MUSCLE STRUCTURE AND TEXTURE AS INFLUENCED BY PHYSICAL EXERCISE OF PIGS

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SUMMARY

Adaptations in muscular structural proteins induced by physical training may affect meat quality. Therefore, distribution of muscle fibre types, collagen content and its heat stability, mechanical strength, and tenderness were determined in *M. longissimus dorsi* (LD) and *M. biceps femoris* (BF) from pigs submitted to different types of physical activity during their growing/finishing periods.

The 48 animals were allocated to one of three rearing conditions (treatments): "confined" (C), "exercised" (E), or "free" (F). Treatment C consisted of individual housing in pens of 1.5 m², E consisted of individual housing and submission to regular treadmill exercise, and F consisted of group housing in pens of 36 m² (each pen contained 8 experimental and 32 other pigs). All the pigs were slaughtered at 100 kg.

In treatment E, the ratio of fast twitch oxidative/glycolytic (FTa) to fast twitch glycolytic (FTb) fibres was significantly increased in BF from male pigs compared to their analogues in treatment C. The content of collagen and its heat stability was significantly increased in BF from female pigs in treatment E compared to C. In contrast, there was no significant effect of either treatment E or F on the collagen content and its heat stability in male pigs. Exercise tended to decrease the bite force measured in BF from both sexes (E compared with C). No significant difference was found in tenderness among treatments.

Thus, depending on muscle and sex, physical exercise changed the distribution of the three muscle fibre types and the content of collagen and its heat stability as well.

Introduction

In the current discussion of animal welfare and product quality, questions regarding the relation between muscle function, muscle physiology, and meat quality arise. Numerous studies where pigs, sheep, cattle, horses, rats, and mice were submitted to different physical training regimens or rearing conditions have been conducted to answer some of these questions.

For example, Hawrysh et al. (1974) trained pigs on a treadmill and found no effects in tenderness (assessed by a sensory panel) or shear force in LD. Enfält et al. (1993) enforced pigs to run 500 m per day and found no effect in shear force in either LD or BF. On the other hand, Essén-Gustavsson et al. (1988) have shown that treadmill training of pigs increased the tenderness in LD and BF, and in treadmill trained sheep, Aalhus et al. (1991) revealed a decrease in the shear force value in *M. vastus lateralis* (VL) and *M. semimembranosus* (SM). Moreover, an increase in the oxidative capacity of muscles induced by physical training was demonstrated in several animal species (e.g. Jørgensen and Hyldegaard-Jensen, 1975; Snow, 1984; Kovanen and Suominen, 1987) and in treadmill trained pigs Essén-Gustavsson (1990) reported an increase in the ratio of FTa to FTb fibres in *M. gluteus*.

The content of intramuscular connective tissue plays an important role on meat quality. However, the effect of physical activity on intramuscular collagen has been the target of only a few studies of meat quality. In one of these, Berge et al. (1989) showed that the collagen content and its heat stability were increased in LD from "intensively" compared to "extensively" reared pigs. Aalhus et al. (1991) found a decreased collagen content in VL but not in SM in which the heat stability of collagen was increased due to physical training. Hawrysh et al. (1974) did not detect any effect of training in the collagen content of LD.

Thus, depending on species and muscle type, adaptations occur in structural proteins of muscles involved in the physical activity. The effect of these adaptations on meat texture is not clear. Therefore, the objective of this study was to compare the effect of different types of physical exercise on structural proteins, mechanical strength, and tenderness in two skeletal muscles (LD and BF) contrasting in myofibre composition in pigs.

Material and methods

A total of 48 pigs (crossbreds of Danish Landrace, Large White, and Duroc) were included in the experiment covering the growth period from 30 to 100 kg. The animals originated from 8 litters each consisting of three entire male and three female pigs, and were fed standard growing/finishing diets *ad libitum*.

Within litter and sex the pigs were allocated at random to one of the following three rearing conditions (treatments): "confined" (C), "exercised" (E), or "free" (F). Treatment C consisted of individual housing in pens of 1.5 m^2, offering a minimal level of voluntary exercise. Treatment E consisted of individual housing in pens similar to those used in C and submission to regular treadmill exercise. Treatment F consisted of group housing in pens of 36 m^2, each pen contained 8 experimental and 32 other pigs. A treadmill running at a speed adjustable from 0-12 km/h was used to exercise the pigs in treatment E for five consecutive days per week during their growth from 30 to 100 kg. The exercise period increased progressively from 10 min at the beginning to 20 min at the end of the experiment. The average walking/running distance during the whole experimental period was 1.0 km per day at 4.0 km/h.

Immediately after slaughter, muscle samples (200 mg) were taken for histochemical identification of muscle fibre types of LD at the level of the last rib curvature and of BF at the center of the muscle. The samples were mounted in an embedding medium, frozen in isopentane, kept in liquid nitogen, and stored at -80°C until analysis. After resting for three hours at 15°C, the carcasses were chilled at 2°C overnight. The day after slaughter, the left side of the carcass was dissected into meat, fat, bone, and skin, and samples were taken from LD and BF for determination of total content of collagen and its heat stability, mechanical strength, and tenderness. All the samples were vacuum packed, aged for 6 days at 2°C, and stored at -20°C. Furthermore, samples for analysis of collagen content and its heat stability were freeze dried and then stored in airtight bags at -20°C.

Serial transverse sections (10 µm) of frozen muscle autopsies were cut at -20°C in a cryostat and stained for myofibrillar ATP-ase activity after acid as well as alkaline preincubations (pH = 4.37, 4.6, and 10.3). Thereafter, approximately 200 fibres (1 mm^2 from the stained sections) were classified as either slow-twitch (ST or type I) fibres or fast twitch (FTa and FTb or type IIa and type IIb) fibres (Brooke and Kaiser, 1970), using computerized image analysis (Henckel, 1989).

The freeze dried muscle samples were trimmed off surface tissue, and subsequently powdered. The content of total and heat stable collagen was estimated from the amount of hydroxyproline multiplied by 7.5. To determine the amount of heat stable collagen, the samples were heated during two hours in a 90°C water bath according to the method of Bergman and Loxley (1963) modified by Bonnet and Kopp (1992).

For determination of mechanical strength and tenderness, samples were thawed overnight at 8°C, wrapped in polyethylene bags, immersed into a 72°C water bath for 65 min and finally cooled in running tap water. Bite force was determined in five strips of 10 x 20 x 50 mm dissected from each sample, parallel to the myofibre axis. The strips were compressed 80%, using Volodkewich jaws, installed on a Karl Frank testing machine, and the maximum resistance was registered.

Tenderness was evaluated by nine trained sensory panelists on a scale from 0 to 10 (0 referring to poor and 10 referring to excellent quality) as described by Bejerholm (1984). Initially, samples of LD were cut into pork chops (2 cm) fried for 7 min at 150 - 180°C, resulting in a core temperature of 65°C. Samples of BF were wrapped in polyethylene bags and roasted in an oven at 200°C until the core reached 60°C.

Data were analysed statistically by the least squares analysis of variance method, using the GLM procedure of SAS (SAS, 1989). Since data were obtained in two muscles from each animal, a split-plot model was applied including the fixed effects of treatment, sex, and muscle as well as the random effects of litter and interactions. To test the effect of treatment the interaction between treatment and litter was used as error term, whereas the effect of muscle was tested against the interaction between muscle and litter. Estimated means were obtained using the LSMEANS option in SAS.

Results

Two of the pigs allocated to treatment E refused to run on the treadmill, and were thus redistributed to treatment C. From treatment F one pig died and another was discarded because of growth retardance. Consequently, 46 of the initial 48 pigs accomplished the experiment.

The carcass lean percentage was not significantly affected by either treatment or sex (data not shown). In Table 1 the muscle fibre distribution in LD and BF from animals in treatment C and E is shown. It appears that the ratio of FTa to FTb fibres (number and area) was significantly higher in BF from male pigs in treatment E

compared to C. In BF from female pigs only a tendency was found towards an elevation of the ratio of the number of FTa to FTb fibres. In LD this ratio was not affected significantly by treatment.

Results regarding intramuscular collagen are shown in Table 2. It appears that the total content of collagen was higher in BF than in LD, whereas the percentage of soluble collagen was higher in LD than in BF. Comparison of the effect of treatment shows that in LD from female pigs the percentage of soluble collagen was slightly higher in treatment E than in F. In LD from male pigs treatment did not affect the content of collagen or the percentage of soluble collagen. Concerning BF from female pigs, the total content of collagen was significantly higher in treatment E than in C, also the content of heat stable collagen was higher in treatment E than C. This lead to a significant decrease in the percentage of soluble collagen in treatment E compared to C. In BF from male pigs neither the collagen content nor the percentage of soluble collagen were affected significantly by treatment.

Statistical analysis of resistance to bite force showed no significant differences between the three treatments. However, as shown in Table 2, a tendency was found towards a decrease in the bite force value in BF from pigs in treatment E in comparison to C and F. In tenderness, the effect of treatment was only significant in LD from female pigs in treatment E and F which recieved a score 0.5 point lower than did female pigs in treatment C.

From the significant interactions just mentioned it can be concluded that muscular structural proteins adapt to physical exercise depending on: type of physical exercise, sex, and muscle. These findings will be taken into account in further studies of exercise induced adaptations in muscle physiology and mechanical strength of meat.

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Table 1 Muscle fibre distribution of *M. longissimus dorsi* (LD) and *M. biceps femoris* (BF) in relation to "confined"(C) or "exercised" (E) treatment and sex. Estimated means with standard error of the mean (SEM).

Table 2 Collagen and dry matter (DM) content and texture of *M. longissimus dorsi* (LD) and *M. biceps femoris* (BF) in relation to "confined" (C), "exercised" (E), or "Free" (F) treatment and sex. Estimated means with standard error of the mean (SEM).