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Waterless Shipment of Warm-Water Shrimp

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Live shrimp sales in niche markets provide an important avenue to obtain high profit margins for the domestic shrimp farmer. As consumer demand and the marketplace develops capacity for the supply of live shrimp, the price conditions will shift, providing a competitive supply for specific markets. Figure 1 represents a live seafood market display.

In addition to the cost of producing or capturing shrimp (as in caught fisheries), the primary cost associated with the conventional delivery of live shrimp to market is the freight cost of the weight of water. For example, if live shrimp are shipped at a ratio of 1:3 — shrimp weight to water weight — 75 percent of fuel and logistics costs are attributed to just hauling the water; these costs are in addition to the costs of maintaining temperature and oxygenation or aeration. While shipping shrimp in water is a proven method for high survival rates in transport and delivery, sufficient margins can only be realized with very high volumes of sales in niche markets.

Figure 1. A live market equipped for different temperature tanks.

Background

Live shipments of many crustaceans were established a couple of decades ago, some of which were performed out of water. These include many cold-water crustaceans such as the Northern lobster, cold-water shrimp of the Pandalus genus, langoustine (Nephrops norvegicus), spiny lobster, blue crab, Dungeness crab, mud crab, and others. Warm-water shrimp, such as Pacific whiteleg shrimp (Litopenaeus vannamei) and freshwater prawns (Macrobrachium rosenbergii) have not been well-established yet in the live shipping marketplace in the United States, and they present challenges due to their sensitivity to colder shipping temperatures, which complicates shipping in a sealed atmosphere.

In these shipping conditions, shrimp undergo an anesthetization procedure by slowly reducing water temperature before packing; thereafter, they are placed on top or within a mass of moist wood shavings or novel hemp material and packed in insulated containers (e.g., Styrofoam coolers) with a method of sealed oxygen enrichment (typically in sealed bags). When shrimp are received at the destination, they are inspected for survival and re-acclimated into tanks or placed on a chilled table (with wood shavings or other moist medium) for live sale.

With the opportunities presented by live shipping in waterless conditions, this method also presents several challenges that require some practical experience and testing. The principle behind waterless shipping is minimizing metabolism (proportional to temperature) and keeping the shrimp gills moist with moisture-saturated air, not liquid. Even at low temperatures, if the shrimp gills are submerged in water, the rate of oxygen uptake and production of carbon dioxide will outpace the rate at which a sufficient content of either can exchange with atmospheric air (air

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within the sealed container); this results in dead shrimp. Maintaining a sufficient level of humidity in the packaging for moisture will provide the proper conditions for shrimp to breathe out of water. With good temperature control and proper packaging, acceptable survival rates have been observed for shipping times longer than 48 hours.

Potential Issues

As with conventional shipping of live shrimp, timing is important. The viability of shrimp at the market will largely be implicated by the molt stage (post-, inter-, or premolt) at harvest and whether purging, shipping, and re-acclimation can disrupt the molting cycle. A tankful of stressed shrimp — with many of them molting — and increasing temperatures will likely result in moderate to high losses. Meanwhile, shipping at the intermolt stage will yield significantly higher survival rates. Marketability of some transparent shrimp, such as L. vannamei, relative to other shrimp species can be hindered by the drastic change in post-mortem appearance when their translucence is quickly replaced by highly recognizable, opaque, enzymatic-denatured flesh. Other shrimp, such as the pink shrimp (Farfantepenaeus duorarum), do not have such a drastic change in appearance in a chilled post-mortem state. The practice of selling fresh shrimp, whether live or dead, is a matter that consumers will ultimately judge. Several species of shrimp and prawns, namely those with opaque or colored shells, have a market advantage over the transparent species in the considerable changes in near post-mortem appearance because they can be sold at live prices as long as some shrimp in the same container are still active.

Market Conditions

Seasonality in the marketplace is important for the farmer to consider because live shrimp from wild-caught sources will tend to flood the market for a period of time, while pond farmers in temperate states will tend to focus harvest events toward the end of the summer or in the fall. Indoor farms might be able to deliver consistent harvests, which is an attractive quality because vendors prefer consistency in supply. Intermittent harvests generally find success in aggregating small markets or other avenues (restaurants, schools, etc.) or by establishing relationships with distributors and merchants in larger metropolitan areas.

One critical consideration for the re-acclimation and preservation of value is the temperature and water quality of tank water at the receiving end. Many live seafood aquaria or recirculating systems are maintained below 7 degrees Celsius (44.6 degrees Fahrenheit) to hold colder water crustaceans, and they might not be well-equipped to set up another system for the warmer water species. However, if they allow the tanks to equilibrate with the temperature of the air (typically near room temperature), this will be suitable for shrimp.

Different salinities, pH, alkalinity, the presence of disinfectants, or again, temperature, can trigger molting and stress. Dissolved oxygen (sufficient aeration) in the receiving tank should be emphasized because other crustaceans under controlled study have shown that there is a recovery stage after reintroduction to water, though the mechanisms of metabolic respiratory regulation and/or autonomous biochemical gas exchange dynamics require further study.

Packing Considerations

Many different configurations and preferences of packaging are observed in the live shipping trade. Typically a cooler or other insulated container is packed with moist wood shavings, and it is all sealed in an oxygen-saturated environment. Wood shavings, commonly known as “excelsior” in the United States, can be sourced in several different classifications that vary by the dimensions of the average strand (i.e., fine to coarse). Selecting a type of wood shavings for shipping should be based on availability and costs. Even though material such as sawdust will hold more water than wood shavings, recipients of live shipments typically prefer the courser material because it is easier to handle postshipment. In practice, there is not much difference between the grades as far as shipping shrimp is concerned. More importantly, other parameters, such as temperature and positioning should be carefully controlled.

Thus shipping procedures are important to optimize for high survival rates, the receipt and re-acclimation are important for price (and profit) maximization, and species-market coupling is crucial for a successful operation. The following procedures, with descriptive texts, are intended to assist the shrimp farmer in developing and optimizing waterless shipping procedures to live markets.

Key Concepts

- Waterless shipping can drastically reduce weight-based shipping expenses.
- From harvest to market delivery, standard practices should be established, tested, optimized, and implemented.
- Work with merchants to synchronize shipping schedules (intermolt harvest) and receiving conditions (fresh or salt water tanks with capability for temperature control).
- Test shipping conditions on a simulated or pilot-scale basis. Measure temperature dynamics, shrimp densities, protocol changes, and shrimp survival.
- Shrimp are first anesthetized (by cooling) and then packed with moist wood wool (excelsior) in an oxygen-rich insulated environment. Then the shrimp are re-acclimated to normal conditions in a tank or sold the same day.
- Temperature data loggers can be used to track the temperature inside and outside the package of shrimp. Collecting this data will be helpful for refining procedures and ensuring success.

Post-Harvest Chilling Procedures

1. Harvest shrimp and purge using preferred methods.

2. After purging, transfer shrimp to a tank or tanks suitable for chilling. Tanks with high surface area and low volume (i.e., large, shallow tanks) are best to optimize chilling rates on an energy basis. Provide sufficient aeration/oxygenation by maintaining oxygen saturation at greater than 70 percent. Water in these tanks should be very similar to the culture water. This will reduce stress and other physiological issues.

3. Place a sufficient amount of wood shavings in a separate tank or mesh bag and in the shrimp-chilling tank. This will increase adsorption of water and maintain the temperature in the shipping container. A large handful or a 6-inch by 6-inch dense square of wood shavings is suitable per 12-liter bag, or use a 1-inch or larger layer to cover the bottom of a shallow cooler. Shrimp should be mixed in with the moist wood shavings so they remain off of the bottom where water will accumulate.

4. Chill water gradually by circulating through a chiller, floating plastic bags with ice on the surface of the tanks or by other means of heat exchange at a rate not in excess of 7.5 C (18 F) per hour. Slower chilling rates have been found to result in higher survival. Moderate circulation of water by pump or aeration provides better temperature distribution and heat transfer. The target chilling temperature (for L. vannamei) should be between 12 C (54 F) and 15 C (59 F); M. rosenbergii should not be chilled below 15 C (59 F). Table 1 (using equation (1)) shows a sample chilling schedule. A chilling schedule can be made by using the following equation. For example, if the initial temperature is 27 C (81 F) and chilling is conducted at a rate of 7.5 C (13.0 F) per hour, after 30 minutes the chilled water temperature should be 23.3 C (74.0 F).

$$\text{Target termperature} = \text{Initial Temperature} - \left(\text{Chilling rate} * \frac{\text{time point}}{60}\right) \quad (1)$$

Table 1. Guide for rate of temperature reduction in water.

Time (minutes)	Target temperature at a given time in degrees Celsius and equivalent degrees Fahrenheit			
	5 C/hour	7.5 C/hour	9 F/hour	13 F/hour
0	30 C	30 C	86 F	86 F
10	29 C	29 C	85 F	84 F
20	28 C	28 C	83 F	82 F
30	28 C	26 C	82 F	79 F
40	27 C	25 C	80 F	77 F
50	26 C	24 C	79 F	75 F
60	25 C	23 C	77 F	73 F
70	24 C	21 C	76 F	70 F
80	23 C	20 C	74 F	68 F
90	23 C	19 C	73 F	66 F
100	22 C	18 C	71 F	64 F
110	21 C	16 C	70 F	61 F
120	20 C	15 C	68 F	59 F
130	19 C	14 C	67 F	57 F
140	18 C	13 C	65 F	55 F
150	18 C	11 C	64 F	52 F
160	17 C	—	62 F	—
170	16 C	—	61 F	—
180	15 C	—	59 F	—
190	14 C	—	58 F	—
200	13 C	—	56 F	—
210	13 C	—	55 F	—
220	12 C	—	53 F	—

5. After reaching the target chilling rate, the source of chilling should be removed, although temperatures should continue to be tracked because packing the shrimp could take some time and temperatures can climb. Reapply chilling to maintain the target temperature.

6. Label packages with "Handle With Care - Live Animals" or similar language to denote the package contents.

7. At this point, shrimp are ready to be shipped.

Packing

There are several packaging options, each with its own advantages, associated with the cost of materials, shipping volumes, shipping times, or personal preference. In every packing method, a cooler and a means to maintain temperature is used (e.g., ice packs, gel packs, cold bricks, and other materials). Cold packs are effective at maintaining temperatures close to their phase change temperature (from solid to liquid), so normal ice is most suitable for materials to remain near zero C (32 F), while many cold packs are designed to maintain a range of temperatures. Cooling capacity for the cold pack in the packaging configuration will largely depend on the size and number of packs, their placement, the volume of the container, the shipping time, the amount of liquid in the container, and the insulating properties of the container. Proportionally, the shipping container will be mostly air and — depending on the number of shrimp and amount of wood shavings — some water. Positioning the cold pack(s) in the container should typically minimize direct contact with shrimp, wood shavings, or water. Water will maintain thermal energy more efficiently than air. There is a potential for the temperature of the shrimp and water to quickly drop below the target shipping temperature.

The simplest method for good temperature distribution is to separate the wood shavings and shrimp from the cool pack with a plastic, waxy cardboard, rubber, or waxed paper layer. Ice should be avoided because it cools more rapidly and to a higher degree than cool packs — especially as it melts — due to increased surface area contact. Over 24 hours, temperatures within the cooler should remain relatively stable if the cool pack has been sized correctly and shipping conditions are reasonable (for example, not sitting on a hot runway in Miami during the summer months).

Common packaging methods include at least a cooler, moist wood shavings, a hermetic seal (airtight), pure oxygen, and a cold pack; however, the configuration of these can vary considerably. The most commonly used methods are (1) inflated bag(s) within an insulated box (fig. 2); (2) an insulated box within an inflated bag (fig. 3); and (3) a shallow or large insulated box that is hermetically sealed and enriched with oxygen (fig. 4). It has also been reported that stacked trays of shrimp mixed with moist wood shavings that are transported in refrigerated trucks have been tested with acceptable performance. This method would require good air circulation and consistent temperature and humidity.

Figure 2. Cutaway showing two small, inflated bags in a cooler with a gel pack. This shipping method is good for smaller batches and has a high survival potential, but it is a suboptimal use of space.

Figure 3. Cutaway showing a cooler in an inflated bag with shrimp situated on top of the wood shavings. A gel pack goes on the top layer of wood shavings, directly under the lid, and the enclosed cooler is placed in a large box.

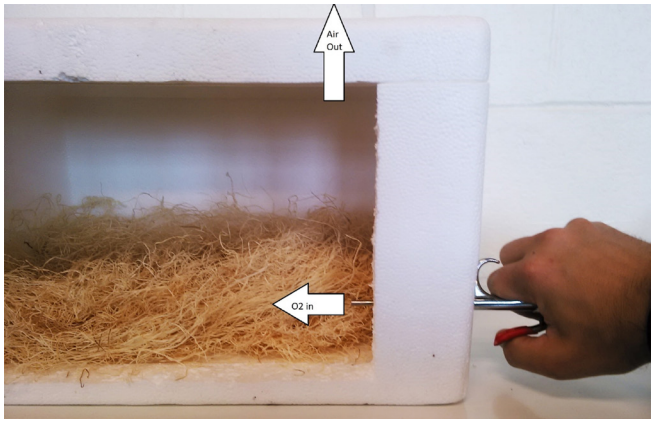

Figure 4. Cutaway of a hermetically sealed cooler. Shrimp sit on top of wood shavings in layers, with a gel pack on the top layer directly under the lid. Pressurized oxygen is injected at the base, flushing ambient air out from a vent in the lid. Holes and the lid are sealed after oxygen is injected and air is flushed out.

Shipping shrimp within an inflated plastic bag ensures oxygen containment and is a useful method of transport for waterless shipping. It is a carryover from shipping live animals in water. The most common methods reported for the shipment of live shrimp is by placing the animals on a bed of wood shavings — in layers or mixed with the wood shavings — and shipping them within the cooler. The main difference is whether the cooler is left unsealed and placed in a bag that is then inflated with pure oxygen, or the container is sealed and then flushed with pure oxygen, thereafter sealing the lid and holes. The advantage of enclosing the container within an inflated bag is to ensure oxygen enrichment throughout the shipment because Styrofoam containers can easily break or crack. Selecting a packing method will be a matter of personal and distributor/retailer preference. Market surveying has shown that distributors and retailers prefer larger containers with less interference (e.g., fewer bags).

Packing the shrimp in the wood shavings can be simple; however, there are several very important considerations for assuring high survival rates.

Packaging Procedures

1. Following anesthetization procedures, remove wood shavings from water, shake off excess water, and place the shavings at the bottom of the container or bag. If the wood shavings are packed densely, pull them apart so the layer resembles a cushion rather than a block.

2. Net enough shrimp from the chilling tank to make a layer of one to two shrimp. Shake the net in order to remove as much water as reasonably possible but in a gentle enough manner to not injure the shrimp. Loosely place shrimp on top of the wood shavings layer, preventing shrimp from creeping under the wood shavings to the bottom of the container. Place another layer of moist wood shavings on top of this shrimp layer and repeat layers of alternating shrimp and wood shavings for three to five layers per container (approximately 0.5-0.75 pound of shrimp per gallon container). Alternatively, after an initial base layer of moist wood shavings, the container can be filled with an equal amount of shrimp and moist wood shavings blended together. This is accomplished by pulling apart the moist wood shavings, nesting the shrimp, and interspersing them while packing the container. It is helpful to have two people perform this operation together.

3. After the shrimp are packed (fig. 5), place the cool pack(s) on the top layer of wood shavings, with the barrier material between the wood shavings and cool pack; wrapping in parchment paper is also acceptable. If there are enough wood shavings to act as a barrier, the cool pack might not need a barrier layer; individual methods should be tested and refined.

Figure 5. Shrimp packed in moistened wood shavings.

4. Once everything is set, it is time to enrich the atmosphere and seal the environment. Shipping without a sealed bag, the cooler itself becomes the sealed environment. First, punch a hole at the base

of the cooler and in the lid. Place the lid onto the cooler and seal it with good quality tape. Using low-pressure oxygen (10-15 pounds per square inch or 70-100 kilopascal), inject oxygen into the container to sufficiently enrich the atmosphere to between 50 and 75 percent oxygen; this should take about a minute for a 20-gallon (75-liter) cooler, longer for larger containers. Thereafter, seal the holes with good tape or plugs. These procedures are also recommended for the method in which the cooler is sealed in a bag (except for sealing the holes). Both bag methods require pressurized oxygen and an air nozzle. Regulate the pressure to a level high enough to inflate the bag over a few seconds (5-10 seconds), but not so fast as to blow around packing material and shrimp within the bag. You can control the pressure using the regulator. A pressure range that works well is 30-40 psi (200-275 kpa). Inflate the bag as much as possible and secure it with cable ties (also called zip ties or hose ties) or banding; castrating banding tools (fig. 6) are regularly used by twisting the bag end and folding it over before banding.

Figure 6. Castrating tool for sealing bags with rubber bands.

5. Now the packages are ready to ship. Carefully seal and label the packages and deliver immediately to the shipping depot or airport or for pickup. It is not known if labeling the box "Live Animals" will affect the shipment, and anecdotal reports have differed. Be sure to insure the shipment for the retail cost of the product and shipping materials — this value should represent the production and opportunity costs from your hard work raising these animals. Communicate with the designated recipient or buyer to schedule delivery.

Key Concepts

- Minimize standing water by shaking off wet wood wool and netted shrimp, and try to prevent too much water from dripping from the net into the container.
- Do not submerge shrimp in water during shipment — they will likely suffocate.
- Time the harvest and shipment to match logistics in order to minimize transit time.
- Constantly refine methods to maximize survival and profitability.
- Contact local Extension offices to help validate your methods.
- Consult with appropriate authorities before shipping live animals from one location to another.

Seek Assistance

Reaching out to local academic institutions and Extension offices is highly recommended because Extension employees can help conduct optimization trials and might be able to provide instrumentation to record temperature and other important factors.

Robust procedures and proven methods of shipment can result in strong relationships with merchants and a drastic difference in the value of the shrimp at market. Shrimp that are moribund (lacking vitality but not declared dead) are priced much lower than active, good-looking shrimp. A poor shipment can result in a high proportion of dead, moribund, off-flavor, or "softening" shrimp, or shrimp with poor aesthetic qualities, such as cramping or necrosis (especially of the gills). At the live market, vitality and freshness go hand in hand, and prices will reflect such qualities.

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