LWT - Food Science and Technology 54 (2013) 377–382

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Cryogenic and air blast freezing techniques and their effect on the quality of catfish fillets

Luis A. Espinoza Rodezno, Srijanani Sundararajan, Kevin Mis Solval, Arranee Chotiko, Juan Li, Jie Zhang, Luis Alfaro, J. David Bankston, Subramaniam Sathivel*

Department of Food Science, Louisiana State University Agricultural Center, Baton Rouge, LA 70803-4300, USA

ARTICLE INFO

Article history:
Received 22 February 2013
Received in revised form
20 June 2013
Accepted 5 July 2013

Keywords:
Catfish fillet
Cryogenic freezing
Air blast freezing
Catfish quality

ABSTRACT

The effects of cryogenic and air blast freezing techniques on catfish fillet quality during frozen storage was evaluated. Fresh channel catfish fillets were cryogenically frozen by liquid carbon-dioxide using a pilot plant size cabinet type cryogenic freezer (CF) and by air blast (BF) frozen to −21 °C, separately. Freezing time (FT), freezing rate (FR), and energy removal rate (ERR) for freezing depend on the freezing techniques, which affect energy consumption and frozen seafood quality. The frozen fillets were stored at −20 °C and analyzed for weight loss, relative moisture loss, color, and lipid oxidation (Thiobarbituric acid; TBA) after 1-day, 1-month, 3-months, and 6-months of storage. Triplicate experiments were conducted and data were statistically analyzed at $\alpha = 0.05$. FT for cryogenic freezing and air blast freezing were 19.3, and 55.1 min, respectively. Cryogenic freezing had higher FR (1.29 °C/min) and ERR (10.62 J/s) than BF (0.46 °C/min and 3.38 J/s, respectively). The cryogenically frozen catfish fillets had a lower freezing loss than fillets frozen by air blast freezing. TBA (mg MDA/kg sample) of the fillets frozen by CF was 0.94 which was lower than BF (1.25). The study demonstrated that catfish fillets cryogenically frozen had better quality characteristics than blast frozen catfish fillets after 6-months of storage.
© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Freezing is one of the best methods for long-term preservation of seafood. It can produce long storage times and, if done correctly, quality approaching that of a fresh product. There is a growing market segment for frozen seafood. However, freezing can also be a major cost of operating a seafood processing plant. A number of freezing techniques are used in the seafood industry including air blast freezing, plate freezing, immersion freezing, cryogenic freezing and cryo-mechanical freezing. The most versatile and commonly used techniques are air blast freezing and cryogenic freezing. The freezing technique affects not only energy consumption but also frozen food quality. The quality of the frozen seafood is related to freezing rate (Goswami, 2010). The choice of the most favorable technique is dependent upon value received for dollars spent. Developing high quality frozen seafood products using minimal energy for freezing will significantly benefit the frozen seafood market, allowing increased market share, particularly for high quality products, and increased profit margin.

Freezing involves lowering the product temperature generally to −18 °C or below (Fennema, Karel, & Lund, 1975). The cold temperature retards the growth of microorganisms and slows down chemical changes that affect quality or cause food to spoil (George, 1993). The main purpose of frozen storage of seafood is to extend its shelf life and to limit microbial and enzymatic activities which cause deterioration. Freezing is the only large-scale method that bridges the seasons, as well as variations in supply and demand of seafood while maintaining quality close to that of fresh products. It is important to control the freezing process, including the pre-freezing preparation and post-freezing storage of the product, in order to achieve high quality products (George, 1993). Although freezing is an effective method of preservation, some quality changes do occur during storage. Freezing does not improve product quality; it only increases shelf life with minimal quality changes, when done correctly. The extent of these changes depends on many factors, including the rate of freezing and thawing, storage temperature, temperature fluctuations, freezing-thawing abuse during storage, transportation, retail display and consumption (Boonsumrej, Chaiwanichsiri, Tantratian, Suzuki, & Takai, 2007; Hui et al., 2004). The most important changes occurring during storage

* Corresponding author. Department of Biological and Agricultural Engineering, Louisiana State University Agricultural Center, Baton Rouge, LA 70803-4300, USA. Tel.: +1 225 578 0614.

E-mail address: ssathivel@agcenter.lsu.edu (S. Sathivel).

0023-6438/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.lwt.2013.07.005

of frozen foods are discoloration (Chandrasekaran, 1994), lipid oxidation, denaturation of protein (Bhobe & Pai, 1986) and sublimation and recrystallization of ice (Londahl, 1997). These can result in off-flavors, rancidity, dehydration, weight loss, loss of juiciness, drip loss, and textural changes (Londahl, 1997).

Cleland and Valentas (1997) have reported that actual freezer design and operation must be a compromise between quality and cost criteria. Kolbe and Kramer (2007) have reported that slow freezing results in a small number of large crystals, most of which are extracellular. Fast freezing, produces a large number of small ice crystals both intracellular and extracellular. Smaller ice crystals are associated with, higher quality with lower drip loss and good texture. Nicholson (1973) has reported that the type of freezer, operating temperature (difference between product and contact medium), air speed, initial product temperature, product thickness, and shape, density, and species affect freezing rates.

Channel catfish (*Ictalurus punctatus*) was used for the demonstration purpose. Channel catfish is the fourth-most popular fish consumed in the United States. The four major commercial catfish producing states in the United States are Alabama, Arkansas, Louisiana, and Mississippi. In 2011, these states produced over 336,000 metric tons of catfish with a stable monthly production of about 28,000 tons (NASS, 2010). The farming of channel catfish is the largest food fish aquaculture industry in the United States.

There has been a resurgence of interest in evaluating the effect of freezing rate on the quality of seafood. Seafood can be frozen using different freezing techniques and then after which the frozen seafood is stored in a freezer. Previously, studies emphasized the effect of freezing techniques and freezing rates on quality as a result of the freezing and were not necessarily concerned with whether the effect persisted through storage (Cleland & Valentas, 1997; Grujić, Petrović, Pikula, & Amidžić, 1993). Frozen storage shelf life is a major concern for seafood, especially quality changes due to lipid oxidation (Flick George, Hong, & Knobl Geoffrey, 1992). Even very low levels of oxidized fat can produce a rancid flavor which is objectionable (Sundararajan et al., 2011). Quick freezing is known for reducing quality loss of seafood during freezing but there are not many studies available on the effect of energy removal rate, freezing rate, and freezing time on the quality and shelf life of the seafood (Jiang & Lee, 2004). Therefore, the objectives of this study were to evaluate the energy removal rates, freezing rate, and freezing time of cryogenic freezing and air blast freezing for freezing catfish and to determine the effect of cryogenic and air blast freezing on the quality and shelf life of the catfish.

2. Materials and methods

2.1. Catfish fillet freezing process

Live catfish purchased from a local seafood store (Baton Rouge, LA) were stunned, decapitated, eviscerated, skinned and filleted and then transported to Louisiana State University Agricultural Center's Food Processing pilot plant. The fillets were cut into 85–100 g pieces and stored at 4 °C for 3 h. Recovered CO_2 from chemical industries emissions, purified, and supplied as a Liquid CO_2 by Air-Liquide (2009), was used in this study. Catfish fillets were arranged on aluminum trays and placed in a cabinet type cryogenic freezer (Air-Liquide, Houston, Texas). The ambient temperature of the cryogenic freezer employing liquid CO_2 was −59.06 °C. The fillets were frozen until the temperature in the fillets geometric center reached at −21 °C ± 0.5 °C. The temperature of the fillets was recorded at 3 s intervals using thermocouples (Comark®, Comark Limited, Stevenage, Herts, UK) connected to a temperature data logger (Comark®).

The air blast freezer (Master-Bilt Products, New Albany, Mississippi) was at −25 °C and fillets arranged on aluminum trays in the same manner as was done for cryogenic freezing were frozen until the center of the fillets reached −21 °C ± 0.5 °C. A Taylor anemometer (Taylor 3132 Jewelled Anemometer, Taylor Instrument, Sybron Corporation, Arden, NC) was used to measure the air velocity at 9 locations in the blast freezer according to the instruction of the freezer manufacturer (Master-Bilt Products) and the average air velocity in the blast freezer was determined to be 4.91 ± 1.9 m/s. For both freezing methods, the frozen catfish fillet samples were weighed, packed in Ziploc bags (Ziploc double Zipper, S. C. Johnson & Son, Inc., Racine, WI, USA) and stored in an air blast freezer at about −20 °C ± 1 °C for 6 months.

2.2. Energy removal rate

The energy removal rate (ERR) from the catfish fillets (the average amount of energy removed over the freezing time) was estimated based on product heat load (Δh), freezing time and Eq. (1). Freezing time was determined based upon the internal temperature of the catfish fillets.

$$Q = \frac{\Delta h}{t} \tag{1}$$

where Q is the average rate of heat transfer (kJ/s) and t is the time taken for freezing (s).

$$\Delta h = m\left[C_{pu}\left(T_o - T_{if}\right) + L + C_{pf}\left(T_{if} - T_f\right)\right] \tag{2}$$

where Δh is the product heat load (kJ); m is the weight of frozen catfish (kg); T_o is the initial temperature of the catfish fillets ($T_o = 4.2$ °C for cryogenic freezing and 4.82 °C for air blast freezing); T_{if} is the initial freezing point temperature and T_f is the final freezing temperature ($T_f = -21$ °C for cryogenic and −21.03 °C for air blast freezing). The specific heat capacity of the unfrozen catfish fillets and frozen catfish fillets was calculated using Siebel (1892) equations.

$$C_{pu} = 0.837 + 3.349X_w \tag{3}$$

$$C_{pf} = 0.837 + 1.256X_w \tag{4}$$

where C_{pu} is the specific heat capacity (kJ kg^{-1} K^{-1}) of unfrozen catfish fillets; C_{pf} is the specific heat capacity (kJ kg^{-1} K^{-1}) of frozen catfish fillets and X_w is the moisture content of fresh catfish fillets expressed as a fraction (wet basis). This computation was based on the following estimations: (1) water is the only substance being frozen; (2) the measured internal temperature of the catfish fillets is a representative of the overall temperature of the fillets, (3) all the ice crystals are formed at the T_{if}.

Latent heat (L) was calculated using Eq. (5):

$$L = x_i L' \tag{5}$$

where L' is the latent heat of fusion of water (333.6 kJ/kg) and x_i is the weight fraction of ice. x_i was calculated using Eq. (6):

$$x_i = \left(x_{wu} - Bx_S\right)\left(\frac{T_{if} - T_f}{T_o - T_f}\right) \tag{6}$$

where x_{wu} is the weight fraction of water, x_s is the weight fraction of solute, B is kg bound water per kg solute. Bound water was calculated using Eq. (7):

Download English Version:

https://daneshyari.com/en/article/6404572

Download Persian Version:

https://daneshyari.com/article/6404572

Daneshyari.com