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Icing of fish: A way to retain nutritional quality and food safety

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Abstract
Aquaculture has shown a consequent upward trend based on scientific farming practices, technological advancement and mechanisation of fishing gear and craft that leads to transportation of harvested fish from landing centres to the distant market or processing factories especially in in live form to meet up the consumer's preference. Transportation and handling procedures of live-fish comprise of several potential stressors including capture, onloading, transport, unloading, temperature differences, water quality changes and stocking, accelerate post-mortem metabolism, quickened rancidity and develop softer muscle texture, thus, having shorter shelf-life and worse taste than fillets from quickly killed fish. Whereas, iced fish followed by subsequent freezing having benefits in terms of retention of taste, convenience, price, nutritional quality and lower risk of microbial-parasitic infestation as in live fish, thus offering longer shelf life. Thus, iced and frozen table fish may be a healthier choice of consumption compared to stressed live fish.

Keywords: Live-fish transportation, stress, icing of fish, nutritional quality.

Introduction

Aquaculture has shown a consequent upward trend based on scientific farming practices, technological advancement and mechanisation of fishing gear and craft. Transportation of fish is generally an important practice in aquaculture. The problem of transportation of harvested fish from the landing centres to the distant market or processing factories of about more than hundreds of kilometres at times has been somewhat successfully solved, even though much remains yet to be done for further improving the conditions [1]. In transporting live fishes, there are technicalities in which one need to understand for successful transportation of the fish. In most cases, fries, fingerlings and brood stock and even harvested fish may also be transported in live form to the market. Table size fish are transported from the farm to the market in live form to meet up the consumer's preference [2].

Buoyant on a predictably good amount of rain during the monsoon season of the year 2016, State Fisheries Department, Govt. of Jharkhand, announced that Jharkhand is going to be a self-sufficient state in terms of fish production by this year-end itself. In 2010-11, 80 government fish firms produced 71,886 metric tonnes of fish [3]. The fish seed production increased from 32 Crores to 67 Crores, along with construction of 116 new fish seed hatcheries in private and government sector in 2010-11 [3]. The department has set a target of 1.40 lakh Metric Ton of fish production at per the demand of fish consumption of around 3.29 Crores of state population [3]. Seeing the fish production trend of meeting ambitious production targets, it can be expected that Jharkhand will start exporting fishes to neighbouring states by 2017-18 [4].

Jharkhand is known as the leading state in country for cage farming and the department plans to use this system to increase fish production. By the end of 2015, Jharkhand had around 900 cages installed across the state for fish farming which were supposed to be increased 5000 more cages in two subsequent financial years that would help increase the production by at least 20,000 metric tons [5].

Various containers, especially clean and waterproof containers, such as cans of different shapes and size, ceramic or metal pots, metal or wooden buckets, vat, barrels, plastic bags, styrofoam boxes, bottles, jugs, even animal skins and bamboo sections are generally employed for transportation of fish. Whereas, wood and styrofoam containers provide good insulation, metal or plastic containers are poor insulators and may be wrapped with wet towels or packed with ice to keep temperature down [6].

Fish are to be transported by the quickest possible means that will provide relatively smooth and direct route to reach at destination such as by foot, animal cart, bicycle, boat, motorized vehicle, train and plane wherever applicable respectively.

Methods For Transporting Live Fish

The two basic systems for transportation of live fish include the closed system and the open system. The choice of transport system depends on the facilities available to the purchaser, the distance, number and size of fish species [2].

Transportation by open system: The open system includes small tanks, plastic containers, cans, buckets, bowls, boxes, calabashes, clay-pots, trucks, vans, etc, where the basic requirement for survival is continuously supplied to the water filled containers from outside sources. It is suitable for movement of fish within the farm for short distances and for periods not longer than 2 hours except for catfishes which can endure 5 hours. For longer distances, air or oxygen should be supplied constantly or intermittently and water must be renewed (changed) at intervals of 4-5 hours or less if the weather (water) gets hot. Although the method is advantageous because of its simplicity, economically viable nature and least requirement of special skill for adoption; it is however risky and limited by time and distance. Fingerlings can die through water splashing in the container.

Transportation by closed system: The closed system involves transportation of fish in sealed containers in which all the basic requirements for fish survival are self-contained. It is so far the most ideal method for live fish transport especially fingerlings of Tilapia, Carp, Heterotis and other weak species of fish. The suitable container is oxygenated polyethylene (plastic) bags or tanks. Plastic bags are not recommended to transport brooder/adult fish or post fingerling with sharp spines, as this will result in bursting of the container. It is essential to maintain adequate oxygen in the water while transporting fish using this method. The technique recommended for oxygenating water during fish transport is the use of pure bottled oxygen. It may be bubbled continuously into an unsealed container during transport, or injected into a plastic bag containing water and fish which is then sealed air-tight for transport.

Oxygen is added after placing water and fish during using plastic bags. One-fourth of the bag usually contains water and fish and three fourths contains oxygen. After adding oxygen, the bag is sealed shut with a twisted rubber band, string or other material. To prevent leakage, the first plastic bag should be placed inside a second bag whenever possible. The sealed double bag of fish is then placed in a box or in other container for added protection and loaded into transporting vehicle. If properly packaged and insulated from heat, these containers can transport fish for 24 to 48 hours without water exchange.

The common problems associated with transportation of live fish are followings: (1) Low solubility of oxygen in water together with its poor capacity to dissipate the end product of metabolism, (2) Transportation of live fish requires extreme care during handling. Due to ultra-sensitivity, some delicate fish species loses the essential protection from osmotic stress if mucus layer is driven away from a very small surface of the skin of the fish either by abrasion or some other means. (3) Harvest and post-harvest handling stress causes the fish to be stimulated to an extreme level where dangerous level of lactic acid accumulate in their blood. (4) Excessive thermal shock from catching, handling and live transportation is deleterious to the fish.

Consideration for Fish Transport

Fish must be transported carefully and delicately in order to prevent premature mortality and take them to their destination successfully. The following factors directly influence fish transportation includes,

a. Tolerance to transport: The ability to withstand handling and transportation stress and adaptation to stressful conditions is designated as tolerance of fish to transport.

b. Presence of food in the intestine: Empty gut leads to better survival of fish during transport. Thus, fishes need to be starved for 1 or 2 full days prior to the time they will be transported. Fish can also be harvested and held in net enclosures or tanks for 24 to 48 hours with clean, preferably gently running water. The fish pass food out of their intestines and will be in good condition for transport.

Age and size of fish: Smaller fish suffer from higher transport stress compared to larger fish of similar weight. For smaller fish, number of fishes will be higher per unit volume of water leading to deteriorating the water quality as compared to larger fish of similar weight.

Stress is defined as the imbalance in which the dynamic equilibrium of an organisms called homeostasis is threatened or disturbed due to action of intrinsic or extrinsic stimuli, commonly defined as stressors [7]. Acute stressors produce effects that threaten or disturb the homeostatic equilibrium, and they elicit a coordinated set of behavioural and physiological responses thought to be compensatory and/or adaptive, enabling the organism to overcome the threat. If an animal is experiencing intense or chronic stress, the stress response may lose its adaptive value and become dysfunctional, which may result in inhibition of growth, reproductive failure, and reduced resistance to pathogens [2].

Stress During Transportation

1. Handling: Post-harvest transportation and handling procedures consists of several potential stressors, such as capture, onloading, transport, unloading, temperature differences, water quality changes and stocking [7, 8] which may be combinedly designated as handling stress, affecting fish badly. Barton and Iwama [9] also reported that stress of capture and handling has profound effect on the blood chemistry and stimulated gonadotropin, androgen and the stress hormone cortisol.

Over-crowding: There is a difference between loading and density [7]. While loading is defined as the weight of fish per unit of flow (kg/l/min), density refers to weight of fish per unit space (kg/m3). This type of stress is often associated with high stocking densities leading to crowding stress. Short term crowding stress occurs commonly in aquaculture practices; possess characteristics of acute as well as chronic stress with long-term compromised immune systems resulting in disease or death [7]. Therefore, optimal densities during loading and in transport tanks should always be taken care of regardless of profitability or convenience [7].

Temperature: Fish are poikilotherms and an increase in ambient temperature results in increasing metabolic rate. Thermal stress occurs when the water temperature exceeds the optimal temperature range, with energy demanding stress responses and potential decrease in individual survivorship [7]. Most fish can gradually acclimate to normal temperature changes but sharp changes in temperature gradient, as may happen during fish loading and transportation, may result in thermal stresses or lethal conditions [7]. The ionic balace and osmoregulatory functions may be depressed due to thermal stress [10]. Reduced feed intake and growth, abnormal swimming behaviour, sudden or erratic movements with possible collision with the tank wall or other fishes, increased regurgitation, defecation and gill ventilation are prevalent among thermal stress related behaviours [7]. Omeji *et al.* [2] reported that the ideal temperature for fish transportation is 21 to 25 ^{O}C. The changes in water temperature during transport leads to lowering the dissolve oxygen, thus respiratory stress of fish takes place.

Water quality: Temperature, dissolved oxygen, ammonia, nitrite, nitrate, salinity, pH, carbon dioxide, alkalinity and hardness in relation to aluminium and iron species are the most common water quality parameters affecting physiological stress [2].

Symptoms of Stressed Fish during Live Fish Transport [11]

1. **Gasping and gulping air at the surface:** Fish is gasping the mouth at the surface and start gulping air due to lack of dissolved oxygen in transport water which means poor water condition.
2. **Disease:** Itching and prickling, characterized by white patchy spots on the body surface of the stressed fish caused due to microbial infestation.
3. **Strange swimming:** When fish are stressed, they often develop odd swimming patterns. Fish swim frantically and erratically without going anywhere, crashing or rubbing itself at the bottom or edges of the container tank and/or locking the fins.

Effect of Stress during Transportation

Physical disturbances during transportation of fish [12] are unavoidable in aquaculture and have potential to induce stress responses that affect meat quality. In general, stressed fish undergo accelerated post-mortem metabolism and develop softer muscle texture in a manner similar to that of mammals [13].

Researchers have reported that meat from stressfully slaughtered fish which may occur during transportation of live fish, may have a shorter shelf life and worse in taste than fillets from quickly killed fish. Fillets from the asphyxiated fish tasted bitter and smelled rancid after 105 days, whereas fillets from the quickly killed fish never started to smell. Reviewed literature suggests that, a higher concentration of hydroperoxides compounds that accrue in the body during stress led to quickened rancidity and accelerate spoilage, thus reduces consumer preference and acceptability [14]. Hydroperoxides break down into aldehydes and ketones that give rise to off flavour and bitter taste of fish flesh [14].

The less trauma a fish goes through, before and during slaughter, the higher the quality of the meat. So, unlike red meat where little protein breakdown is required to enhance tenderness and succulence, fish muscle is delicate enough so that anything that breaks down the structure of fish muscle is detrimental. Stress causes the fish muscle tissue to break down. Stress before or during slaughter, which may occur during handling and transportation of live fish, results in the muscles of exhausted fish with a lower pH (due to lactic acid production in the muscle). That low pH enhances the action of enzymes present in the muscle that break down muscle protein. Higher stress also leads to more stress-related compounds in the blood that facilitates muscle degradation. Finally, tired and stressed fish have less available ATP in their muscles. ATP is the energy source that makes biological systems run. After death of the fish, its muscles remain pliable for as long as it has some reserves of ATP. Muscles from stressed fish with low ATP reserves accelerates rigor-mortis, that finally leads to weakening of the connective tissues and breakdown of the muscle fibres, causes gaping of the fillets, thus consumer acceptability decreases [15].

To maintain fish health and maximize long-term survival, common stressors during loading and transport operations including handling, confinement, unfavourably high densities, and degraded water quality conditions must be considered [16]. Fish loading and transportation, particularly at high densities, can result in mechanical abrasion, poor water quality conditions and physiological stress, which can contribute to reduced survivability [17]. Exposure to stress elicits a general adaptive physiological and behavioural stress response in most fishes [18], consisting of primary and secondary levels and, if the stressor persists, a tertiary level [19]. The primary stress response, as a result of capture, loading, and transport, is generally exhibited as the release of circulating catecholamines and corticosteroids (i.e., cortisol) by activation of the hypothalamus-pituitary-interrenal axis [20]. As a result, cortisol is commonly measured as an indicator of fish primary stress response [21]. The secondary stress response, among other physiological processes, can result in increased blood glucose and lactate, as well as increased heart rate, blood flow and metabolic rate [19]. Measures of metabolism (oxygen consumption (MO_2) and ammonia production (MTAN) are common means to measure the secondary stress response in fish [19]. The secondary stress response elicited in fish during fish-loading and transport, and glucose production in particular, is a response to fish energetic requirements, but can coincide with elevated MO_2, carbon dioxide production (MCO_2), and MTAN rates, accelerating the rate of water quality decline [21, 19]. In truck transport systems, accumulated fish metabolic and excretory by-products can result in toxic levels of CO_2, total ammonia nitrogen (TAN) and unionized ammonia (NH_3), which can impair performance, health and survival of fish [16]. Similarly, elevated MO_2 can result in low O_2 levels, leading to a hypoxic state, which can also contribute to deteriorating health and mortality. As a result, maintenance of appropriate water quality is often a limiting factor during fish transport and is generally considered when developing fish transportation chains [16].

To overcome the drawbacks offered by transportation of live fish, transportation of iced fish immediate after harvesting can be a good option. In fact, the best, easiest, cheapest and reasonably efficient method for preservation of fish onboard is lowering the temperature of fish by icing, the effective and ideal cooling medium to delay the enzymatic degradation and bacterial spoilage and in terms of retention of nutritional quality. While live fish which are already stressed during transportation, can only last for few hours more after reaching to the market, iced fish followed by subsequent freezing has a longer shelf life. Very rapid cooling can be achieved through intimate contact between fish and crushed ice flakes and thus fish remains cool, moist, glossy and controls deterioration. The rate of post-mortem enzymatic degradation and bacterial spoilage is twice as fast as 2.5 ^{O}C to that of 1.1 ^{O}C. Thus, immediately after harvesting chilling of fish followed by icing delays bacterial spoilage. Even fish can be stored and transported in good condition for 3 to15 days by icing till it reaches either to the consumer or subjected to subsequent freezing.

There are many good reasons to buy iced fish, in terms of retention of taste, convenience, price and lower risk of microbes and parasites occurrence in live fish. Since the fish is iced at its peak of freshness, its aroma, flavour, nutritional profile as well as its texture are locked in. Subsequently, if the fish is processed and frozen properly, it extends the season of the fish, making the fish delicacy throughout the year. For extended shelf life and quality retention of harvested fish followings are must be done. Firstly, the fish must be iced as soon as they are harvested on boats. Secondly, the fish must then remain frozen at a stable and low temperature till consumption. For long term preservation, freezing must be taken place at an ambient temperature of (-35 ^{O}C to -40 ^{O}C) or below and to be stored at -18±2 ^{O}C in tropical continent like India. Finally, thawing is to be taken place immediately before consumption of frozen fish.

There are a variety of reasons for preferring people iced fish over live fish. The debate of consumer preference between live and iced fish is often the hot cake considering the nutritional value. Generally, it is believed that fresh live fish being more nutritious, but that may not be the case every time. While it is true that some nutrients may be leached while thawing out frozen fish that are frozen followed by icing, the amount is minimal. Often, fish that is immediately iced after harvesting retains as many as nutrients which were offered during culture environment and feeding practices. Whereas, transportation of live fish induces stress that generates a general adaptive physiological and behavioural stress response in most fishes [18], that finally leads to quality deterioration. Of course, improper thawing of fish or purchasing fish that hasn't been iced immediately after catching can compromise the nutritional value.

If the fish is iced immediately after harvesting, nucleotide degradation is arrested. During post-mortem, nucleotides are degraded such as; ATP>ADP>AMP>IMP>Inosine>Hypoxanthine. Immediate icing after harvesting retards the nucleotide degradation, i.e., formation of hypoxanthine (which is responsible for the bitter taste of fish) is delayed in low temperature. During transportation of live fish, the water itself will be loaded by fish slime, faecal matter and excreta which must be the harbour of different pathogens and spoilage microbes. Whereas, the rate of bacterial spoilage gets retarded during icing and subsequent frozen storage, thus offering longer shelf life.

Conclusion

Although consumer preference should play a large role in purchase decisions, during purchasing iced or frozen fish, patches of freezer burn or ice crystals must be checked carefully to avoid the malpractice of repeated thawing and refreezing which can affect taste, texture and quality. Maintaining quality standards are to be ensured by the producers throughout the farm to fork chain. After purchasing iced or frozen fish, it has to be ensured that the fish has to be kept frozen till thawing and subsequent cooking so that it can retain its taste, quality and nutrients. Thawing is to be done by defrosting the fish by rinsing under cold water. Thus, iced and frozen table fish may be a healthier choice for population as compared to stressed live fish.

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