An NMR-based investigation on two different strategies for improving pH_{24h}, WHC and juiciness in pork: rapid chilling and pelvic suspension

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Abstract

The effects of *i*) pre-rigor excision, which results in a rapid post mortem chilling, and *ii*) pelvic suspension, which results in a muscular stretching, on pH_{24h}, WHC, water distribution measured by ^{1}H NMR relaxometry and on sensory properties of porcine *m. longissimus* were investigated. Determination of sarcomere lengths revealed significant effects of the treatments on the degree of contraction. In addition, an effect of treatment on pH_{24h} was found, as pre-rigor excision was associated with a higher pH_{24h}. NMR measurements revealed that the effect of treatment on water distribution was dependent on which part of the muscle that was analysed, consistent with sarcomere length determinations. Sensory analysis revealed that the effects of treatment on water distribution were accompanied by effects on juiciness and tenderness.

Introduction

In order to optimise pork quality, various modifications in the slaughter procedure and/or handling of the carcasses have been attempted. Hanging the carcass in the pelvic *obturator foramen* (pelvic suspension) will prevent some muscles from shortening, and it has been shown that Pelvic suspension of pig carcasses results in an increase sarcomere length and a decrease in Warner-Bratzler shear force values and cooking loss in *m. longissmus dorsi* (Møller & Vestergaard, 1986). The chilling regime applied is another factor in the slaughter procedure that is known to affect pork quality, and minor improvements in water-holding capacity (WHC) has been shown when applying a faster carcass chilling instead of slower chilling (Gigiel et al., 1989). Accordingly, there seems to be two different strategies in the optimisation of pork quality: *i*) stretching of muscles, for example using pelvic suspension; this procedure is associated with longer sarcomere length, prevents toughening of the meat and may improve WHC, or ii) applying a fast cooling of the carcass. In general a fast cooling procedure improves WHC, but it may cause cold-contraction with resultant toughening of the meat and potentially reduced WHC. The aim of the present study was to study the effects of pelvic suspension and pre-rigor excision on sarcomere length, pH measured 24 h *post mortem* (pH_{24h}), WHC, water distribution measured by low-field proton NMR relaxometry, and sensory properties of pork.

Materials and methods

Two sub-studies were carried out including a total of 16 pigs. For further details on the experimental design, animals, the slaughter procedure and carcass characteristics, see Bertram & Aaslyng (2007). Three treatment groups were included in the study: pre-rigor excision, pelvic suspension and controls. The pre-rigor excision treatment was carried out by cutting out the right *m. longissimus dorsi* immediately after splitting (approx. 20 min *post mortem*) and placing the muscle at 4°C. Pelvic suspension was carried out after splitting of the carcasses (approx. 20 min *post mortem*), where carcass halves were suspended from the obturator foramen of the *os coxae*, and a 10 kg weight was hung from the foot. For the control treatment *m. longissmus dorsi* remained on the carcasses, which were suspended conventionally from the Achilles tendon.

Water-holding capacity (WHC) was determined 24 h *post mortem* as drip loss assessments using Honikel's bag method, and pH was measured 24 h *post mortem*. Sarcomere lengths were determined in the anterior and posterior as well as in the middle of the loin. Sensory analysis was carried out using a trained sensory panel consisting of 8-9 assessors. The loins were cooked in an oven at 190°C until a core temperature of 65°C. Sensory attributes were assessed on a 15-cm non-structured linescale anchored at the extremes (0=slight and 15=intense). Proton NMR T_2 relaxation measurements were performed on a Maran Benchtop Pulsed NMR Analyzer (Resonance Instruments, Witney, UK) operating at 23.2 MHz and equipped with an 18 mm variable temperature probe. Samples (approx. 4 cm along the fiber direction and 1x1 cm in cross-sectional area) were cut, and NMR measurements were carried out both on fresh and cooked samples. The obtained T_2 relaxation decays were analysed using distributed exponential fitting analysis.

Results and discussion

The study revealed a strong significant effect of pelvic suspension and pre-rigor excision on the sarcomere length in *m. longissimus dorsi* (Table 1). For pelvic suspension an interaction between position on muscle was observed, as the effect of pelvic suspension on sarcomere length was most pronounced in the posterior end.

Table 1. Sarcomere length, pH_{24h} and drip loss determined in *m. longissimus* for the different treatments. LS Mean values are given. Standard errors are given in parentheses

	Pre-rigor excision	Pelvic suspension	Control	P-value
Sub-study 1				
Sarcomere length A*	1.68 μm (0.06)[a]	2.17 μm (0.06)[b]	1.83 μm (0.04)[a]	<0.0001***
Sarcomere length M*	1.63 μm (0.06)[a]	2.39 μm (0.06)[b]	1.80 μm (0.04)[a]	<0.0001***
Sarcomere length P*	1.36 μm (0.06)[a]	2.55 μm (0.06)[c]	1.78 μm (0.04)[b]	<0.0001***
pH_{24h}	5.63 (0.05)[a]	5.57 (0.05) [a]	5.54 (0.03) [a]	0.33
Drip loss	3.6 % (0.6) [a]	4.8 % (0.6) [a]	4.3 % (0.4) [a]	0.30
Sub-study 2				
Sarcomere length A*	1.63 μm (0.05)[a]	1.92 μm (0.05)[b]	1.82 μm (0.05)[b]	<0.0001***
Sarcomere length M*	1.53 μm (0.05)[a]	1.83 μm (0.05)[b]	1.83 μm (0.05)[b]	<0.0001***
Sarcomere length P*	1.63 μm (0.05)[a]	2.38 μm (0.05)[c]	1.79 μm (0.05)[b]	<0.0001***
pH_{24h}	5.78 (0.04)[a]	5.56 (0.04)[b]	5.54 (0.03)[b]	0.002**
Drip loss	4.9 % (0.7) [a]	5.0 % (0.7) [a]	4.9 % (0.5) [a]	0.97

*A=anterior position, M=middle position, and P=posterior position. Letters a-c indicate significant differences (P<0.05) within rows.

Treatment was found to affect pH_{24h}, and in sub-study 2 pH_{24h} was significantly higher in pre-rigor-excised muscles compared with control and pelvic-suspended muscles (Table 1). No significant effects of treatment on drip loss were found, however, a tendency for a lower drip loss in pre-rigor-excised muscles was observed. Water distribution measured in the anterior and posterior end of fresh *m. longissimus* by proton NMR relaxometry showed a more pronounced effect of treatment in the posterior end, where pelvic suspension was characterised by a longer relaxation time of the major myofibrillar water population (Figure 1). It has been established in previous studies that an increase in pH causes a shift in the major T_2 water population towards longer relaxation times (Bertram et al., 2004), while a decrease in sarcomere length will move the major T_2 water population towards shorter relaxation times (Bertram et al., 2002). Accordingly, we have to have two opposing effects on the myofilament lattice spacing and thereby localisation and mobility of myofibrillar water. Apparently, the effects almost equal each other out in the anterior end of the muscle, as the water distribution is very similar in the samples independent of treatment. In contrast, in the posterior end, where a larger effect of pelvic suspension on sarcomere length was obtained, the effect of sarcomere length seems to dominate, causing a shift of the myofibrillar water populations towards longer relaxation times. This was also depicted in the sensory analysis, which revealed that in the anterior end, the higher pH associated with pre-rigor excision resulted in a tendency for more juicy meat, while no differences in juiciness between the different treatments were observed in the posterior end (Table 2). In addition, the sensory analysis revealed that in the posterior end of the loin, pelvic-suspended meat was more tender than control and pre-rigor excised meat, while no pronounced differences between treatments were observed in the anterior end of the muscle (Table 2).

Table 2. Juiciness and tenderness determined in the anterior and posterior end of *m. longissimus dorsi* by sensory analysis. Standard errors are given in parentheses

	Pre-rigor excision	Pelvic suspension	Control	P-value
Juiciness A*	6.6 (0.5) [a]	5.5 (0.5) [a]	5.5 (0.4) [a]	0.18
Juiciness P*	5.5 (0.6) [a]	5.1 (0.6) [a]	4.9 (0.5) [a]	0.78
Tenderness A*	8.2 (0.6)[a]	6.9 (0.6) [a]	8.2 (0.5) [a]	0.20
Tenderness P*	6.2 (0.6)[a]	8.5 (0.6)[b]	7.5 (0.5)[ab]	0.05*

*A=anterior position, and P=posterior position. Letters a-c indicate significant differences (P<0.05) within rows.

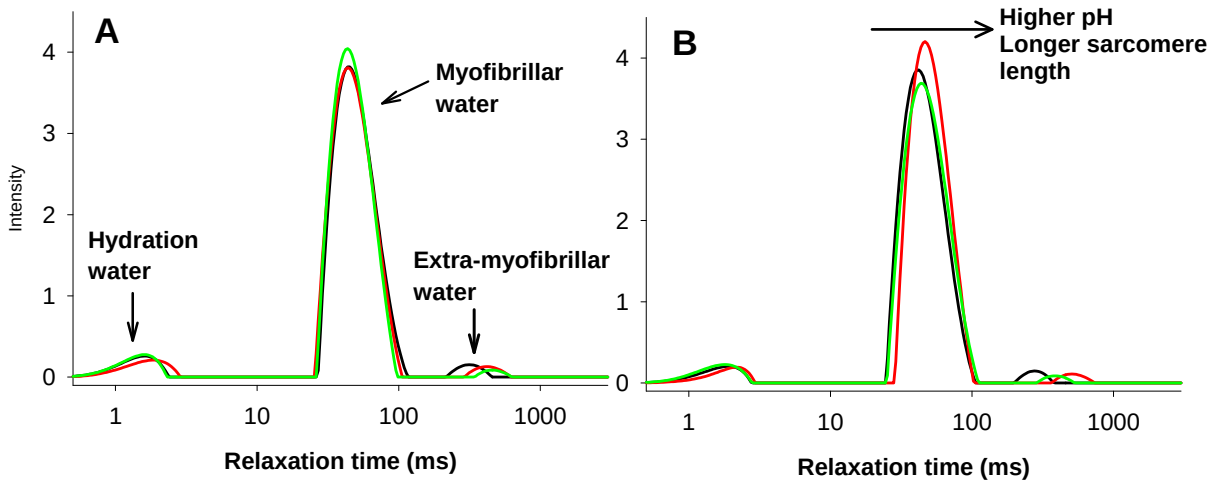

Figure 1. Water distribution measured in anterior (A) and posterior (B) end of fresh *m. longissimus* by proton NMR T_2 relaxometry. Black line: Pre-rigor excision, red line: pelvic suspension, and green line: control. Three water populations are detected and assignment is shown in (A), while the arrow in (B) shows the effect of increasing either pH or sarcomere length on the position of the myofibrillar water population on the relaxation time scale.

Conclusions

In conclusion, the study demonstrates that both pH_{24h} and sarcomere length affects water distribution, juiciness and tenderness, and it seems that under the present conditions, pH_{24h} is more important for juiciness than the sarcomere length.

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