Innovative Food Science and Emerging Technologies 42 (2017) 25–32

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Post-thawing quality changes of common carp (*Cyprinus carpio*) cubes treated by high voltage electrostatic field (HVEF) during chilled storage

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ARTICLE INFO

Keywords:
Common carp
Thawing
High voltage electrostatic field (HVEF)
Freshness

ABSTRACT

In recent years, high voltage electrostatic field (HVEF) technology has been demonstrated to be a viable alternative to high-temperature treatments in processing for inhibiting microbial growth and maintaining post-thawing quality of foods. In this study, common carp (*Cyprinus carpio*) meat cubes were treated with HVEF, and compared to air-thawed and running tap water-thawed controls to investigate how HVEF affects common carp meat quality after thawing and low-temperature storage (4 °C). The results showed that thawing under − 6, − 12 kV HVEF and running tap water significantly decreased the thawing time by 30, 50 and 45 min, respectively, compared to air thawing control. In addition, − 12 kV HVEF treatment also reduced the moisture loss, which the initial drip loss of it was lower by 2.95% than CK. The initial total viable counts, *Aeromonas*, *Pseudomonas*, and lactic acid bacteria were 3.58, 3.15 2.88 and 3.25 log CFU/g in CK after thawing, respectively, which were higher than that in the cube thawed by − 12 kV HVEF (3.11, 2.93 2.71 and 2.91 log CFU/g). Additionally, − 12 kV HVEF treatment enhanced adenosine monophosphate deaminase (AMP-deaminase) activity, reduced acid phosphatase (ACP) activity and delayed the degradation of inosine monophosphate (IMP) to hypoxanthine (Hx). These results suggested that HVEF treatment could be useful in the thawing and storage of frozen common carp fish.

Industrial relevance: The study investigated the effects of high voltage electrostatic field (HVEF) thawing on the water-holding capacity, adenosine triphosphate degradation and microbial community changes of frozen common carp (*Cyprinus carpio*) cubes when stored at 4 °C. HVEF under − 12 kV was found to have positive influence on reducing the thawing time, maintaining water-holding capacity, decreasing the level of microbe, and delaying adenosine triphosphate (ATP) degradation. A potential application for HVEF in the thawing and storage of frozen aquatic product was highlighted in food industry.

1. Introduction

Freezing and thawing processes play a vital role in the preservation of the quality of foods. However, the process of thawing has received much less attention compared to either chilling or freezing (Alizadeh, Chapleau, De Lamballerie, & LeBail, 2007a; He, Liu, Nirasawa, Zheng, & Liu, 2013; Kong et al., 2016; Lagerstedt, Enfalt, Johansson, & Lundstrom, 2008). The quality of food is significantly affected by freezing and thawing processes through a series of physical and chemical changes (Li & Sun, 2002; Park, Ryu, Hong, & Min, 2006). Prolonged thawing time is associated with meat discoloration, microbial growth, weight decrease and oxidation of lipids. However, reduced thawing time has been reported to decrease microbial growth and chemical deterioration (Icier, Izzetoglu, Bozkurt, & Ober, 2010; Taher & Farid, 2001). In addition, quick thawing can effectively curtail drip loss of meat (Eastridge & Bowker, 2011; Min, Hong, Chun, & Park, 2016).

Usually, frozen food is thawed in air or in cold or hot tap water

Abbreviation: HVEF, high voltage electrostatic field; ATP, adenosine triphosphate; ADP, adenosine diphosphate; AMP, adenosine monophosphate; IMP, inosine monophosphate; HxR, hypoxanthine ribonucleoside; Hx, hypoxanthine; AMP-deaminase, adenosine monophosphate deaminase; ACP, acid phosphatase; TVC, total viable counts; PCA, plate count agar; AMB, Aeromonas Medium Base; LAB, lactic acid bacteria; CK, the control group; RW, running tap water

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http://dx.doi.org/10.1016/j.ifset.2017.06.005
Received 19 December 2016; Received in revised form 1 June 2017; Accepted 7 June 2017
Available online 08 June 2017
1466-8564/

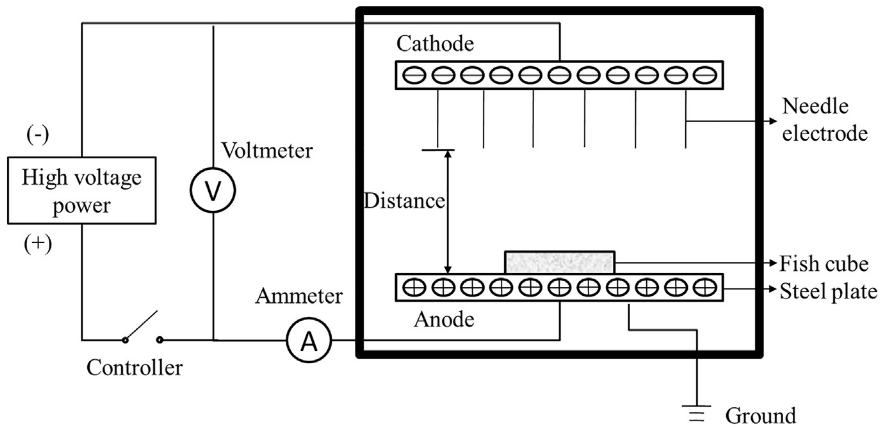

Fig. 1. Schematic diagram of the HVEF treatment system used in this study.

(Eastridge & Bowker, 2011). In recent years, several novel technologies such as high voltage electrostatic field (HVEF), ohmic heating, microwaving, high pressure and ultrasound have been applied for the thawing of frozen foods (Li & Sun, 2002; Min et al., 2016; Park et al., 2006). HVEF thawing, in particular, reduces thawing times of frozen foods with minimal changes in quality and low energy consumption compared to conventional thawing (He, Jia, Tatsumi, & Liu, 2016; He, Liu, Tatsumi, Nirasawa, & Liu, 2014; Mousakhani-Ganjeh, Hamdami, & Soltanizadeh, 2015). Unlike hot water and microwave thawing, HVEF can avoid the harmful effects of heat on food flavor, color, and nutritional value by non-thermal systems (Dinani, Havet, Hamdami, & Shahedi, 2014; Orlowska, LeBail, & Havet, 2014; Singh, Orsat, & Raghavan, 2012). Recently, several studies have reported the use of high voltage electric field (HVEF) in drying food materials and for shelf-life improvement. The rise of total plate counts, K value and total volatile basic nitrogen of tilapia (*Orechromis niloticus*) are effectively inhibited and the shelf-life extended during refrigeration in HVEF (Hsieh, Lai, Lee, & Ko, 2011; Ko, Yang, Chang, & Hsieh, 2016). In addition, He et al. (2016) reported that the energy consumption which is provided by the HVEF is an important factor to reduce thawing time and accelerate the entire thawing process. The thawing time of frozen pork tenderloin meat is reduced by HVEF by shortening electrode distance and increasing voltage (He et al., 2014). Hsieh, Lai, Ho, Huang, and Ko (2010) demonstrated that HVEF thawing could lower the cooking loss of chicken thigh meat. However, there is little information about the quality changes of frozen fish thawing by HVEF.

Common carp (*Cyprinus carpio*) is an important fish species among freshwater fishes in the world with the harvest of 4,159,117 tons in 2014 (FAO, 2016). Common carp is highly nutritious as it contains a significant amount of complete proteins. Kong et al. (2016) investigated the quality changes of brined common carp during frozen storage at different temperatures. Compared with thawing in air, Mousakhani-Ganjeh et al. (2015) found that the drip loss and the total volatile basic nitrogen (TVB-N) of frozen tuna fish (*Thunnus albacares*) decreased significantly after thawing by HVEF. However, the scientific literature is scanty on the storage quality changes of frozen freshwater fish after thawing by HVEF. In addition, carp is a highly perishable commodity even with refrigerated. Freshness is considered one of the most important criteria of fish quality in most markets. The spoilage of fish occurs rapidly with the growth and metabolism of microorganisms (Gram & Huss, 1996). In addition to microbes, adenosine triphosphate (ATP) degradation can strongly affect the final quality of fish and fish products. The ATP is degraded into hypoxanthine (Hx) by following the pathway of ATP-adenosine diphosphate (ADP)-adenosine monophosphate (AMP)-inosine monophosphate (IMP)-hypoxanthine ribonucleoside (HxR)-Hx (Hong, Regenstein, & Luo, 2015). In fish products, the amount of IMP is an important indicator of freshness, and it is responsible for desirable odor and taste (Hong et al., 2015; Minami, Sato, Shiraiwa, & Iwamoto, 2011; Ocaño-Higuera et al., 2011). The generation and degradation of IMP are controlled by AMP deaminase and acid phosphatase (ACP). Hx is a bitter substance that causes a bad taste in fish (Hernandez-Cazares, Aristoy, & Toldra, 2011). However, the effects of HVEF treatment on adenosine triphosphate degradation and related enzyme activities have not been studied. Therefore, development of novel methods like HVEF for thawing of fish would be useful for food processors.

The objective of the present study was to investigate the changes in water loss (drip, cooking and centrifugal losses and moisture distribution), adenosine triphosphate degradation (AMP-deaminase and ACP activity, the content of IMP, HxR and Hx) and microbial community (total viable counts, the level of *Aeromonas* sp., *Pseudomonas* sp., lactic acid bacteria and H_2S-producing bacteria) of common carp cubes during thawing by HVEF and 4 °C storage.

2. Materials and methods

2.1. Preparation of fish material

A total of 40 fresh common carps (weight 1.45 ± 0.07 kg, length 40.67 ± 1.29 cm) were purchased from an aquatic product wholesale market in Beijing, China. All the carps were raised in the same aquaculture farm (Miyun District) in the suburban area of Beijing. The carps were transported to the laboratory alive in aerated foam boxes that contained water and the live carps were killed by a blow on the head, scaled, gutted, decapitated, washed and divided into cubes (size: $4.0 \times 3.0 \times 1.5$ cm^3; mean weight: 25.27 ± 1.68 g). All the cubes were drained by placing on a clean steel frame for 10 min, and then packaged in polyvinyl chloride bags. There was only one cube was packed to each bag. After packing, all the pouches were stored in a refrigerator at − 18 ± 1 °C for one month.

2.2. Thawing process

2.2.1. HVEF experimental apparatus

The experimental setup for HVEF is shown in Fig. 1. It mainly consists of a high voltage power generator (DW-N303-1AC, Tianjin, China) with an adjustable voltage (from − 30 to 0 kV) controller, a high voltage electrostatic treatment chamber, and a multiple points-to-plate electrode system. The voltmeter and ammeter are connected to the circuit to monitor the changes in voltage and current of HVEF. In this experiment, the multiple points-to-plate electrodes comprised of needle electrode connected to the negative pole of the high voltage electrode and a steel plate connected to the ground electrode. The needle electrode was formed by a 9×9 cm^2 integrated plate embedded with 16 sharp-point needles (0.001 mm in diameter, 3 cm between two needles). To perform thawing under HVEF, a frozen carp cube was placed on the steel plate (the anode) and the electric field was set up between the two electrodes.