SOMATOTROPIN ACTION ON MUSCLE AND BACKFAT CELLULARITY IN RELATION TO BREED AND HALOTHANE SENSIVITY IN PIGS

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SUMMARY

The effects of longterm application of porcine somatotropin (pST) on cellular characteristics of skeletal muscle and backfat were examined in biopsy samples from pigs of different breed and stress-susceptibility. Schwerfurter and Piétrain pigs of positive or negative halothane reaction (H^+; H^-) were treated with a placebo (controls) or with 2 to 4 mg pST/d from about 120 to 190 days of age. Porcine somatotropin exerted minimal effects on muscle structure characteristics in Piétrain pigs. Only the fibre type frequency shifted to the fast twitch glycolytic (FTG) fibres (+ 2.8 % units) at the expense of the fast twitch oxidative (FTO) fibres (- 2.4 % units). On the other hand in Schwerfurter pigs the mean muscle fibre diameter was increased by 12%. In H^+ Schwerfurter pigs pST induced a decline of the fibre nucleus-cytoplasm-ratio (-53%) and a shift to the FTG-fibre proportion (+ 6.1 %units) at the expense of slow twitch oxidative (STO) fibres (- 4.6 %units). No changes in the proportions of abnormal muscle fibres such as giant fibres (carcass samples only), light violet or small dark angulated fibres were observed in response to pST. The major effects on the thickness of backfat and its individual layers as well as on fat cell diameter and number were caused by breed and pST-treatment.The relative differences in fat characteristics of Piétrains *vs.* Schwerfurters and pST-treated pigs *vs.* controls, respectively, were -58%/-48% for backfat thickness, -31%/-19% for fat cell diameter and -36%/-29% for fat cell number. In contrast with the muscle fibre traits both breeds responded to pST to nearly the same extent. PST exerted a higher inhibitory effect on H^- pigs. The results suggest that the pST response of muscle is higher in a breed of lower meat content and is accompanied by a shift to unfavourable characteristics in stress-susceptible animals. Fat growth seems to be more inhibited by pST in stress-resistant pigs.

Introduction

Numerous studies on the effects of administration of exogenous porcine somatotropin to growing-finishing pigs demonstrated tremendous changes in growth performance and body composition. The major mechanism involved is known to be the repartitioning of feed energy from fat to protein accretion. Surprisingly, no impairment of meat quality characteristics in terms of pale, soft, exudative muscle (PSE) has been reported in response to pST (Beermann et al., 1990; Ender and Lieberenz, 1991) despite the known relationship between high meat content and poor meat quality. In addition, either negligable or small changes in the oxidative capacity or in fibre type frequencies of the muscle have been observed (Beermann et al., 1990; Solomon et al., 1990, Oksbjerg, 1992, Rehfeldt and Ender, 1993). In this regard it is not known, whether the pST-response would depend on stress-susceptibility or whether it would be different in breeds known to be stress-susceptible. In this investigation, therefore, muscle and fat characteristics were examined in pigs of different breed and halothane-sensivity.

Materials and methods

38 Schwerfurter castrates and 33 Piétrain castrates and females of positive or negative halothane reaction (H^+; H^-) were treated with a placebo (control) or 2 to 4 mg porcine somatotropin (pST, changing the dose on day 42 of treatment) from about 120 to 190 days of age. The pST (Pitman-Moore, IN, USA) was injected intramuscularly dissolved in arginine buffer (pH 6.4). Biopsy samples were taken from backfat and *longissimus* muscle by the shot biopsy technique (Schöberlein, 1976; Wegner and Ender, 1990) about one week before slaughter near the 13/14th thoracic vertebra. After measurement of the backfat thickness, samples from the two

superficial fat layers and from muscle were cut quickly and frozen in liquid nitrogen. Serial transverse sections (10 _m) from the frozen *longissimus* muscle were stained for NADH-tetrazolium-reductase and acid-stable ATPase (pH 4.2) or by haemalum-eosin. Backfat sections (10 _m) were mounted on slides and without staining embedded in glycerol jelly. The thickness of backfat layers 1 + 2 divided by the mean fat cell diameter was defined as fat cell number index. For giant fibre counting carcass muscle samples were used. Histological and histochemical techniques and microscopy were carried out as described by Wegner and Ender (1990) and Rehfeldt and Ender (1993). The data were subjected to multiple analyses of variance with $P < 0.05$ deemed significant.

Results and discussion

Longissimus muscle characteristics

Loin muscle area enlarged to a similar extent in both breeds (Table 1). The intrinsic differences between Schwerfurter and Piétrain pigs are clearly seen, indentifying the Piétrains again as the leaner genotype as shown in detail for other carcass data by Nürnberg et al. (1994). In Piétrain pigs this increase was mainly observed in castrates but was not reflected in fibre diameter response, which was independent of sex. In contrast the Schwerfurter pigs responded to pST with a 12% increase in fibre diameter. Possibly, the loin area enlargement in Piétrain pigs was due more to enhanced storage of water than to real protein accretion. This idea is supported by higher drip losses in the *longissimus* (Table 2) and almost unchanged (+ 3%) daily protein gain (Ender and Rehfeldt, 1993) in pST-treated Piétrain pigs compared to controls. The results of the fibre diameter response suggest that the genetic capacity for lean tissue growth is fully realised in Piétrains. This is in agreement with former results when pigs with a higher genetic potential for fat deposition showed a higher response to pST in muscle or protein accretion compared with genetically lean pigs (e.g. Kanis et al., 1990; Beermann and DeVol., 1991). No different fibre diameter responses to pST in relation to the halothane-status were observed, and only in Schwerfurter pigs were initial significant differences between H^+ and H^- animals seen as shown earlier for German Landrace pigs (Fiedler et al., 1993).

Nuclear proliferation in muscle, measured as number of nuclei per muscle fibre, remained almost unaffected by pST. In other words, fibre hypertrophy was not accompanied by an intense satellite cell proliferation. Consequently, the nucleus-cytoplasm ratio, measured as nuclear number/mm² muscle fibre area, was clearly diminshed by pST in Schwerfurter pigs (-22%) and remained unchanged in Piétrain pigs. From former experiments it has been concluded, that nuclear proliferation and protein accretion in muscle are stimulated by pST to almost the same extent (Beermann et al., 1990; Rehfeldt and Ender, 1993). This seems not to be true for stress-susceptible H^+ pigs, because in this case a marked decrease in the nucleus-cytoplasm-ratio was seen. Interestingly, H^+ pigs of both breeds showed slightly lower values in this trait compared to H^- pigs ($P < 0.1$ for Piétrains) as also found by Fiedler et al. (1993) for German Landrace pigs. In addition, Piétrain pigs differed from Schwerfurter pigs in having significantly larger muscle fibres and lower nuclear numbers. Thus impaired muscle function in stress-susceptibility seems to be related to unphysiologically enlarged functional DNA-units (Cheek et al., 1971).

Significant halothane status-pST treatment-interactions were also apparent for the effects on fibre type frequencies. On the whole in Schwerfurter pigs no pST- induced differences were observed, but a shift to the FTG-fibre proportion at the expense of STO-fibres ($P < 0.1$) occurred in H^+ pigs indicating changes in metabolic and contractile properties of the muscle. Meat quality was almost unchanged in Schwerfurter pigs, although a slight shift to pale meat was observed as increase of the remission value (Table 2). Piétrain pigs showed a significant increase in FTG-fibres at the expense of FTO-fibres indicating a shift to more glycolytic metabolism. Accordingly, meat quality characteristics such as colour and water holding capacity were adversely affected as shown by increases in remission value and drip loss. Significantly less STO-fibres and more FTG-fibres were found in H^+ compared to H^- pigs in the Schwerfurter breed but not in Piétrain. On the other hand, Piétrains showed less STO-fibres and more FTG-fibres compared to Schwerfurter pigs.

To date changes in fibre type frequencies by pST were only found after prolonged treatment and fattening of pigs (Rehfeldt and Ender, 1993) and no detrimental changes in meat quality were previously observed (Beermann et al., 1990; Ender and Lieberenz, 1991). According to our results, stress-susceptible pigs exhibit a greater propensity to develop unfavourable muscle structure and meat quality characteristics related to PSE in response to longterm pST-treatment. On the other hand, pST exerted no effects on the proportions of giant fibres, of light violet or small dark angulated fibres (Table 3). However, H+ animals developed more giant fibres than H^- pigs, and Piétrain pigs tended to exhibit more giant fibres than Schwerfurter pigs, suggesting that this fibre anomaly is related to stress-susceptibility.

Backfat characteristics

Large initial differences between Schwerfurter and Piétrain pigs in the measured backfat characteristics were apparent and reflected the leaness of the Piétrain breed. The backfat thickness of Piétrains was only half that of Schwerfurter pigs and this was reflected in lower fat cell diameters and visible fat cell numbers. Most of the data given in table 4 are significantly different between the breeds. The adipocyte size of the second fat layer was higher than that of the first fat layer in Schwerfurter pigs (Figure 1) as already previously shown for German Landrace pigs (Rehfeldt et al., 1994). However, in Piétrains the fat cell diameters of the second fat layer were equal or even smaller which confirms results obtained by Rothfuss (1981). Thus, in Piétrain the adipocyte growth seems to be especially slower in the second layer of backfat.

The growth of backfat was considerably inhibited by pST-administration in both breeds (by almost 50%) due to less fat cell formation or slower fat cell growth. This confirms results of former experiments on German Landrace pigs (Rehfeldt et al., 1994). It was seen clearly, that H^- animals of both breeds showed a somewhat higher response compared with H^+ animals. This effect might be attributable to the slightly higher initial values in H^- pigs, although no significant differences in relation to halothane reaction were seen. In addition, the relative pST-response in Piétrain pigs was independent of sex, although altogether higher values were found in castrates. In contrast the higher pST response of H^- pigs has not been found for backfat weight and fat % in the carcass of Piétrain castrates at slaughter (Nürnberg et al. 1994).

Conclusions

The response to porcine somatotropin in muscle structure characteristics of stress-susceptible Schwerfurter pigs with positive halothane reaction differs from the response of stress-resistant pigs. The positive halothane pigs seem to develop unfavourable muscle structure and meat quality characteristics. The same is evident for the lean genotype Piétrain with initial lower meat quality both in halothane-positive and -negative pigs. In addition the results suggest, that fat growth is more inhibited by pST in halothane-negative pigs with higher stress-resistance.

References

Beermann, D.H. and De Vol, D., (1991). Effects of somatotropin, somatotropin releasing factor and somatostatin on growth. In: Growth regulation in farm animals, Advances in Meat Research, vol. 7. Ed.: A.M. Pearson, T.R. Dutson, London, New York, 373-426.

Beermann, D.H.; Fishell, V.K.; Ronecker, K.; Boyd, R.D.; Armbruster, G. and Souza, L., (1990). Dose-response relationships between porcine somatotropin, muscle composition, muscle fiber characteristics and pork quality. J. Anim. Sci., 68:2690-2697.

Cheek, D.B.; Holt, A.B.; Hill, D.E. and Talbert, J.L., (1971). Skeletal muscle mass and growth: The concept of the deoxyribonucleic acid unit. Ped. Res., 5:312-328.

Ender, K. and Lieberenz, M., (1991). Die Wirkung von Somatotropin auf die Schlachtkörperzusammensetzung und Fleischqualität beim Schwein. Fleischwirtsch. 71:1195-1201.

Ender, K. and Rehfeldt, C., (1993).Effects of porcine somatotropin. Meat Focus, 2:501-505.

Fiedler, I.; Ender, K.; Wicke, M. and Lengerken, G.v., (1993). Zusammenhänge zwischen der Mikrostruktur des Muskelgewebes bei Schweinen der Landrasse und ihrer Streßempfindlichkeit (Halothanreaktion). Arch. Tierz., 36: 525-538.

Kanis, E.; Nievwhof, G.J.; De Greef, K.H.; Van der Hel, W.; Verstegen, M.W.A.; Hiusman, J. and Van der Wal, P., (1990). Effect of recombinant porcine somatotropin on growth and carcass quality in growing pigs: interactions with genotype, gender and slaughter weight. J. Anim. Sci. 68, 1193-1200.

Nürnberg, K.; Kuhn, G.; Ender, K. and Nürnberg, G., (1994). Wirkung von porcinem somatotropin (pST) auf die Schlachtkörperqualität und Fettgewebezusammensetzung von genetisch differenten Schweinen. Arch. Tierz. 37, in press.

Oksbjerg, N., (1992). Effects of body weight, ß-adrenergic agonists, and porcine growth hormone on muscle growth and muscle histochemical and metabolic properties in growing pigs. PhD Thesis, The Royal Vet. and Agricult. University, Copenhagen.

Rehfeldt, Ch. and Ender, K., (1993). Skeletal muscle cellularity and histochemistry in response to porcine somatotropin in finishing pigs. Meat Sci. 34: 107-118.

Rehfeldt, C.; Nürnberg, K. and Ender, K., (1994). Effects of exogenous porcine somatotropin on the development of fat cells and fatty acid compositon in backfat of live finishing pigs. Meat Sci. 36: 321-331.

Rothfuss, U., (1981). Lipogene und lipolytische Parameter im Fettgewebe von Large White- und Piétrain-Schweinen in Abhängigkeit vom Mastgewicht, PhD Thesis, Universität Hohenheim.
Schöberlein, L., (1976). Die Schußbiopsie - eine Methode zur Entnahme von Muskelproben. Mh. Vet.med. 31: 457.
Solomon, M.B.; Campbell, R.G. and Steele, N.C., (1990). Effect of sex and exogenous porcine somatotropin on longissimus muscle fiber characteristics of growing pigs. J. Anim. Sci. 68, 1176-1181.
Wegner, J. and Ender, K., (1990). Mikrostrukturelle Grundlagen des Wachstums von Muskel- und Fettgewebe und die Beziehung zu Fleischansatz und Fleischbeschaffenheit. Fleischwirtsch., 70: 337-340.