Modelling the time-course of *post mortem* pH changes in pig *Longissimus dorsi* muscle

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Background

Skeletal muscle cells are highly adapted to carry out mechanical work by releasing chemical energy. The most readily available energy is stored in the form of ATP and creatine phosphate. Other energy sources available are glycogen and triglycerides. In the muscle cell glycogen is metabolized to pyruvate, which during aerobic conditions, is entering the mitochondria and the Krebs cycle, and a large number of ATP molecules are produced. At slaughter, the blood flow ceases and with it the oxygen supply to the muscle also ceases and oxidative phosphorylation cannot continue. Under these anaerobic conditions, glycolysis *per se* is responsible for maintaining the ATP concentration in the muscle cell, and the pyruvate so produced from the glycogen is metabolized to lactate, which is accumulated in the muscle cell, as the circulatory system has ceased to function. The pH therefore decreases, from that in the living normal muscle cell of about 7.1, to about 5.4 to 5.7, depending on the level of muscle glycogen.

It has been shown by Briskey (1964) that both the rate and range of *post mortem* pH decline is of great importance for meat quality attributes, such as the colour and the water-holding capacity. The rate of glycolysis post mortem depends on several factors such as the temperature, muscle fibre type composition, hormonal secretion, the intensity of the nervous stimuli reaching the muscle before and during slaughter, and the presence of major genes. If a rapid pH decline occurs when the muscle temperature is still high, the muscle becomes pale, soft and exudative (PSE) due to denaturation of muscle proteins. If the glycogen supplies are exhausted at slaughter, the range of post mortem pH decline will be short and there is inadequate formation of lactate. This meat, which has a high ultimate pH, is called dark, firm and dry, or DFD (Warris et al., 1989). For identifying PSE-meat, the rate of pH changes is often measured early *post mortem* at 45 or 60 min post mortem, and for identifying DFD-meat, the range of the pH decrease is evaluated by measuring the ultimate pH at 24 h post mortem (Scheper, 1971; Hofmann, 1988).

Objectives

The aim of this study was to estimate polynomial parameters describing the time-course of pH and temperature changes *post mortem* in porcine *Longissimus dorsi* muscle. The relationships between these parameters and technological meat quality was investigated.

Methods

Animals and treatments. In this experiment 79 slaughter pigs from 20 litters were used (Henckel, unpublished). The pigs were crossbreeds, between purebred Danish Duroc sires and Danish Large White X Danish Landrace dams. The Halothane gene was not present in this animal material. All pigs used were reared at the experimental farm at Foulum and were given a standard diet at an *ad libitum* level. From each litter, 4 female were selected (split-litter design). Each of these pigs was used in one of 4 models: (A) control with no treatment, (B) exercise on a tread mill at a rate of 3.8 km/h for 10 min immediately prior to stunning, (C) 0.2 mg epinephrine/kg live weight 15 h pre slaughter, and (D) 0.3 mg adrenaline/kg live weight 15 h pre slaughter and exercise on a tread mill at a rate of 3.8 m/sec at 5 min immediately prior to stunning. Models A and B were given saline as a placebo treatment at the same time as models C and D were administered epinephrine.

Slaughter. The pigs were transported from the stable to the experimental slaughter plant (200m), and were stunned by 80 percent CO_2 for 3 min. Thereafter the pigs were exsanguinated, scalded at 62°C for 3 minutes, cleaned and eviscerated within 30 minutes. After 60 min, the carcasses were stored at 4°C in a chilling room.

pH measurements. In the *Longissimus dorsi* muscle (LD; at the last rib) duplicate pH measurements were performed with a pH-meter (Metrohm Model 704, Switzerland) equipped with a insertion glass electrode (Hamilton Tiptrode P/N: 238'080,Switzerland) at fixed time intervals *post mortem*: 1min, 15min, 30min, 45min, 1h, 3h, and 24h.

Meat quality. Water-holding capacity was measured at 24 h p.m. according to the method of Rasmussen and Andersson (1996), on samples that were 25mm thick and 25mm in diameter taken from the loin muscle at the last rib and placed in a container equipped with a lid. The containers were stored at 4°C for 24 h before measurement. Meat colour was analysed as lightness (L-value), redness (a-value), and yellowness (b-value) using the Minolta system.

Statistical methods. All statistical analyses were performed by using the SAS package. For each pig, quadratic polynomials parameters for both the time-course of pH were estimated (intercept, β_1 and β_2) by using linear models. Differences between the four models for the estimated curve parameters were tested by using a model including the pig model as a fixed factor (A, B, C, D) and litter as a random factor. Slaughter weight was included when significant.

Results and discussion

Differences between the models for the parameters describing the time-course of the pH fall *post mortem* were found (Tab. 1 and 2), where the intercept was lowest for the stressed pigs (B) and highest for the pigs with the highest glycogen depletion (D). The time-course of the *post mortem* pH fall for the models was calculated by using these parameters (see Fig. 1). This showed that the stressed pigs (B) had the lowest pH-values during the first 3 h *post mortem* compared to the other models. The parameters were also used to calculate the rate of pH fall *post mortem* by differentiating the polynom (pH') (see Fig. 2). Differences between the models during the first 2 h *post mortem* were found. At time 0, the stressed (B) and control (A) pigs both had the highest initials pH rates (pH/min), and the glycogen depleted models (C and D) had the lower rates. After 3 h *post mortem* no differences between the models were found. Significant relationships between the parameters describing the pH fall, and technological meat quality were found (Tab. 3). In the B pigs drip loss was correlated to the β_1 and β_2 (Fig. 3), and redness (a-value) was correlated to β_1. The A pigs showed the same relationships as the B pigs, but the correlations were not significant. This may be explained by the fact the variations for the traits were higher in the B pigs compared to the A pigs (Tab. 2). In the D pigs ultimate pH (pH_u) was correlated to β_1 and β_2 and the same, but not significant tendencies, were found for the C pigs.

These results show possibilities to use parameters estimated from a quadratic polynomial describing the pH fall *post mortem* in pig loin muscle for predicting technological ultimate meat quality in pork.

Conclusions

The results of this study show that parameters estimated from a quadratic polynomial describing the pH fall *post mortem* in pig loin muscle, are related to ultimate meat quality.

Literature references

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Table 1. Estimation of curve parameters for pH within the 3 first hours *post mortem*

Parameter	Model A (n=20)	B (n=19)	C (n=20)	D (n=20
β_0, Intercept	6.85[ac]	6.72[b]	6.83[a]	6.91[c]
β_1	-11.3×10^{-3a}	-10.9×10^{-3a}	-7.0×10^{-3b}	-8.7×10^{-3b}
β_2	3.7×10^{-5}	3.4×10^{-5}	2.5×10^{-5}	3.1×10^{-5}

Table 2. Standard deviation of curve parameters for pH within the 3 first hours *post mortem* and drip loss

Parameter	Model A (n=20)	B (n=19)	C (n=20)	D (n=20
β_0, Intercept	0.19	0.22	0.13	0.17
β_1	4.6×10^{-3}	5.9×10^{-3}	5.1×10^{-3}	5.0×10^{-3}
β_2	2.5×10^{-5}	2.7×10^{-5}	2.5×10^{-5}	2.3×10^{-5}
Drip loss	0.92	1.60	0.30	0.27

Table 3. Correlations between the curve parameters and ultimate meat quality

Model	Relationship		Correlation
A, n=20	drip loss	– β_0	-0.09
		– β_1	-0.35
		– β_2	0.39
B, n=19	drip loss	– β_0	-0.32
		– β_1	-0.54*
		– β_2	0.56*
	Redness	– β_1	-0.57*
C, n=20	pH_u	– β_1	0.23
		– β_2	-0.05
D, n=20	pH_u	– β_1	0.44*
		– β_2	-0.37+