total, the project is financially feasible subject to the assumptions made in the study.

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