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Microstructural, protein denaturation and water holding properties of lamb under pulse vacuum brining

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ABSTRACT

The objective of this study was to investigate the microstructure, protein denaturation and water holding capacity of lamb pickled under pulse vacuum. Sixty topside samples (M. semimembranosus) were randomly assigned into two groups and cured for 0, 1.5, 3, 4.5 and 6 h by pulse vacuum brining (PVB) and atmospheric brining (AB) (control), respectively. The salt content of samples by PVB was about 1% higher than AB from 1.5 h to 6 h. The water holding capacity was greater for PVB group before 4.5 h ($P < 0.05$). The actomyosin was dissolved more after being pickled for 1.5, 3, 4.5 and 6 h under PVB. The myofibril swelled more intensively and myofibril diameters with PVB were significantly larger than that of AB ($P < 0.05$). In summary, pulse vacuum brining can be used to improve the brining efficiency, promoting the actomyosin dissociation and improving the water holding capacity of lamb, which will be a potential technology to be used in practice.

1. Introduction

Curing is an important process in the production of meat products, which is not only used for preservation, but also developed to improve yield, flavor, color and texture of meat products. In practice, brining is an indispensable process in the production of dry-cured ham, air-dried jerky, smoked bacon, toasted duck and salted fish, in order to evenly distribute sodium chloride in the muscle, to enhance lipid emulsification and protein dissolution in the system, and to obtain a unique flavor and stable texture for the final meat product (Chiralt, Fito, & Barat, 2001). Dry-curing and wet salted brining in atmosphere are two common traditional salting methods, of which the brining period is usually long and sodium chloride can't be evenly distributed into muscles. Modern pickling methods, like injection pickling and tumbling salting, can increase the salt content of products effectively and uniformly in a shorter time (Casiraghi, Alamprese, & Pompei, 2007), but the former always leaves some pinholes in the meat surface (Devine & Dikeman, 2014), which might be subject to contaminate the deeper layer of the meat due to polluted water or air entry (Nollet & Toldra, 2006), while the latter can affect the product shape and cause meat deformation (Nollet & Toldra, 2006).

Pulse vacuum brining refers to the curing pressures which are fluctuated alternately between vacuum and atmospheric pressure in the process of curing (Deumiera, Trystram, Collignan, Guédier, & Bohuon, 2003b). The fluctuation promotes curing solution diffusion and accelerates the migration of solute, mainly due to the fluid dynamics, mechanical deformation relaxation effect and capillary force (Fito & Pastor, 1994). Porosity is one of the most important factors affecting the function of pulse vacuum brining. For this reason, some vegetables with big leaves or thicker fibers and many varieties of fruits with more and larger pores are recommended to be pickled under pulse vacuum (Fito & Pastor, 1994). In the past twenty years, many studies have been conducted to investigate the mass transfer, water activity, curing time in vegetables or fruits, such as apple slices (Barat, Chiralt, & Fito, 2001), guava chips (Corrêa, Pereira, Vieira, & Hubinger, 2010), and muskmelon slices (Martínez-Valencia et al., 2011). In addition, Chiralt and Fito (1997) reported that cheese was cured more efficiently and uniformly with pulse vacuum brining. As an efficient static curing method, pulse vacuum brining can also effectively improve the curing rate and maintain the perfect shape of meat (Deumiera, Bohuon, Trystram, Saber, & Collignan, 2003a). Recent research on pulse vacuum brining mainly focused on the diffusion of salt and water. Corzo and Bracho (2007); Corzo, Bracho, and Marval (2006)) and Reyes, Corzo, Bracho, and Rodrîguez (2008) studied the water distribution in sardine sheets cured in pulse vacuum. Deumiera et al. (2003a,b) investigated the salt and water transfer mechanism in turkey chops handled with pulse vacuum brining. In the literature, information about salt permeability and the quality of meat products processed by pulse vacuum brining is

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very limited, with no studies found on lamb. This study was aimed to: (1) highlight the effects of pulse vacuum brining on the microstructure, protein denaturation and water holding properties of lamb, and (2) improve the brining efficiency, reduce the curing time and provide the scientific basis for industrialized meat production.

2. Materials and methods

2.1. Sample preparation

Thirty male Sunite sheep (a Chinese sheep breed) were pastured to approximate 35 kg for six months on the Xilinhaote grassland in Northeast of China, and slaughtered by severing the trachea, carotid arteries, esophagus in a local commercial abattoir (Little Sheep Industry Food Co., Ltd., Xilinhaote, Inner Mongolia, China). After cooling at 4 °C for 24 h, M. *semimembranosus* were removed from left hind legs of carcasses. Muscles were wrapped in aluminum-foil papers (0.065 mm thick F8M, Glad®, Guangzhou, China), snap-frozen in liquid nitrogen, vacuum packaged with nylon/polyethylene (9.3 mL O_2/m^2/24 h, 0 °C, 0.19 mm thick, Magic Seal®, Dongguan, China), and transported to laboratory in dry ice, and stored at −80 °C until analysis. The thirty muscle samples were trimmed of visible fat and connective tissue, cut into cubes (3 cm × 3 cm × 2 cm) and randomly assigned to two groups. Fifteen cubes were statically brined in solution (15% NaCl, *w*/*w*) under pulse vacuum (vacuum −70 kPa for 15 min and atmospheric pressure 101 kPa for 15 min, and then vacuum −70 kPa for 15 min again, recycling for 3, 6, 9, 12 times between vacuum and atmospheric pressure) in a brining cylinder block of the pulse vacuum brining machine designed by ourselves. The machine included brining cylinder block (5 cm thick stainless steel with seal cap), pressure regulatory and control cabinet. The other fifteen cubes were brined in solution (15% NaCl, *w*/*w*) under atmospheric pressure all the time (control). Three cubes from each group were sampled randomly at 0, 1.5, 3, 4.5 and 6 h for analysis. All the procedures were repeated in triplicate and the results were expressed as means and standard errors.

2.2. Sodium chloride determination

As shown in Fig. 1, the sodium chloride content was determined by salinometer (PAL-FM1, ATAGO®, Tokyo, Japan) at fifteen points of the pickled muscle cubes. For each sample, ten values were read by injecting the surveying pin of the salinometer 0.5 cm below the muscle surface at locations as shown in Fig. 1A. An internal cube B was then dissected from the sample and salt was measured at four locations as shown in Fig. 1B. Finally, the fifteenth reading was obtained from the center of cube B. The sodium chloride content was calculated using Eq. (2.1):

$$\text{NaCl content}(\%) = \frac{\sum_{i=1}^{15} Ai}{15} (i = 1, 2, 3, \ldots, 15). \quad (2.1)$$

Ai means *A*1, *A*2, *A*3 …, *A*15; *A*1, *A*2, *A*3 …, *A*15 means the reading value of each point shown in Fig. 2, respectively.

2.3. Cooking loss

The cooking loss was determined by Tobin, O'Sullivanm, Hamill, and Kerry (2013) with a little modification. Briefly, four cubes (A1, A2, A4 and A5 in Fig. 1) were weighed (W_1), packed into cooking bags and cooked in water bath at 80 °C for 30 min. After chilled to 4 °C, cubes were wiped with filter paper (102, ø9 cm, Jiaojie®, Fushun, China) to remove juice on surface and weighed (W_2). The cooking loss was calculated using Eq. (2.2):

$$\text{Cooking loss}\ (\%) = (W_1 - W_2)/W_1 \times 100. \quad (2.2)$$

2.4. Centrifugal loss

Centrifugal loss was measured by Sun, Wu, Xu, and Li (2012) with little modification to estimate the water holding capacity of meat. Briefly, approximately 5 g (W_1) muscle, which was almost the same size as the cube in Fig. 1b, was cut from the interior of pickled muscle cubes. After wrapping with gauze (142–11, 70 cm × 50 cm, Jingguan®, Beijing, China), the 5 g muscle sample (W_1) was placed into a centrifuge plastic tube with absorbent cotton and centrifuged at 1550 ×*g* and 20 °C for 20 min. The meat was then taken out and weighed (W_2). The centrifugal loss of pickled lamb was calculated using Eq. (2.3):

$$\text{Centrifugal loss}(\%) = \left(\frac{w_1 - w_2}{w_1}\right) \times 100. \quad (2.3)$$

2.5. SDS-PAGE analysis of sarcoplasmic and myofibrillar proteins

Sarcoplasmic and myofibrillar proteins were extracted as described by Xiong, Loum, Wang, Moody, and Harmon (2000) with little modification. Briefly, 1.0 g minced brining cube (A3 in Fig. 1) was added with 8 mL of extraction buffer (0.1 M NaCl, 10 mM Na_3PO_4, 2 mM $MgCl_2$

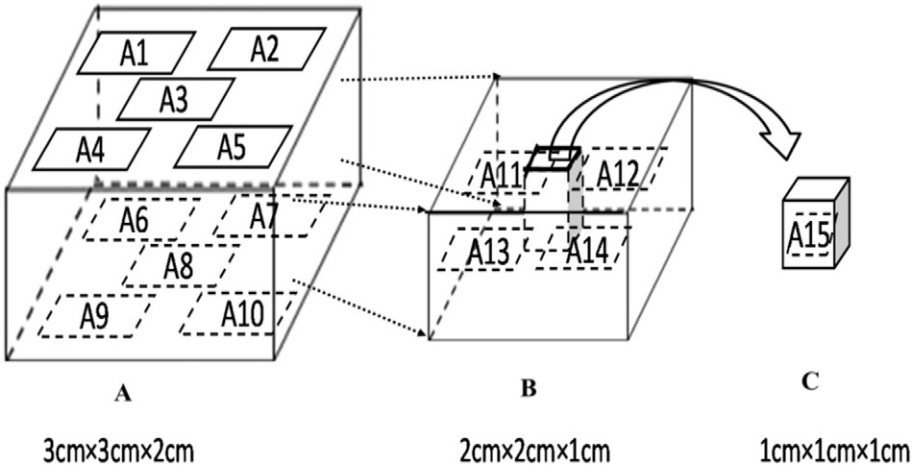

Fig. 1. Illustration of locations to measure salt content in lamb using a salinometer.