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BIOCHEMICAL EFFECTS OF LIVE FISH TRANSPORTS: A COMPREHENSIVE REVIEW

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Abstract: Transporting fish is a part of aquaculture and fisheries as it allows for moving organisms, for various reasons like breeding, restocking and trade. However this process can have impacts on fish due to their extended confinement. It leads to changes in the environment. Exposes them to stress resulting in biochemical responses. This comprehensive review aims to explain the relationship between stress, physiology and overall fish health during fish transportation. During transportation fish experience stressors such as disturbances, changes in water quality parameters and stress caused by handling. These stressors cause changes that affect the health and survival of the fish. Prolonged exposure to these stressors weakens their system making them more susceptible to diseases. Additionally disruptions in metabolic processes and energy utilization can lead to mortality rates after transportation or slower growth rates. To mitigate these effects several strategies have been suggested including acclimating the fish before transportation optimizing transport conditions such as water temperature and oxygen levels and using compounds that reduce stress like antioxidants or corticosteroid blockers. In conclusion live fish transportation is a process that significantly affects the environment of aquatic organisms. Understanding these complexities is essential, for improving the welfare and survival of transported fish. We should focus on enhancing transport protocols and coming up with strategies to reduce the negative impact of stress. This will help sustain the aquaculture and fisheries industries in the run.

Keywords: fishing experience, parrotfish, fisherfolk attitudes

Introduction

Aquaculture and fisheries industries are vital components of the global food supply chain, providing a significant source of protein for human consumption and supporting economies worldwide. A fundamental aspect of these industries is the transportation of live fish, facilitating the movement of aquatic organisms for purposes ranging from reproduction and restocking to trade. However, the seemingly routine process of live fish transportation encompasses a complex interplay of factors that extend far beyond the mere physical relocation of fish. Live fish transportation, while essential, often subjects aquatic organisms to a series of challenges that can profoundly impact their biochemical makeup. These challenges include prolonged confinement, fluctuating environmental conditions, and the imposition of physiological stressors. As a consequence, these sensitive organisms undergo intricate biochemical reactions during transportation that have far-reaching implications for their overall health and well-being.

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This comprehensive review endeavors to elucidate the multifaceted biochemical effects of live fish transportation. We delve into the intricate interactions between stressors, physiological responses, and the overall health of transported fish. Within the confines of transportation, fish are confronted with a complex amalgamation of stressors, encompassing physical disturbances, shifts in water quality parameters, and stress induced by handling. These factors collectively create an environment ripe for the manifestation of biochemical changes that can significantly influence fish health and survival. Prolonged exposure to these stressors can compromise the immune system of fish, rendering them more susceptible to pathogenic agents. Furthermore, disruptions in metabolic pathways and energy utilization may manifest as post-transport mortality or hindered growth rates. The consequences of these biochemical alterations are far from trivial, challenging the sustainability of aquaculture and fisheries industries, which are vital contributors to global food security.

In our exploration, we also assess various strategies that have been proposed to mitigate the adverse biochemical effects of live fish transportation. These interventions range from pre-transport acclimation to the optimization of transport conditions, such as water temperature and oxygen levels. Additionally, the administration of stress-reducing compounds, such as antioxidants and corticosteroid blockers, has demonstrated promise in alleviating stress-induced biochemical changes. In conclusion, live fish transportation constitutes a complex process that exerts a profound influence on the biochemical milieu of aquatic organisms. Understanding the intricacies of biochemical reactions is essential not only to improve the welfare of transported fish and reduce transfer-dependent mortality, but also to secure the long-term sustainability of the aquaculture and fisheries sectors. As we move forward, we emphasize the importance of improving transportation processes and pioneering interventions that reduce the negative effects of stress during transportation.Stressors in Live Fish Transportation: Explore the various stressors that fish experience during transportation, including physical disturbances, changes in water quality parameters, and handling-induced stress.

In aquaculture and fisheries, fish transfers are a common practice for a variety of reasons. These transfers become necessary when fish cannot meet their needs in their current habitat, when they need to relocate for reproduction or restocking, or when water quality in their current habitat is compromised (Amend et al., 1982; Berka, 1986; Shabani et al., 2016). Additionally, transfers are essential for optimizing resources and ensuring sustainable production. Various transfer systems are employed, ranging from simple containers for short distances to advanced closed systems for longer journeys. These systems must carefully consider factors like water quality, temperature, and handling procedures to minimize stress and ensure the well-being of the transported fish (Amend et al., 1982; Tuna Keleştemur et al., 2010). The selection of an appropriate transfer system depends on the specific requirements and conditions, highlighting the need for a comprehensive understanding of the process.

There are two basic transportation systems for live fish: closed and open. A closed system is a closed container, partially filled with water and air, in which all the requirements for fish survival are contained. The open system consists of water-filled tanks in which the survival requirements are continuously supplied from external sources. The simplest of these is a small tank with an aerator stone. In addition to these systems, Atlantic bluefin tuna are also transferred live to the farms where they are to be fattened. During this transfer, there is no need for any external treatment as the fish are still in the sea where they were caught. However, this forced migration causes stress to the fish (Mylonas et al., 2010). The method used in rainbow trout, seabass, and seabream farming is open system. Closed systems are mostly used for short distance transportation of aquarium fish (Berka, 1986).

This review holds significance for academia as it provides a comprehensive understanding of the biochemical responses of fish during transportation in aquaculture and fisheries. The exploration of stressors, physiological changes, and potential impacts on fish health contributes valuable insights to the scientific community. The suggested strategies for mitigating adverse effects offer practical applications for improving the welfare of transported fish. Enhancing transport protocols and reducing stress-related impacts are vital for sustaining the aquaculture and fisheries industries, making this review pertinent for academic researchers, practitioners, and policymakers in the field.

Biochemical Reactions in Transported Fish

As fish undergo transportation, they face an array of stressors that set off a chain of biochemical reactions. "Oxidative Stress", which is characterized by an increase in reactive oxygen species, is an important aspect to consider. This heightened ROS production can be associated with factors like transportation, crowding, and shifts in water quality. High ROS levels can affect fish health by damaging cellular components. Additionally, transport causes hormonal responses through the secretion of stress hormones such as cortisol. These hormonal changes play a role in regulating the fish's response to stress factors. Additionally, metabolic pathways in fish may change during transportation to meet increased energy demands associated with stress.

Understanding these biochemical reactions is vital to improving shipping practices, minimizing stress, and ensuring the welfare of transported fish populations. Research in this area continues to shed light on the complexity of fish physiology during transport, facilitating better management and optimization of this critical process.

In a study conducted by Ritola et al. in 1999, findings revealed a significant increase in plasma cortisol levels under both normoxic and hyperoxic conditions. In both of these groups, cortisol levels were comparable to the control group 24 hours post-transfer. However, under hyperoxic conditions, there was a notable surge in plasma cortisol levels 70 hours after the transfer (Ritola et al., 1999). Conversely, in another study by Shabani et al., the mean plasma cortisol concentration of trout in the control group was reported as 12.5 nmol/L. Following immediate transfer, cortisol values spiked to 312 nmol/L, with plasma cortisol levels gradually decreasing to 123 nmol/L 48 hours post-transfer (Shabani et al., 2016). These observations indicate a rapid increase in cortisol levels in rainbow trout during the transfer process, initiating an acute stress period. Notably, cortisol levels returned to baseline values within 24 hours. Additionally, glucose levels exhibited a parallel increase with cortisol during the transfer process, returning to baseline values within 12 to 24 hours following the transfer process, as reported by Keleştemur et al. in 2008 (Tuna Keleştemur and Özdemir, 2008).

Such insights contribute to the ongoing refinement of transportation practices and the development of measures aimed at enhancing the well-being of transported fish populations. Further research in this field promises to yield additional valuable information for the sustainable and ethical management of fish transport operations.

Biochemical Responses to Hypoxia and Hyperoxia

As fish oxygen uptake decreases, they do not have enough energy for swimming and need more oxygen to feed. The first sign of a decrease in the level of dissolved oxygen in the water is a decrease in feed consumption and reduced movement of the fish. At this stage, it can be mistaken for symptoms of some diseases and it may be appropriate to try medication, but in fish lacking sufficient metabolic energy, this can lead to mass mortality (Mallya et al., 2007). Therefore, when such symptoms are detected in aquaculture practices, the dissolved oxygen levels of the water should be carefully checked. In closed-circuit farms, increasing dissolved oxygen levels in the water can help to eliminate these symptoms (Chen et al., 2022).

Metabolic Shifts

One of the hallmark biochemical responses triggered by hypoxia in fish is increases or decreases in metabolic pathways within their tissues. Numerous studies have supplied substantial evidence indicating that under hypoxic conditions, a decrease in hepatic glycogen takes place. This glycogen reduction primarily occurs through glycogenolysis to produce glucose, mainly to fuel anaerobic metabolic pathways. This phenomenon is distinctly characterized by elevated plasma lactate levels, stemming from the utilization of glucose within anaerobic pathways, ultimately resulting in increased plasma lactate concentrations. (Fazio et al., 2015; Ham, 2003; López-Patiño et al., 2014; Vasconcelos-Lima et al., 2021). Nevertheless, the antioxidant response within the context of tissue-level dynamics exhibits noteworthy variability, as exemplified by observations in the common carp species. Specifically, within these piscine specimens, catalase (CAT) activity displayed a discernible augmentation in cerebral tissues, while conspicuously lacking a corresponding upregulation in CAT activity within hepatic, renal, or muscular tissues. Furthermore, when subjected to hypoxic conditions, the common carp demonstrated an elevation in glutathione peroxidase (GPX) activity in cerebral tissue concomitant with a concurrent reduction in GPX activity within the liver and muscular tissues. These trends align with antecedent studies that have reported analogous outcomes (Abdel-Tawwab et al., 2019; Lushchak et al., 2005). Furthermore, the current investigation unveiled a notable decline in glutathione levels during exposure to hypoxia, whereby both reduced glutathione (GSHt) and oxidized glutathione (GSSG) levels exhibited a discernible reduction (Lushchak et al., 2005). Lushchak and Bagnyukova have postulated that the maintenance of the GSH/GSSG ratio emerges as a pivotal protective mechanism for piscine organisms confronted with oxidative stress, particularly when examined within the framework of studies exploring cyclical transitions between normoxic and hyperoxic conditions (Lushchak and Bagnyukova, 2006).

In conclusion, when oxygen levels experience a significant reduction, fish undergo metabolic adaptations to combat the constraints posed by limited oxygen supply. These adaptations include of a transition from oxygen-dependent aerobic metabolism to anaerobic metabolism, which operates independently of oxygen. Consuquently, lactic acid level increases because of the anaerobic glycolysis (Omlin and Weber, 2010). The accumulation of lactic acid triggers a condition known as 'lactic acidosis,' inducing a reduction in pH levels within the bloodstream and bodily tissues. This metabolic phenomenon aids fish in temporarily generating energy in the absence of oxygen, albeit with reduced efficiency compared to aerobic metabolism. As a result, it can lead to an overall decrease in energy levels and a decline in fish activity both during and after the hypoxic event, thereby posing a threat to fish welfare (Valotaire et al., 2020). Because of this reasons recommended to routinely monitor dissolved oxygen levels during the transfer and implement measures to prevent the occurrence of hypoxic conditions.

Impact on Fish Health and Survival

The physiological response of the organism as a result of the intervention of an external or internal factor is called stress, and the stressor is called a stress factor or stressor. Factors and practices such as starvation of fish for transfer purposes, transportation of cages to the shore for aquaculture in the dam facility, mobility during loading and transportation in transport trucks, and dissolved oxygen and water temperature in transport tanks all cause stress in fish. The antioxidant defense system plays a role in cell hemostasis and helps prevent damage to tissues and cells by free radicals that are formed in the body in various ways. As in other vertebrates, this defense mechanism can take both enzymatic and non-enzymatic forms (Keleştemur, 2012). In fish, the behavioral response to stressful situations initiates the endocrinal response by triggering the release of the hormone cortisol and the hormone adrenaline. These hormones, which are transported to the tissues through the bloodstream, accelerate metabolic activity in cells, leading to increased energy requirements (Tort, 2011). When the stressor starts to have an effect on metabolic activities, it causes many biochemical changes in cells as a physiological response. These changes cause reversible or irreversible damages in the metabolism and limit many vital functions of the fish such as growth, respiration, development, reproduction and deaths occur as a result of disruption of hemostatic balance and failure to re-establish it.

Mass occurrences of fish diseases seldom result from singular causative agents. They typically arise due to intricate interactions among the host organism, the pathogenic agent, and a spectrum of environmental variables. Notably, this interplay is frequently exacerbated by the influence of one or more stressors, which inflict damage upon the integumentary or gastrointestinal systems of the host organism (Overstreet and Hawkins, 2017). Environmental stressors, such as diminished salinity and heightened levels of organic pollutants, can substantially contribute to the initiation and dissemination of such maladies (Overstreet and Van Devender, 1978). Furthermore, Mellergaard and Nielsen (1995) posit that stress, induced notably by hypoxic conditions, has the capacity to incite outbreaks of viral diseases, including but not limited to lymphocystis (Mellergaard and Nielsen, 1995). An extensive body of research underscores the foundational role of stress factors in the genesis of widespread fish mortality incidents. Consequently, the meticulous oversight of processes in fish farming, which may exacerbate stress, such as handling, transfers, grading, and hypoxic conditions, is imperative. This endeavor is of paramount significance for the preservation of fish health and the longevity of the aquaculture industry, warranting further scholarly inquiry and investigation.

Mitigation Strategies and Recommendations

Handling and Loading

The process of loading fish into tanks before their transfer represents a physically demanding task for both aquaculturists and the fish themselves. The pivotal moment during this transfer process is the exposure of fish to air during loading, recognized as the most stressful event in the transportation of salmonids (Maule et al., 1988). Several references, as highlighted by McDonald and Milligian (1997), have indicated that post-exercise exposure to air, even for brief durations, can significantly impact mortality rates (McDonald and Milligan, 1997). Ideally, fish should be transported without necessitating their removal from water. Specially designed transfer scoops, resembling tanks, facilitate the movement of fish into transportation tanks while keeping them submerged. Additionally, the utilization of jet fish pumps in this process has been demonstrated to be a safer practice for fish health (Long et al., 2016).

In conclusion, minimizing air exposure during the loading phase of fish transport is imperative for reducing stress and preserving the well-being of transported fish populations. The use of innovative tools such as jet fish pumps and the development of procedures that minimize air exposure continue to be crucial for the sustainable and ethical management of fish transport operations.

Transport Capacity

The efficacy of fish transfers is intricately linked to the quantity of fish that can be accommodated in a single transport operation. This parameter is contingent upon several factors, including the quality of the transport water, the specific fish species, and their size. For instance, the maximum stocking density appropriate for trout is closely associated with their weight and length dimensions. To illustrate, empirical observations have indicated that the permissible stocking density for rainbow trout, falling within the length range of 20.3 - 27.9 cm, lies between 300 - 400 g/L (Piper et al., 1982). Carmichael and Tomasso (1988) found that there is a relationship between length and biomass of fish. Accordingly, they suggested that if 40 kg of fish of 5 cm length can be loaded into a tank, it is appropriate to load a maximum of 20 kg of fish when the fish length is 10 cm and thus the stock density will remain constant (Carmichael and Tomasso, 1988). In a study conducted in the USA, it was observed that fish farmers were carrying stock densities of 0.05 - 0.29 kg/Lt for brown trout and 0.02 - 0.30 kg/Lt for rainbow trout. As a fundamental guideline, it should be acknowledged that as the duration of transfer operations extends, a commensurate reduction in the stock density is advisable.

Dissolved Oxygen

Fish transportation is a process sensitive to environmental factors and biological characteristics of fish species. One of the most crucial elements in this process is ensuring the provision of adequate levels of dissolved oxygen. Nevertheless, an abundance of oxygen in a tank or transport medium doesn't necessarily equate to the fish being in good health. The fish's capacity to effectively utilize oxygen can fluctuate based on various determinants. Among these determinants, environmental parameters such as water temperature, pH levels, and the concentrations of metabolic byproducts like carbon dioxide and ammonia hold significance (Dejours, 1975; Dmitry, 2013; Vinagre et al., 2012).

During transportation, one of the most critical factors affecting fish oxygen consumption is fish weight. Larger and heavier fish require more oxygen. In addition, water temperature also affects oxygen consumption. For every 10°C increase in water temperature, oxygen consumption approximately doubles. Therefore, it is extremely important to consider water temperature during the fish transportation process. During fish transportation, measures should be taken to accommodate temperature changes. For example, every 0.5 °C increase in water temperature means that the fish load should be reduced by approximately 5.6 %. Conversely, every 0.5 °C decrease in temperature may require an increase in the load (Harmon, 2009). Therefore, a delicate balance against temperature fluctuations must be maintained during fish transportation. Furthermore, the oxygen consumption of fish can be affected by the stressfulness of the handling and transportation process. Excitement can increase oxygen demand three to five times. Fish, especially salmonid fry, can take several hours to return to normal oxygen metabolism after transportation.

Efficient fish transportation constitutes a critical component for the prosperity of aquaculture operations, demanding meticulous attention to salient factors to optimize the well-being of the fish stock. Prioritizing systematic monitoring of dissolved oxygen levels, especially throughout the transportation process, is imperative, given its direct correlation to the health of aquatic organisms. It is essential to acknowledge that variables such as water temperature, pH levels, and the presence of metabolic byproducts, including carbon dioxide and ammonia, exert a substantial influence on oxygen utilization dynamics. During fish transportation, prudent consideration should be given to the weight of the stock, recognizing that larger and heavier fish necessitate an augmented oxygen supply. Attentiveness to fluctuations in water temperature is crucial, with an awareness that each 10°C increase results in a twofold rise in oxygen consumption. Attaining an intricate equilibrium necessitates the adjustment of fish load in response to temperature variations, thereby ensuring a seamless and efficacious transportation process.

Moreover, an explicit recognition of stress's impact on oxygen consumption, especially during handling and transportation, is pivotal. Implementation of measures aimed at stress reduction becomes imperative, given that agitated fish, particularly salmonid fry, may undergo a three to fivefold surge in oxygen demand. Allowing a sufficient recuperation period for fish, particularly fry, to revert to normal oxygen metabolism post-transportation is indispensable for comprehensive transport management.

In conclusion, consideration of environmental factors, especially water temperature, and minimizing fish stress levels during fish transportation are important issues that affect oxygen utilization and hence fish health. Careful management of these factors is essential for successful fish transportation.

Water Temprature

Since fish are poikicotherms, the water temperature they are in is very important for their metabolic reaction rate. Lower water temperature reduces the metabolic rate and hence the release of CO_2 and the pH of the water remains more stable. Wedemeyer (1997) found that oxygen consumption and ammonia production would be reduced by 50 % if the transport water was lowered by 10 ºC and recommended that the transport water be lowered by 5-7 ºC during transfer (Wedemeyer, 1997). However, this will need to be done carefully as a sudden drop in water temperature can cause stress. Transporters and breeders transferring live fish should be aware of the limitations of each species and adjust the temperature of the transport water accordingly (Harmon, 2009). Optimum water temperatures for transferring fish are 6-8 ºC in winter and 10-12 ºC in summer for cold water fish such as trout (Piper et al., 1982).

In summary, regulating water temperature during fish transport is a critical factor in managing the metabolic response and overall well-being of the fish. Careful consideration of species requirements and gradual temperature adjustments can help ensure the successful transfer and reduced stress in transported fish populations.

Conclusion

Live fish transportation serves as a fundamental component of the aquaculture and fisheries industries, facilitating the movement of aquatic organisms for various purposes. However, this complex process is accompanied by a multitude of stressors that induce significant biochemical reactions in fish, affecting their physiology and overall health. The interactions between stress, physiology, and the biochemical responses during transport are indeed intricate. Throughout the transportation process, fish experience a range of stressors, including physical disturbances, alterations in water quality parameters, and handling-induced stress. These stressors can have profound implications for fish health and survival. Prolonged exposure to stress weakens the immune system, rendering fish more vulnerable to pathogens. Additionally, disruptions in metabolic pathways and energy utilization may result in post-transport mortality or delayed growth rates. To mitigate the adverse biochemical effects of live fish transportation, various strategies have been proposed. These include pre-transport acclimation, the optimization of transport conditions, such as water temperature and oxygen levels, and the administration of stress-reducing compounds, such as antioxidants and corticosteroid blockers. These strategies show promise in alleviating stress-induced biochemical changes and enhancing the welfare of transported fish.

This review serves as a noteworthy contribution to academic literature, offering an in-depth exploration of the biochemical responses exhibited by fish during transportation within the realms of aquaculture and fisheries. The meticulous examination of stressors, physiological alterations, and the consequent implications on fish health provides valuable insights that significantly enrich the scientific community's understanding of these intricate processes. The suggested strategies to alleviate adverse effects hold practical implications, offering tangible applications for the enhancement of the well-being of transported fish. The emphasis on refining transport protocols and mitigating stress-related impacts underscores the critical role of such measures in ensuring the sustained success of the aquaculture and fisheries industries. This comprehensive review, therefore, holds relevance for a diverse audience, including academic researchers, fish farmers, and policymakers, who stand to benefit from its recommendations in advancing the field.

In conclusion, the biochemical effects of live fish transportation represent a crucial area of research and management in the aquaculture and fisheries sectors. Understanding the complexities of these biochemical reactions is essential for improving the overall welfare and survival of transported fish populations. Future research endeavors should focus on refining transport protocols and developing innovative interventions aimed at minimizing the negative impacts of stress during transport. By doing so, the sustainability and ethical considerations of the aquaculture and fisheries industries can be further advanced.

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