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Computational modelling of spatial distribution of hydrodynamic shockwave technology towards improved tenderisation of beef *Longissimus lumborum*(#141)

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Introduction

Meat tenderness is a highly valuable attribute but it can often be inconsistent which can deter consumers from repurchasing. Shockwave (SW) technology has been reported to improve tenderness by disrupting muscle fibres and connective tissue [1]. This can be achieved by a controlled electrical discharge underwater, generating pressures of up to 1 GPa for milliseconds. In order to optimise the technology towards consistent tenderisation of meat and subsequent commercialisation, it is necessary to model the spatial distribution of the hydrodynamic shockwaves. This study aims to model the distribution kinetics of SW and subsequently, apply this knowledge to preliminary tenderisation studies on beef *longissimus lumborum*.

Methods

Study A. Computational modelling of hydrodynamic shockwave distribution

Laminated pressure sensitive paper (Fujifilm low pressure 2.5-10 MPa, Bestech, Australia) was used to quantify the distribution and penetration of hydrodynamic shockwaves. Following SW treatment (15-30 kV) by electrical discharge underwater in a customised SW unit (Fig. 1. DIL, Quakenbrück, Germany), the pixel intensity on the pressure paper was analysed by an Epson Perfection V370 Photo Scanner. Colour pixel intensity and distribution was measured in terms of pressurised area (mm^2), average pressure (MPa), maximum pressure (MPa) and load (N). Pressure paper and rubber mats (polymer: styrene-butadiene and isoprene rubber; 230 x 250 x 10 mm and 230 x 250 x 25 mm L x W x H) were layered in various stacked configurations to simulate meat for modelling purposes. The mathematical model considered the system as isothermal with transient turbulent fluid flow. The highly coupled non-linear partial differential equations (PDEs) in the space-time domain, together with the set of initial and boundary conditions, were numerically solved by the finite element method (FEM) using a commercial software package (COMSOL Multiphysics™, Comsol AB, Stockholm, Sweden).

Study B. Preliminary study assessing the effect of shockwave on beef

Paired striploin (*longissimus lumborum*) muscles from four carcasses (male steers with dentition 6, 321-368 kg) were trimmed into two samples per muscle (L x W x H =10 x 14 x 5.5 cm) and vacuum packaged. Samples were subjected to SW treatment (25 kV, 8 pulses, ambient temperature in stationary mode) by placement directly under the source. Samples were randomly allocated to 0 day (analysed immediately post-treatment) or 7 days storage (-0.5 °C). A steak (25 mm) from the centre of each striploin was cooked to a core temperature of 72 °C in a water bath (75 °C, 30 min). After overnight storage at 5 °C, samples were analysed using a modified Warner-Braztler shear force (WBSF) method [2]. Data were analysed using Genstat (19th Edition, VSN International, UK) by two-way analysis of variance with factors of voltage (0 or 25 kV) and storage time (0 or 7 days), and animal set as a block.

Results

As shown in Fig. 2A, the pressure paper detected pressure variations from SW treatment whereby green, red and yellow zones indicate pressures of < 2.5 MPa, 2.5 to 10 MPa and > 10 MPa, respectively. Results showed that the pressure distribution within the treatment chamber was even from top (5.32 MPa) to bottom (4.70 MPa) of the belt with only a slightly increase in pressure towards the SW source. The predicted and measured values were comparable which allowed a model to be generated which could simulate pressures at various distances above the treatment belt (Fig 2B and C). The findings from the model were used to design the preliminary tenderness study. For the preliminary tenderness study (Study B), WBSF measurements were undertaken after each storage time point. WBSF results (Fig. 3) indicated that SW treatment could significantly reduce peak force (N) at day 0 by 15N ($p<0.05$). Storage days also reduced peak force ($p<0.01$), whilst the interaction of voltage with days was not significant ($p>0.05$), indicating the largest effect of SW is found directly after treatment.

Conclusion

The computational modelling was successful in predicting pressure at various distances from the belt and can be applied to understanding the parameters for further optimisation of SW treatment of beef. The results of texture analysis indicated that the most significant effect of SW was immediately after treatment i.e. at 0 days storage. These initial findings indicate that SW technology could improve production efficiencies and reduce costs by reducing ageing times. However, further research is required to validate these initial findings and apply SW to different muscles to explore wider applications of this technology.

Notes

Acknowledgments
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References
1. Warner, R.D., McDonnell, C.K., Bekhit, A.E.D., Claus, J., Vaskoska, R., Sikes, A., Dunshea, F.R., Ha, M. (2017) Systematic review of emerging and innovative technologies for meat tenderisation, Meat Science, 132, 72-89.
2. Bouton P.E., Harris P.V. (1972). A comparison of some objective methods used to assess meat tenderness. Journal of Food Science, 37, 218-221.

Notes

Figure 1.
The Shockwave unit at CSIRO Coopers Plains, Brisbane used for this project

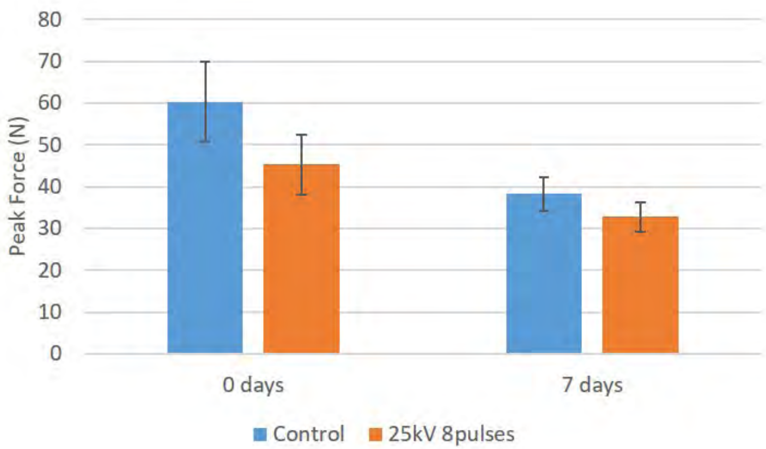

Figure 3.
Peak force (N) for beef samples treated with Shockwave at day 0 and 7 analysis. Error bars indicate the standard deviation from the mean

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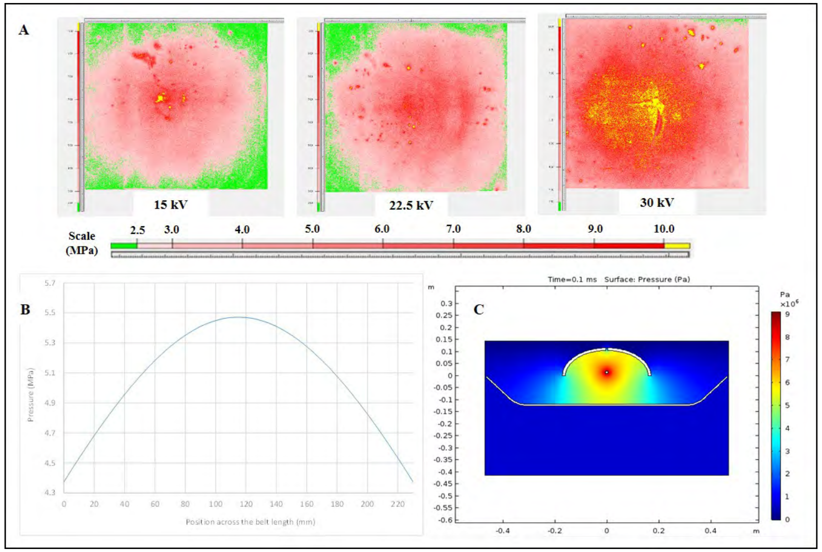

Figure 2.
A. Representative images of the pressure distribution at different voltage settings; B. Pressure distribution across the 230 mm width of the belt (at 10 mm from above the belt surface; time = 0.1 ms after shockwave application). C. A 2D surface plot of the pressure distribution in the SW system (time = 0.1 ms after SW application)

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