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Development and evaluation of key ambient factors online monitoring system in live Urechis unicinctus transportation strategies

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ABSTRACT

This paper puts forward the reasonable choice of live transportation strategy to guarantee survival rate and quality of Urechis unicinctus by designing its packaging mode and carrying out real-time monitoring technologies. Ambient data sensing devices are designed and deployed in water and waterless transportation facilities by which the simulation of real live transportation is tested. During the delivery process of live Urechis unicinctus, the key ambient factors – temperature, dissolved oxygen/oxygen, carbon dioxide, PH, salinity–are dynamically sampling by on-line electronic monitoring equipment. Urechis unicinctus transport ambient data and their correlations are statistically calculated and analyzed by transportation monitoring and analysis system for the two transportation strategies. Through five control groups test for water and waterless shipment, it is found that waterless transportation is more suitable for over 30 h live transportation by studying transportation facilities management, surface characteristics and survival rate, which can provide a sound statistical basis of reasonable transportation mode to guarantee consumers to eat healthier and cheaper seafood with more convenient and economical way.

1. Introduction

Urechis unicinctus (Wang et al., 2010b; Ma et al., 2016b) is known as a fat innkeeper worm or penis fish, which live in the seaside intertidal mud or coral reef area that are mainly distributed Russia, Japan, South Korea and China Bohai Bay. Live Urechis unicinctus possesses delicious meat with high economic value (Gatica et al., 2010b; Abe et al., 2014; Gianasi et al., 2016b; Tan et al., 2016), rich in protein and a variety of body wall muscle essential amino acids. Regular consumption can increase human health. So it attracts many seafood enterprise sales more and more live Urechis unicinctus to satisfy consumer demand.

The transportation of seafood (Zamora and Jeffs, 2015) from farm to outlet, consisting of different events such as netting, weighing, loading, delivering, possible disturbances may cause stressful incident during seafood transportation. Water quality (temperature, pH, dissolved oxygen, ammonium nitrogen, organic carbon, alkalinity, and color) are assessed along with all stress measurements (Ma et al., 2016b; Sampaio and Freire, 2016; Treasurer, 2012b; Zhang, 2016). It is found that seafood live transportation, including the effects of loading and transportation, represented the stress response to affect its live quality.

In water transportation systems (King, 2009b; Shabani et al., 2016b), water is a major expense and important factor for seafood to survive but it is costly in transportation as extra expenses. The vast amount of water is needed to contain seafood, but water quality rapidly will deteriorate due to seafood respiration and excretion. Waterless preservation in cooling live transportation can be an alternative efficient economical logistics to water transportation. However, a comprehensive study of ambient characteristics (Ma et al., 2016b) of Urechis unicinctus in transportation is relatively rare and the key factors for monitoring and transportation assessment are hardly reported.

As for live transportation of Urechis unicinctus, some research aims to explore the impact of cold acclimation and storage temperature on seafood in a waterless preservation(Zeng et al., 2014b; Mao, 2012; Skudlarek et al., 2011), but only from the view of stress level. Live seafood survival rate is significantly enhanced by using salinity (Stieglitz et al., 2012) tests in tolerance trials by different packing densities. Live seafood muscle quality and physiological responses (Sampaio and Freire, 2016) to the hibernation are characterized in

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terms of drip loss and cooking loss. It is feasible to optimize their current shipping methods in closed cooling containers with the waterless condition, allowing a reduction in labors, materials, and mass-dependent transportation costs.

This study brings an integrated monitoring and analysis about the relationship between water and waterless transportation of Urechis Unicinctus by comprehensive comparison of its survival rate, physiological consequences as well as ambient changes. The on-line monitoring and correlation analysis system (OMCAS) in live Urechis unicinctus transportation strategies is focused on the transportation ambient factors (Tang et al., 2009a,b; Farrell, 2006b) influencing on its deterioration, and physiological challenges impose on the live seafood. Usual commercial handling procedures (Bar et al., 2015b) employed to restrain live Urechis Unicinctus stress during transportation is discussed.

This paper takes Urechis unicinctus as experimental subjects to monitor its real-time ambient changes that impact on survival rates during simulated water and waterless transportation by acquiring the changes in pH, dissolved oxygen/oxygen, carbon dioxide, salinity, and temperature. The water and waterless delivery strategies for live Urechis Unicinctus are investigated, which demonstrate waterless cool packaging shipment is more effective and efficient through experimental evaluation. The paper is organized as follows. In Section 2, from the view of system analysis and design, hardware and software implementation is specifically described. Consequently, the system models of OMCAS in Section 3 are suggested to make the system can handle the complex task of space-time ambient monitoring and on-line correlated analyzing. System test and evaluation are carried out and checked the efficiency of overall integrated OMCAS that is stated in Section 4. Additionally, waterless and water transportation strategies for live Urechis unicinctus are compared from monitoring technological indices and survival results. Finally, it is made the conclusion of this keep live delivery research in Section 4 after analyzing the result of monitoring and the correlations of ambient factors.

2. System design and implementation

2.1. Field survey for live Urechis unicinctus transportation in cold chain logistics

A field survey for live Urechis unicinctus in cold chain logistics was conducted in 2016, in Shandong province, China. The purpose is to understand the actual process of live transportation that is in the water and waterless condition, including any factors that may affect the survival and quality of live Urechis unicinctus. The whole monitoring procedure and workflow during transportation is demonstrated in Fig. 1, and specific live delivery description that is being described as follows.

- The temporary aquaculture was a necessary period before packaging ahead of waterless transportation. The experimental objects after the purchase were put on the bottom of culture pond and covered with 8–10 cm sand culture cylinder, every day at the regular time fed with algae food, continuously aerated for 24 h; daily water changed. Aquaculture farmer picked up the healthy Urechis unicinctus with a well appearance from aquaculture ponds, and temporary seafood bred for 10–15 h without feeding before the experiment.
- The preparation of equipment deployment for dynamic observation in different transportation mode of live Urechis unicinctus transportation.
  (a) As for the waterless transportation monitoring mode, the micro air ambient monitoring equipment was deployed in the cold fresh-keeping box to monitor the changes of ambient air to detect the concentration of oxygen and carbon dioxide as well as temperature. The chilled box was placed with two 200 ml ice packs to keep it in cooling condition. The box was put in a plastic board to isolate the ice pack and to prevent frostbite of Urechis unicinctus. The ambient devices fixed in a box were powered by a portable battery that can be used for more than about 40 h.
  (b) As for water transportation monitoring mode, water ambient monitoring equipment was deployed to monitor the changes of water body (dissolved oxygen, pH, salinity, and temperature). Fresh-keeping box was placed with two 400 ml ice packs to keep the water temperature in a low state. That equipment in the vehicle were powered by a portable battery that could be used for continuous monitoring for about 36 h.
- Cold chain simulation management system was composed of a vibration simulation system and a cold chain simulation system, which was integrated with software and hardware. There were two components of the system. The first was a miniature version of the refrigerated vehicle vibration control part. Simulation and test reflect the real road condition of actual transportation. The second part was the control software, which was the realization of the simulation control system of the road transportation. The simulation system could simulate the vehicle status of optimization processing to adjust transportation parameters.
- At the end of the delivery phase, we carried out survival statistics for destination recovery. After the transportation, the Urechis Unicinctus was placed in seawater with a pH of 7.5–8.0, a salinity of 27–30, water temperature about 17–20 °C.

The results of the investigation would help the researcher to identify system requirements and functional module arrangement of on-line monitoring and correlation analysis, which is discussed in the system architecture below.

2.2. System architecture design and implementation

In this section, the monitoring and analysis system architecture of live transportation is discussed in more detailed for the system design and implementation. This architecture has three sub-architecture parts, which is demonstrated in Fig. 2. The whole architecture has two layers that are software and hardware system. The application software part is composed of road chill transportation management system and transportation data analysis system; these two sub-systems are integrated into the monitoring and analysis system for key parameters of live seafood in cold logistics.

From the view of hardware, the hardware is composed of three key components that are live transport ambient monitoring part, wireless communication part of data exchanging, data analysis and modeling part for aquatic delivery. On-site ambient information collection device harvests the micro-ambient data during live transportation. The wireless communication device interchanges the data from the terminal sensors or the instruction data from the management centers. The back-platform is for data analysis and modeling of the live aquatic product delivery according to different categories. The monitoring and analysis system for key parameters of aquatic products is constructed on above hardware system, which coordinates the cold-chain transportation monitoring and charges the concerned ambient parameters during simulated transportation.

2.2.1. Hardware design and implementation

In water monitoring system, the specific electronic components are demonstrated in Fig. 3(a) for water monitoring hardware module. The ADC module (ADS 1256) collects the water sensor information with voltage signal output, which is processed by STM32, and the data is transmitted through CC2530 for analysis. PH value, dissolved oxygen, temperature, salinity sensor output received by the analog pin of ADC, the 3-axis sensor is connected with STM32 by IIC interface circuit, these sensors are powered by the portable vehicle battery.