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Exploring the use of low-intensity ultrasonics as a tool for assessing the salt content in pork meat products

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Abstract

Meat industry demands non-destructive techniques for the control of the salting process to achieve a homogeneous final salt content in salted meat products. The feasibility of using low-intensity ultrasound for characterizing the salting process of pork meat products was evaluated. The ultrasonic velocity (V) and time of flight (T_F) were measured by through-transmission and pulse-echo methods, respectively, in salted meat products. Salting involved an increase of the V in meat muscles and a decrease of the time of flight in whole hams. Measuring the V before and after salting, the salt content could be estimated. Moreover, online monitoring of the salting process by computing the T_F could be considered a reliable tool for quality control purposes.

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Keywords: Ultrasound; non-destructive technology; pork meat; salting process; quality control; online monitoring

1. Introduction

Salted meat products with anatomical integrity, such as loin or ham, achieve a heterogeneous final salt content. Therefore, meat industry demands non-destructive techniques for controlling the salting process. The salt content characterization would allow classifying the product in batches with homogeneous salt content, improving the subsequent processes and the final product homogeneity. In the meat industry, ultrasound velocity has been used to estimate the intramuscular fat content in beef samples (Whittaker et al. [1]), to classify fresh hams according to the

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fat level (De Prados et al. [2]) or to characterize dry-cured meat products according to the breed and diet of pigs (Niñoles et al. [3]). The main aim of this work was to evaluate the feasibility of using low-intensity ultrasound (LIU) for the characterization of the salting process of pork meat products.

2. Materials and Methods

Individual muscles (*Biceps femoris* and *Longissimus dorsi*) and whole pieces (ham) were salted by brining (20% NaCl, w/w) and dry-salting, respectively, at different times (up to 16 days) and 2 ºC. Moreover, samples with preset salt content were formulated from minced *Biceps femoris* (model meat samples). The ultrasonic velocity (1MHz) was measured before and after salting by the through-transmission method. In addition, the salting process was online ultrasonically monitored by conducting through-transmission and pulse-echo measurements.

3. Results and discussion

3.1 Influence of the salt and water content on the ultrasonic velocity for model meat samples

The V rose with the X_S increase (Fig. 1A) and the X_W decrease (Fig. 1B) for formulated meat samples, due to the higher solid content, where ultrasound travels faster (Benedito et al. [4]). From Figs. 1A and 1B, it may be concluded that a change of 1% w.b. in salt produces a change of 13.0 m/s, while it is only of 5.0 m/s for water, showing the larger influence of salt compared with water.

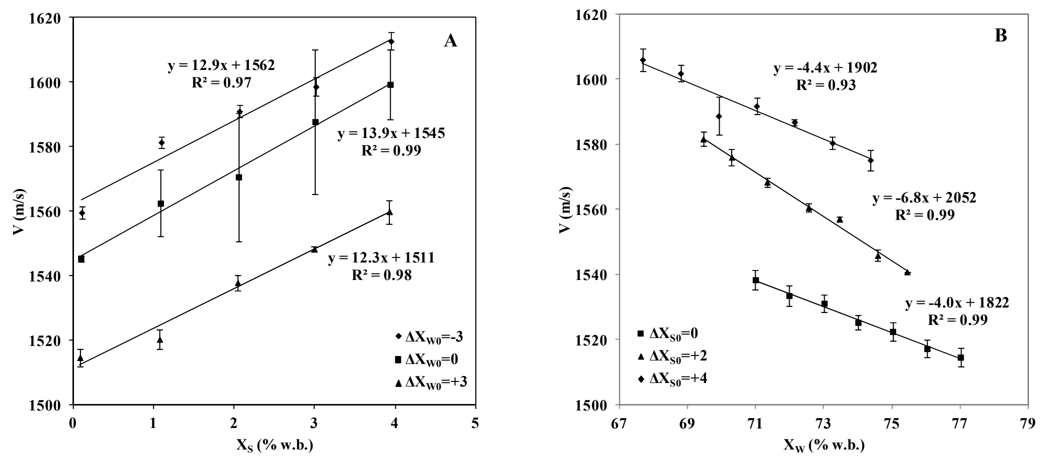

Fig. 1. Influence of the salt (X_S-A) and water (X_W-B) content on the ultrasonic velocity (V) for formulated model samples.

3.2 Salt content characterization

The initial ultrasonic velocity (V_0) measurement showed a high variability (1557.0±6.3 m/s for LD, 1533.9±3.98 m/s for BF, 1547.8±6.4 m/s for hams) due to the heterogeneity in the composition of the raw meat. For this reason, the ultrasonic velocity variation ($\Delta V = V_{final} - V_{initial}$) was considered. The ΔV increased with the salt gain (ΔX_S) in BF and LD samples and hams, significant ($p<0.05$) lineal relationships being established in both cases (Fig. 2). ΔV increased during salting due to the net increase in solids ascribed to the salt gain and water loss. The slope of the linear relationships indicates that the ultrasonic velocity variation increases about 13 m/s per 1% of salt gain, similar to the influence of salt content on the ultrasonic velocity variation in a water solution (Fig. 2, Kinsler equation).

Therefore, regardless of the different salting processes (brining for muscles or dry salting for hams) and product structure (meat or water solution), the slope of the linear relationships are similar. A predictive model based on the ΔV allowed a reliable salt gain estimation in BF and LD samples with an average prediction error of 0.48% w.b. Thus, low-intensity ultrasound could be a reliable non-destructive method to assess the salt content in meat products and monitoring the salting process.

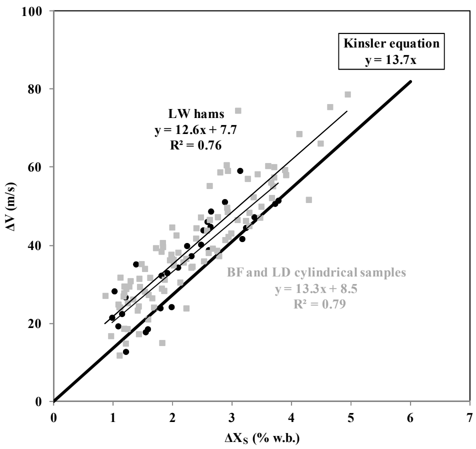

Fig. 2. Relationship between the ultrasonic velocity variation (ΔV) and the salt gain (ΔX_S) in BF and LD samples, hams and Kinsler equation.

3.3 Online monitoring of the salting process

The ΔV evolution of a dry salted BF muscle is shown in Fig. 3A. The ΔV increased gradually during salting up to 32.2 m/s at 48h. Similar curves were found for the salting of the remaining muscles. As previously mentioned, the increase of the ΔV is caused by the increase of the solid content in the meat pieces. The opposite behavior was observed for the time of flight variation (ΔT_F) evolution measured in dry-salted whole hams (data not shown). Thus, on average, the ΔT_F decreased -10.5±1.06µs during 11 days of dry salting.

The time of flight variation corrected by the initial T_F ($\Delta T_F \cdot T_{F0}$) was satisfactorily correlated ($R^2 = 0.89$) with the salt gain in hams dry-salted for 4, 7, 11 and 16 days (Fig. 3B). The significant ($p<0.05$) negative linear relationship between both variables shows that the salt gain leads towards a $\Delta T_F \cdot T_{F0}$ decrease.

Taking into account the previous results, the V and T_F may be considered as reliable ultrasonic parameters for online monitoring of meat salting. Nevertheless, the T_F measurements conducted through the pulse-echo method only need a single transducer located under the hams; in addition it is not necessary to measure the sample thickness. For those reasons, the pulse-echo technique would facilitate the industrial application of the ultrasound devices reducing the cost of the system and minimizing the impact of the measurements on the salt and water transfer.

In order to develop the industrial application, new transducers should be designed to deal with the need of reducing their size while maintaining the penetration capacity and maximizing the resistance of both transducers and connectors to the action of salt.

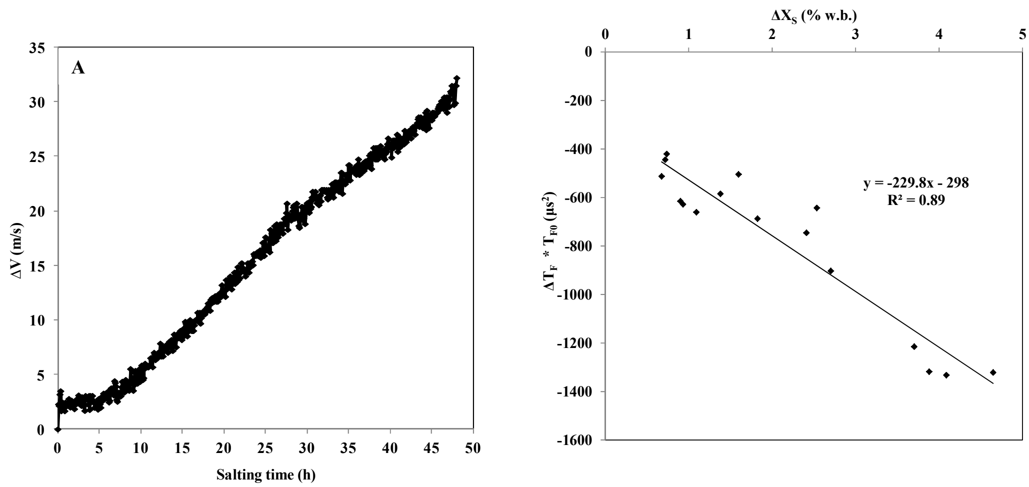

Fig. 3. **A**.Ultrasonic velocity variation (ΔV) evolution in a BF muscle during dry salting (48 h) at 2ºC. **B**. Relationship between the time of flight ($\Delta T_F T_{F0}$) and the salt gain (ΔX_S) in hams dry salting (4, 7, 11 and 16 days).

4. Conclusion

Low-intensity ultrasound could be considered a reliable non-destructive technique for controlling the meat salting process. Measurements could be conducted before and after salting, for quality control purposes, but also could be used for monitoring the process, which would allow describing the salt evolution to determine the optimal salting time according to the targeted salt content.

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