THE USE OF PULSED ELECTRIC FIELDS TO ACCELERATE THE SALTING OF PORK

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Abstract – Pulsed electric fields (PEF) is a processing technology that can induce cell permeabilization through electroporation. The efficiency of PEF as a pre-treatment for the accelerated salting (15% w/v NaCl) of pork was assessed in a 2 × 2 × 2 factorial design (7 or 14 kV, 100 or 200 Hz and 150 or 300 pulses). A non-treated sample acted as a control. NaCl and water content (g/100g) acted as indicators for increased saline migration. Weight change, pH, cook loss, water-binding capacity (WBC) and texture profiles were also assessed. PEF at 14 kV caused greater weight loss than 7 kV ($p<0.05$). Two treatments (7 or 14 kV at 100 Hz for 300 pulses) increased the NaCl content of samples ($p<0.05$) above the control. There was no difference in the water content of PEF treated samples in comparison to the control however within PEF treatments, 100 Hz caused greater water content than 200 Hz ($p<0.05$). There was no significant effect of PEF on weight change post-curing, cook loss, WBC or texture profiles of samples. The findings of this study indicate that there is potential for reduced curing time through PEF, however further work on the optimization of treatment parameters would be beneficial.

Key Words – Curing, Electroporation, Processing

I. INTRODUCTION

Curing is an ancient preservation technique which affects the flavour, texture and water-holding characteristics of meat. For successful curing, NaCl must diffuse into the meat and reach an equilibrium concentration throughout. Due to the slowness of this process, research has been conducted for the acceleration through novel technologies such as high-pressure [1] and power ultrasound [2]. Pulsed electric fields (PEF) is a technology which can induce cell permeabilzation through electroporation [3]. The efficiency of the technology for microbial inactivation in liquid foods has been proven [4, 5]. However, few studies exist on batch treatment of solid foods where it is generally more difficult to achieve high field strengths [3, 6]. Nonetheless, factors such as treatment time and pulse number may also influence the solid food matrix [6], thus accelerating mass transfer processes such as curing. This study aims to assess the effect of several PEF parameters (voltage, frequency and pulse number) on saline migration and assess the impact of these treatments on the meat quality characteristics.

II. MATERIALS AND METHODS

A. Sample preparation and treatment

Pork *M. Longissimus thoracis et lumborum* (LTL) were obtained from a local slaughter plant at 48 h post-mortem. The pH was recorded at three points along the length of the muscle by direct insertion of a glass pH electrode EC-2010-11 (Refex sensors Ltd., Westport, Co. Mayo, Ireland) and only muscles of pH >5.5 were used. All visible fat and connective tissue was removed. Using a cutting guide, nine samples (6 × 2 × 2 cm, 30 ± 0.5 g) were cut with fibre direction parallel to the long axis. Samples were randomly assigned to PEF treatments (Elcrack-HPV5, DIL IFT, Quakenbruck, Germany) according Table 1. Parameters of voltage, frequency and pulse number were varied in a 2 × 2 × 2 factorial experimental design. A non-PEF treated sample acted as the control. After PEF treatment, the sample weight and temperature were recorded. Samples were covered with cling film and stored at 4°C until the temperature reduced. Samples were immersed in individual 150 ml containers with 110 ml saline (15% w/v NaCl) for 30 min. Constant agitation of the brine was ensured by placing samples on a platform shaker (Stuart SSL2, Bibby Scientific Limited, 180 Staffordshire, UK) at 200 cycles per minute. Following salting, samples were rinsed with deionised water, reweighed, blotted dry and vacuum packed until further analysis. The small sample size meant that many replicates of the experiment had to be conducted for analysis. A total of 9 replicates were conducted and new muscle was used for each replicate.

Table 1 Pulsed electric field parameters applied to meat samples before salting

Treatment	Voltage (kV)	Frequency (Hz)	Pulse no	Actual Field strength (kV/cm)
0	0	0	0	0
1	7	100	150	1
2	14	200	300	2.1
3	7	200	150	1
4	14	200	300	1
5	7	100	150	2
6	14	100	300	2.1
7	7	100	300	1.1
8	14	200	150	2

B. Proximate analysis

The pH of samples was recorded at 3 locations along the sample as previously described. Water content was determined by weight loss after overnight oven drying at 103 ± 2°C [7]. NaCl content was determined by standard titrametric Volhard method [8].

C. Cook loss and water-binding capacity

The sample shape may have caused variation in NaCl content along the length, which would affect the water-binding properties; therefore to ensure representative analysis, samples underwent standardized blending (3 × 15 s; rpm, Waring Blender). A 5 g aliquot was placed into customized centrifuge tubes as described by Farag et al [9]. Samples were cooked (90°C; 10 min) in a water bath, reweighed and centrifuged (220 × *g*; 10 min; 4°C). The cook loss was calculated as the weight difference after cooking while the WBC was determined as the weight difference before cooking and after centrifugation.

D. Texture profile analysis

Samples were cooked in a water bath (77°C, 10 min) to a core temperature of 72 °C. Three cores (15 ϕ × 15 mm) were generated from each sample. Texture profile analysis (TPA) was performed on an Instron Universal testing machine (Model no. 5543, Instron, UK) with a 5 kN load cell. Samples were compressed to 70% of the original height in a dual-compression at 50 mm/min. Sample hardness (N), chewiness (N), gumminess (N) and springiness (mm) were calculated from the force time deformation curve.

E. Statistical Analysis

Two separate statistical tests were conducted using Genstat software (Genstat, 14th Edition, VSN International Ltd, UK). Firstly, the effect of treatment was assessed in a one-way analysis of variance (ANOVA) where the control was included. Where a significant difference was detected between the treatments a three-way ANOVA was conducted to assess the effect of voltage (kV), frequency (Hz), pulse number or an interaction. Where a statistical difference was detected, the least significant difference test was used to compare mean values. Muscle was set as a block for all statistical analyses.

III. RESULTS AND DISCUSSION

A. Weight changes & pH

A small weight loss (0.057 ± 0.005 g) was evident in samples following PEF treatment, however this was not affected by overall treatment ($p>0.05$). There was an effect of voltage whereby samples treated with 14 kV had greater weight loss than samples treated with 7 kV ($p<0.05$). A similar effect was reported by O'Dowd et al [10]. It is possible that the increased voltage induced cell permeabilization and water losses. On average samples gained 1.05 ± 0.01 g during curing but this was not affected by treatment ($p>0.05$). Similarly, there was no effect of any factor on the pH of samples ($p>0.05$).

B. NaCl and water content

There was a significant effect of overall treatment on NaCl content in samples ($p<0.05$), whereby treatments 6 and 7 (Table 1) increased the NaCl content 10.4 and 13%, respectively above that of the control (Fig. 1). When the control was removed from the statistical analysis, there was an interaction between frequency and pulse number. Treating samples with 300 pulses at 100 Hz resulted in greater NaCl uptake than other combinations ($p<0.01$). Whittner et al [11] also reported an increase in the dry matter of pork loin pre-treated with PEF (1 or 3 kV/cm) and salted for up to 5 h, indicating the potential for increased mass transfer.

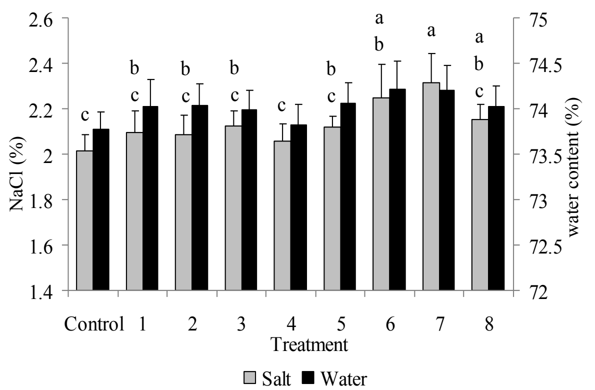

Figure 1. Least square means for NaCl and water content as affected by PEF treatment (Table 1). Error bars show the standard deviation from the mean.

In the present study, a similar trend was evident in the water content (g/100 g) of samples (Fig. 1), but the effect of treatment was not significant ($p>0.05$). However, within PEF treatments water content was significantly affected by frequency such that samples treated with 100 Hz had greater water content that samples treated with 200 Hz ($p<0.05$).

C. Cook loss and water-binding capacity

The average cook loss and WBC of samples were 14.1 ± 1.0 and 70.7 ± 1.5, respectively. There was no effect of treatment on cook loss or WBC ($p>0.05$), however a similar trend to NaCl and water content was evident whereby treatments 6 and 7 (Table 1) caused slightly greater cook loss than other treatments (Fig. 2). This further indicates that treatments 6 and 7 induced cell permeabilization through electroporation. Toepfl [3] also found that PEF (0.5 – 3.5 kV/cm) causes increased cook loss in samples however a synergistic effect exists between PEF and phosphate which leads to improved water-binding properties.

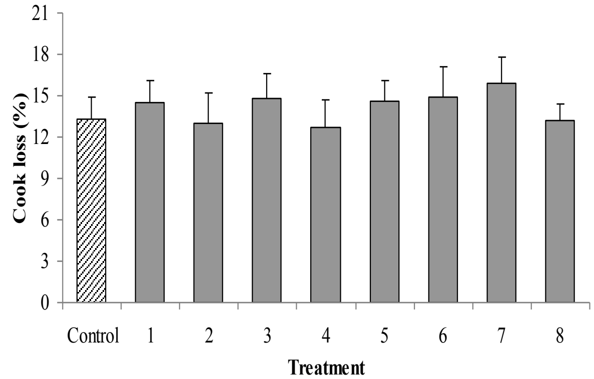

Figure 2. Least-square means for cook loss (%) as affected by PEF treatment (Table 1). Error bars show the standard deviation from the mean.

D. Texture profile analysis

The average TPA values as affected by treatment are presented in Table 2. There was no significant effect of treatment or any factor on TPA values ($p>0.05$), however there was a trend for increased hardness and chewiness in treatments 6 and 7.

Table 2 Least-square means of hardness, chewiness, gumminess and springiness as affected by PEF treatment (details in Table 1). S.e.d indicates the standard error from the mean

	Hardness (N)	Chewiness (N)	Gumminess (N)	Springiness (mm)
Control	94.9	148.7	31.1	4.7
1	93.8	142.0	30.2	4.7
2	98.2	149.1	34.3	4.5
3	90.6	151.6	30.8	4.9
4	98.5	146.4	31.2	4.7
5	95.1	146.7	30.5	4.8
6	101.3	152.7	33.2	4.6
7	103.6	168.0	35.4	4.7
8	91.7	143.9	31.7	4.5
S.e.d.	33.8	9.1	2.1	0.2

O'Dowd et al [12] found slight increases in shear force (N) for PEF treated samples, though these proved non-significant. The same research group reported that PEF caused smaller myofibrils indicating some effect of PEF on texture. Smaller myofibrils could also lead to increased diffusion of a saline solution.

IV. CONCLUSION

The findings of this study indicate that there is potential for the use of PEF to accelerate the curing of pork. It is possible that applying treatments with lower frequencies and higher pulse number leads to greater electroporation as indicated by a trend for increased saline migration, cook loss and hardness. Further work on the optimization of treatment parameters could lead to reduced curing time.

ACKNOWLEDGEMENTS

The authors wish to thank the Department of Agriculture, Food and the Marine for their funding through the Food Institutional Research Measure.

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