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Cold-anaesthetization and Live Transportation of Penaeid Shrimps

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A review of present practices followed in live transportation of cold-anaesthetised penaeid shrimps is attempted in this paper. Live transportation is used as a means to enhance the unit value of the marketed shrimp. Japanese Kuruma shrimp *Penaeus japonicus* has been found amenable to this practice. Several countries such as Taiwan, Korea, China and recently Australia established a sizeable market for Kuruma shrimp transported alive to Japan, after cold-anaesthetisation. Research on live transportation of other shrimp species such as *Penaeus monodon* has shown encouraging result.

Key words: Live transportation, cold anaesthetization, shrimp, *Penaeus japonicus*

Live transportation has become one of the most significant practices in the shrimp industry that constantly endeavours to find ways to enhance the final product value. Much research has gone into increasing the marketability of cultured and wild captured shrimp and transporting them live in order to preserve the maximum freshness. This is important, since one of the most favoured destinations of shrimp in the world is Japan where the per capita consumption of fresh seafood is very high. Live shrimp restaurants with ready-to-cook fresh live shrimp are a common sight in Japan. Japanese Kuruma shrimp *Penaeus japonicus* is traditionally transported in live condition.

Raw shrimp has long been appreciated as a delicacy in Japan, the dish being known as *odori ebi* meaning moving shrimp, prepared from fresh live shrimp (Ovenden & Kriz, 1993). Quality of the food prepared from crustaceans is highly dependent on their freshness because of the rapid autolysis that starts immediately after death. The Kuruma shrimp with prime quality has a transparent pale grey coloured body with distinct maroon or brown stripes and a blue tail tinged with yellow. The bands are also very distinctive when cooked, turning from maroon to bright red with fleshy parts turning white. The product should be free from pine smell from the sawdust used for packaging or fishy odour, but should have a mild to sweet flavour (Kriz, 1994).

The present review summarizes the prevailing practices of live transportation as a means for increasing the acceptability of the harvested shrimps. The conditions of live packing for different species and the packing media have also been covered.

Principles of live transportation

The basic principle behind the technology of live transportation is temperature-induced cold anaesthetization. The water temperature is brought down to a limit at which the metabolic rate of the animal is reduced to a minimum, so that its storage and transport in this condition does not effect any apparent increase in metabolic rate. The movements of the cold-anaesthetised shrimp are minimum, there is no stress caused by vibrations, noise and light; weight loss is usually negligible, and the animals produce no excreta because there is no feed intake and metabolism (Schoemaker, 1991). The shrimps are conditioned for a period of

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time before cold-anaesthetization by starvation, which facilitates effective lowering of metabolic rate at low temperature. Immobilized shrimps are then layered densely using a suitable packing medium such as chilled sawdust. On arrival at the destination, the water temperature is gradually raised to the ambient level, so as to revitalize the shrimp from the anaesthetised state. This ensures maximum freshness of the harvested produce up to the point of final sale.

Live transportation of Kuruma shrimp

Live transportation practices have so far been commercially successful only in the case of Kuruma shrimp *P. japonicus*, fetching it very high prices in the Japanese market. Live shipment technology was perfected in Japan way back in the 1960s where wild or cultured Kuruma shrimp, packed in chilled sawdust, were airlifted live to market, in a cold-anaesthetised state (Shigueno, 1992). Earlier reports on live transportation of *P. japonicus* (Noda, 1973; Shigueno, 1975; 1979; Korringa, 1976; Imai, 1977) have provided similar accounts of the various practices in vogue in Japan. Shigueno (1979) reported that *P. japonicus* could tolerate extremely low temperatures and hence low temperature storage and transportation in live condition was convenient.

The cultured shrimps are made to moult at a rapid rate by changing the water quality and diet. Shrimp with hard shells at the inter-moult stage are harvested for packing. Harvesting is usually done using a pound net, pump or electric fishing system, which causes minimum stress during capture. The harvested shrimp are immediately transferred to a net basket or a net tray, which are then placed in aerated cold water tanks with refrigeration coils on the inner wall. The water is then cooled down to a temperature of 12–14°C, over a period of at least 8 h, which makes the shrimp inactive except for movement of their walking legs and pleopods. During mid-summer, the tank water is first cooled down to about 8°C lower than that of the pond water. This is to prevent moulting and to acclimatize the shrimp gradually to the low temperature, which is not necessary in winter. The cold anaesthetized shrimp, which are well tamed and easily handled, are sorted according to size, and weighed in baskets in lots of 2.5–3.0 kg. Packing medium used is sawdust, which is first sun dried and then kept in cold storage at –10°C, in polyethylene or hemp bags. Corrugated hardboard boxes lined with PVC or styrofoam are used for packing. A layer of chilled sawdust is spread on the bottom of the box, followed by a layer of shrimp, which is covered by another layer of sawdust. Three or four alternate layers of shrimp and sawdust are thus placed in the box. The full and tightly packed cartons are then sealed by cellophane tape and stored at 5–10°C in the cold room.

The major countries exporting live *P. japonicus* to Japan are Taiwan, Australia, Korea and China. In 1990, Taiwan monopolized the live shrimp export market to Japan (94%) followed by Korea (4%) and China (2%). However, the outbreak of virus disease in Taiwan and China drastically reduced the production in these countries. During 1990–1993, there was a decline of over 80% in the import of live shrimp from Taiwan. The contributions from other countries also declined in 1993, when Korea exported 1.4%, China 1.15% and Hong Kong 0.2% of the total market size. Recently, Australia succeeded in live shrimp transportation to Japan by exporting sizeable quantities of *P. japonicus* (Anon, 1991; Ovenden, 1993). Japan imported 402 t of live Kuruma shrimp in 1995, Australia being the biggest supplier (Rosenberry, 1996).

Taiwan and Australia employ almost similar technologies for cold-anaesthetisation and live packing of *P. japonicus* as in Japan, except minor variation in the anaesthetizing temperature and the chilling rates. In Taiwan, the temperature of the chilling trough in which the conditioned shrimp in net baskets are kept is lowered by 7-8°C over a period of 4 h depending on the pond water temperature. During winter, the temperature is lowered from 18°C to 11°C and during other periods, from 25°C to 17°C (Chen, 1990). The packing room temperature is maintained at 10–20°C. One kilogram of shrimp is packed in each box. During summer, a 5 mm thick bag of frozen wet sawdust about the same size of the bottom of the box is placed above the shrimp in each box. The shrimp survive for about 30 h in the insulated boxes.

In Australia, the survival of *P. japonicus* was found to be highest when the shrimps were transported at temperature between 12 and 15°C, but survival improved at 10°C as winter approached (Goodrick *et al.*, 1993). Survival rates in excess of 95% were commercially viable as the product fetched premium prices on arrival at the Japanese markets. In Korea, packing of live *P. japonicus* is done inside a cold room of 10-15°C, and the temperature inside the sawdust box is kept at 15°C (Gil Rho, 1990). Ferdouse (1992) noted that the Kuruma shrimp once destined for Japan alone, was selling at a higher price in local markets of Korea. It was reported that one has to pay a very high price for shrimp in Korea, where the per capita seafood consumption was as high as 47 kg. Similar is the case with Taiwan which exported only 18% of the total harvested *P. japonicus* to Japan, during 1991, and a major share of the rest was sold live in local markets (Chen, 1990). Apart from Japan, Singapore also remained a lucrative market for high value live and fresh shrimp for the neighbouring countries.

Live transportation of other shrimp species

The commercial success of live shipment of farmed *P. japonicus* apparently inspired researchers to try these techniques on other species of farmed and wild-caught shrimps. Encouraging results have been obtained in Australia where species such as *P. monodon*, *P. esculentus*, *P. semisulcatus* and *P. plebijus* were transported in live condition on trial basis (Goodrick *et al.*, 1995). Farmed *P. monodon*, which were cooled at a rate of 3°C per hour to 12°C and packed in chilled sawdust survived for about 24 h. However, the survival of farmed *P. monodon* was slightly better at 16°C than at 12°C. In Australia, *P. monodon* farms form the mainstay of the shrimp culture industry. However, with the insatiable demand in Japan for live *P. japonicus*, intensive *P. japonicus* farms are also seen to flourish. Research in Australia on live transportation is mainly aimed at catering to the Japanese markets. The wild brown tiger shrimp, *P. esculentus*, abundantly obtained from trawl catches, have maroon or brown stripes like Kuruma shrimp and were favoured for their attractive appearance. However, they are not normally cultured in Australia, unlike the Kuruma shrimp, which though uncommon in Australian waters, are grown in ponds and exported live to Japan.

Goodrick *et al.* (1995) suggested that taking advantage of the similarity of the brown tiger shrimp with the Kuruma shrimp, a live market for the former could be developed using shrimp from the capture fishery. When wild *P. esculentus* that had apparently recovered from the stress due to capture were tested, they survived for 12-18 h, after being cooled at the rate of 3°C per hour, and packed in chilled sawdust at 12°C. Wild caught *P. semisulcatus* also showed a similar response. These results did not favour commercial trials, since survival for at least 24 h is required for overseas marketing from Australia. Further, farmed *P. esculentus* did not survive in sawdust as long as *P. monodon* caught at the same farm, though the result was confounded by evidence that the brown tiger shrimp at the farm were in poor condition. Goodrick *et al.* (1995) also reported that the observation while handling *P. esculentus* at 12°C indicated that this temperature might be too cold. Therefore, they suggested that the survival of *P. esculentus* might be slightly extended by maintaining higher temperatures (about 15°C) rather than the 12°C routinely used for shipping Kuruma shrimp, though there are doubts that this temperature would immobilize the brown tiger shrimp. It may be noted that as reported by Paterson (1993), the Kuruma shrimp experience no metabolic stress when held in sawdust at 12°C.

Experiments conducted at the Fisheries College, Cochin revealed that 14±1°C is the optimum temperature at which farmed *P. monodon* could be cold-anaesthetized for live storage in chilled sawdust (Salin, 1997). Of the three chilling rates tested, the moderate chilling rate (2.76±0.32°C), which took 4 h to effect cold-anaesthetization, was found to be the optimum, though the choice of different chilling rates depended on the duration of live storage desired. A statistically valid safe duration (for obtaining 100% survival) of 22.9±1.09 h was obtained by employing a chilling rate of 1.38±0.16°C which took 8 h for cold-anaesthetization. This clearly shows that *P. monodon* could be safely kept live under cold storage in chilled sawdust for up to 24 h, signifying its potential for live transportation.

Huq *et al.* (1991) suggested that simulated hibernation of *P. monodon* of marketable size could be done at about 8°C, both in summer and winter. Huq *et al.* (1994) conducted simulated hibernation experiments using 5 month old *P. mondon* and found that dormant shrimp kept in chilled sawdust with 5% moisture and guarded by 2 outer layers of relatively colder, frozen sawdust with 10% and 15% moisture in an insulated box could be kept under hibernation with survival rates of 100, 86, 70 and 60.5% after 12, 18, 24 and 27 h, respectively.

In Taiwan, the red tail shrimp *P. penicillatus* was subjected to cold-anaesthetization studies. However, it did not survive out of water and was not found suitable for live transport (Liao & Chien, 1990).

The white-legged shrimp *P. vannamei*, one of the major species of cultured shrimps in Central and South America, has been tested for live transportation in South Carolina, USA (Jiang *et al.*, 1995). After acclimatisation from 27°C, the shrimps were packed in boxes with absorbent paper as the medium, and kept in a refrigerated chamber at 14°C. The mean survival after shipment/storage was found to be inversely related to the rate of chilling: i.e., chilling rates of 1-2°C, 3-4°C and 5-6°C per hour resulted in average survival rates of 86.4, 77.6 and 56% respectively. The shrimp revived almost completely when reacclimatized from 14°C to 27°C at the rate of 3-4°C per hour. It was also found that an initial increase or decrease in temperature of up to 7°C for acclimatisation had no adverse effect on survival.

Although several species of shrimps have been tried and found successful for live transportation, there has not yet been a ready market available for any of these species, unlike that for *P. japonicus*. The consumer preference is unique for *P. japonicus* in Japan and shrimps having similar appearance such as *P. esculentus*, need to be further tried to substitute *P. japonicus* in the live shrimp market.

Packing media

Sawdust seems to be the most common material used as packing medium in commercial live transport of shrimps. In Japan, coarse sawdust of Cedar tree *Cryptomeria japonica* locally called *Sugi* is usually used (Korringa, 1976). The sawdust used should be low in resin, untreated and pesticide-free. One of the characteristic features of sawdust is that it is a poor conductor of heat, light in weight and since it contains minute air spaces, respiration of the shrimp, though minimum, is unaffected (Imai, 1977). However, the sawdust sometimes removes the water remaining in the gills or on the body of the shrimp during transit and leads to dehydration of the packed animals. Therefore, other packing materials have also been investigated.

Imai (1977) described a commercial product called *parite* which when moistened remained cold for a longer time and was about 30% lighter than sawdust, giving better survival rates of packed animals than sawdust, but more expensive. Schoemaker (1991) suggested the substitution of sawdust with algae or seaweeds with the added advantage that algae also humidified the packed shrimps. Huq *et al.* (1994) found sawdust to be the best packing medium when compared to rice husk and wheat bran. Jiang *et al.* (1995) used absorbent paper as the medium for packing cold-anaesthetized *P. vannamei*. Packing the cold anaesthetized shrimps in an ambience of oxygen was also investigated. Imai (1977) reported that the sawdust packs without oxygen were more economical in terms of the better survival rates obtained, than when the sawdust packs were kept airtight in boxes filled with oxygen. Jiang *et al.* (1995) however, reported that packing of *P. vannamei* after cold-treatment in pure oxygen markedly improved survival when compared to that in air. Oxygen also appeared to increase resistance of the shrimps to lower temperature.

Critical biological criteria have to be fulfilled while shipping cold-anaesthetized live crustaceans (Richards-Rajadurai, 1989). The condition of the animal before shipping, maintenance of low storage temperature, maintenance of appropriate humidity and prevention of stress and drying are very important.

Cultured shrimp and live transportation

Aquaculture products enjoy distinct advantages over capture fisheries as far as live marketing is concerned (Subasinghe, 1996). Harvesting could be suitably timed for maximum benefit. The quality and uniformity of the product would improve the marketability compared to capture fisheries. The farmers could also adopt stock manipulation to suit specific customer preferences. Live export of penaeid shrimps thus offers a challenging opportunity for aquaculturists. The expanding demand for live shrimps all over the world, and the competitive advantage of aquaculture over capture fisheries suggest that the outlook for live shrimp market is extremely positive.

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