PRESSURE-INDUCED CHANGES IN WATER CHARACTERISTICS IN FRESH AND COOKED BEEF

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I. INTRODUCTION

Many studies have investigated the effects of high pressure processing (HPP) on modifications to muscle proteins in whole meat systems, and the resultant impact on meat quality attributes such as texture [1] and water-holding capacity (WHC) [2]. The temperature at which HPP is applied has varied effects on the texture of muscle, but generally higher temperatures are required to achieve tenderisation [3]. When pressure or heat is applied to myofibrillar proteins, a 3-D network can form that has the ability to retain water [4]. However, if pressure or heat is excessive, denaturation leads to a loss of the ability to bind water, and therefore a decrease in the WHC. Water characteristics in muscle impacts meat quality attributes, such as juiciness and tenderness. Water present in muscle exists in three forms – bound water, immobilised water and free water [5]. Low-field nuclear magnetic resonance (LF-NMR) proton relaxometry is a non-destructive technique that gives direct information about physical and chemical water properties in muscle [5]. The aim was to investigate the pressure-induced changes at different temperatures in the water mobility and distribution in fresh and cooked beef muscle, using LF-NMR.

II. MATERIALS AND METHODS

The experiment was designed as a 4x2 factorial, with 4 treatments (control, C1H; pressure treatment at high temperature (76°C), P-H; control, C2L; pressure treatment at low temperature (5°C), P-L) and 2 cooking treatments (uncooked vs cooked). For logistical reasons, HPP of samples at each temperature occurred on consecutive days. To negate this day effect, controls were allocated for each temperature, i.e. C1H and C2L. *Pectoralis profundus* muscles were boned out from the right sides of four Chinese Yellow cattle at 24 h post-mortem (PM). After trimming of fat and connective tissue, 8 portions from each muscle were randomly allocated to treatments. Pressure treatment (200 MPa for 20 min) was performed using a 0.3 L capacity 850 Mini FoodLab high pressure vessel (Stansted Fluid Power Ltd, Stansted, UK) connected to a circulating water bath, to allow adjustment of the compression fluid (water) temperature to either 76°C (high temperature) or 5°C (low temperature). After HPP, all samples were held in ice water for 20 min and stored at 5°C. Following HPP, half of the samples were cooked at 76°C for 20 min. Water mobility and distribution was measured by LF-NMR as described by Liu et al. [6]. Transverse relaxometry (T_2) data was collected using a τ-value of 250 µs at room temperature. Relaxation times (T_{2b}, bound water, T_{21}, immobilised water, T_{22}, free water) and the corresponding water populations (P_{2b}, P_{21}, P_{22}) were recorded. The data was sorted by cooking, and each data set was analysed separately. A general ANOVA was used to analyse the effect of pressure at each temperature (Genstat 16th edition). Animal number was used as the block in the structure.

III. RESULTS AND DISCUSSION

Although the experiment consisted of 2 cooking treatments, in effect, the P-H treatment could be considered as 'cooking under pressure'. Therefore, a greater number of significant differences in water characteristics was observed in the uncooked samples compared to the cooked samples (Table 1). For the uncooked samples, the P-H treatment resulted in a faster (P<0.001) T_{21} time than the control (C1H), suggesting that water became more tightly trapped within the protein network. However, this is not reflected in the water distribution results. Immobilised water in the intra-myofibrillar space (P_{21}) in the P-H treatment was lower (P=0.007) compared to the control, and the water in the extra-myofibrillar space (P_{22}) was higher (P=0.025) than the control. No further cooking after P-L treatment resulted in a slower (P<0.001) T_{21} time than the control (C2L), indicating a higher mobility and a shift from immobilised water (T_{21}) to free water (T_{22}), possibly due to swelling of myofibrils. The relaxation time for the intra-myofibrillar water (T_{21}) was faster (P<0.001) with the P-H treatment than the P-L treatment. The distribution of both the bound and intra-myofibrillar water for the P-H samples was lower (P=0.003 and 0.007, respectively) than the P-L treatment, however P_{22} was higher (P=0.025) with P-H than P-L.

Table 1 Water characteristics (mobility, T_{2x}; distribution P_{2x}) of beef brisket treated with high pressure at low and high temperatures, followed by cooking or uncooked.

Cooking	Water parameters	Treatment [b]				LSD	*P*-value
		C1H	P-H	C2L	P-L		
Uncooked	T_{2b} (ms)	2.98	1.63	1.91	1.56	1.234	0.093
	T_{21} (ms)	49.77	39.06	51.63	57.22	3.080	<0.001
	T_{22} (ms)	288	248	289	202	82.7	0.130
	P_{2b} (%)	2.65	1.99	2.85	3.21	0.522	0.003
	P_{21} (%)	96.98	88.60	96.62	95.27	4.435	0.007
	P_{22} (%)	0.06	9.41	0.13	2.79	5.732	0.025
Cooked [a]	T_{2b} (ms)	1.39	2.20	1.37	1.88	0.657	0.054
	T_{21} (ms)	26.60	26.10	34.30	24.90	11.31	0.278
	T_{22} (ms)	307	148	330	253	128.9	0.049
	P_{2b} (%)	2.05	2.52	2.22	1.89	0.824	0.409
	P_{21} (%)	92.03	87.56	89.54	95.46	7.203	0.147
	P_{22} (%)	5.92	9.65	8.24	3.27	8.352	0.373

[a] cooked at 76°C/20 min after pressure treatment

[b] C1H=control for high temperature treatment; P-H = pressure (200 MPa, 20 min) applied at 76°C (high); C2L=control for low temperature treatment; P-L= pressure (200 MPa, 20 min) applied at 4°C (low)

IV. CONCLUSION

Differences in water characteristics as measured by LF-NMR in pressure-treated beef brisket muscle have been observed and are dependent on the temperature at which HPP is applied. Any change in water characteristics implies alterations in the structural organisation of myofibrillar water, and affects WHC. The measurements in this study will be correlated to other meat quality attributes, such as WHC, texture, and structure, in future work. A better understanding of the mechanisms by which HPP modifies structure and how this influences the water characteristics in muscle and impacts meat quality attributes such as WHC or tenderisation is still needed to optimise conditions for processing. This optimisation will improve WHC and hence yield, which is beneficial to the meat industry.

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