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Physicochemical characteristics and quality parameters of a beef product subjected to chemical preservatives and high hydrostatic pressure

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ABSTRACT

The use of high hydrostatic pressure (HHP) on fresh beef causes a deleterious effect on red colour. A beef product subjected to HHP exhibiting acceptable colour and microbiological stability was developed; the process requires as a first step the immersion in a preservative solution containing ascorbic acid, sodium nitrite, and sodium chloride. Desirability functions were used to optimise the composition of this solution in order to maintain the colour attributes minimising the concentration of sodium nitrite. The product was packed in low gas permeability film before HHP treatment. The effect of the applied pressure (300, 600 MPa) on quality parameters (colour, texture) was analysed. The stability of the product during storage at 4 °C was determined by microbial counts, colour, texture, and exudate. The combination of treatments provided acceptable colour and microbiological stability during four and six weeks of refrigerated storage after the product has been subjected to 300 and 600 MPa, respectively.

1. Introduction

High hydrostatic pressure (HHP) processing is a non-thermal technology for food preservation that meet consumer demands for minimally processed products and environmentally friendly technologies (Toepfl, Mathys, Heinz, & Knorr, 2006). Important aspects to be taken into account are those concerning the effect of the pressure treatment on the quality characteristics of the food product, since treatments can affect texture, colour, external appearance (Cheftel & Culioli, 1997), and potentially, the aroma and taste (Campus, Flores, Martinez, & Toldrá, 2008; Fulladosa, Serra, Gou, & Arnau, 2009).

The application of high hydrostatic pressure on meat and meat products has been focused mainly on studying its effect on microorganisms as a treatment to improve the microbiological safety of the final product (Aymerich, Jofré, Garriga, & Hugas, 2005; Cheftel, Carlez, & Veciana-Nogues, 1995; Garriga, Grébol, Aymerich, Monfort, & Hugas, 2004; Tanzi et al., 2004; Vaudagna et al., 2012). Nevertheless, high-pressure treatment can also be used to develop new meat products.

This technology can be applied in packaged foods, avoiding possible recontamination after the treatment (Toepfl et al., 2006). This together with the possibility of treating products that cannot be preserved by heating, such as fresh meats and cured products, makes HHP a useful tool to preserve for example sliced packaged dry-cured ham during refrigerate storage (Clariana, Guerrero, Sárraga, & Garcia-Regueiro, 2012).

High pressure treatment has been used for the preservation of chicken, pork, meat products, surimi gels as well as salmon products, with considerable positive effects on protease activity, textural properties, taste and flavour (Bajovic, Bolumar, & Heinz, 2012; Carballo, Cofrades, Solas, & Jiménez-Colmenero, 2000; Garriga, Aymerich, & Hugas, 2002; Knorr, 1993; O'Brien & Marshall, 1996; Ohshima, Ushio, & Koizumi, 1993). The use of HPP for the microbial decontamination has been extensively reviewed but complete microbial inactivation is currently not possible (Knorr, 1995; Smelt, 1998).

Pressures in the range of 100 to 800 MPa are applied on meat products (Cheftel & Culioli, 1997), although commercial pressure vessels have a limit at 700 MPa (Torres & Velazquez, 2005). Pressures above 300 MPa help to inactivate microorganisms, making the product microbiologically safe (Davidson, 2001). Meat products are mainly pasteurized, which is generally done in the range of 300–600 MPa, inactivating vegetative cells (Aymerich, Picouet, & Monfort, 2008; Chung, Vurma, Turek, Chism, & Yuosef, 2005). However, the effect is dependent on temperature. The degree of microbial inactivation is lower at the optimum growth temperatures than at higher or lower temperatures (Hugas, Garriga, & Monfort, 2002). Furthermore, HHP preserves micronutrients better than thermal treatment (Aymerich et al., 2008); however, HHP can affect colour, texture, and flavour of meat products, which is not always accepted by the consumers (Bak et al., 2012; Cheftel & Culioli, 1997; Fulladosa et al., 2009). Nevertheless, HHP treatment induces undesirable changes on meat and meat product characteristics increasing lipid oxidative reactions, which decline the acceptability, especially in some protein-rich foods treated at pressures of >400 MPa (Cheftel & Culioli, 1997).

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For meat products, colour is one of the most important quality features (Feiner, 2006; Risvik, 1994; Young & West, 2001). HHP commercial application in fresh bovine meat has been underutilized due to severe discolouration of the meat to pressure levels necessary for inactivation of pathogenic and spoilage microorganisms (Fernández et al., 2007). Meat discolouration is produced at pressure levels higher than 300 MPa, which are required for inactivation of vegetative cells. In the range of 200–350 MPa discolouration occurs due to meat myoglobin denaturation and the displacement or loss of haem-iron. In the range of 300–600 MPa the characteristic red colour of meat is lost (Szerman et al., 2011).

Colour problems on HHP beef products may be reduced by applying short chemical pre-treatment using salts that are commonly applied in the curing process. In cured meat ascorbic acid favours the decomposition of nitrite ion to nitrous oxide that also reacts with myoglobin producing nitrosomyoglobin, conferring the characteristic red colour of beef. Besides, ascorbic acid is a strong inhibitor, decreasing the formation of nitrosamines (Ohshima & Bartsch, 1981; Stich, Hornby, & Dunn, 1984).

The application of HHP on red meats has been studied on fresh and salted samples (Realini, Guàrdia, Garriga, Pérez-Juan, & Arnau, 2011) and in cured and cooked products (Aymerich et al., 2008; Bover-Cid, Belletti, Garriga, & Aymerich, 2011; Hugas et al., 2002; Szerman et al., 2011). The addition of nitrites improved myoglobin stability after HHP treatments, however the colour was modified (Rubio, Martinez, Garcia-Cachan, Rovira, & Jaime, 2007). Other researchers reported that topical addition of ascorbic acid inhibits discolouration on the surface of cut beef (Grobbel et al., 2006; Mancini, Hunt, Hachmeister, Kropf, & Johnson, 2004; Mancini et al., 2007). The reducing activity of ascorbic acid improves muscle colour stability via metmyoglobin reduction (Lee, Hendricks, & Cornforth, 1999). However, because ascorbic acid acts as both an antioxidant and a pro-oxidant, the appropriate levels for preventing muscle discolouration are not straightforward and depend on a number of factors (Lee & Hendricks, 1997; Lee et al., 1999; Shivas et al., 1984). This behaviour could be attributed to the presence and concentration of metals within a food (Decker, 1998). Yamamoto, Takahashi, and Niki (1987) suggested that ascorbic acid pro-oxidant nature could be due to the production of ferrous haem proteins, which may be more reactive and more oxidative than ferric derivatives.

As HHP treatment modifies the colour of the tissue, it is important to include a pre-treatment in which the meat is immersed in a preservative solution. The composition of this solution must be optimised to maintain colour attributes and to minimise the concentration of sodium nitrite.

The objectives of the present work were:

1) To develop a red beef product subjected to high hydrostatic pressure including a short chemical pre-treatment by dipping in preservative solutions containing sodium nitrite, ascorbic acid and sodium chloride.
2) To analyse the influence of applied pressure and the effect of vacuum packaging in low permeability films on the quality parameters of the product.
3) To optimise the composition of the preservative solution in order to maintain the colour attributes minimising the concentration of sodium nitrite by using desirability functions.
4) To assess the stability of the developed meat product by determining microbial counts, colour, texture, and exudate production during refrigerated storage at 4 °C.

2. Materials and methods

2.1. Raw materials

Beef muscles were obtained from the local retail market. The used commercial cut was top inside round (top side); this cut is integrated by the following muscles: *adductor femoris* and *semimembranosus*. The average weight of the cuts was about 3.9 kg. 25 cuts from different animals were used in the experiments. The muscles were separated after 48 h post-mortem and all visible fat was removed. pH values ranging between 5.4 and 5.7 were measured in the raw beef muscles from the different animals ($n = 25$) used in the experiments. These pH values were consistent with the requirements of SENASA (National Control Service for Animal Sanitary Status — Argentina, 2013) that establish a pH < 5.9 for raw beef.

2.1.1. Physicochemical analyses of the raw material

Moisture, ash, protein, and lipid contents were determined according to AOAC methods 24.003, 24.009, 24.027, and 24.005, respectively (AOAC, 1980) in triplicates. Fat content was determined on samples previously dried with sodium sulphate anhydrous (SO_4Na_2) by Soxhlet method, using ethyl ether as extraction solvent. pH was measured using a spear tip glass electrode (Cole-Palmer, cat. U-05998-20) on a pH meter (Hach Sension pH 3, Loveland USA).

2.2. Experiments

The general procedure consisted of: a) sectioning the meat samples in cylindrical sections (3 mm thickness and 6 cm diameter); b) immersion of the samples in preservative solutions modifying the concentration of the components in order to optimise their composition (Tests A and B that are described in the following sections) c) vacuum packaging of the samples in Cryovac BB4L films (Sealed Air Co., Buenos Aires, Argentina, PO_2: 35 (cm^3/m^2 day bar) at 23 °C); d) High pressure treatment of the samples in a Stansted Fluid Power Equipment, model FPG9400:922 with a cylindrical vessel (2 l capacity, maximum working pressure 900 MPa, operating temperature range −20 to 120 °C) located at the ITA Institute (INTA Castelar, Argentina). Pressurization rate was 300 MPa/min and de-pressurization was instantaneous. Experiments were carried out at different pressures 150, 300, and 600 MPa and a temperature of 20 ± 5 °C; the samples were maintained at the working pressures for 5 min. In all cases control samples (not submitted to HHP) were also analysed. Quality attributes (colour and texture) were determined in all cases to find adequate processing conditions.

2.3. Instrumental colour measurements

The colorimetric measurements were carried out using a tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR-400 Minolta, New Jersey, USA). Each measurement was performed on 3 slices with 6 replicates per slice.

The CIE-L*a*b* scale was used in terms of L*(lightness), a* (redness), and b* (yellowness).

2.4. Texture analyses

Textural analyses were performed in a TAXT2i Texture Analyser (Stable Micro Systems, UK) at 25 °C, using the Texture Expert Exceed software supplied by Texture Technologies Corp. The Volodkevich bite jaws (HDP/VB) probe, which simulates the action of an incisor tooth (Wen-Ching, Wen-Chian, Yu-Ting, & Chang-Wei, 2007), was used in measuring the texture of the meat product, because it has been observed that the first bite of the product is done with the fore teeth. Maximum breaking force (F, N) was determined when compression is done until 30% of the specimen. A minimum of three slices were used for each formulation; measurements were done in triplicates for each slice and mean values were reported.

2.5. Test A: selection of additives to be incorporated in the dipping solution

Different experiments were performed to find the preservative solution that meets the appropriate requirements for the development of the meat product.