Innovative Food Science and Emerging Technologies 13 (2012) 42–50

Contents lists available at SciVerse ScienceDirect

Innovative Food Science and Emerging Technologies

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

Effects of high hydrostatic pressure on microstructure, texture, colour and biochemical changes of red abalone (*Haliotis rufecens*) during cold storage time

V. Briones-Labarca [a,b,*], M. Perez-Won [a], M. Zamarca [a], J.M. Aguilera-Radic [c], G. Tabilo-Munizaga [d]

[a] Department of Food Engineering, Universidad de La Serena, Av. Raúl Bitrán s/n. 599, La Serena, Chile
[b] CEAZA, Centre for Advanced Studies in Arid Zones, Universidad de La Serena, Av. Raúl Bitrán s/n, Box 599, La Serena, Chile
[c] Department of Chemistry Engineering, Pontificia Universidad Católica de Chile, Chile
[d] Department of Food Engineering, Universidad Bio-Bio, Chile

ARTICLE INFO

Article history:
Received 23 March 2011
Accepted 2 September 2011

Editor Proof Receive Date 30 September 2011

Keywords:
High hydrostatic pressure
Abalone
Colour
pH
TVB-N
TMA
Microstructure

ABSTRACT

This study was carried out to evaluate the effect of high hydrostatic pressure on quality changes (microstructure, colour, texture and biochemical) of red abalone (*Haliotis rufecens*) during storage time at 4 °C. High hydrostatic pressure (HHP) treatments were applied at 500 MPa for 8 min and 550 MPa for 3 and 5 min. Biochemical indices covering pH, total volatile basic nitrogen (TVB-N) and trimethylamine (TMA), as well as instrumental texture, microstructure and colour of abalone samples were determined immediately after treatment and throughout subsequent storage at 4 °C. Results have shown that HHP-treated abalones have significantly ($p \leq 0.05$) higher pH, moisture and ash content than untreated abalones. Protein and fat contents of treated abalones were significantly ($p \leq 0.05$) lower compared to untreated sample (control). TVB-N and TMA levels for HHP-treated abalones rose over the storage period but did not exceed 28 mg TVB-N/100 g and 3 mg TMA/100 g, respectively at the end of 60 days. Instead, the untreated sample exceeded the allowed limit in a 30 day period for the TVB-N and TMA. However, all HHP treatments had less negative effects on tissue colour of abalone than untreated samples in the cold storage time; moreover, whiteness index was reduced to 8% at the end of day 60. A more compact structure was identified as high hydrostatic pressure was higher. Thus, it was concluded that holes in muscle fibres were often due to protein gelation, whenever pressure and protein concentration are high enough, confirming that the structure of abalone muscle treated with high hydrostatic pressure differed significantly from that of raw abalone meat.

Industrial relevance: This paper provides information on microstructural and biochemical stability under prolonged storage time of abalone after pressure treatments which are quite scarce. In base of the data accumulated, criteria for commercial production of high quality abalone with safety requirements could be established.

1. Introduction

Seafood includes a number of high quality products with considerable economic importance. Abalone is considered exotic seafood and is known as one of the most expensive marine foods. Due to overfishing and poaching, fisheries are not able to meet the market demand for abalone. Abalone aquaculture over the last decade has increased its share of the world abalone market with the decline of abalone fisheries. Abalone aquaculture helps fill this gap. Approximately 70% of the abalone consumed globally is produced on farms. Farming of abalone began in the late 1950s in Japan and China. Abalone culture technology is now well established in several countries, and the industry can be considered to be entering a maturation phase. The global leader in abalone production is China, where more than 80% of farmed abalone is grown. Most of this is consumed domestically. The remaining 20% of production happens in South Korea, South Africa, Taiwan, Australia, Chile and the United States. Aquaculture in Chile has experienced a strong growth during the last two decades, and its total aquaculture production has risen from 70,500 t in 1990 to 853,000 t in 2007 (FAO, 2009).

Abalone is considered as a highly valued delicacy with a unique taste and texture, but given the perishable mature of seafood, the development of satisfactory methods for shelf life extension that ensures quality maintenance and a continuous supply of refrigerated quality products with minimum losses, has occupied the attention of food technologists. With the aid of processing technology, these abalones can be stored and transported with minimal quality degradation, and processed to value-added products that will draw attention from consumers worldwide. Freshness makes a crucial contribution to the quality of abalone. Evaluation of abalone quality is, hence, required by food industry, motivating a continuous search for effective freshness index methods. A number of seafood spoilage indicators have been used, including total volatile basic nitrogen (TVB-N) and trimethylamine (TMA). In general, seafood is highly perishable with a 14 day-shelf life for a fresh or thawed product. Usually

* Corresponding author at: Department of Food Engineering, Universidad de La Serena, Av. Raúl Bitrán s/n. 599, La Serena, Chile. Tel.: +56 51 204455; fax: +56 51 204446.
E-mail address: vbriones@userena.cl (V. Briones-Labarca).

1466-8564/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ifset.2011.09.002

beyond 7 days of cold storage, the product is considered of a lower grade and frequently sold at reduced cost or discarded. Moreover, seafood is more susceptible to post-mortem texture deterioration than meats from land animals (Ashie, Smith, & Simpson, 1996).

High hydrostatic pressure (HHP) processing has been applied to food as a preservation method being its major advantage the maintenance of fresh quality attributes. High pressure processing is a promising seafood preservation method. HHP treatment is being increasingly employed for the commercial processing of oysters (Murchie et al., 2005) and fish (Erkan, Üretener, & Alpas, 2010).This novel technology reportedly provides long shelf-life and minimum quality loss since it does not have many of the undesirable changes that are associated with thermal processing because it retains a fresh taste, and has shown enhanced flavour with no indication of oxidation; however, structure, texture and colour can be negatively affected (Angsupanich & Ledward, 1998; Ashie & Simpson, 1996; Chevalier, Le Bail, & Ghoul, 2001; Cruz-Romero, Smiddy, Hill, Kerry, & Kelly, 2004; Cruz-Romero, Kelly, & Kerry, 2007; He, Adams, Farkas, & Morrissey, 2002; Hoover, Metrick, Papineau, Farkas, & Knorr, 1989; Lopez-Caballero, Pérez-Mateos, Montero, & Bonderías, 2000; Ohshima, Ushio, & Koizukmi, 1993). There is limited information on the influence of high hydrostatic pressure on the oxidative stability and quality changes of abalone muscle. The major purpose of HHP is to enhance the safety of most of the seafood by inactivating microorganisms and parasites without changing sensorial quality attributes (Cheftel & Culioli, 1997).

The aim of this study was to investigate the effect of high hydrostatic pressure on quality changes (microstructure, colour, texture and biochemical) of red abalone (*Haliotis rufecens*) during cold storage time.

2. Materials and methods

2.1. Abalone supply and handling

Red abalones (*H. rufecens*) of commercial size, i.e., measuring 14–16 cm in shell length, cultured in Coquimbo, Chile, were purchased directly. They were delivered alive in plastic bags acclimated with aerated seawater to the Food Processing Laboratory within 1 h. Abalones were slaughtered by immersing in ice-cold water (hypothermia). Abalones were scrubbed under running water to remove fouling organisms, mud and other debris adhering to the shell and allowed to drain. Before processing, the abalones were hand-shucked with stainless steel knife and immediately immersed in salt water (NaCl, 10 g/1000 mL) for 12 h, which allowed for pigment removal. Immediately after pigment removal, abalones were packed in polyethylene flexible pouches. Samples were kept under chilling conditions (traditional flake ice) in a refrigerated room (4 °C) until further analysis.

2.2. High hydrostatic pressure (HHP)

A preliminary study was undertaken before choosing the HHP treatment range to be applied in the present experiment. Then, two independent variables were considered (pressure to be applied and holding time) and their effect on visual analysis of abalone (colour, elasticity and firmness) was carried out. Pressure and holding time conditions corresponding to the best visual appearance obtained were selected for the current research (Briones, Reyes, Tabilo-Munizaga, & Pérez-Won, 2010).

Abalones were individually packed and hermetically sealed in high density polyethylene bags. Packaged abalone samples were loaded in a cylindrical loading container and HHP-treated at 500 MPa for 8 min and 550 MPa for 3 and 5 min at room temperature (20 °C) in a 2 litter-pilot high pressure unit (Avure Technologies Incorporated. Kent, WA, USA) using water as the pressure-transmitting medium, working at 17 MPa/s ramp rate and compared to untreated samples (control) for 3 and 5 min at 20 °C in a processing unit (Avure Technologies Incorporated. Kent, WA, USA) using water as the pressure-transmitting medium. The maximum operating pressure of the pressure vessel was 550 MPa. The time to reach the designated pressure was less than 10 s, and depressurisation was less than 5 s. Pressurisation was carried out at ambient temperature. An increase of 5 °C/100 MPa was observed during pressurisation process.

2.3. Physico-chemical analysis

Moisture content was determined by AOAC method no 934.06 (AOAC, 1990) employing a vacuum oven (Gallenkamp, OVL570, Leicester, UK) and an analytical balance with an accuracy of ±0.0001 g (CHYO, Jex120, Kyoto, Japan). Crude protein content was determined using the Kjeldahl method with a conversion factor of 6.25 (AOAC no. 960.52). Lipid content was analysed gravimetrically following Soxhlet extraction (AOAC no. 960.39). Crude fibre was estimated by acid/alkaline hydrolysis of insoluble residues (AOAC no. 962.09). Crude ash content was estimated by incineration in a muffle furnace at 550 °C (AOAC no. 923.03). All methodologies followed the recommendations of the Association of Official Analytical Chemists (AOAC, 1990). All measurements were done triplicate. All solvents and reagents were purchased from Sigma-Aldrich Company Ltd. (St. Louis, MO, USA) with analytical grade.

3. Quality parameters

3.1. Determination of pH and water activity

A sample of 10 g of homogenised whole abalone tissue was diluted 1:10 with distilled water, homogenised using an Ultra-Turrax® homogeniser for 1 min and pH-measured (AOAC, 1999) using a potentiometer (Extech Instruments, Microcomputer pH-Vision 246072, Waltham, Massachusetts, USA) with a glass electrode. The water activity values of homogenised whole abalone tissue were determined by the AW-Sprint Novasina water activity instrument (TH-500, Pfäffikon, Lachen, Switzerland). All determinations were done in triplicate and during storage time.

3.2. Determination of trimethylamine (TMA)

The current official method (AOAC n° 971.14, 1995) was used for the determination of TMA in abalone. This method is based on the reaction of TMA with picric acid to form coloured complex as follows. One millilitre of abalone sample extract and 3 ml of deionised water were placed in a test tube. For the calibration curves, 1, 2, 3 and 4 ml of a 10 μg/ml TMA standard solution were placed in different test tubes and 3, 2, 1 and 0 ml of deionised water were added, respectively. Another test tube containing 4 ml of deionised water was used as a blank. One millilitre of 20% formaldehyde was added to each test tube, followed by 10 ml of anhydrous toluene and 3 ml of saturated potassium carbonate solution. The test tubes were then stoppered and shaken vigorously. The toluene phase was then transferred into a tube containing 0.2 g of anhydrous sodium sulphate and shaken to eliminate water residues. A 5 ml aliquot of the water-free toluene extract was transferred to another test tube and mixed with 5 ml of 0.02% picric acid solution. The absorbance of the standards and samples was measured at 410 nm using a spectrophotometer (Spectronic Instruments, Spectronic® 20 GenesysTM, Chicago, IL, USA). All determinations were done in triplicate. All solvents and reagents were purchased from Sigma-Aldrich Company Ltd. (St. Louis, MO, USA) with analytical grade.