Meat Science 98 (2014) 709–717

Contents lists available at ScienceDirect

Meat Science

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

The suitability of plasma powder for cold-set binding of pork and restructured dry ham

M.D. Romero de Ávila, J.A. Ordóñez, R. Escudero, M.I. Cambero *

Departamento de Nutrición, Bromatología y Tecnología de los Alimentos, Facultad de Veterinaria, Universidad Complutense, 28040 Madrid, Spain

ARTICLE INFO

Article history:
Received 5 March 2012
Received in revised form 21 March 2014
Accepted 13 June 2014
Available online 23 June 2014

Keywords:
Plasma powder
Pork
Cold-set binder
Binding parameters
Restructured dry ham
Microstructure

ABSTRACT

To determine the ability of cold-set binder plasma powder (PP) for manufacturing restructured deboned dry ham, the effect of meat pre-treatment and PP preparation on the binding rate (k) and maximum binding force (BF_{max}) of pork model systems and deboned ham were evaluated. In pork model systems, the highest values for k (about 0.4 $Ncm^{-2}\ h^{-1}$) and BF_{max} (about 2.5 Ncm^{-2}) were obtained when powder or rehydrated plasma [in water or in NaCl aqueous solution at 0.5%] was applied onto the meat surface without additional pre-treatment or prior immersion in saline aqueous solution. Similar meat pre-treatment and PP preparation were used to restructure fresh deboned leg resulting in stable meat binding performances during salting and drying. An important increase in the binding force ($BF_{max} > 10\ Ncm^{-2}$) occurred over the drying period (after 4 weeks). Scanning electron microscopy showed different morphologies of the binding area, mainly depending on whether powder or rehydrated plasma was used.

1. Introduction

Several countries, mainly in the Mediterranean area, manufacture dry-cured hams (Álvarez de la Puente, 2003). There is a great variety of dry-cured hams, differing in the pig breed, type of feed, meat weight, type of cut and processing conditions (Martín-Bejarano, 2001; Ockerman, Basu, León Crespo, & Céspedes, 2002; Ventanas, Ruiz, & Córdoba, 2001). In Spain dry-cured ham is manufactured from whole pork legs cutting at the level of the ischio-pubic symphysis, with foot and bone (Martín-Bejarano, 2001). The typical production process of Spanish dry-cured hams [e.g. *Serrano*, from white pig and processed in accordance with "Traditional Speciality Guaranteed (TSG)" (EC, 1999) and *Iberian*, from black pig corresponding to the Protected Designations of Origin (MAPA, 2007)] includes the following steps (Martín-Bejarano, 2001; Ventanas et al., 2001): salting, washing–brushing, rest or post-salting, drying–ripening and refinement by ageing (cellar phase).

Several non-meat ingredients or systems (such as alginates, blood clotting factors and enzyme binders) have been successfully used as cold meat binders in the manufacture of restructured meat products and to improve the stability, texture and consistency of meat and fish gels (Cambero, López, de la Hoz, & Ordoñez, 1991; Mandigo, 1988; Romero de Ávila, Ordóñez, De la Hoz, Herrero, & Cambero, 2010).

Recently, plasma powder, from bovine and porcine blood, has been successfully employed as a cold-set binding agent (Herrero, De La Hoz, et al., 2009; Ofori & Hsieh, 2012; Roodink & Zuijdweg, 2003). For many years, several meat products with added animal blood or plasma proteins have been produced and consumed in different countries without adverse effect (EFSA, 2005; USDA/FSIS, 2005). Blood plasma is not considered to be a food additive by the European Regulation (European Parliament and the Council of the European Union, 1333/2008). This blood derived product is obtained from blood and hygienically collected in slaughterhouses under veterinary inspection (European Parliament and the Council of the European Union, 2004a, b). Plasma is a multifunctional ingredient (Tarté, 2009), including gelling and binding activity. Several plasma derived products (such as thrombin:fibrinogen, hydrolysates, and plasma powder) can be used as additives or ingredients in the meat industry. Governmental regulation concerning the application, status and labelling of plasma proteins and blood derived products varies slightly from country to country (EFSA, 2005; European Parliament, 2010; Ofori & Hsieh, 2012; USDA/FSIS, 1995, 2005).

The production of dry-cured ham essentially consists of salt diffusion into the meat and progressive dehydration. However, these phenomena may affect the action of the plasma powder (Gentry, 2004; Herrero, Cambero, Ordóñez, De la Hoz, & Carmona, 2009; Herrero, De La Hoz, et al., 2009; Othrner & Kosow, 1980; Weisel, 2005). As far as the authors are aware, no study has been found related to the use of this cold-set binder in dry-cured ham processing. The main objective of this work was to assess the efficacy of plasma powder to restructure fresh deboned pork leg either before or after a salting and drying process in

* Corresponding author at: Departamento Nutrición, Bromatología y Tecnología de los Alimentos, Facultad de Veterinaria, Universidad Complutense, 28040 Madrid, Spain. Tel.: +34 913943745; fax: +34 913943743.
E-mail address: icambero@vet.ucm.es (M.I. Cambero).

http://dx.doi.org/10.1016/j.meatsci.2014.06.014
0309-1740/

order to ultimately produce deboned dry-cured ham. Likewise, the microstructure of the resulting binding surfaces was analysed by scanning electron microscopy.

2. Material and methods

2.1. Experimental layout

Two types of pork samples were considered: (1) pork model systems and (2) fresh deboned whole leg. A dried plasma protein preparation elaborated from porcine blood plasma with increased fibrinogen concentration (Herrero, Cambero, et al., 2009; Herrero, De La Hoz, et al., 2009; Roodink & Zuijdweg, 2003) was used. This plasma product was supplied by Sonac B.V. (Loenen, Netherlands) and is commercialized as plasma powder FG. The variables (meat pre-treatment and plasma powder preparation) used to obtain the pork model systems are described below. The experiments were carried out at three different times (February, May and October). In the three cases, each of the pork model systems was elaborated in triplicate (a different pork piece being used in each case).

2.2. Meat preparation and treatment

Fresh pork (M. *biceps femoris*) was purchased from a local abattoir at 48 h post mortem to elaborate the model systems. To achieve homogenous samples, only meat from female white pigs (Landrace × Large White) fed in confinement with a commercial diet were acquired. Animals were stunned, slaughtered and exsanguinated at a local slaughterhouse at 100.3 ± 8.01 kg liveweight (about 6 months of age).

The model systems were elaborated by cutting the meat into portions (cubes of about 10 cm wide) and the visible fat and connective tissue were removed. Then, the meat was subjected to one of the following pre-treatments: U, fresh samples without additional treatment; I, samples were immersed in a saline (NaCl with about 200 ppm of KNO_3 and 100 ppm of $NaNO_2$) aqueous solution (3%, w/v) for 10 min at 4 °C, after which the excess fluid was removed with a filter paper; and SS, a mixture of salts (NaCl with 200 ppm of KNO_3 and 100 ppm of $NaNO_2$) was evenly spread on the meat surface. After 10 min of setting time, the pork cubes were washed with the same saline aqueous solution (3%, w/v) then the excess liquid was removed using a filter paper.

2.3. Preparation of plasma powder

Different procedures were used to apply plasma powder onto binding meat surface: powder (PP), the powder rehydrated in distilled water (PPW0) and in a NaCl aqueous solution (w/v) at 0.5 (PPW0.5), 1.5 (PPW1.5) and 3% (PPW3). The proportion of plasma powder and liquid was 3/8 (w/v).

In addition, two meat batters and rehydrated plasma powder (ME0PPW0 and ME2PPW0) were prepared. These mixtures were performed using the following procedure: pork was pre-cut into small portions (cubes of about 3 cm wide). Then, the meat was chopped for 1 min at 1200 rpm in a vertical cutter-mixer with blend blades (Robot Coupe R 8 m.m., Vincennes Cedex, France with two blend blades) equipped with a vacuum pump (Telstar S-8, Terrassa, Spain). Following this, water (ME0) or NaCl aqueous solution at 0 ± 1 °C was added to the chopped meat and mixed for 1 min at 1500 rpm to get a homogeneous mixture. The NaCl aqueous solution added was prepared to obtain a 2% salt concentration in the meat batter mixture (ME2). In both mixtures (ME0 and ME2), the proportion of meat and liquid was 9/1 w/w. Finally, a PPW0 mixture was added (meat batter/PPW0, 6/4, w/w) to obtain the ME0PPW0 and ME2PPW0 mixtures. These mixtures were carefully prepared for 1 min at a lower speed (300 rpm). The process was performed under partial vacuum (500–700 mbar). The mixture temperature was measured several times throughout the process (when ingredients were added, and after mixing and chopping) using thermocouples (Yokogawa Hokushin Electric YEW, Mod. 3087, Tokyo, Japan). The registered temperature was below 2 °C at any time.

2.4. Preparation of the pork model system

One surface of a previously treated (U, I or SS) meat piece was covered with a plasma powder preparation (PP, PPW0, PPW0.5, PPW1.5, PPW3, ME0PPW0 or ME2PPW0) and immediately was placed in contact with a similarly pre-treated (U, I or SS) pork portion surface. The resulting model system (meat/cold-set binding/meat, M/CSB/M) was packed into plastic bags of low permeability (diffusion coefficient of 35 $cm^3/24\ h\ m^2$ bar to oxygen and 150 $cm^3/24\ h\ m^2$ bar to carbon dioxide) in a high vacuum machine (750/400 model, Vapta, SL, Spain) until a vacuum of 20 kPa. The pork model systems were stored at 4 °C during the first 34 h (binding period). Following the different binding periods, the pork model systems (M/CSB/M) were removed from the plastic containers and the analyses were performed.

2.5. Processing of fresh deboned leg

Fresh deboned pork legs were purchased 48 h post mortem at a local meat processor. The legs were obtained from female white pigs with the same characteristics (feeding system, slaughter weight, etc.) specified in Section 2.2. The variables (meat pre-treatment and plasma powder preparation) used to prepare the pork model system were also considered to restructure the deboned pork leg. Five deboned legs were used for each restructured dry ham manufacturing process. The distal meat portions and external flaps or hanging flaps were removed from the deboned pork legs to obtain homogeneous pieces of a similar cross-sectional area, obtaining deboned pork portions weighing about 3 kg.

The exposed muscle surfaces resulting from the deboning process were treated with procedures U, I or SS. To restructure the fresh deboned legs, a preparation of plasma powder (PP, PPW0, PPW0.5, PPW1.5, PPW3, ME0PPW0 or ME2PPW0) was gently applied onto the pre-treated (U, I or SS) uncovered muscle surfaces. The pork legs were then restructured by placing in contact parallel meat surfaces and, afterwards, were immediately vacuum packed (20 kPa) into plastic bags and stored at 4 °C during the binding time. At the end of the binding period, the restructured deboned legs (RDL) were removed from the plastic bags and the pieces were covered with a dry mixture of salts (salting). The mixture of salts (NaCl with 200 ppm of KNO_3, and 100 ppm of $NaNO_2$) was similar to that used for dry-cured ham manufacture and the amount used was equivalent to 2% of the weight of the pork model complex (Santos, Hoz, Cambero, Cabeza, & Ordóñez, 2008). The salting period lasted 0.75 days/kg of restructured leg. At the end of the salting period (about 2.25 days), the excess salt was removed from the surfaces (post-salting restructured deboned legs, PSRDL) and dried for up to 8 weeks at 10 °C and 80% relative humidity. The final product was named restructured deboned dry ham (RDDH).

2.6. Physico-chemical determinations

The dry matter (oven air-drying method) and ash (muffle furnace) were analysed following AOAC (1995) procedures. The salt content of the PSRDL and RDDH was estimated by subtracting the ash content of the fresh meat from the content of salted samples. To calculate the defatted dry matter, the fat content was estimated by the Bligh and Dyer method (Santos et al., 2008). The pH and water activity (a_w) were determined at 25 °C using a Crison Digit-501 pH meter (Crison Instruments LTD, Barcelona, 224 Spain) and a Decagon CX1 hygrometer (Decagon Devices Inc., Pullman, WA) respectively. The water-holding capacity (WHC) was measured by using the Carver Press Method (Kauffman, Eikelenboom, van der Wal, Merkus, & Zaar, 1986). For that, 0.3 g sample was pressed onto an oven-dried Whatman 125-mm filter paper. The WHC values were calculated as the percentage of