Thermal stability of connective tissue and meat quality of loose structured porcine *semimembranosus* muscles

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Loose structure and PSE like zones on the lateral surface of porcine *semimembranosus* muscle have been observed by other researchers. However the role of connective tissue in this abnormally loose structure in *semimembranosus* muscle has not yet been clarified. We collected about 100g samples from 7 loose structured and 7 normal structured Irish commercial porcine *semimembranosus* muscles in order to compare the onset and peak of thermal transition temperature of intramuscular connective tissue between the samples from the two groups. Meat quality parameters, ultimate pH, rough estimate for drip loss, lightness (L), redness (a) yellowness (b) and as well as electrical conductivity and reflectance were also measured on the samples. Four of the samples characterized as normal by visual assessment showed DFD characteristic so the statistical analysis was carried out both including and excluding those samples. In both cases the onset ($p<0.001$; 56.94ºC vs. 59.82ºC) and peak ($p<0.001$; 62.59ºC vs. 64.06ºC) of thermal transition temperature were significantly lower in loose structured meat than in normal structured meat. Also reflectance% was lower ($p<0.01$; 45.18% vs. 69.17%) and the colour lighter (higher L value; $p<0.01$; 55.05 vs. 45.52) and more yellow (higher b value; $p<0.001$; 18.27 vs. 14.78) in loose structured meat than in normal structured meat when the DFD like samples were excluded. These results indicate that loose structure in porcine *semimembranosus* muscle could be attributed in part to connective tissue properties possibly in conjunction with PSE effects.

Key Words: Connective tissue, porcine *semimembranosus*, meat quality, differential scanning calorimetry

Introduction

The main roles of connective tissue in muscle are to ensure the passive elastic response of muscle transform the force from muscle fibres into mechanical movement and to mechanically support the vessels and nerves. Collagen is the main protein of all connective tissues and type I collagen is the most abundant one in intramuscular connective tissue (Bailey & Light 1989, Kjær 2004). Researchers have found that collagen solubility decreases with animal age and varies between muscles and animal species (Hill, 1966; Kovanen et al. 1980; Nakano & Thompson 1980). This is due to the maturation of collagen cross-links in muscles. Also different proportions of collagen types have an effect on thermal stability of collagen (Bailey & Light 1989). Thermal stability of collagen has originally been measured to obtain information on the relationship between collagen solubility and meat tenderness (Goll et al. 1963; Carmichael & Lawrie 1967).

Zones of PSE (pale, soft, exudative) like meat, which are accompanied by loose fibre structure have been observed on the lateral surface of porcine *semimembranosus* muscle (Minvielle et al. 2001; Franck et al. 2002; Franck et al. 2003; Laville et al. 2005). Risk factors for these zones, seem to include high carcass weight and low ultimate pH in *semimembranosus* muscle (Minvielle et al. 2001). There are also studies showing that PSE zones appear in higher percentage of hams from pigs carrying *n* allele at HAL locus (Aubry et al. 2000) and RN^- allele at the RN locus (Le Roy et al. 2001). Higher collagen solubility, glycolytic potential, free glucose, glucose-6-phosphate and lactate have been observed in defective muscles compared to normal muscles (Minvielle et al. 2001).

This loose structured meat is also characterised by the ease at which bundles can be pulled away by hand (personal observations on Finnish and Irish samples). It is possible that these abnormalities can be attributed in part to connective tissue properties. Therefore it would be of interest to study these properties and any subsequent influence on quality attributes.

The objective of this study was to compare thermal stability of connective tissue from normal and loose structured *semimembranosus* muscle and to measure general meat quality parameters of the two groups of meat.

Methodology

Porcine *semimembranosus* muscles were visually assessed at 24hr postmortem in the boning hall of commercial abattoirs in Ireland following standard slaughter, chilling and boning procedures. Approximately 100g of sample was taken from muscles showing 'loose structure' (n=7) and 'normal structure' (n=7) (photo 1).

On return to The National Food Centre, reflectance [Opto-star (SFK technology, Denmark)], conductivity [Pork Quality Meter (PQM) (Inteck GmbH, Industriestrabe 9, D-86551 Aichach, Germany)] and colour [Miniscan XE Plus (Hunter Associates Laboratory Inc., Virginia, USA)] measurements were recorded on all samples. A rough estimate of drip loss was obtained by holding the samples (approx. 100g) at +1ºC for three days (modification of method of Honikel 1998). pH was recorded after drip loss assessment [meter model no: 420A (Orion Research Inc., Boston, MA 02129, USA); Amagruss pH electrode (pH/mV Sensors Ltd., Murrisk-Westport, Co. Mayo, Ireland)]. Meat was blended with Robot coupe blender (R301 Ultra, Robot coupe SA, France) in order to blend the drip back into meat before pH measurements. Results for individual meat samples for reflectance, conductivity and colour were an average of four readings across each sample surface.

Connective tissue was extracted from myofibril proteins according to King (1987) and Aktas & Kaya (2001) with few modifications. Thermal properties of connective tissue were determined in Differential Scanning Calorimeter DSC2010 with refrigerating cooling system (RCS) (TA Instruments, AGB Scientific, Dublin, Ireland). The samples were heated +10 - +95^{o}C with the rate 5^{o}C/min in the DSC which was calibrated with mercury (mp –38.8^{o}C, ΔHm 11.4Jg-1) distilled water (mp –0.0^{o}C, ΔHm 334.5Jg-1), gallium (mp 29.8^{o}C, ΔHm 80Jg-1 and indium (mp 156.6^{o}C, ΔHm 28.45Jg-1). Both the onset temperature and the peak of thermal transition temperature of connective tissue were recorded from the thermogram. Statistical analysis was carried out using SPSS12 (SPSS 12.0.1 for Windows).

Results & Discussion

Following analysis of the data it was noted that a number of the ‘normal structure’ muscles were exhibiting DFD like characteristics. Therefore statistical analyses were conducted including and excluding these data. Table 1 shows the results obtained with the DFD like muscles removed. No significant differences were noted in ultimate pH (pH$_u$), conductivity, Hunter a value and drip loss values. Colour in loose structured meat was lighter (L), more yellow (b) and had higher Reflectance% than in ‘normal structured’ meat. This was anticipated as ‘loose structured’ muscle was visibly paler.

The onset and peak of thermal transition temperature of connective tissue (in Table 1.) measured with DSC were lower ($p<0.001$) in loose structured meat than in normal structured meat. Although the number of samples was very small the results were statistically significant. It was interesting to note that when the full set of data was analysed (n=7 for both groups) similar results were obtained (results not presented). As the selection of samples was based on visual structure this is not so surprising. Franck et al. (2002) concluded that the defective *semimembranosus* muscles show PSE characteristics, low pH at 30-45 post mortem with high temperature and lower pH$_u$ than normal looking meat. It was not feasible in this experiment to obtain early *post mortem* pH data therefore we do not have direct evidence of fast pH fall which could have related the loose structure to PSE defect. Although, Horgan et al. (1991) already found that decreasing the pH of connective tissue decreases the thermal transition temperature. They also noted that in addition to pH thermal transition temperature of connective tissue is dependent on the composition of the cross-links of collagen. Even though the conditions of Horgan et al. (1991) study were not corresponding to raw meat, this could indicate that lower pH$_u$ in loose structured muscles had some effect on connective tissue by lowering the thermal transition temperature. Also findings of Aktas & Kaya (2001) support the theory that low pH$_u$ lowers thermal transition temperature. After marinating connective tissue in lactic acid they recorded thermal transition temperatures around 39^{o}C which was 23-25^{o}C lower than that of control group but again, the conditions were not corresponding to raw meat.

Table 1. Mean values and standard deviations of meat quality and DSC traits of loose and normal structured pork *semimembranosus* muscles.

	Loose (n=7)	Normal (n=3)	P
pH (day 3)	5.63 ± 0.128	5.79 ± 0.038	
L (day 3)	55.05 ± 3.311	45.52 ± 2.794	**
a (day 3)	10.88 ± 1.948	8.98 ± 1.529	
b (day 3)	18.27 ± 1.074	14.78 ± 0.528	***
Conductivity (day 1), mS/cm	14.07 ± 0.588	11.52 ± 4.003	
Reflectance (day 1), %	45.18 ± 8.013	69.17 ± 6.526	**
Rough estimate for drip loss, %	3.5 ± 2.03	2.0 ± 1.06	
DSC onset, ^{o}C	56.94 ± 0.784	59.82 ± 0.766	***
DSC peak, ^{o}C	62.59 ± 0,396	64.06 ± 0,397	***

*** $p<0.001$ ** $p<0.01$

Photo 1. Examples of ‘normal structure’ (RHS) and ‘loose structure’ (LHS) *semimembranosus* muscle.

Conclusions

Thermal properties of connective tissue were compared in ‘loose structure’ and ‘normal structure’ porcine *semimembranosus* muscles. A significantly lower thermal transition temperature of intramuscular connective tissue was observed in the ‘loose structure’ muscle. It would be interesting to further clarify the role of connective tissue in weakening of the structure in *semimembranosus* muscles and the interaction with meat quality characteristics.

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