Food Packaging and Shelf Life 15 (2018) 43–51

Contents lists available at ScienceDirect

Food Packaging and Shelf Life

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

Combinatory effect of osmotic and high pressure processing on shelf life extension of animal origin products – Application to chilled chicken breast fillets

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ARTICLE INFO

Keywords:
Chicken cuts
Osmosis
High pressure
Hurdle effect
Shelf life

ABSTRACT

The objective was to produce chilled chicken breast fillets with extended shelf life using osmotic (OD) and high pressure (HP) processing. Samples were processed in osmotic solution (60% maltodextrin:5% NaCl; 15 °C–45 min), subsequently cold-pasteurized in-pack (600MPa–25 °C–5 min) and stored at 0–15 °C. Quality parameters considered were: microbiological (TVC, *Pseudomonas* spp., LAB, *Brochothrix thermosphacta*), physicochemical (texture, color) and sensory attributes. Both OD and OD-HP combined process led to improved texture and color characteristics. Application of HP alone reduced microbial load and ensured stability during storage, but negatively affected texture (20% increase of hardness) and color of breast fillets (increase of luminosity-color comparable to lightly cooked product). The combined application of OD and HP led to significant extension of shelf life and quality improvement of chicken breast fillets. Based on microbial growth and sensory acceptability the shelf life at 5 °C was estimated as 6, 9, 16, 25 d for untreated, OD, HP and OD-HP samples, respectively.

1. Introduction

Over the past decade, there has been an increase in the demand for convenient cuts of fresh poultry products (i.e. legs, thighs, breasts or deboned breasts). Poultry meat and its products are of high commercial interest because of their desirable nutritional qualities, such as low fat content, relatively high concentration of polyunsaturated fatty acids, high quality proteins and essential amino acids but suffer from short shelf life (Zhang, Wu, & Guo, 2016). Application of even minimal thermal treatment for shelf life extension causes irreversible color and texture changes, not acceptable for fresh products. Alternative technologies have been applied to reduce the microflora of fresh poultry meat with retention of "fresh" product characteristics. High Pressure (HP) processing of meat and poultry products has been an active area of research and application because of its potential to extend shelf life (Castro et al., 2017; Jofre, Aymerich, & Garriga, 2009; Jofre, Aymerich, Grebol, & Garriga, 2009; Ma, & Ledward, 2013; Slongo et al., 2009; Xue et al., 2017). HP has very successfully been applied industrially on processed ready-to-eat meat products, allowing in pack cold pasteurization that achieves remarkable shelf life extension. Nevertheless, HP processing may adversely affect the color, texture and sensory attributes of fresh meat and poultry (Guyon, Meynier, & de Lamballerie, 2016; Ha, Dunshea, & Warner, 2017). Ma and Ledward (2004) reported that structural alterations in the contractile myofibrillar proteins are the main factor responsible for texture changes. In the pressure range from 100 to 300 MPa, the changes are usually reversible (the samples usually obtain their initial state), whereas at higher pressures they are non-reversible as reported by Rastogi, Raghavarao, Balasubramaniam, Niranjan, & Knorr, 2010. The lysosomes rupture at pressures around 200 MPa, promoting an increase in autolytic activity and tenderization of the meat (Lamballerie-Anton, Taylor, & Culioli, 2002). The HP treated products have a typical color of "cooked product", not accepted for fresh meats. Potential application of HP on fresh meats, including poultry could be considered only after specific pre-treatments targeting in color stabilization. Osmotic Dehydration (OD) could be used prior to HP treatment to enhance color stabilization.

During Osmotic Dehydration water flows from the product into the osmotic solution, while osmotic solute is transferred from the solution into the product. OD has been applied to obtain intermediate moisture foods and as a pre-processing step for air drying, pasteurization and freezing (Botha, Oliviera, & Ahrne, 2012; Dermesonlouoglou et al., 2016; Tsironi & Taoukis, 2012; Guiamba, Ahrne, Khan, & Svanberg,

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https://doi.org/10.1016/j.fpsl.2017.11.002
Received 26 July 2017; Received in revised form 4 October 2017; Accepted 2 November 2017
Available online 17 November 2017

2016). OD by reducing water activity (a_w) controls microbial growth extending shelf life while it can improve nutritional, sensorial and functional properties of foods. For plant origin tissue the potential of OD for quality enhancement and shelf life extension of chilled and frozen products has been well demonstrated (Ahmed, Qazi, & Jamal, 2016; Dermesonlouoglou, Giannakourou, & Taoukis, 2007; Dermesonlouoglou et al., 2016, 2017; Tappi et al., 2017). For fish and meat (including poultry) products, however, limited references are available (Corzo & Bracho, 2004; Dimakopoulou-Papazoglou & Katsanidis, 2016; Laurindo, 2007, 2009; ; Tsironi & Taoukis, 2012, 2014,2017). Previous works on osmotic dehydration of poultry products have focused on the use of sodium chloride solutions and the mass transfer mechanisms (Collignan and Raoult-Wack, 1994; Schmidt et al., 2007, 2009).

Although current literature on the application of either OD or HP is extensive, few works investigate the benefits of using the combination of OD and HP (Dermesonlouoglou et al., 2017; Núñez-Mancilla, Pérez-Won, Uribe, Vega-Gálvez, & Di Scala, 2013; Núñez-Mancilla et al., 2014; Pérez-Won et al., 2016; Verma et al., 2014). The aspect of combining two alternative technologies for minimizing the negative effect of each technology if used as stand-alone, may be considered innovative, especially in the case of meat products that are usually affected by any treatment.

The aim of this study was to evaluate the combined effect of Osmotic Dehydration as pre-treatment and High Pressure technology on the quality characteristics of chicken breast fillets and to investigate the potential of using OD and HP as innovative minimal treatment to extend the shelf life of chilled poultry products.

2. Materials and methods

2.1. Raw materials

Chicken breast fillets were provided by a leading Greek meat producer. Samples were cut into rectangular slices ($3 \times 3 \times 1$ cm^3, 10 ± 1 g) in a laminar flow hood.

Osmotic solutions were prepared by dissolving 40–60% w/w of high-Dextrose Equivalent (DE) low molecular weight maltodextrin (GLUCIDEX® 47, Roquette, France) (Taoukis, 2012, 2014;). Sodium chloride (NaCl, 5% w/w) was also added to increase the driving force of the process and also attenuate the low sweetness obtained during osmotic pre-treatment (Lerici, Pinnavaia, Dalla Rosa, & Bartolucci, 1985).

2.2. Osmotic dehydration (OD) and selection of OD processing conditions

Preliminary experiments were designed for the selection of the OD processing conditions Sliced samples were treated with concentrated solutions of maltodextrin and NaCl (40:5, 50:5 and 60:5 g maltodextrin:NaCl/100 g) for 20–240 min at 15, 25 and 35 °C. The solution to sample ratio was 5:1 to avoid significant dilution of the medium by water removal, which would lead to local reduction of the osmotic driving force during process (Dermesonlouoglou et al., 2007, 2016; Tsironi and Taoukis, 2012, 2014, 2017).

Beakers filled with pre-weighted osmotic solutions were put in a water-bath and brought up to 15, 25 and 35 °C. Seven beakers were used for each osmotic solution and for each processing temperature (one for each sampling time). Slices were submerged in the osmotic solution by means of a grid. At the selected times of sampling, one beaker with each osmotic solution was removed from the water-bath. Samples were removed from the osmotic solution and blotted gently with a tissue paper in order to remove the excess coating solution and then weighed.

OD parameters investigated were water, solid gain, salt content and water activity; the effect of solution concentration, immersion time and temperature on the dehydration process was determined.

Water Loss (*WL*) and Solid Gain (*SG*) were calculated according to Eqs. (1) and (2) (Panagiotou, Karathanos, & Maroulis, 1998):

$$WL = \frac{(M_0 - m_0) - (M - m)}{m_0} \text{ (g of water/g initial dry matter)} \quad (1)$$

$$SG = \frac{(m - m_0)}{m_0} \text{ (g of total solids/g initial dry matter)} \quad (2)$$

where M_o is the initial mass of chicken breast fillet slices before osmotic treatment, M is the mass of chicken breast fillet slices after time t of osmotic treatment, m is the dry mass of chicken breast fillet slices after time t of osmotic treatment and m_o is the dry mass of slices before osmotic treatment.

Moisture content was determined by drying at 110 °C (WTB BINDER 7200, Type E53, Tuttlingen, Germany) for 24 h. Salt content was determined titrimetrically using silver nitrate solution by the Mohr method (AOAC, 1995). Water activity (a_w) was determined using an a_w-meter (Rotronic AG, AM3 + Aw VD, Bassersdorf, Switzerland).

The effective coefficients of water and solute diffusivity were calculated by fitting the experimental measurements to the following analytical solutions based on Fick's 2nd law for diffusion in a slab being dehydrated from both sides, after suitable assumptions and boundary conditions (Eqs. (3) and (4)) (Rastogi & Raghavarao, 1997).

$$M = \frac{m_t - m_\infty}{m_0 - m_\infty} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-\left(n+\frac{1}{2}\right)^2\pi^2 F_{ow}\right]F_{ow} = \frac{D_{ew}}{l^2}t \quad (3)$$

$$S = \frac{s_t - s_\infty}{s_0 - s_\infty} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-\left(n+\frac{1}{2}\right)^2\pi^2 F_{os}\right]F_{os} = \frac{D_{es}}{l^2}t \quad (4)$$

where M and S are the diffused moisture and solute ratio, respectively, M and S are the moisture and solute content, the subscripts *o, t* and ∞ represent the relevant values at time *0, t* and at equilibrium, D_{ew} and D_{es} (m^2/s) are the effective coefficients of water and solute diffusivity, respectively, l (m) is the half thickness of the slab, F_{ow} and F_{os} are the Fourier numbers for water and solute diffusion, respectively.

2.3. High pressure processing and selection of HP processing conditions

Preliminary experiments were conducted at 25 °C for the selection of the processing conditions, at the following combinations of pressure and time: 400 MPa for 5 min, 400 MPa for 10 min, 600 MPa for 1 min and 600 MPa for 10 min. Non-treated samples (referred as Control) as well as osmotically pre-treated samples (referred as OD) (at the selected optimal conditions; 45 min at 15 °C, in 60 g maltodextrin:5 g NaCl/100 g) were HP treated (referred as HP and OD-HP for non-treated and OD treated samples respectively, prior to HP treatment).

The High Pressure unit (Food Pressure Unit FPU 1.01, Resato International BV, Roden, Holland), comprised a pressure intensifier and one vessel (1.5 L), the dimensions of which are 7 cm diameter and 40 cm length, with a maximum operating pressure and temperature of 1000 MPa and 90 °C. The pressure transmitting fluid used was polyglycol ISO viscosity class VG 15 (Resato International BV, Roden, Holland). Process temperature in the vessel was achieved by liquid circulation in the outer jacket controlled by a heating-cooling system. The desired value of pressure was set and after pressure build up (20 MPa/s), the pressure vessel was isolated. This point defined the time zero of this process. Pressure of the vessel was released ($t_{release} < 3$ s) after a pre-set time interval (according to the experimental design) by opening the pressure valve. The temperature in the chamber was monitored during the process. The initial adiabatic temperature increase during pressure build up was taken into consideration in order to achieve the desired operating temperature during pressurization. Samples were pre-cooled at appropriate temperatures in order to reach the target temperature after pressure build up, taking into