MASS TRANSFER EFFECTS DURING MEAT ULTRASONIC BRINING

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Abstract

Mass transfer processes in meat brining can be enhanced by taking advantage of the effects produced by high intensity ultrasound. Pork loin slices were immersed in a saturated solution of NaCl at 2 ºC during 45 minutes. Different conditions of agitation of the solution and different levels of ultrasound intensity were applied during brining. Ultrasounds were applied with a probe system and the intensity was measured by means of a calorimetric method. The water and NaCl content of samples after treatments showed a high influence of the ultrasound intensity on the mass transfer. Above a threshold of ultrasonic intensity, NaCl and water transport were affected. NaCl content was higher in sonicated than non sonicated samples. At intensities higher than this threshold, water content of samples was higher than initial water content of meat.

Introduction

Brining is a common operation in some meat processes. In this operation, meat is immersed in saturated brine and two main mass transfer processes take place. The water migrates from meat to brine and the solutes migrate from brine to meat. As a consequence the changes in solid composition due to the mass transfer processes produces a decrease of the amount of water available for degradation reactions by enzymes and microorganisms.

The flows of matter should overcome several resistances. In particular, the meat has itself an internal resistance to water and solutes transfer. On the other hand, an external resistance to mass transfer appears between the meat surface and the brine. Any factor that affects these resistances, can affect the mass transfer processes.

These processes are characterized by the relatively slowness of the mass transfer. Several methods such as the application of vacuum [1], [2], [3], centrifugal forces [4], electric pulses [5], [6] or high intensity ultrasound [7], [8] have been tested to accelerate the operation

The ultrasounds produce a series of effects when traveling across a medium that can affect mass transfer processes [9]. The main effects that can affect the resistance to mass transfer are the implosion of bubbles produced by cavitation [10], heating of materials due to thermoacustic effects [11], microstirring, mainly at interfaces [9] and structural effects [12], [13].

For these reasons ultrasound has been used to accelerate mass transfer in several food systems, products and processes. Examples of these are brining of meat [14] and cheese [15], drying of rice [12], carrots [15] or onions [16], osmotic dehydration of apples [9], [7] and several extraction processes [17], [18], [19], [20].

The aim of this work was to study the effect of the intensity of ultrasound in the water and solute transfer during meat brining.

Materials and Methods

Pork loin slices of 5 x 40 x 50 mm were cut from a fresh whole piece of *Longissimus dorsi* (pH 5.5). Individual samples were wrapped in a plastic film and frozen at -20 ºC. Before the salting experiments, samples were slowly thawed at a constant temperature of 2 ºC during 12 h to avoid the influence of the thawing conditions in the meat brining treatments.

Brining experiments were carried out in 800 mL of saturated brine of NaCl into a 1000 mL glass beaker. During the experiments brine temperature was kept constant at 2 ± 0.5 ºC placing the glass beaker into a temperature controlled bath. The saturation of the brine was visually monitored by the existence of solid NaCl at the bottom of the beaker during brining experiments. In all experiments, the time of brining was 45 min. This time was chosen from results reporte in the literature, [7] and [8]. In these cases, this time allowed to observe differences between treatments since it was apart enough from the initial and the equilibrium conditions of the samples.

Several types of brining experiments were carried out: without agitation of brine, with mechanical agitation and with ultrasound application. In the last case, experiments were performed without mechanical agitation of brine.

The brine was stirred by using an agitator Heidolph RZR1 (Heidolph Instruments GMBH & Co., Schwabach, Germany) provided with a marine type impeller that described a circle of 55 mm diameter. Samples of meat were placed in the zone of maximum agitation. 2000 r.p.m. was the maximum possible velocity of the impeller. Higher levels of agitation produced the overflow of the brine.

Ultrasound energy was applied to the brine using a probe system (100 W and 20 kHz, SONICS &

MATERIALS Inc.) provided with horns of 6 and 13 mm of diameter (Figure 1). This probe equipment had the possibility to modify the electrical power applied to the transducer from 0 to 100 %. 7 different levels of ultrasonic intensity were tested.

Ultrasonic intensity was measured using a calorimetric method. This method consisted of recording the heat generated into the liquid by measuring the temperature increase with time [21]. For this purpose, a thermocouple type K connected to a digital data logger (HP Data Logger 34970; Hewlett-Packard Española, S.A., Madrid, Spain) was used. The temperature was recorded at intervals of 0,5 seconds.

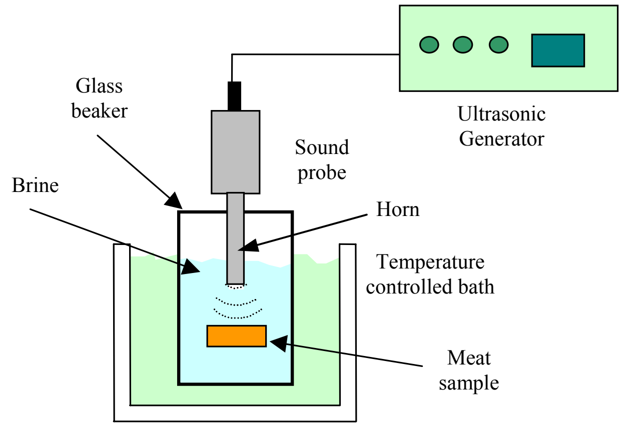

Figure 1. Ultrasonic brining set-up.

The power (P) was calculated from Equation 1:

$$P = MC_p \frac{dT}{dt} \qquad (1)$$

Where M is the mass of solution, Cp is the heat capacity of the brine and $\frac{dT}{dt}$ was estimated from the slope of the temperature-time curve. The ultrasonic intensity considered was the power (P) divided by the surface of the horns.

The distance between samples and the horn tip was standardized for all ultrasonic treatments at 1,5 cm.

The samples were brined individually and brine was not reused. The experiments were carried out at least by triplicate for each kind of treatment.

After the salting treatments, the samples were immersed into distilled water for 30 seconds to remove adhered brine, superficially dried and the moisture and the sodium chloride content determined by triplicate.

The increase of water and the NaCl gain were used to compare the brining treatments applied. Water increase was estimated from Equation 2.

$$DW = W_{fin} - W_{ini} \qquad (2)$$

Where W_{ini} is the water content of the fresh samples and W_{fin} is the water content of the samples after brining. Both water contents were referred to the initial dry mater content of the samples.

To evaluate the significance of the differences between treatments, an ANOVA and the estimation of the LSD intervals (Least Significance Difference) were performed using the software Statgraphics ™.

Results and discussion

Water content

The increase of the water content of samples after the treatments can be observed in Table 1.

Table 1. Increase of water content of loin slices. Treatments in saturated brine of NaCl during 45min at 2ºC.

Treatment		**DW**
		kg W/kg initial dry matter
With agitation		- 0,23 ± 0,12
Without agitation	2000 r.p.m.	- 0,22 ± 0,21
Ultrasound		
Horn of 13 mm	14,7 W/cm^2	- 0,21 ± 0,04
Horn of 13 mm	21,3 W/cm^2	- 0,19 ± 0,03
Horn of 6 mm	29,2 W/cm^2	- 0,20 ± 0,03
Horn of 6 mm	39,3 W/cm^2	- 0,08 ± 0,02
Horn of 6 mm	51,3 W/cm^2	0.05 ± 0,10
Horn of 6 mm	64,2 W/cm^2	0,08 ± 0,02
Horn of 6 mm	75,8 W/cm^2	0,17 ± 0,09

The samples brined without ultrasound application showed a lower moisture content after treatments than the samples brined with ultrasound. The change of the water content was similar in the samples brined with and without agitation of brine.

In the experiments with high intensity ultrasound application, it was observed an influence of the intensity applied in the change of water content of the samples after brining. Lower intensities applied (≤ 29 W/cm^2) provided similar water contents than non ultrasonic experiments. At intensities around 40 W/cm^2 the dehydration level of samples was lower than experiments without agitation of brine. Finally, when intensities applied were above 51,3 W/cm^2, the water content of samples after brining was higher than the initial water content of the meat.

To study the significance of these differences, an ANOVA and the LSD (Least Significant Difference) intervals (95%) were estimated. The results showed no significant differences between non ultrasonic and ultrasonic experiments when the intensity applied was lower than 39.3 W/cm^2. Ultrasonic experiments performed with higher ultrasonic intensities showed significant lower dehydration levels of the samples. The water content of the ultrasonic experiments carried out with an intensity of 75.8 W/cm^2 was significantly higher than the initial water content of meat samples.

NaCl content

The NaCl content of the samples after the brining processes is showed in Figure 1.

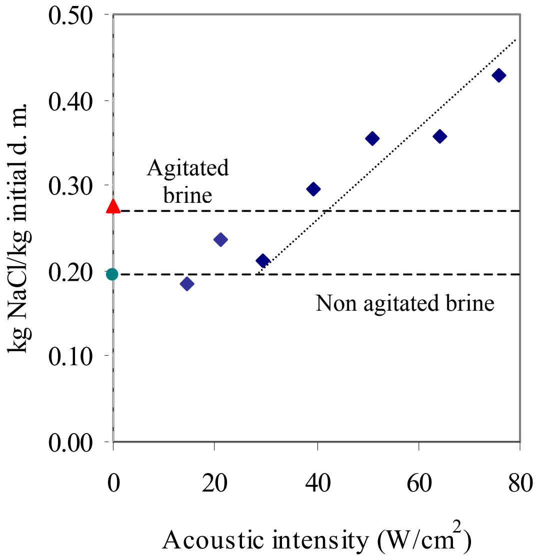

Figure 1. NaCl content of pork loin slices after 45 min of brining. Treatments: ● non agitation; ▲ agitation; ◆ ultrasound.

The samples treated with brine agitation showed a higher NaCl content (0,28 ± 0,06 kg NaCl/kg initial dry matter) than those treated without brine agitation (0,20 ± 0,04 kg NaCl/kg initial dry matter). Agitation could affect the external resistance of NaCl transfer.

On the other hand, the gain of NaCl in the ultrasonic experiments depended on the intensity applied. The samples brined with intensities lower than 29.2 W/cm^2 showed a similar NaCl content than those in non agitation experiments. Above this intensity, NaCl content of samples increased proportionally to the applied intensity.

In the case of NaCl content, an ANOVA and LSD intervals also were determined to identify significantly different treatments. The results showed that the differences between agitated and non agitated experiments were non significant (95%). Probably, a higher number of replicates could produce a decrease of LSD intervals and obtain a better test of procedure.

Above an intensity of 51.2 W/cm^2 the experiments with ultrasound application were significantly different from the experiments without agitation of brine. The highest intensity tested (75.8 W/cm^2) produced a gain of NaCl in samples (0.43 ± 0.12 kg NaCl/kg initial dry matter) significantly higher than that of the experiments carried out with brine agitation (0,28 ± 0,06 kg NaCl/kg initial d. m).

Conclusions

No significant differences were found in water and NaCl content when the brine was agitated with regard to treatments without agitation.

The influence of ultrasound in mass transfer process during meat brining depended on the applied intensity. There is a threshold above which the influence of ultrasound appeared. For water transfer, the application of ultrasound produced a decrease of the dehydration of the samples. At the higher level of intensity tested, the water content of samples was significantly higher than the initial water content of meat. Concerning NaCl transfer, the increase of the NaCl content was proportional to the ultrasonic applied intensity.

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