EFFECT OF SEX AND EXOGENOUS PORCINE SOMATOTROPIN ON LONGISSIMUS MUSCLE FIBER CHARACTERISTICS OF GROWING PIGS

M. B. Solomon, R. G. Campbell and N. C. Steele

U.S. Department of Agriculture, Beltsville, MD 20705

ABSTRACT

Thirty-seven pigs with an initial live weight of 60 kg were used to investigate the effects of daily exogenous porcine somatotropin (pST) administration at two dose levels (0 and 100 µg·kg⁻¹·d⁻¹) for a 31-d period on muscle fiber characteristics and meat tenderness of boars, gilts and barrows. Excipient boars and gilts had more αW and fewer αR fibers than did those receiving pST. The percentage of muscle fiber type for barrows was not affected by pST treatment. The administration of pST resulted in an increase in muscle fiber size for all three fiber types in all three sexes, but these changes were of greater magnitude in barrows (31.8%) and gilts (27.8%) than in boars (9.3%). Somatotropin negated the intrinsic sex effect differences in fiber area of the pigs. There was no difference in tenderness among excipient boars, barrows and gilts; however, with the inclusion of pST, shear force decreased in boars and gilts and increased in barrows. A high proportion of the pST-treated pigs contained giant fibers in the longissimus muscle. Furthermore, a small proportion of the pST-treated pigs exhibited pale, soft, exudative muscle. Whether the giant fiber anomalies occurred through increased muscle activity or from fibers undergoing degenerative changes was not determined.

(Key Words: Pigs, Somatotropin, Sex, Muscle Fibers, Tenderness.)


Introduction

Administration of exogenous porcine somatotropin (pST) to growing pigs remarkably improves performance and alters body composition (Boyd et al., 1986; Etherton et al., 1987; Campbell et al., 1988). Essentially all studies involving pST have utilized castrated males, which have an inherently low capacity for protein deposition and a high rate of fat accretion (Campbell and Taverner, 1985). Information is lacking on the relationship of animal sex and pST administration. Because changes in growth and body composition invoked by pST are mediated via stimulation of muscle protein deposition (Campbell et al., 1988), factors that intrinsically regulate growth and development (e.g., animal sex) may alter a pig's response to pST.

Reviews by Cassens and Cooper (1971) and Ashmore (1974) discussed a relationship between ultimate meat quality and muscle fiber composition. Except for research reported by Beerman et al. (1987) and Solomon et al. (1988), little work has been done to characterize muscle fiber types and meat quality of pigs receiving pST. We (Solomon et al., 1988) demonstrated that pST administration to young barrows resulted in an increase in muscle hypertrophy with no effect on muscle fiber distribution. Sex condition has been demonstrated to alter meat quality (Seideman et al., 1982). Jones et al. (1985) using a beta-adrenergic repartitioning agent (cimaterol) and Solomon et al. (1988) using pST reported decreases in meat tenderness with the administration of these repartitioning agents to pigs. This study was undertaken to investigate the effects of daily pST administration and sex.
condition on muscle fiber characteristics and meat tenderness.

Materials and Methods

Thirty-seven Duroc x Yorkshire pigs were assigned at 60 kg body weight to a 2 x 3 factorial treatment array consisting of pST administration (0 and 100 μg·kg⁻¹·d⁻¹) and sex type (boar, gilt, and barrow). The experimental diet (Campbell et al., 1989) was formulated to contain 3.5 Mcal digestible energy (DE)/kg with a lysine:DE value 25% greater than that required by boars growing from 50 to 90 kg. Pigs had ad libitum access to this diet.

Pigs receiving pST were injected daily (into the extensor neck muscles) with pST (USDA- pGH-B1, obtained from the National Pituitary Agency) that was solubilized in sterile bicarbonate buffer (50 mM pH 9.4). Control pigs were injected daily with a comparable volume of bicarbonate buffer. All pigs were treated for 31 d. Somatotropin administration improved growth rate and feed conversion efficiency (Campbell et al., 1989) for the pigs used in this study.

Each pig was slaughtered on d 32 of the experiment. A sample of the longissimus (LM) muscle (13th rib location) was excised within 1.5 h postmortem and immediately restrained on flat sticks. Muscle samples subsequently were frozen in liquid N₂. Frozen samples were stored at -70°C until histochemical analyses were performed. A 1-cm³ fragment of tissue removed from each frozen sample was mounted on a cryostat chuck with a few drops of water, so that muscle fiber orientation was perpendicular to the cutting blade of the microtome. Mounted samples were allowed to equilibrate to -20°C before coring. A minimum of five cores (1.27 cm in diameter) was removed from these chops, parallel to the muscle-fiber orientation, for shear-force determinations using a Warner-Bratzler shear device mounted on a testing machine. Data were analyzed using the General Linear Model procedure (SAS, 1985). Weight at slaughter was included as a covariate to determine the significance of variation among treatments for a completely randomized 2 x 3 factorial arrangement. Treatment means as displayed are the least square means of the sex x pST subgroup. All animals were within 2 wk of the same age at the onset of the experiment.

Results and Discussion

The distribution and areas of muscle fiber types in the LM as affected by sex and pST treatment are shown in Table 1. Significant pST x sex interaction were found for the percentage of αR and αW fiber types. Boars and gilts receiving pST had more αR and fewer αW fibers than those receiving only bicarbonate buffer. In contrast, administration of pST to barrows had no effect on the percentage distribution of the different fiber types. In our previous study (Solomon et al., 1988), administration of pST at the same dose level to barrows growing from 25 to 55 kg body weight had no effect on fiber type distribution. Ashmore et al. (1972) concluded that αR fibers have the capacity to transform into αW fibers during growth. The differences in the proportion of αR and αW fibers as a
<table>
<thead>
<tr>
<th>Sex</th>
<th>pST dose, µg(kg-d)</th>
<th>No.</th>
<th>Fiber types %</th>
<th>Fiber area μm²</th>
<th>Giant fiber</th>
<th>Shear force</th>
<th>PSE</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>βR</td>
<td>αR</td>
<td>αW</td>
<td>βR</td>
<td>αR</td>
<td>αW</td>
</tr>
<tr>
<td>Boar</td>
<td>0</td>
<td>7</td>
<td>12.5</td>
<td>21.0</td>
<td>66.5</td>
<td>3,311.2</td>
<td>2,784.5</td>
<td>4,543.7</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>6</td>
<td>14.0</td>
<td>24.5</td>
<td>61.5</td>
<td>3,712.7</td>
<td>3,120.9</td>
<td>4,794.9</td>
</tr>
<tr>
<td>Barrow</td>
<td>0</td>
<td>6</td>
<td>12.1</td>
<td>16.0</td>
<td>71.9</td>
<td>2,089.1</td>
<td>2,564.6</td>
<td>4,022.9</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>6</td>
<td>11.7</td>
<td>18.0</td>
<td>70.3</td>
<td>3,121.5</td>
<td>3,032.4</td>
<td>5,285.3</td>
</tr>
<tr>
<td>Gilt</td>
<td>0</td>
<td>6</td>
<td>13.5</td>
<td>16.9</td>
<td>69.6</td>
<td>2,760.5</td>
<td>2,848.3</td>
<td>4,004.1</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>6</td>
<td>13.4</td>
<td>25.6</td>
<td>61.0</td>
<td>3,643.6</td>
<td>3,543.2</td>
<td>5,095.0</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td></td>
<td>2.0</td>
<td>1.9</td>
<td>2.3</td>
<td>226.4</td>
<td>225.1</td>
<td>407.2</td>
</tr>
</tbody>
</table>

Significance of Treatment, P<:

<table>
<thead>
<tr>
<th>Sex</th>
<th>pST</th>
<th>pST × pST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>pST</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>pST × pST</td>
<td>.05</td>
<td>.05</td>
</tr>
</tbody>
</table>

*Classified according to Ashmore and Doerr (1971). Photomicrograph had a × 180 magnification.

*Number of occurrences in an 8.8 × 12.5 cm area with a × 50 magnification. Statistics were not performed due to lack of numbers in excipient pigs.

*Kilograms/1.27 cm core.

*Pale, soft, exudative longissimus muscle.

*NS = not statistically significant.
result of sex and pST treatment conceivably could be associated with differences in the physiological maturation rate of the animals as described by Solomon 1989, with pST-treated boars and gilts having fiber distributions resembling those of less mature animals.

Administration of pST increased fiber area for all three fiber types in all three sexes, but these changes were of greater magnitude in barrows and gilts than in boars. Among excipient pigs, muscle fibers tended to be larger in boars followed by gilts and then barrows, but this difference was virtually eliminated by pST treatment. Average increase in fiber size due to pST was 9.3, 31.8 and 27.8% for boars, barrows and gilts, respectively. In our recent study (Solomon et al., 1988) pST increased the areas of the three fiber types by an average of 23% in the LM. In the present study, the greatest increase in size was observed for βR fibers (28.4%), followed by a 20.7% increase in fiber size for αW fibers and 18.3% for αR fibers. These findings also are in agreement with those by Beerman et al. (1987), who found that pST increased muscle fiber size by 15 to 16% in the semitendinosus muscle of pigs treated with pST. Campbell et al. (1989) found that administration of pST influenced somatic growth and reduced body fat in boars, gilts and barrows and that it eliminated the effects of animal sex on growth performance and body composition.

Large (giant) fibers (Table 1, Figure 1) were present in the LM from all but one boar and one gilt receiving pST. Giant fibers also were present in one excipient boar and in one excipient barrow. These fibers had distinct characteristics and were found both at the periphery and toward the center of a fasciculus. Swelling and rounding of the affected fibers were observed. Not every bundle contained giant fibers and they usually represented less than 1% of the total myofibril population evaluated. All fibers with cross-sectional areas greater than the average area obtained from the measurements of all three fiber types and possessing stain reactions similar to βR and αR fibers were identified as “giant fibers”. These giant fibers were similar to those observed in our earlier study (Solomon et al.,

Figure 1. Cross-section of longissimus muscle, 1.5 h postmortem frozen section and reacted for the combination myofibrillar (acid) ATPase and succinate dehydrogenase staining procedure (x 180). G denotes “giant” fiber.
possessing fiber properties similar to both \( \beta R \) and \( \alpha W \) fibers in combination based on reaction to the staining procedure described by Solomon and Dunn (1988). Whether the giant fiber anomalies occurred through increased activity associated with compensatory (flux) adaptations (Handel and Stickland, 1986) or from fibers undergoing hydropic degenerative changes (Bader, 1987) was not determined. Giant fibers were not included in calculated morphological measurements (i.e., percentages and areas for all three fiber types).

The occurrence of giant muscle fibers has been associated with stress-susceptible pigs, which exhibit pale, soft, exudative (PSE) muscle. Pale, soft, exudative muscle was assessed by visual color appraisal and pH measurements. The pigs that evidenced PSE muscle also displayed giant muscle fibers. In our previous study (Solomon et al., 1988), there was no visual indication of PSE muscle from any of the treatment groups (pST \( \times \) feed intake). Pigs susceptible to stress that ultimately results in PSE muscle generally can be identified by a hyperthermic response to halothane. Halothane sensitivity was not determined on these pigs prior to the initiation of the study and, therefore, it is not known whether pigs treated with pST resulting in PSE muscle were stress sensitive/malignant hyperthermic at the onset. If this were the case, then pST may have exaggerated the stress response; however, there was no definitive evidence based on hormone levels (Campbell et al., 1988) previously found that pST-treated pigs used in the present study were significantly leaner than those of controls (Campbell et al., 1989); thus, cold shortening can be ruled out as a contributor to treatment differences. We have no immediate explanation for higher shear values for barrows and lower ones for boars and gilts receiving pST.

**Literature Cited**


Handel, S. E. and N. C. Stickland. 1986. "Giant" muscle...