POST MORTEM GLYCOGENOLYSIS AND PIGMEAT QUALITY

MAURIZIO SEVERINI,
GIAMPAOLO CENCI and ANTONIO VIZZANI

Istituto di Ispezione degli Alimenti di Origine Animale, Via S. Costanzo, I 06100 Perugia, Italia

INTRODUCTION

Rapid glycogenolysis and glycolysis in muscle post mortem causes an early pH fall to very low values. This process being associated with lactic acid accumulation and increased ATP-turnover strongly affects meat quality and induces PSE condition (Bendall and Wismer-Pedersen, 1962; Briskey, 1964; Honikel and Kim, 1985). Muscle is paler than normal and shows a low water holding capacity (WHC) and high drip loss, probably due to protein denaturation. Swelling induced by NaCl solutions at a low concentration is also affected and PSE muscles at 24hr post mortem absorb more solution than normal (Severini et al., 1987). However, a wide range of intermediate patterns can be detected between normal and PSE conditions and among normal muscles as concerns velocity of glycogenolysis and meat quality (Severini et al., 1984; Monin et al., 1987). This study was aimed at evaluating the influence the glycogen store at slaughter time and the glycogenolytic rate have on the hydration and swelling ability of pig muscles post mortem.

MATERIALS AND METHODS

Samples of Longissimus dorsi muscle taken at the level of the last ribs from 35 crossbred pigs (Landrace x Large white), weighing 120-140kg and conventionally slaughtered at a commercial abattoir were used for this study. The pH, water holding capacity (WHC), lactic acid content, percentage of PAS-positive fibres, L* value were evaluated at 1hr post mortem. Moreover, five slices of about 25g, 1cm thick and with about the same surface area were cut across the muscle. Subsequently, one of them was freely immersed in a 6% NaCl solution (1:4, meat:solution weight) and four were laid on metal nets, put inside covered plastic boxes and stored at 4°C for the following treatments and measurements. At 8hr p.m., pH, WHC and weight loss were determined and a slice was immersed in the 6% NaCl solution. At 24hr p.m., pH, WHC, weight loss, lactic acid content, percentage of PAS-positive fibres and L* value were determined and a slice was immersed in the salt solution.

The pH was measured by a radiometer pH-meter using 10g of muscle homogenized in 50ml of 5mM neutral iodacetate solution. The WHC was determined according to the filter-paper absorption method and the value was espressed as meat film area/fluid area. Lactic acid content was evaluated in the extract (Methods of Enzymatic Food Analysis - Boehringer Mannheim, 1983) using the Automatic Clinical Analyser II (Du Pont Instruments U.S.A.). The percentage of PAS-positive fibres was evaluated on sections cut from samples frozen at -20°C, fixed in Gendre solution and stained with periodic acid Schiff's (PAS). Swelling ability was espressed as percentage of the weight of fresh muscle at 1hr p.m. and was calculated by adding the percentage of weight loss before brining to the percentage of weight gain after immersion in 6% NaCl solution at 4°C for 48hr. Therefore, the value indicates the percentage in weight of salt solution absorbed. L* value was measured (values L* a* b* CIE, 1976) with a Minolta Chroma Meter II Reflectance

colorimeter (Santoro, 1987).

RESULTS AND DISCUSSION

The muscles were classified into six groups according to the characteristics shown in Table 1.

Muscles in group 1 showed high pH, high WHC, high percentage of PAS-positive fibres, small amount of lactic acid, low L* value and good swelling ability at 1hr post mortem. The pH value, WHC and swelling ability decreased slowly and gradually during the following hours and the lowest values were recorded at 24hr. At this stage the lactic acid content and the L* value were quite high, but the value of weight loss was low. These muscles can be regarded as normal (Briskey, 1964), even though the ultimate pH was very low, similar to that found in Hampshire pigs (Monin et al., 1987). They had a large store of glycogen and a slow glycogenolytic-glycolytic rate. At 24hr almost all fibres were depleted of glycogen, the L* value was high and muscles appeared slightly pale, but not exudative.

Muscles in group 2 showed very similar characteristics at 1hr to those in group 1, except for a lower percentage of PAS-positive fibres and a slightly higher swelling ability. The ultimate pH value was reached at 8hr, it was similar to group 1 and remained around 5.70 up to 24hr. The final lactic acid content was lower and the swelling ability at 24hr was higher than group 1. Therefore, it may be assumed that these muscles had a glycogenolysis as slow as group 1, but a smaller amount of stored glycogen.

Muscles in group 3 were quite similar to those in group 2 at all stages, but they showed a slightly lower pH value and a lower percentage of PAS-positive fibres at 1hr, a higher ultimate pH value and lower lactic acid content at 24hr. This indicates that

Table 1. Mean ± SD of pH value, WHC, lactic acid content (mmol/kg), L* value, PAS-positive fibres (%), swelling (%), weight loss (%) in pig Longissimus dorsi muscles at various stages post mortem.

group number	1	2	3	4	5	6
number of samples	3	6	4	8	6	8
1 hour post mortem						
pH range	> 6.20	> 6.20	> 6.20	6.00-6.19	5.80-5.99	< 5.80
mean pH	6.46 ±0.06	6.33 ±0.15	6.24 ±0.07	6.09 ±0.05	5.90 ±0.06	5.61 ±0.08
WHC	5.01 ±0.63	3.17 ±0.93	2.48 ±0.44	3.26 ±1.07	3.18 ±2.26	0.79 ±0.21
lactic acid	52.7 ±1.15	54.7 ±9.2	57.5 ±5.0	73.0 ±5.7	61.7 ±9.8	88.0 ±8.7
L*	42.1 ±2.8	43.1 ±2.2	43.7 ±2.3	44.2 ±3.5	44.8 ±2.2	51.0 ±2.1
fibres pos.	87 ±10	60 ±11	23 ±8	52 ±20	15 ±13	2 ±2
swelling	26.7 ±2.9	31.2 ±2.7	24.3 ±4.1	20.1 ±1.3	21.7 ±2.4	24.6 ±4.4
8 hours post mortem						
mean pH	5.66 ±0.14	5.69 ±0.03	5.85 ±0.07	5.58 ±0.08	5.61 ±0.08	5.56 ±0.07
WHC	1.32 ±0.26	1.00 ±0.49	1.05 ±0.20	1.11 ±0.34	0.83 ±0.16	0.64 ±0.26
weight loss	1.06 ±0.25	1.01 ±0.31	1.14 ±0.19	1.10 ±0.27	0.96 ±0.20	1.36 ±0.34
swelling	25.1 ±2.8	27.7 ±1.6	26.0 ±4.0	20.3 ±3.4	19.9 ±3.1	25.2 ±2.8
24 hours post mortem						
mean pH	5.48 ±0.06	5.72 ±0.03	5.84 ±0.08	5.56 ±0.10	5.59 ±0.10	5.61 ±0.08
WHC	0.99 ±0.11	0.92 ±0.23	1.30 ±0.93	1.08 ±0.20	1.07 ±0.20	0.68 ±0.22
lactic acid	100.0 ±2.0	87.7 ±4.3	73.0 ±2.6	101.2 ±5.1	95.7 ±6.7	100.2 ±8.4
L*	54.1 ±2.8	50.4 ±0.15	50.8 ±0.9	53.0 ±3.4	54.3 ±2.7	56.4 ±1.6
weight loss	1.09 ±0.26	1.37 ±0.39	1.35 ±0.15	1.45 ±0.15	1.35 ±0.31	2.98 ±1.18
swelling	20.8 ±2.5	29.2 ±4.7	22.9 ±2.3	18.5 ±3.3	19.2 ±2.7	24.6 ±2.5

they had an even smaller amount of glycogen at slaughter time and a slightly faster glycogenolysis. The balance between these factors might have played an important role in affecting the swelling ability which was slightly lower than groups 1 and 2 at 1hr and much lower than group 2 and slightly higher than group 1 at 24hr. Muscles in both groups 2 and 3 showed the same L* value at 24hr which was the lowest found for all groups.

The hypothesis that a slightly faster glycogenolysis may reduce the swelling ability of muscles seems to arise from the data for groups 4 and 5. The high content of lactic acid at 24hr indicates that these muscles had a large amount of stored glycogen and the relatively high value of lactic acid content at 1hr together with the low pH-1 and the low number of PAS-positive fibres shows that they had a slightly faster glycogenolytic-glycolytic rate. The swelling ability of the muscles was already low at 1hr and was similar to group 1 at 24hr. At this stage they also had the same L* value and the same weight loss. Only one muscle showed PAS-positive fibres at 24hr, albeit a low percentage. A rapid decrease in phosphagen compounds due to a higher ATP-turnover (Schwägele and Honikel, 1988) might explain the early reduction of the swelling ability in these muscles with pH between 6.19 and 5.80 at 1hr post mortem.

However, the characteristics of the muscles in group 6 indicate that a very rapid glycogenolysis associated with a large amount of glycogen at slaughter time leads to the PSE condition. The pH value is lower than 5.80, the lactic acid content is very high and very few or no fibres with glycogen are present already at 1hr p.m. in these muscles. This causes very low WHC and a high weight loss due to drip loss, but also high swelling ability, in comparison with muscles showing the same glycogen store. The trend is significant even when taking into account the percentage of weight gain (i.e. without calculating weight loss before immersion in salt solution) as shown in Table 2. The swelling was slightly higher in those muscles in group 6 which showed lower lactic acid content at 24hr and therefore a lower glycogen store at slaughter time. Denaturation of sarcoplasmic and myofibrillar proteins as well as membrane damages causing low WHC and high drip loss (Honikel and Kim, 1985; Honikel and Kim, 1986; Offer et al., 1988) may be considered in explaining the high swelling in PSE muscles.

Table 2. Swelling espressed as percentage of salt solution absorbed (a) and as weight gain (b). Mean value ± SD.

	1hr p.m.		8hr p.m.		24hr p.m.	
	a	b	a	b	a	b
group 1	26.7 ±2.9	26.7 ±2.9	25.1 ±2.8	24.1 ±3.1	20.8 ±2.5	19.8 ±2.6
group 2	31.2 ±2.7	31.2 ±2.7	27.7 ±1.6	26.5 ±1.7	29.2 ±4.7	28.0 ±4.7
group 3	24.3 ±4.1	24.3 ±4.1	26.0 ±4.0	24.8 ±4.0	22.9 ±2.3	21.5 ±2.3
group 4	20.1 ±1.3	20.1 ±1.3	20.3 ±3.4	18.7 ±2.3	18.5 ±3.3	17.0 ±3.1
group 5	21.7 ±2.4	21.7 ±2.4	19.9 ±3.1	19.0 ±3.3	19.2 ±2.7	18.0 ±2.7
group 6	24.6 ±4.4	24.6 ±4.4	25.2 ±2.8	23.9 ±2.8	24.6 ±2.5	22.1 ±2.8

CONCLUSIONS

Pig muscles post mortem present differences in the rate and extent of glycogenolysis and glycolysis. Our results show that this greatly affects the hydration and swelling ability of muscle from the first to the 24th hour after slaughter.

Muscles with a large amount of glycogen at the time of death and slow glycogenolytic rate show a gradual decrease in water holding capacity (WHC) and swelling ability. Slightly faster glycogenolysis causes a pH fall to values ranging from 6.19 to 5.80 and a reduction of swelling ability even at 1hr, without greatly affecting WHC.

When the glycogenolysis is very rapid pH falls to values below 5.80, nearly all fibres are depleted of glycogen, the lactic acid content is high and the swelling ability is increased. These muscles are PSE (pale, soft, exudative) and their characteristics do not change very much up to 24hr post mortem, except for the high drip loss.

In muscles with a smaller store of glycogen than normal and slow glycogenolysis, the ultimate pH presents a higher value and the swelling ability is high from the first to the 24th hour.

Moreover, the amount of glycogen at slaughter time and the glycogenolytic-glycolytic rate seem to balance each other and determine intermediate degrees of muscle hydration and of swelling induced by low salt solution.

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