Growth rate, muscle physiology, carcass traits and meat quality
in pigs - A collage of studies on pigs at the University of Helsinki

Abstract
Department of Food Technology/ Meat Technology Section, University of Helsinki, Finland, has focused on interactions between pig (and poultry) physiology and meat quality. The special emphasis in muscle physiology has been put on the effects of growth rate, fibre type distribution, fibre sizes in relation to oxidative capacity, especially carbohydrate metabolism. Also the strength of connective tissue and bones has been studied. In collaboration with Veterinary Physiology, University of Helsinki, the activity of monocarboxylate transporters has also been studied.

Key Words: growth rate, carbohydrate metabolism, muscle fibre types, connective tissue, meat quality

Average muscle fibre cross sectional area and meat quality traits
Porcine *M. longissimus dorsi* contains about 80 per cent of glycolytic type IIB fibres calculated based on the fibre number and about 90 per cent calculated based on the fibre area (OKSBJERG et al., 1995; RUUSUNEN et al., 1996). Therefore, the size of these fibres has a great effect on the average muscle fibre cross sectional area in this muscle. When a muscle grows, the diameter of type IIB fibres increases faster than that of type I. At the slaughter weight, the size of type IIB fibres are twice as large as the size of type I and type IIA fibres (BADER, 1983).

In a study of RUUSUNEN & PUOLANNE (2005) it was investigated, how much the average muscle fibre cross sectional area ranges in pork loins at the live weight of 95-100 kg. The study consisted of 27 Finnish Landrace and 28 Yorkshire pigs slaughtered at the live weight of 95-100 kg. Average muscle fibre cross sectional area in *M. longissimus dorsi* was measured with image analyzer from sections stained with myosin ATPase method. Pork loin cross sectional area was measured one day after slaughter.

In the study it was found that gilts had a larger loin area (p<0.05) and a larger average muscle fibre cross sectional area (p<0.05) than the barrows. KARLSSON et al. (1994) and RUUSUNEN et al. (1996) have also shown that both the muscle fibre cross sectional area and the loin area are larger in gilts than in barrows. The differences in
the loin area and in the average fibre cross sectional area between the breeds were not significant (p>0.05). According to CHRYSTALL et al. (1969), the growth of muscle fibres in *M. longissimus dorsi* is most rapid early in life declining later to a near stationary level. One reason for this is that the fat starts to accumulate in the carcass at that stage. Carcass fat content affects muscle fibre size so that in fat carcasses the average muscle fibre cross sectional area is smaller than in lean carcasses (SEIDEMAN et al., 1989). Therefore, it is important to take both the live weight of the pig and carcass lean fat/content into account when comparing muscle fibre cross sectional area between the pigs. The feeding influences carcass fat content. According to RUUSUNEN et al. (2005a) the pigs with a low-lysine/low-protein supply had a lower carcass lean meat content (p<0.01), but higher carcass fat content (p<0.01) resulting in a smaller average cross sectional area of muscle fibres in light muscles compared to pigs with high-lysine/high-protein supply (p<0.05).

Muscle fibres are oxidative at the early stages of growth due to the dense capillarization and the small cross sectional area of muscle fibres, but when the fibres grow, they become more anaerobic. Thus, selection based on small fibre cross sectional area could result in pigs with more oxidative muscle.

A high number of muscle fibres with small fibre cross sectional area per loin area permits more growth potential to the muscle without a decrease of the oxidativity (ASHMORE & VIGNERON, 1988). It is, however, not yet known which muscle fibre cross sectional area at a certain live weight leads to (i) a fast growth, (ii) oxidative muscles, (iii) pigs whose carcasses contain a lot of lean meat and (iv) also meat with good technological and sensory quality.

RUUSUNEN et al. (2005b) have also found that the light muscles of the pigs with a low-lysine/low-protein supply contain a higher glycogen content resulting in lower pH value measured 45 minutes post mortem from *M. longissimus dorsi* (p<0.05) than those of the pigs with high-lysine/high-protein supply (p<0.05).

**Conclusions:** The muscle fibre cross sectional area can vary considerably in pork loin with the same cross sectional area at the live weight of 95-100 kg regardless of breed or sex. A low lysine/low-protein supply in the diet increases glycogen content and glycolytic potential in porcine light muscles and decreases the pH value measured 45 minutes post mortem from *M. longissimus dorsi*.

**Monocarboxylate transporters**

Professor Reeta Pösö and MSc Katri Sepponen, Department of Veterinary Physiology, have studied in a collaboration study with us the monocarboxylate transporters (MCT) in porcine muscles (PÖSÖ & PUOLANNE, 2005). MCTs cotransport lactate anions and protons across the cell membranes and thus regulate the muscle pH. They measured MCT1, MCT2 and MCT4 isoforms both in oxidative and highly glycolytic muscles. They found that porcine muscles contain MCT2, which has not been reported before. The results together with measured concentrations of lactate suggest that MCT2 may function as housekeeping lactate and proton transporter, preventing acidification especially in highly glycolytic muscles in which the capacity of oxidizing lactate is low. The results also support the view that, as in other species, MCT4 would
be important at high lactate + proton concentrations that occur in stress (SEPPONEN et al., 2003).

The activity of glycogen debranching enzyme in meat animals
The degradation of glycogen is achieved by cooperation of two enzymes: glycogen phosphorylase (PHOS) and glycogen debranching enzyme (GDE) (BROWN & ILLINGWORTH-BROWN, 1966). The GDE breaks down the branching points of glycogen (so-called limit dextrin state), enabling the further action of PHOS on the linear chains of glycogen (BROWN & ILLINGWORTH-BROWN, 1966; NELSON et al., 1969).

The effect of pH value and temperature on the activity of GDE was studied in porcine M. longissimus dorsi and in M. masseter (KYLÄ-PUHJU et al., 2005). In both muscles, the pH had only a weak effect on the activity at the pH values found in carcasses post-slaughter. However, the activity of GDE decreased strongly (p<0.001) when the temperature decreased from values of 39°C and 42°C found just after slaughter to values of 4°C and 15°C found during cooling. The activity of GDE began to fall at temperatures below 39°C and was almost zero when the temperature decreased to below 15°C. Thus, the activity of GDE may control the rate of glycogenolysis during cooling, but does not block rapid glycolysis and pH decrease when the temperature is high, which may be important in formation of PSE meat.

In pig and cattle, the activity of GDE and the activity of PHOS were higher in the fast-twitch glycolytic muscles (M. longissimus dorsi, M. semimembranosus) than in the slow-twitch oxidative muscles (M. masseter, M. infraspinatus) (YLÄ-AJOS et al., accepted). Also in chicken the activity of PHOS was very high in fast-twitch glycolytic M. pectoralis superficialis and low in slow-twitch oxidative M. quadriceps femoris muscle, but in contrast the activity of GDE was lower in the former (YLÄ-AJOS et al., submitted). The activity of GDE was high in porcine muscles, intermediate in bovine muscles and low in chicken muscles, the differences being most significant between the fast-twitch muscles of the animals concerned.

The glycogen content is higher in fast-twitch than in slow-twitch muscles (KARLSSON et al., 1999; MONIN et al., 1987; YLÄ-AJOS et al., accepted; YLÄ-AJOS et al., submitted). Furthermore, the high activity of PHOS in fast-twitch muscles indicates high glycolytic activity. Even though the activities of both GDE and PHOS increased with the fast twitch and glycolytic character of a muscle of a given animal, the increase in the activity of PHOS was more pronounced. Thus, the ratio between the two glycogen degrading enzymes PHOS/GDE was higher in the fast twitch muscles than in the SO muscles and the GDE may restrict the rate of glycolysis in these muscles. The proportionally low activity of GDE in relation to the activity of PHOS in fast twitch muscles may be a protective mechanism against a sudden pH decrease. In strenuous physical stress, a high PHOS/GDE ratio in FG muscles enables a short burst of glycolysis, which leads to a rapid increase in H⁺ content. The high buffering capacity of FG muscles (DAVEY, 1960; KYLÄ-PUHJU et al., 2004; PUOLANNE & KIVIKARI, 2000; RAO & GAULT, 1989; TALMANT et al., 1986) protects these muscles against a sudden pH decrease, but the proportionally low activity of GDE compared to the activity of PHOS may be needed to further restrain glycogenolysis.
Connective tissue in normal and loose structured porcine meat

The main roles of connective tissue in muscle are to ensure the passive elastic response of muscle transform the force from muscle fibers into mechanical movement and to mechanically support the vessels and nerves (KJAER, 2004). In meat science research on the thermal stability of connective tissue has been a tool for efforts to understand mechanisms of meat tenderization (GOLL et al., 1963; CARMICHAEL & LAWRIE, 1967). Animal age and muscle type affect thermal stability of collagen (KING, 1987). Defects in the structure (zones of PSE-like meat, loose structure) on the lateral side of porcine M. semimembranosus have been observed in few countries. 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). These observations on loose structure meat raised a question: Does connective tissue have a role in weakening of the meat structure?

This study was conducted in collaboration with The National Food Centre (Teagasc), Ireland (VOUTILA et al. 2005). We collected 7 loose structured and 7 normal structured porcine M. semimembranosus samples (about 100g each) in the boning halls of two commercial Irish abattoirs. Selection was made by visual assessment (overall a very low percentage of loose structured meat was observed). To obtain information on meat quality we analysed rough estimate for drip loss, pHu, colour, conductivity and reflectance. Connective tissue analysis consisted of onset and peak of thermal transition of connective tissue and total and soluble collagen. DFD (pHu>5.9) was observed in the group of normal structured meat so the statistical analyses were performed by including and excluding the DFD samples.

In both cases (including and excluding the DFD samples) the onset (p<0.001; 56.94°C vs. 59.82°C) and peak (p<0.001; 62.59°C vs. 64.06°C) of thermal transition temperature were significantly lower in loose structured meat than in normal structured meat. No difference between the two groups was observed in total and soluble collagen when the DFD like samples were excluded. There was a tendency for normal structured meat to have more soluble collagen than loose structured meat (0.10<p<0.05; 10.5% vs. 9.4%) when the DFD like samples were included in the statistical analysis. 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. The colour results are in agreement with those of MINVIELLE et al. (1999). 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.

Conclusion: These results suggest that loose structure in pork semimembranosus muscle could be attributed in part to connective tissue properties possibly in conjunction with PSE effects.

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