LWT - Food Science and Technology 87 (2018) 234–240

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Effect of ultra-high pressure treatment on shucking and meat properties of red swamp crayfish *(Procambarus clarkia)*

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A R T I C L E I N F O

Article history:
Received 27 February 2017
Received in revised form
28 July 2017
Accepted 29 July 2017
Available online 30 August 2017

Keywords:
HPP
Crayfish
Meat yield
Texture
Histology

A B S T R A C T

The objective of this study was to investigate the effect of ultra-high pressure treatment (0, 100, 200, 300, 400, and 500 MPa, respectively) on shucking (crayfish meat yield) and meat properties (moisture content, thermal characteristics, texture properties, protein pattern and microstructure) of red swamp crayfish (*Procambarus clarkia*). Comparing to the control, the crayfish meat yield increased and the moisture content decreased for the samples with the high pressure treatments, however no significant difference was observed when the pressure above 200 MPa. The denaturation enthalpy ($\triangle$H) of three endothermic peaks normally found at 50 °C, 65 °C, and 80 °C were all significantly shifted to lower value ($p < 0.05$) after pressure treatment. With the increase of treated pressure, the hardness, springiness and chewiness values were increased sharply at first and then decreased slightly but all higher than those of the control. Microstructure changed obviously with the increase of the ultra-high pressure. Overally, 200 MPa was considered as the optimum treatment condition for crayfish shucking without damage the food quality. The research would provide a reliable reference for ultra-high pressure application in shucking of red swamp crayfish.

1. Introduction

Red swamp crayfish (*Procambarus clarkia*) is one of the most popular and important commercial freshwater species in China, especially in the southeast regions. Introduced from America (Li, Deng, Yang, & Wang, 2012), red swamp crayfish has been widely artificially farmed in inland China, and the total production reached 659,611 tons in 2014 (Lan et al., 2016). In general conditions, most adults are approximately 5.6 cm–11.9 cm in length and resemble small lobsters (Ding et al., 2012). Red swamp crayfish are highly appreciated by consumers on account of their high nutritive value and great flavor when well cooked, and a significant mark has developed due to convenient breeding, excellent yield, and high growth rate.

In order to meet demands in the seafood industry, red swamp crayfishes are usually shucked so that they can be sold as ready raw meats with higher consumer acceptance. Manual shucking is a widely used method, however, it probably impairs red swamp crayfish meat even when carried out by high-skilled persons, leading to quality deterioration (Yi et al., 2013). Meanwhile, the crayfish meat yield is substantially reduced. In addition, the low efficiency of manual shucking can not be neglected. Nowadays, a large number of other shucking methods for bivalve shellfish have been developed to assist manual shucking, such as freezing process and thermal methods for the raw materials. Martin, Supan, Theriot, and Hall (2007) have suggested that yielded meat detachments of *Crassostrea virginica* with a combined shucking treatment of low-pressure steam and cryogenic N_2/CO_2 or ice water could exceed 85%. Nevertheless, automated shucking machines are unlikely to sever the adductor muscle precisely so that their utilization is heavily limited. Furthermore, the shucking with heat treatment will result in the coarse meat quality and the unfavorable taste.

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http://dx.doi.org/10.1016/j.lwt.2017.07.062
0023-6438/

Therefore these processes cannot meet consumer demands which requires seafood to be raw or minimally-cooked (Yi et al., 2013).

Nowadays, ultra-high pressure has been widely employed in efficient food processing, including meat products, shellfish shucking, and fruit and vegetable juices processing (Cao et al., 2012). Ultra-high pressure could disrupt protein conformation and inter-/intra-molecular interactions, including hydrogen bonds, electrostatic bonds, hydrophobic interactions as well as disulphide bonds, resulting in the structural change and the functional modification, such as protein solubilization, aggregation, denaturation, gelation, or depolymerisation (Aertsen, Meersman, Hendrickx, Vogel, & Michiels, 2009). Studies have reported that major changes in the quaternary structure, the tertiary structure, and secondary structure generally take place at mild pressure (150 MPa - 200 MPa), moderate pressure (above 200 MPa), and relatively high pressure (300 MPa - 700 MPa), respectively (Aertsen et al., 2009). Proposed as a promising alternative for oyster shucking, ultra-high pressure treatment has several advantages, including higher muscle integrity, increased meat yield, and enhanced safety due to the inactivation of enzymes and microorganisms with the minimum loss of color, taste, juicy, and nutritional content (Cruz-Romero, Kelly, & Kerry, 2007). Thus the physiochemical and functional properties of seafood products are improved to a certain extent with ultra-high pressure treatment. Cruz-Romero et al. (2007) have compared three different treatments (ultra-high pressure, cool pasteurization and traditional pasteurization) to the manual shucking, it turned out that the treatments had higher oyster shucking yield and cost less labor than pure manual shucking, and ultra-high pressure treatment was better than other treatments (the shucking yield of ultra-high pressure, cool pasteurization and traditional pasteurization treatment was 15.5, 12.5 and 2.6 g/100 g, respectively).

In current, studies on the shucking and meat properties of the red swamp crayfish by ultra-high pressure have not been done. Therefore, the objective of this study was to evaluate the effect of ultra-high pressure treatment on shucking and meat properties of red swamp crayfish, including moisture content, crayfish meat yield, thermal characteristics, textural profile analysis (TPA), protein pattern (SDS-PAGE), and microstructure (histology). The research would provide a reliable theoretical basis and practical guidance for ultra-high pressure application in shucking of red swamp crayfish.

2. Materials and methods

2.1. Materials

Fresh red swamp crayfishes (*Procambarus clarkii*) (approximately 10 cm–11 cm in length, 40 g - 45 g in weight) were purchased from a local fresh supermarket (Wuhan, China). They were kept in crushed ice and transported to the lab within 30 min. Then they were cleaned with pre-cooling water prior to further treatment.

HPP.L2-600/2 ultra-high pressure processor, DSC 200F3 differential scanning calorimeter, TA-XT2 Texture Analyzer, Gel Doc XR gel imaging, and Eclipse Ci microscope were provided by Tianjin Huatai-Senmiao Bioengineering and Technology Co., Ltd (Tianjin, China), NETZSCH Scientific Instrument Co., Ltd (Selb, Germany), Stable Micro Systems Ltd (Goldaming, UK), Bio-Rad Laboratories Inc (Hercules, America), and Nikon Instrument Inc (Tokyo, Japan), respectively.

2.2. Preparation of samples

2.2.1. Ultra-high pressure treatment

Each fresh red swamp crayfish was packaged into a vacuum bag and then processed in sets of ten per batch. They were vacuum sealed and placed in an ultra-high pressure processor (HPP.L2-600/2, Tianjin, China). The pressure inside the processor was increased at a speed of 5 MPa/s to reach the aim pressure (high hydrostatic pressure, 100, 200, 300, 400, and 500 MPa, respectively), and held for 5 min, and finally released within 5 s. The temperature inside the processor during the processing was slightly raised from 25 °C to 28 °C, monitored by a thermometer. Samples without ultra-high pressure treatment were set as the control. After the ultra-high pressure treatment, the red swamp crayfish was shucked manually.

2.2.2. Extraction of myofibrillar protein (MP)

Fresh red swamp crayfish meat was minced and homogenized and then myofibrillar protein (MP) was extracted according to the method described by Xiong, Cheng, Ye, and Cai (2009) using 20 mmol/L Tris-maleate buffer (pH 7.0) respectively containing 50 mmol/L potassium chloride (KCl) and 0.6 mol/L KCl. The mixture was centrifuged at 9000 g for 10 min and 30 min, respectively. The final supernatant was the MP solution.

2.3. Moisture content

Moisture content of red swamp crayfish meat was determined by the oven drying at constant temperature of 105 °C (±5 °C) for 2 h (Juang, Chang, Sung, & Su, 1984). The measurements were taken 3 times.

2.4. Crayfish meat yield

Crayfish meat yield of red swamp crayfish treated under ultra-high pressure were performed according to the method of Kim, Meyers, and Godber (1996) with some modifications. Each group treated with different level of ultra-high pressure contained ten red swamp crayfishes. The measurements were taken10 times. Crayfish meat yield was calculated from the following equation:

$$\text{Crayfish meat yield } (\%) = \left[\sum m_i/M_i\right] \Big/ N \times 100 (i = 1, 2, 3 \ldots\ldots N, N = 10)$$

where M_i was the weight of red swamp crayfish before shucking while m_i was the weight of the shucked crayfish meat.

2.5. Differential scanning calorimetry (DSC)

Thermal properties of the meat of red swamp crayfish treated under ultra-high pressure were performed by DSC according to the method of Meng and Ma (2001) with some modifications. Red swamp crayfish samples of 19 mg–25 mg were accurately weighed into standard aluminum pans and then hermetically sealed. An empty pan was set as the reference. Samples were heated from 20 °C to 100 °C at a rising rate of 5 °C/min in a differential scanning calorimeter (TA Instruments, NETZSCH, DSC 200F3, Germany). The cooling mode was set as mechanical refrigeration. The flow rate of sweeping gas and protecting gas, both N_2, were 20 mL/min and 60 mL/min, respectively. The measurements were repeated 5 times. Statistical analysis was performed by Proteus Thermal Analysis (Version 6.1.0, NETZSCH, Germany).

2.6. Textural profile analysis (TPA)

Texture measurements of the second abdominal segment of crayfish meat were performed using a TA-XT2 Texture Analyzer (Stable Micro Systems Ltd., Surry, UK) according to the method of Truong, Buckow, Nguyen, and Stathopoulos (2016). The compression