Journal of Food Engineering 156 (2015) 39–44

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Impact of high voltage electric field thawing on the quality of frozen tuna fish (*Thunnus albacares*)

Alireza Mousakhani-Ganjeh [a,*], Nasser Hamdami [a,b], Nafiseh Soltanizadeh [a]

[a] Department of Food Science and Technology, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran
[b] Center of Excellence on Food Safety and Quality, Isfahan University of Technology, Isfahan 84156-83111, Iran

ARTICLE INFO

Article history:
Received 8 November 2014
Received in revised form 2 February 2015
Accepted 8 February 2015
Available online 14 February 2015

Keywords:
High voltage electric field (HVEF)
Thawing
Tuna cubes
Thawing rate
Protein solubility

ABSTRACT

Recently, high voltage electric field (HVEF) has been considered as a new technology in the food industry. Since this method has several benefits over conventional methods, the changes in the quality of tuna fish cuts under HVEF thawing were compared with those in control samples. The experimental tuna cubes were thawed under HVEF subjected to three different voltages from corona starting to breakdown voltage (4.5–14 kV) at electrode gaps of 3, 4.5, and 6 cm; the control being thawed at 20 °C without being subjected to HVEF. The results showed that thawing under HVEF significantly improves thawing rate and total volatile binding nitrogen of the frozen fish cubes. The highest thawing rate was 1.78 times greater than that obtained for the control samples. However, color, texture, and protein solubility of fish samples declined as a result of thawing under HVEF. Increasing the applied voltage decreased protein solubility and affected the hardness, gumminess, cohesiveness, and chewiness of the fish samples as compared to the control. The application of HVEF thawing has the potential of extending the freshness of thawed tuna fish.

1. Introduction

Tuna is a generic name for a group of fish species belonging to the *Scombroidae* family. Among the different members of this family, yellowfin tuna is more popular in the Middle-Eastern countries. The yellowfin tuna (*Thunnus albacares*) is a species of tuna found in pelagic waters of tropical and subtropical oceans worldwide. It is appropriate for canned fish production since it lacks large bones in the spine of the blade. Hence, tuna and tuna-like species are important marine fishes due to their high global economic value and their prevalence in international trade for canning (Guizani et al., 2005; Bremner, 2002). However, they cannot be freshly consumed or processed because of their seasonality of fishing, lack of market access in certain places, and cost of transportation to other areas. Freezing is, therefore, used for their preservation. Thawing frozen fish just before its process is an important step in the canning industry. An important factor to consider in selecting the proper thawing method is whether the method is non-destructive so that minimal damage is inflicted to the fish quality. Different systems using air, water, vacuum heat, high pressure, radio frequency, microwave, infra-red, and ultrasonic have so far been applied for thawing frozen fish, each associated with its unique problems such as slow rate, high weight loss, microbiological spoilage, chemical spoilage, overheating and high cost (Bratt, 2010; Uyar et al., 2015; Llave et al., 2015). Hence, it is essential to develop a method that is capable of maintaining the quality and avoiding undesirable changes in the tuna fish.

Novel technologies have been advanced to avoid the deleterious effects of heat on food flavor, color, and nutritional value by non-thermal systems (Orlowska et al., 2014). One such technology involves the application of electric field for thawing frozen foods. Ohtsuki (1991) invented a process for the rapid thawing of food at low temperatures (−3 to +3 °C). In fact, he used negative electrons induced by the high-voltage electrostatic method (Ohtsuki, 1991). In addition to its low energy consumption, the HVEF preserves food freshness, which has recently made attractive for producing high quality products (Dinani et al., 2014; Singh et al., 2012; Song et al., 2000). Some researchers have studied the effect of electrostatic field on the quality of frozen products to observe that electrostatic thawing can limit microbial growth and reduce microbial loads; hence, the amount of volatile nitrogen in products thawed by this method is reduced and storage time is increased (He et al., 2013; Hsieh et al., 2010). Thawing frozen beef and eggs by this innovative method was accomplished in 25–30% of the time taken by conventional methods under the same temperature (Orlowska et al., 2014). Previous studies have indicated that HVEF could reduce the time for thawing frozen pork (20 °C) and chicken

* Corresponding author. Fax: +98 313 391 34 28.
E-mail address: A.mousakhani@ag.iut.ac.ir (A. Mousakhani-Ganjeh).

http://dx.doi.org/10.1016/j.jfoodeng.2015.02.004
0260-8774/

(−3 °C) to 2/3 of the time spent in still air (He et al., 2013; Hsieh et al., 2010). The thawing time of frozen pork tenderloin meat by the HVEF method was reportedly shortened by increasing voltage and decreasing electrode distance (He et al., 2014).

Based on the above considerations, it seems that application of an appropriate method for thawing fish can be a great achievement for food processors. The present study is part of an ongoing study of the application of HVEF thawing for tuna fish cubes, which aims to investigate the changes that are possibly made in the quality of this product during thawing under HVEF and storage time, and to compare it with conventional still air method.

2. Materials and methods

2.1. Materials

Fresh tuna fish (*T. albacares*), each 10 kg, were purchased (caught in the the Persian Gulf, Iran) and transferred to the laboratory in ice. The yellowfin tuna were immediately beheaded and gutted to sample preparation and all the red muscles were separated and removed. All the chemicals used were of analytical grade purchased from Merck Company (Germany).

2.2. Sample preparation

The white fresh fish muscles were cut into cubes ($2 \times 4 \times 4\ cm^3$) using a knife and immediately frozen at −30 °C after vacuum packaging in polyethylene bags. The frozen samples were stored at −18 °C until use.

2.3. HVEF experimental apparatus and thawing conditions

The experimental setup for HVEF is shown in Fig. 1. The main experimental apparatus for HVEF comprised a high voltage power generator with an adjustable voltage ranging from −50 to +50 kV by a controller and a maximum output current of 5 mA (LS50KV-5 mA, China), a HVEF treatment frame, and a multiple points-to-plate electrode. The grounded plate electrode was a 20 × 15 cm rectangular copper plate and the corona discharge electrode was a 20 × 15 rectangular plate with 16 sewing needles 0.4 mm in diameter and 80 mm in length. This electrode was connected to the positive pole of the high voltage power supply.

High voltage electric field formed by a plate electrode that could not improve the thawing rate obviously, while a needle electrode could improve the thawing rate. The corona wind could produce from the needle electrodes. The highly corona wind was responsible for thawing due to increase heat transfer (He et al., 2014). Hereto in our research used a multiple points-to-plate electrodes.

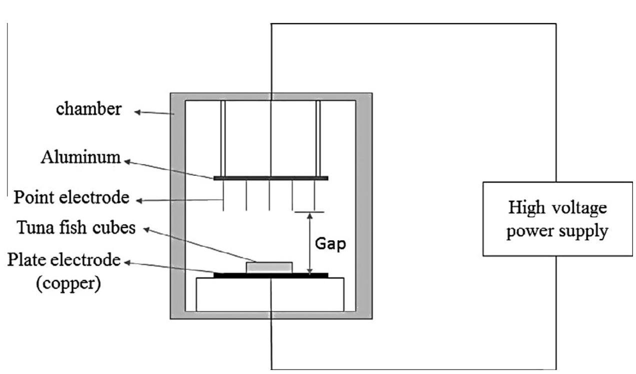

Fig. 1. Schemetic diagram of HVEF thawing system.

The tuna cubes in the experimental groups were thawed under HVEF with three different voltages from corona starting voltage to breakdown voltage at three different electrode gaps, while the control was thawed without HVEF in a controlled incubator (Binder, Germany) at 20 °C. The applied voltages for the experimental groups were 4.5, 7.5, and 10.5 kV; 6, 10.5 and 13.5 kV; and 7.5, 10.5, and 14 kV for electrode gaps of 3, 4.5 and 6 cm (150, 250 and 350; 133.33, 233.33 and 300; 125, 175 and 233.33 kV/m), respectively. The electric field strength calculated from following equation:

$$\text{Electric field strength} = \frac{\text{Voltage}}{\text{Gap}} \tag{1}$$

To perform thawing under HVEF, a frozen fish cube was placed on the rectangular stainless steel plate and the electric field was set up between the two electrodes. A temperature sensor was inserted into the geometric center of the fish sample to record the temperature evolution during thawing. Thawing was continued until the geometric center of the fish sample temperature reached −1 °C.

2.4. Determination of thawing time and thawing rate

The time required to raise the temperature at the center of the frozen fish cube from −18 °C to −1 °C was determined as thawing time. The thawing rate of frozen fish samples was calculated by dividing the sample weight by the thawing time (g/s) as follows:

$$\text{Thawing rate} = \frac{\text{weight of frozen fish}}{\text{Thawing time}} \tag{2}$$

2.5. Determination of evaporation, thawing, and drip losses

Evaporation, thawing, and drip losses were determined by weighing the frozen and thawed fish samples before and after the removal of surface water according to the following equations:

$$\text{Evaporation loss}(\%) = \frac{\text{M0} - \text{MT}}{\text{M0}} \tag{3}$$

$$\text{Thawing loss}(\%) = \frac{\text{M0} - \text{MTT}}{\text{M0}} \tag{4}$$

$$\text{Drip loss} = \text{Thawing loss} - \text{Evaporation loss} \tag{5}$$

where M0, MT, and MTT are the weight of the frozen fish, the thawed fish before removing surface water, and the thawed fish after surface water removal, respectively.

2.6. Determination of cooking and total losses

Ten grams of the thawed samples were placed in a polyethylene bag and cooked at 75 °C in a water bath for 25 min until the sample temperature reached 72 °C. Cooking loss was determined as follows:

$$\text{Cooking loss}(\%) = \frac{\text{M0} - \text{MT}}{\text{M0}} \tag{6}$$

where M0 and MT are the weights of fish sample before and after cooking, respectively.

Total loss was determined as the sum of thawing and cooking losses:

$$\text{Total loss} = \text{Thawing loss} + \text{Cooking loss} \tag{7}$$

2.7. Total Volatile Binding Nitrogen (TVBN)

The thawed fish cubes were stored at 4 °C for a week and TVBN of the fish samples was determined immediately after thawing and after 6 days of storage. To determine the TVBN value, 10 g of fish meat was homogenized with 300 ml of distilled water and the