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Use of RFID temperature monitoring to test and improve fish packing methods in styrofoam boxes

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ABSTRACT

To fulfil the temperature requirements of the cold chain, the fresh fish are usually packed, stored and transported to fish markets with ice in open styrofoam boxes. Some companies offer a more flexible service and they deliver the fish directly to private consumers. In these cases the fish are packed with artificial ice – hydrated and frozen gel pads in specially designed completely closed styrofoam boxes. This study presents the results of the comparison of seven packing methods with the aim to potentially improve them. The temperature outside and inside of the closed box and temperatures in the abdominal cavity of gutted sea bass (*Dicentrarchus labrax*) were measured during the logistics process using Radio Frequency Identification (RFID) technology. The aim of the presented study is to define the optimal cooling materials and methods for different handling options. As an important result, a new efficient, time and energy saving method of packing the fish with the combination of dry non-hydrated gel pads and wet ice instead of the use of frozen gel pads alone is proposed. This method ensures recommended storage temperatures between 0 °C and 4 °C and stable conditions inside the box at room temperatures (or higher) for a longer period of time under the same time-ambient conditions after delivery to the consumer. Furthermore it was established that the part of the ice that melted inside the box, due to higher ambient temperatures, was absorbed by the dry gel pad and only a small quantity of water remained on the bottom of the box.

1. Introduction

In recent years, consumers developed important health related attitudes which lead to increased demands for quality fish products (Pieniak et al., 2010). The proper handling in processing, storage and delivery is very important to ensure the EU food safety policy (Regulation, EC/178/2002). The sea bass is stored in the boxes and covered with ice to ensure handling temperatures from 0 to 4 °C (Poli et al., 2001). The quality processes during shelf life (6–10 days) are influenced by storage conditions in logistics processes. The freshness and shelf life predictions are usually based on chemical and electronic nose methods using sensorial and instrumental parameters. The study of different experiments revealed the possibility of describing the freshness decay and the threshold for about 8 days when the fish was preserved on melting ice. The reduction of temperatures by 1–2 °C can justify the extension of the shelf life to 2–3 days after purchase (Limbo et al., 2009).

The packing methods are very important and represent a value added service to affect the purchase decision (Olsson, 2010). The technological innovation provides quality measurements with expiration of food products to be included in the supply chain and available to consumers. Some studies showed surprising results about the practices of food safety and handling during and after purchase at home (Jevšnik et al., 2008). Often consumers do not use cooling bags for the transport and are not aware of the right storage temperatures of perishable food. The quantitative survey study in Slovenia showed that the consumers' education of food handling is very poor and inadequate. Similar results were obtained in Turkey (Bülent, 2013). The main conclusion was that the food handling practices in the domestic environment are of public concern with the media being very important for the dissemination of food safety concerns. In the last decade, traditional food packaging was replaced with so called active and intelligent solutions using time–temperature indicators and other similar options to delay the effect of the ambient temperature on the product (Brody et al., 2008). Commercial applications with 'smart' devices were developed and their importance was already recognised in the seafood industry. It is very important to provide the

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right packing method for the distribution process, to follow handling recommendations and to avoid increased temperatures in trucks during the exposure to ambient temperatures (Kim et al., 2013). Improper temperatures are associated with bacterial growth that can cause a substantial proportion of food borne disease. A study of an appropriate thermal insulation of two types of expanded polystyrene boxes in protecting super chilled fresh fish products was based on experimental and numerical investigation (Margeirsson et al., 2012; Pacquit et al., 2007). The experimental results showed that a new box type provides significantly better packaging conditions compared to the old box type.

New technologies enable the improvement or even replacement of traditional methods with many useful solutions that offer interaction between food, packaging and environment (Restuccia et al., 2010). The intelligent, active packing methods are supported by RFID systems and temperature monitoring in the cold chain. Recently, RFID smart tags are becoming an appropriate solution to measure the ambient and/or product temperatures in any type of packaging. They are available as semi-passive battery assisted sensor-enabled RFID data loggers (Abad et al., 2009; Delen et al., 2011). The battery energy is only used for supporting the additional functionality of temperature monitoring. The energy for initialisation and reading functionalities is supported by RFID readers (Trebar et al., 2013). The demonstration of an international fresh fish logistic chain with RFID smart tags was validated (Abad et al., 2009). The results proved important advantages regarding the use of temperature monitoring with wireless reading and writing in real time at any time in the chain. Very often, long distance shipments are not supported with the information about the product conditions (Delen et al., 2011). As the air flow and temperatures can vary in different areas inside the containers, the proper monitoring can be performed with RFID-based sensors. The temperatures of the product and surrounding environment are the most important factors to affect the product quality evaluation (Wang et al., 2010). RFID data loggers have been demonstrated as a useful tool of temperature monitoring inside a cooled vehicle to analyse the changes of food quality and freshness.

The aim of the presented study was to define the optimal cooling materials and methods for fresh fish packing. Several handling options were considered, including a new RFID technology approach. The temperature monitoring was performed with RFID data loggers in the logistics phase. The experiments and analysis were developed as the part of the traceability system in the EU project "RFID from Farm to Fork" (F2F, 2013) where RFID technology was used in the implementation of a web-based solution in the supply chain of farmed sea bass to demonstrate tracking of data forward in the chain and tracing the data backwards to present the consumer with all applicable information at the point of sale. The main purpose of the proposed solution was to give all stakeholders in the supply chain, including consumers, a time–temperature indication of fish handling with the monitoring results in combination with the traceability data.

The paper is structured as follows. Section 2 provides an overview of fish packing methods, RFID technology and cold chain monitoring scenarios in styrofoam boxes during the logistics process. Section 3 introduces results with temperature graphs of several experiments to present the benefits of the proposed innovative solution of the combination of the dry, non-hydrated gel pad and wet ice in the box to maintain necessary cooling conditions. Finally, the conclusion gives some interesting outcomes, further ideas and possibilities to improve RFID monitoring.

2. Materials and methods

2.1. Fish packing methods and materials

To guarantee the required temperatures until the delivery, fresh fish are normally packed in opened perforated or closed styrofoam boxes covered with wet ice. When the ice melts, the water flows out from the perforated box but stays inside the closed box resulting in a drop of product quality due to water exposure.

Prior to the present study the Fonda Fish Farm (Fonda, 2013) was packing the fish destined for the delivery to the private consumer in a closed styrofoam box described below and shown in Fig. 1 with one stripe of frozen gel placed on top of the fish (FG). In comparison to the usage of wet ice alone this method proved to be an improvement for the company. It kept the content of the box cold for the needed time, while keeping it dry and in the same time humid enough for efficient fish storage. Nevertheless the company was searching for a way to control the efficiency of their packing method and potentially improve it.

In the present study, packing methods depend on the packaging material and on the type of cooling agents used in the box. Closed styrofoam boxes, wet ice (WI), dry ice (DI) and gel pads were used in monitoring experiments. Gel pads consist of cooling powder packed and sealed in polyethylene cells, called PolarPads (Gel pad, 2013). They are available in a dry, non-hydrated form, in rolled strips which need to be cut, placed into a container with tap water for at least 10 min and after that into a freezer until they are completely frozen and ready for use.

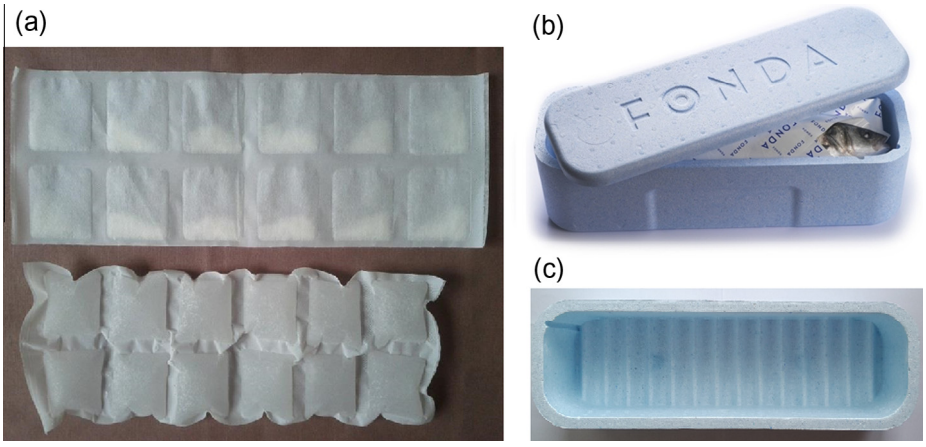

Fig. 1. A stripe of dry, non-hydrated, gel pad (above) and a stripe of hydrated and frozen gel pad (below) (a); packed styrofoam box for fish delivery (b); empty styrofoam box with wave shaped bottom (c).