THE ACCELERATED CURING OF PORK USING POWER ULTRASOUND: A PILOT-SCALE PRODUCTION TRIAL

Ciara K. McDonnell[1, 2*], James G. Lyng[2], Joshua Arimi[2] and Paul Allen[1]

[1] Department of Food Chemistry and Technology, Teagasc Food Research Centre, Ashtown, Dublin 15, Ireland.

[2] School of Agriculture and Food Science, University College Dublin, Dublin 4, Ireland.

Abstract – Lab-scale studies show that power ultrasound (US) accelerates meat curing and produces superior quality hams through cavitation. This study aims to optimize pilot-scale production of US hams for quality and sensory analysis. Firstly, optimization trials were conducted whereby samples were cured in an US bath (900W) with 2 × US probes inserted (each set at 40, 56 or 72 W cm^{-2}) for 2, 4 or 6 h. At all US powers, a desired NaCl level (2.25 ± 0.05%) was attained in 2 h while the control required 4 h. Secondly, samples were assessed for weight change, texture profile analysis, cook loss and expressible moisture. A 9 member trained sensory panel assessed hams in a quantitative descriptive test. Two treatments (US bath + 2 US probes at 40 or 56 W cm^{-2} each) caused greater weight loss than the control ($p<0.001$), possibly due to protein losses. Treatment had no effect on the cook loss, expressible moisture or TPA ($p>0.05$). Sensory analysis revealed a tendency for cooked-ham flavor to increase with increasing power ($p=0.061$), however all other attributes were unaffected by treatment ($p>0.05$). This demonstrates the potential of US at industrial level for reducing meat curing time without affecting quality.

Key Words – Processing, Scale-up, Sensory

I. INTRODUCTION

Several ultrasonic mechanisms have been attributed to accelerated mass transfer in foods, notably cavitation, which is the implosion of microscopic gas bubbles within a medium due to sound wave propagation at frequencies of 16-100 kHz. When cavitation occurs in a liquid-medium system, shock-waves, micro-jetting, acoustic streaming and biological tissue damage can occur [1, 2]. There has been interest in applying US technology to traditional meat curing processes, as they are generally characterized as slow. Although the potential has already been proven [3, 4], few scaled-up sensory studies exist [5]. Power US has been shown to alter the meat structure [6] and cause free-radical production [2], which could alter sensory attributes. This study aims to firstly, optimize pilot-scale US curing to produce hams of equal NaCl concentration (2.25 ± 0.05 %) with reduced processing time and secondly, assess the sensory and quality attributes of these hams.

II. MATERIALS AND METHODS

Experiment 1: Optimization studies

A. Sampling and preparation

Pork *m. longissimus thoracis et lumborum (LTL)* (48 h post-mortem) muscles were obtained from a local slaughter plant. By direct insertion of a glass pH electrode EC-2010-11 (Refex sensors Ltd., Westport, Co. Mayo, Ireland), the pH was recorded along the length of the muscle and only muscles of pH >5.5 were used. The ends (8 cm) of the muscle were discarded and all visible fat and connective tissue was removed. From each animal (2 × *LTL*), six samples (300 g; 90 × 80 × 30 mm) were prepared. Three samples were subjected to a to US treatment for 2, 4 and 6 h, while three were assigned as controls. Sample location was randomized with respect to treatment. At each US intensity tested, a new animal was used and a new set of controls processed. The optimization study was repeated three times, totaling 9 animals.

B. Experimental set-up & processing

Samples were weighed and placed into polyethylene bags (200 × 200 mm) with 225 ml brine solution containing 18.4 % w/w nitrate salt (99.4% NaCl + 0.6% $NaNO_2$). The bag was sealed

(Impulse Sealer, TEW Electronic Heating Equipment Co. Ltd., Taiwan) at the liquid level, ensuring that all visible gas was removed. A standardized 30 min preparation time was allowed; therefore samples were in contact with the brine for 30 min before the treatment began. Control samples were placed at 4°C for 2, 4 or 6 h, while US samples were placed in the in a 900 W, 34-40 kHz US bath (KS525, Guyson International Ltd., UK). Power outputs were varied using 2 × 1000 W 20 kHz US probes (UIP1000hd, Hielscher Ultrasonics GmbH, Germany). The US probes work with functionality between 50 and 100 % power, therefore chosen treatments are described in Table 1.

Table 1. Ultrasonic power settings for each of 2 ultrasonic probes during treatments.

Treatment	Treatment time (h)	Power Output (%)	US intensity (W cm^{-2})	Amplitude (µm)
Control*	2, 4 or 6	0	0	0
1	2, 4 or 6	50	40	15.5
2	2, 4 or 6	70	56	21.7
3	2, 4 or 6	90	72	27.9

* Ultrasonic bath not operating for control treatment

The temperature was controlled by disabling the heating function on the US bath and immersing copper tubing (25 m) into the water of the US bath, through which glycol coolant (-8°C) was circulated using a refrigerated unit (Grant LTD 20G, Grant Instruments Ltd., UK) (Fig. 1).

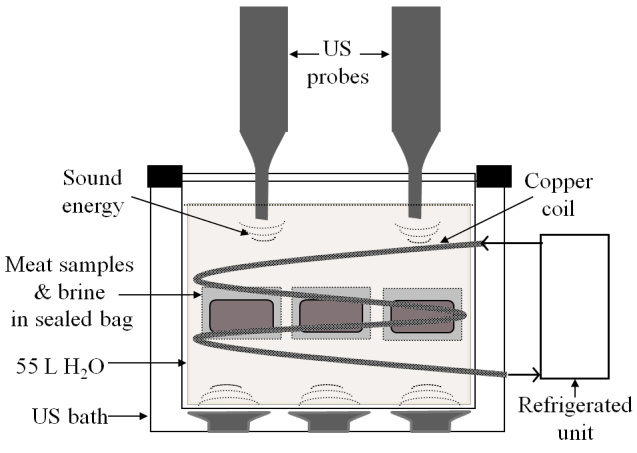

Fig. 1. Schematic diagram of experimental set-up for ultrasonic treatments

At each intensity tested, three samples were treated simultaneously inside the US unit. Samples were rotated midway through the treatment time i.e. at 1, 2 or 3 h with treatments being completed at 2, 4 or 6 h, respectively. Dimensions and energy flow were kept constant by placing an imitation sample in place of removed samples until the 6 h treatment was complete. Following treatment, samples were removed from the bag, rinsed with deionised water, blotted dry and re-weighed. Samples were vacuum packed and stored at 4°C for 6 days to allow for NaCl equalization.

C. Proximate analysis

Samples were blended (Robocoupe R301 Ultra, SA, France). Moisture analysis was determined by weight loss after overnight oven drying at 103 ± 2°C [7]. NaCl content was determined by standard titrametric Volhard method [8].

Experiment 2: Quality and sensory

A. Treatments

From the optimization trials, 4 treatments which gave equal NaCl concentration of 2.25 ± 0.5 % NaCl were chosen (see results, section A). Samples were processed as previously described. Three replicates of the study were completed.

B. Cook loss and expressible moisture

Samples were cooked at 77 °C for 65 min in a water bath (Model No Y-38, Grant Instruments Ltd., Cambridge, UK) until an internal temperature of 72 °C was reached. The cook loss was calculated as the weight change before and after cooking.

Expressible moisture analysis was performed on 4 cores (17 ϕ × 12.7 mm) as described by Schilling et al. [9].

C. Texture profile analysis

Texture profile analysis (TPA) was performed on 4 cylindrical cores (17 ϕ x 20 mm) taken from each sample. Samples underwent a double compression (70%) at a speed of 50 mm/min with a 5 kN load cell on an Instron Universal testing machine (Model no. 5543, Instron, UK). Readings of hardness (N), chewiness (N), cohesiveness, gumminess (N) and springiness (mm) were calculated.

D. Sensory Analysis

Samples were sliced to 2 mm thickness and stored at 4°C before being presented to a 9 member trained sensory panel who are familiar with meat products. Panellists were chosen following screening for good performance with taste and odour. Quantitative descriptive analysis was carried out on all samples for 9 attributes to be scored on a 0-10 non-structured intensity scale (0= non-detectable; 10= maximum detection of an attribute). For each sensory session (N = 3), panellists were presented with 4 hams (one from each treatment) in a randomized design.

E. Statistical analysis

One-way analysis of variance (ANOVA) was used to assess the effect of different treatments on quality and sensory attributes. Where a significant difference was detected the F-protected least significant difference test was used at the $p < 0.05$ level. All statistical analyses were performed using Genstat software (Genstat, 14th Edition, VSN International Ltd, UK).

III. RESULTS AND DISCUSSION

A. Experiment 1: Optimization studies

The desired NaCl concentration of 2.25 ± 0.5% was achieved at all US intensities tested (40, 56 or 72 W cm^{-2}) for a duration of 2 h; however the control required 4 h to reach the same concentration ($p<0.001$) (Fig. 2).

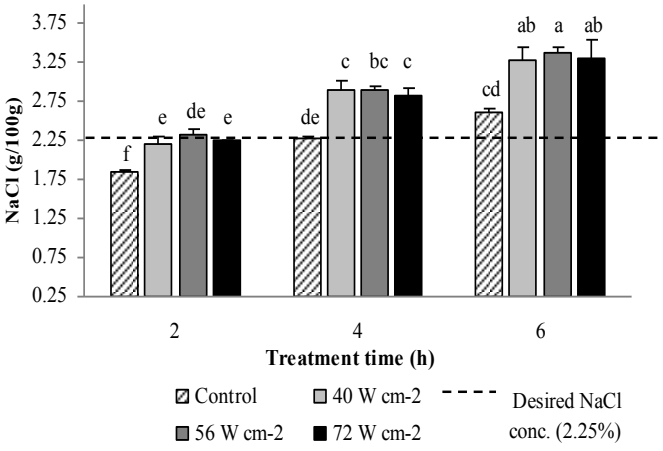

Fig. 2. NaCl content (g/100g) of controls and sonicated samples. US intensities refer to the setting of each US probe operating in a 900 W US bath. Error bars indicate the standard deviation from the mean.

The moisture content of samples was 72.7 ± 0.3 %. There was a trend for lower moisture content in sonicated samples ($p>0.05$) and a decrease in moisture with increasing treatment time ($p<0.05$), however the moisture content for all US intensities for 2 h and the control for 4 h did not differ ($p>0.05$), therefore treatments for further studies were chosen as a control at 4 h curing and 3 US treatments; treatments 1, 2 and 3 corresponding to the US bath and 2 US probes working at 40, 56 and 72 W cm^{-2}, respectively.

B. Experiment 2: Weight change, cook loss & expressible moisture

All samples gained weight (3 ± 1.2 g) during curing. Treatments with US probes operating at 40 and 56 W cm^{-2} caused greater weight loss ($p<0.001$) than the control and 72 W cm^{-2} (Fig 3). It is possible that these US intensities (40 and 56 W cm^{-2}) caused protein losses. US has been shown to cause increased myofibrillar protein extraction [10], which could contribute to lower weight gain.

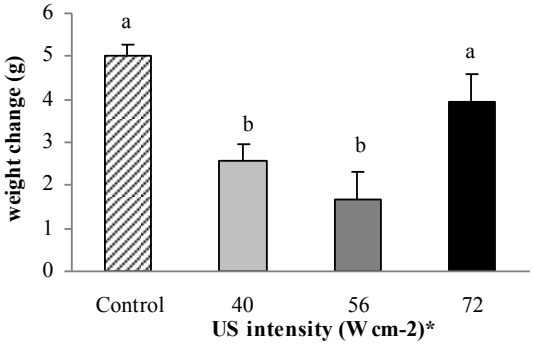

Fig. 3. The effect of treatment on the weight change of hams. US intensities refer to the setting of each US probe operating in a 900 W US bath. Error bars indicate the standard deviation from the mean

The average cook loss and expressible moisture were 18.4 ± 1.3 and 17 ± 1.3 %, respectively. There was no effect of treatment ($p>0.05$), nor was there a visible trend in the data.

C. Texture profile analysis

The mean TPA values for hardness (N), chewiness (N), cohesiveness, gumminess (N) and springiness (mm) were 109.4, 230.3, 0.9, 40.5 and 5.7, respectively. There was no effect of treatment ($p>0.05$).

D. Sensory analysis

The results of the sensory analysis are presented in Fig. 4. There was no effect of treatment on any of the attributes analyzed ($p>0.05$), however there was a trend for cooked-ham flavour to increase with increasing power input ($p = 0.061$). Also, there was a tendency for a less juicy ($p = 0.057$) and more cohesive ($p= 0.097$) product when the probes were operating at 56 W cm^{-2} but this did not affect the liking-scores of the hams. It has been suggested that US intensity thresholds for optimum NaCl diffusion exist, while other intensities may be optimum for protein denaturation [3]. Perhaps 56 W cm^{-2} caused greater protein denaturation; however as no other scaled-up studies exist, it is difficult to make conclusions.

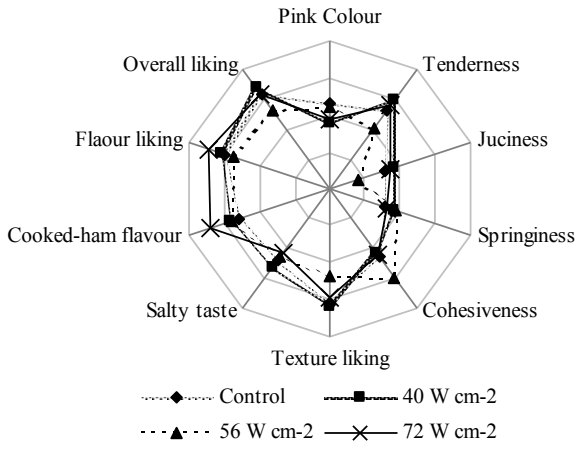

Fig. 5. The effect of treatment on the sensory attributes of hams. US intensities refer to the setting of each US probe operating in a 900 W US bath

IV. CONCLUSION

In the present study, it was found that ultrasonic treatment with two probes 40-72 W cm^{-2} in a 900 W US bath can decrease the salting time of meat by up to 50%, independent of the intensity used. Moreover, US treatment did not have any significant effect on the quality or sensory attributes of the product. This study proves that scaled-up US curing is viable and that industrial potential exists.

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REFERENCES

1. Jambrak, A. R., Herceg, Z., Šubariæ, D., Babiæ, J., Brnèiæ, M., Brnèiæ, S. R., Bosiljkov, T., Èvek, D., Tripalo, B. & Gelo, J. (2010). Ultrasound effect on physical properties of corn starch. Carbohydrate Polymers 79: 91-100.
2. Kuijpers, M. W. A., Kemmere, M. F. Keurentjes, J. F. T. (2002). Calorimetric study of the energy efficiency from ultrasound-induced radical formation. Ultrasonics: 40, 675-678.
3. Cárcel, J. A., Benedito, J., Bon, J. & Mulet, A. (2007). High intensity ultrasound effects on meat brining. Meat Science 76: 611-619.
4. Siró, I., Vén, C., Balla, C., Jónás, G., Zeke, I. & Friedrich, L. (2009). Application of an ultrasonic assisted curing technique for improving the diffusion of sodium chloride in porcine meat. Journal of Food Engineering: 91, 353-362.
5. Paulsen, P., Hagen, U. & Bauer, F. (2001). Physical and chemical changes of pork lion. Ultrasound curing compared to conventional curing. Fleischwirtsch 81: 91-93.
6. Jayasooriya, S. D., Torley, P. J., D'Arcy, B. R. & Bhandari, B. R. (2007). Effect of high power ultrasound and ageing on the physical properties of bovine Semitendinosus and Longissimus muscles. Meat Science: 75, 628-639.
7. AOAC (1990). Official method 950.46, moisture in meat, B. Air drying. In K. Helrich (Eds.). Association of Official Analytical Chemists Inc., (pp. 931). Arlington Inc.
8. Kirk, R. S. & Sawyer, R. (1991). In Pearson's Composition and Analysis of foods (pp. 530-608). London: Longman Scientific and Technical.
9. Schilling, M. W., Marriott, N. G., Acton, J. C., Anderson-Cook, C., Alvarado, C. Z. & Wang, H. (2004). Utilization of R to evaluate the effects of non-meat adjuncts and combinations of PSE and RFN pork on water holding capacity and cooked color in the production of boneless cured pork. Meat Science 66: 371-381.
10. Reynolds, J. B., Anderson, D. B., Schmidt, G. R., Theno, D. M. & D.G., S. (1978). Effects of Ultrasonic Treatment on Binding Strength in Cured Ham Rolls. Journal of Food Science, 43: 886-869.