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Non-destructive salt content prediction in brined pork meat using ultrasound technology

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ABSTRACT

This works aims to show the feasibility of using low-intensity ultrasound (US) to predict the salt content in brined *Biceps femoris* (BF) and *Longissimus dorsi* (LD) pork muscles. For this purpose, meat samples were salted in brine solution (20% w/w at 2 °C) for different times (24, 48, 96 and 168 h) and the US velocity measured before and after salting. In addition, model samples with preset water and salt contents were formulated and the US velocity was measured. In the model samples, the salt content (X_S) had a more marked effect on the US velocity (13.0 m/s per ΔX_S = 1% wet basis) than the water content (5.0 m/s per ΔX_W = 1% wet basis). The salt gain and the water loss during brining caused the US velocity to increase (61.5 and 49.3 m/s for 168 h in LD and BF, respectively). Significant linear relationships between the US velocity and both factors (X_S and X_W) were established ($R^2 > 0.771$). A predictive model of the salt content based on the US velocity was proposed; this was successfully validated (average estimation error 0.48%), which shows the feasibility of using US for industrial quality control purposes.

1. Introduction

In the last few decades, the application of ultrasound in the food industry has been the focus of increased attention. In particular, as a non-destructive technology, the use of low-intensity ultrasound has been the subject of many contributions aiming to characterize the structural and compositional properties of food commodities (Povey and Harden, 1981; Contreras et al., 1992; Ghaedian et al., 1998; Mizrach, 2000; Aparicio et al., 2008; Corona et al., 2014). In the meat industry, low intensity ultrasound (US) has already been used to characterize animal carcasses. Thus, Morlein et al. (2005) have classified pig carcasses based on the intramuscular fat content of *Longissimus dorsi* by means of the spectral analysis of US echo signals (at ≈3.5 MHz). Faulkner et al. (1990) and Ribeiro et al. (2008) used ultrasonic measurements to estimate the fat cover and carcass composition in cows and in growing lambs, respectively. Llull et al. (2002) evaluated the textural properties of a pork meat-based product (sobrassada) from ultrasonic velocity measurements. Corona et al. (2014) tested the feasibility of using ultrasonic velocity measurements to estimate the fat content and identify the fat source used in formulated dry-cured sausages. Similarly, the fat, water and protein content were assessed in raw meat mixtures by using ultrasonic velocity (Benedito et al., 2001). In addition, the time of flight of ultrasound waves has also been used to assess the percentage of frozen meat in blocks of chicken and beef during freezing (Sigfusson et al., 2004). However, the ability of ultrasound to determine the salt content in meat products, such as salted hams or loin, has not been reported in the literature.

Salting is among the most relevant stages in the processing of dry-cured meat products, since salt inhibits foodborne pathogens and spoilage bacteria growth (Liu et al., 2013) and contributes to necessary flavor and textural modifications of the raw meat (Larrea et al., 2006). However, the salting process of whole pieces, such as ham or loin, is complex since the biological and chemical characteristics of meat are greatly heterogeneous (Vestergaard et al., 2007). Consequently, the use of a fixed salting time/product mass ratio is rarely optimal. In addition, the conventional analytical techniques used for the salt content measurement in meat products are not suitable for quality control purposes, due to the fact that they are destructive, laborious and time-consuming. Thus, great effort has been made by the meat industry to search for non-destructive techniques which allow reliable real time measurements of the salt content. Some of the most relevant non-destructive technologies previously applied to characterize the salt content in meat-based products are microwave dielectric spectroscopy (Castro-Giráldez et al., 2010), computer tomography (CT) (Vestergaard et al., 2004), near infrared spectroscopy (NIR) (Collell et al., 2011; Prevolnika et al., 2011) and hyperspectral

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imaging (Liu et al., 2013). These techniques have great potential for the rapid and non-destructive prediction of salt content. However, some of these techniques have limitations which include the high cost, the limited capacity of the equipment to be modified for on-line measurements and the reduced penetration capacity, for which reason they are barely used in the meat industry. In contrast, ultrasound is especially suitable for use as an industrial process quality control tool (Scanlon, 2004), because of its affordable portable equipment and easy adaptability to the process lines. Moreover, ultrasound can also be used to measure the internal composition of thick opaque samples. Therefore, the objective of this study was to test the feasibility of using low-intensity ultrasound to predict the salt content in brined pork meat (*Biceps femoris* and *Longissimus dorsi* muscles).

2. Materials and methods

2.1. Raw material

Biceps femoris (BF) and *Longissimus dorsi* (LD) muscles were obtained from *Large White* breed pigs from a local market. In both muscles, the subcutaneous fat was removed before processing. The pieces selected had a pH of 5.65 ± 0.05, which was measured at three different points along the muscle avoiding fatty areas. Two different types of samples were prepared and analyzed by ultrasound. On the one hand, cylindrical samples (0.037 m in diameter (Ø) and 0.060 ± 0.010 m in length (*L*)) were taken from 16 BF and 12 LD muscles by using a cylindrical cutter. The cut of the muscle was carried out perpendicularly to the direction of the fibers. On the other hand, model samples were formulated with specific moisture and salt contents, for which purpose 2 BF muscles were ground.

2.2. Salting experiments in brine solution

BF and LD cylindrical samples were placed into metallic cylinders (0.04 m in diameter and 0.07 m in length) in order to avoid the radial mass transfer during salting (Fig. 1A and B). The base's cylindrical perimeter of the sample in contact with the brine was sealed with contact adhesive (Loctite Superglue-3, Loctite, Henkel) to avoid brine penetration along the walls, while the upper base was covered with a plastic film and paraffin to avoid sample dehydration. Salting experiments were carried out in a thermostatic bath with 15 L of brine 20% NaCl (w/w), which was held at 2 °C, a common temperature for meat salting, and vigorously stirred (Fig. 1A). In each experiment, 12 samples were partially immersed in the brine, supported by a hollow polystyrene sheet. During salt-

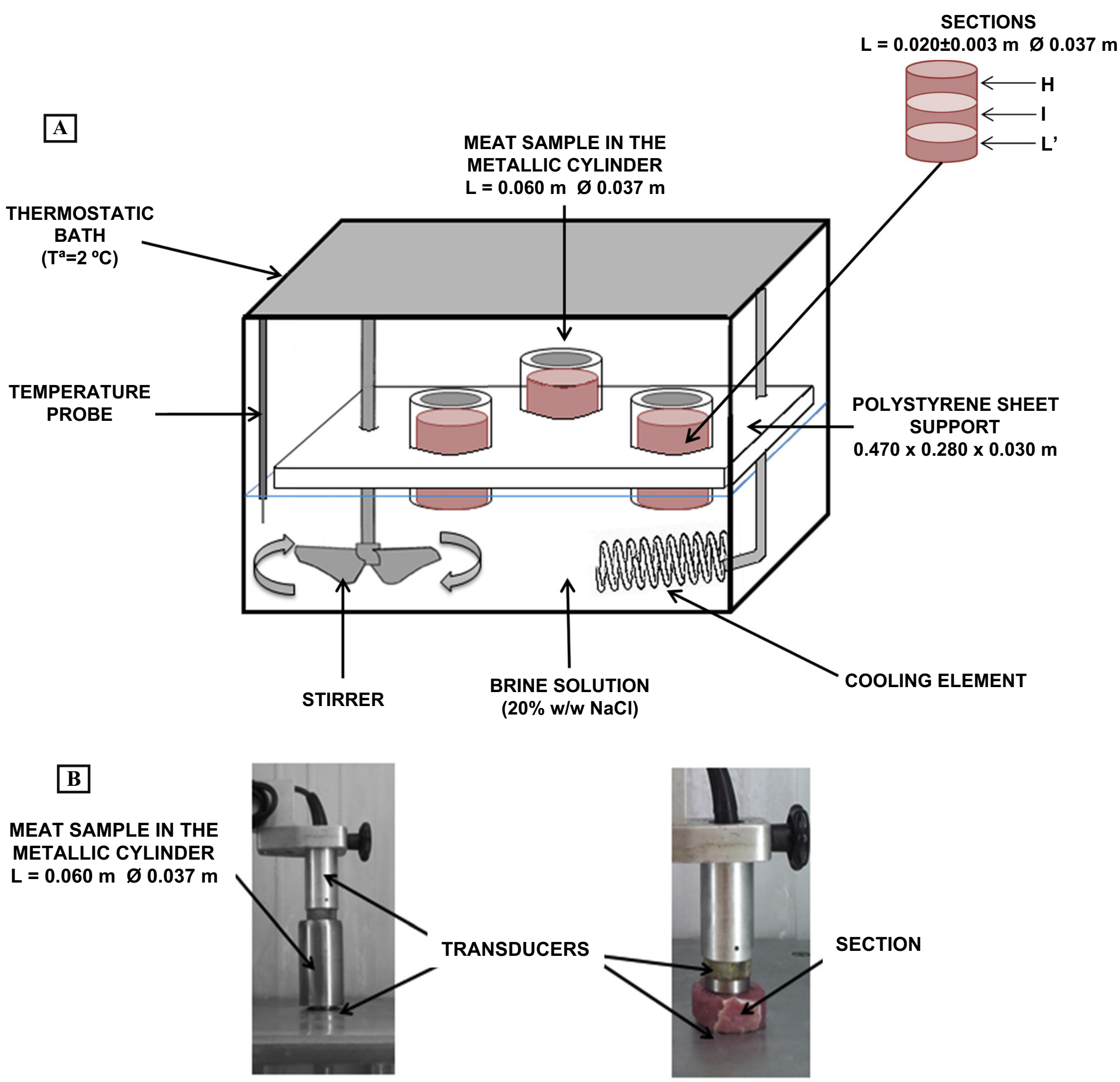

Fig. 1. (A) Scheme of experimental device used for meat salting in brine solution including a detail of the meat sample sections (*H*, *I* and *L'*). (B) Ultrasonic measuring procedure in the meat sample inside the metallic cylinder (left) and in the meat sample section (right).