Composition and cross-sectional area of muscle fibre types in relation to daily gain and lean and fat content of carcass in Landrace and Yorkshire pigs

Marita Ruusunen
Department of Food Technology, P.O.Box 27, FIN-00014 University of Helsinki, Finland, e-mail: marita.ruusunen@helsinki.fi
Marja-Liisa Sevon-Aimonen
Agricultural Research Centre of Finland, Institute of Animal Production, FIN-31600 Jokioinen, Finland
Eero Puolanne
Department of Food Technology, P.O.Box 27, FIN-00014 University of Helsinki, Finland

The muscle fibre-type properties of longissimus were compared between Landrace and Yorkshire breeds and between the sexes in an attempt to shed light on the relationship of these histochemical parameters to animal growth and carcass composition. Muscle fibres were classified into three groups, type I, type IIA and type IIB, using the myosin ATPase method. At a given live weight, the cross-sectional area of type I fibres (CSA_I) was smaller (p<0.01) and the cross-sectional area of type IIB fibres (CSA_IIB) larger (p<0.01) in longissimus of Landrace than in that of Yorkshire. The CSA_IIB (p<0.01) was larger in gilts than in castrated males. At an average live weight of 97 kg, the Landrace pigs were significantly younger (p<0.01) than the Yorkshire pigs. The pH value of Landrace was lower (p<0.01) than that of Yorkshire. The percentage of high-value cuts in carcass with head (M%) was lower (p<0.01) and the percentage of fat in back and loin (F%) higher (p<0.01) in castrated males than in gilts. The cross-sectional area of loin (CSA_loin) was larger (p<0.01) in gilts than in castrated males. All the histochemical and other traits varied considerably between the animals. The correlations between histochemical properties and growth and histochemical properties and carcass composition were rather low.

Key words: pig breed, muscle fibre cross-sectional area, longissimus, carcass traits

Introduction

The pig breeds or crosses used for pork production tend to vary from country to country. The breeding goals also vary, and hence there may be genetic differences in the same breed between countries. The traditional pig breeds reared in Finland are Landrace and Yorkshire. Both have been bred intensively and separately for many years, although with similar breeding goals. The most important selection criteria in pig breed-
ing have been high daily gain and carcass leanness. Genetic selection is thought to influence muscle fibre composition by increasing the number and area of type II fibres in domestic pigs (Staun 1972, Swatland 1977, Rede et al. 1986). The muscles of wild pigs have a higher percentage of type I and type IIA fibres and a lower percentage of type IIB fibres than do domestic pigs, and also the CSA of muscle fibres is smaller in wild pigs than in domestic pigs at the same live weight (Bader 1983).

Muscle fibre composition affects both growth and lean meat content. Miller et al. (1975) found in longissimus and Dwyer et al. (1993) in semitendinosus that faster growing pigs appeared to possess more, but smaller, fibres than slower growing pigs at the same live weight. Staun (1972) and Miller et al. (1975) established that the total number of muscle fibres in longissimus was more closely related to muscle mass than was fibre diameter. Dwyer et al. (1993) reported similar results in their study on porcine semitendinosus. A positive correlation has also been found between the percentage of type IIB fibres in longissimus and the CSA of pork loin (Bader 1981, Fiedler and Otto 1982, Wegner and Ender 1990, Fewson et al. 1993). Tornberg et al. (1993) pointed out that in lean carcasses, the CSA of muscle fibres is larger than that in fat carcasses of the same weight.

This study sought to compare the histochemical properties of Finnish Landrace and Yorkshire breeds, to establish the differences in these properties between the sexes and also between pigs within the same breeds, and to investigate the relationships between these histochemical properties and animal growth and carcass composition.

### Material and methods

The material consisted of 107 pure-bred pigs, 54 Finnish Landrace and 53 Yorkshire (N=53), raised at four different test stations. The progeny of 39 Landrace and 41 Yorkshire sires were used. The pigs were slaughtered at an average live weight of 97 kg. Before slaughter, the pigs were allowed to rest overnight. They were then stunned with carbon dioxide. The day after slaughter, the left side of the carcass was dissected.

### Histochemical properties

Muscle samples for histochemical analysis were taken from the right side of the carcass about 30–40 min after exsanguination from longissimus between the 13th and 14th ribs. The muscle sample, about 20 g, was cut into pieces measuring 0.5x0.5x1.0 cm, which were frozen in liquid nitrogen and stored at –80 °C until analysed.

The fibres were classified into three groups, type I, type IIA and type IIB, with the myosin ATPase method (Brooke and Kaiser 1970) and an acid preincubation solution (pH 4.6). Stained sections were examined with an image analysis system using CUE 2 Planomorphometry software (Olympus, Germany). The magnification was 160x. The fibres were counted in an area of about 0.9 mm², containing about 150–200 fibres. Three different pieces of each muscle sample were stained, and thus 450–600 fibres were analysed. The following parameters were computed: percentage of type I (% number), type IIA (IIA% number) and type IIB (IIB% number) muscle fibres, percentage of the total area of type I (% area), type IIA (IIA% area) and type IIB (IIB% area) muscle fibres, and the cross-sectional area of each fibre type (μm²) (CSA_I, CSA_{IIA} and CSA_{IIB}).

The number of muscle fibres in longissimus per whole loin area (Num_{ fibre}) was calculated as the loin area (at last rib) (CSA_{ loin}) divided by the average fibre cross-sectional area (CSA_{ fibre}).

### Other traits

The following station test traits were used in the study: age at slaughter (age), live weight at the end of the test (LW), average daily gain during
the test period adjusted to a weight of 25–100 kg (ADG), carcass weight (CW), loin area at 13–14 rib (CSA\textsubscript{loin}), percentage of fat in back and loin (F\%) and percentage of high-value cuts in carcass with head (M\%).

The pH value of \textit{longissimus} was measured between the 13th and 14th ribs at 45 min (pH\textsubscript{1}) and 24 h (pH\textsubscript{2}) post mortem on each carcass (Knick Portamess pH meter 752 equipped with a Xerolyte electrode; Ingold Xerolyt LoT406-M6, Germany).

\section*{Statistical methods}

Data were analysed with the GLM procedure and the CORR procedure of the SAS/STAT program (SAS Institute 1990). The effects of breed and sex were studied using the following statistical model:

\begin{align*}
y_{ijk} &= u + \text{breed}_i + \text{sex}_j + e_{ijk} \\
y_{ijk} &= \text{observation} \\
u &= \text{overall mean} \\
\text{breed}_i &= \text{effect of breed } (i=1,2) \\
\text{sex}_j &= \text{effect of sex } (j=1,2) \\
e_{ijk} &= \text{residual term}
\end{align*}

The relationship between histochemical properties and animal growth and between histochemical properties and carcass composition was described with correlation coefficients. The effect of breed and sex was taken into account.

\section*{Results and discussion}

\textbf{Difference in histochemical properties between breeds and sexes}

The muscle fibre composition of different breed has been compared in only a few studies. Here, \textit{longissimus} of Landrace contained a significantly higher percentage of type I fibres and a lower percentage of type IIB fibres (p<0.01) than did that of Yorkshire (Table 1). The percentages of muscle fibre types of animals within both breeds varied, however, more than did those between the breeds on average. On the basis of histochemical properties, similar pigs can be found in both breeds. Miller and coworkers (1975) did not find any differences in fibre type composition in \textit{longissimus} between Hampshire, Yorkshire and Hampshire x Yorkshire pigs, and Essen-Gustavsson and Fjelkner-Modig (1985) found none between Swedish Landrace, Yorkshire and Hampshire pigs. Here, no significant difference (p>0.05) was found in fibre type composition between the sexes (Table 1).

At the same live weight, however, the CSA\textsubscript{i} was smaller (p<0.01) in \textit{longissimus} of Landrace than in that of Yorkshire, but the CSA\textsubscript{m} was larger (p<0.01) (Table 1). In Danish Landrace-Yorkshire crossbred pigs the CSAs of type I and type IIB fibres were 2824 and 6120 \(\mu\text{m}^2\), respectively at a live weight of 90 kg (Oksbjerg et al. 1990), and in Swedish Landrace-Swedish Yorkshire crossbred pigs 3200 and 5600 \(\mu\text{m}^2\), respectively at a live weight of 100 kg (Essen-Gustavsson et al. 1992). The CSAs of different fibre types reported in various studies are difficult to compare because the muscle samples were excised from the carcasses at different times post mortem, and the CSA measurements were made on sections stained with different methods.

In this study, no significant difference was found in the estimated \textit{Num\textsubscript{m}fib} between Landrace and Yorkshire or between sexes. The CSA\textsubscript{m} (5051 \(\mu\text{m}^2\)) (p<0.01) and the CSA\textsubscript{fib} (4476 \(\mu\text{m}^2\)) (p<0.05) were larger in gilts than in castrated males (4593 and 4153 \(\mu\text{m}^2\), respectively). Karlsson et al. (1994) also showed that the CSA of all fibre types was significantly smaller in \textit{longissimus} of intact Yorkshire male pigs than in gilts at a live weight of 103 kg.

\textbf{Difference in growth and carcass traits between breeds and sexes}

When pigs grow, the CSA of all fibre types grows as well, but the area of type IIA and type IIB is
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Table 1. The means and standard deviations of studied traits (mean ± s.d.) of Landrace and Yorkshire breeds and of castrated males and gilts.

|               | Breed     | Sex        | Statistical significance |
|---------------|-----------|------------|--------------------------|
|               | Landrace  | Yorkshire  | Castrates                | Gilts       | Breed     | Sex        |
| Number of animals | 54        | 53         | 49                       | 58          |           |            |
| **Histochetocal traits** |           |            |                          |             |           |            |
| I%_number     | 13.2 ± 3.7| 9.9 ± 3.8  | 11.2 ± 3.1               | 11.8 ± 4.8  | **        | NS         |
| IIA%_number   | 9.0 ± 3.8 | 8.6 ± 3.1  | 8.7 ± 3.3                | 8.9 ± 3.7   | NS        | NS         |
| IIB%_number   | 77.9 ± 3.9| 81.6 ± 3.8 | 80.1 ± 4.0               | 79.3 ± 4.5  | **        | NS         |
| I%_area       | 6.9 ± 2.1 | 6.4 ± 2.4  | 6.6 ± 2.0                | 6.7 ± 2.5   | NS        | NS         |
| IIA%_area     | 4.9 ± 2.3 | 5.3 ± 2.0  | 5.0 ± 2.2                | 5.2 ± 2.2   | NS        | NS         |
| IIB%_area     | 88.2 ± 2.4| 88.3 ± 2.6 | 88.4 ± 2.8               | 88.1 ± 2.2  | NS        | NS         |
| CSA_i, 1000 μm² | 2.4 ± 0.5  | 2.7 ± 0.6  | 2.4 ± 0.5                | 2.6 ± 0.6   | **        | NS         |
| CSA_IIA, 1000 μm² | 2.4 ± 0.6   | 2.6 ± 0.5  | 2.4 ± 0.5                | 2.5 ± 0.5   | NS        | NS         |
| CSA_IA, 1000 μm² | 5.1 ± 0.9   | 4.6 ± 0.8  | 4.6 ± 0.7                | 5.1 ± 1.0   | **        | **         |
| CSA_fibre, 1000 μm² | 4.5 ± 0.8   | 4.2 ± 0.6  | 4.2 ± 0.6                | 4.5 ± 0.8   | **        | *          |
| Num_fibre, 10² | 0.97 ± 0.16| 1.01 ± 0.18| 0.99 ± 0.15              | 1.00 ± 0.19 | NS        | NS         |
| **Other traits** |           |            |                          |             |           |            |
| Age, d        | 149 ± 8   | 155 ± 8    | 149 ± 7                  | 154 ± 8     | **        | **         |
| LW, kg        | 97.3 ± 5.0| 97.1 ± 3.8 | 97.7 ± 4.4               | 96.7 ± 4.7  | NS        | NS         |
| ADG, g        | 937 ± 62  | 929 ± 66.1 | 960 ± 60.7               | 910 ± 67.8  | NS        | **         |
| CW, kg        | 71.3 ± 4.1| 71.7 ± 3.2 | 71.4 ± 3.4               | 71.4 ± 4.0  | NS        | NS         |
| pHᵢ           | 6.28 ± 0.24| 6.41 ± 0.23| 6.36 ± 0.24              | 6.34 ± 0.25 | **        | NS         |
| pH₄           | 5.50 ± 0.09| 5.51 ± 0.13| 5.51 ± 0.13              | 5.50 ± 0.10 | NS        | NS         |
| CSA_loin (cm²) | 42.4 ± 4.5| 41.5 ± 4.0 | 40.3 ± 3.3               | 43.4 ± 4.5  | **        | **         |
| M%, %         | 57.0 ± 2.7| 56.6 ± 2.2 | 55.7 ± 1.9               | 57.7 ± 2.5  | NS        | **         |
| F%, %         | 20.0 ± 3.2| 20.0 ± 3.0 | 21.4 ± 2.6               | 18.9 ± 3.1  | NS        | **         |

NS = not significant, p>0.05; * = significant, p<0.05; ** = significant, p<0.01

CSA_fibre = cross-sectional area of fibre
Num_fibre = CSA_loin / CSA_fibre
ADG = average daily gain (g) during test period adjusted to weight of 25–100 kg
CSA_loin = cross-sectional area of loin
M% = percentage of high value cuts in carcass with head
F% = percentage of fat in back and loin

affected the most. In this study, a positive correlation was found between CSA_IA and age (p<0.05) but not between CSA_i or CSA_IIA and age. The CSA of type IIB fibres could therefore be expected to increase more than the CSA of type I or type IIA fibres (Table 2). Fiedler et al. (1991) likewise found that the area of type IIB fibres increases more during growth than does the area of type I and type IIA fibres.

The average age, live weight, daily gain, carcass weight, pHᵢ and pH₄ values, CSA of loin and M% and F% of the pigs studied in both breeds and sexes are given in Table 1. The Landrace pigs were significantly younger (p<0.01) when they reached the average live weight of 97 kg than were the Yorkshire pigs, although there was no significant difference in ADG between the breeds during the test period. The castrated males grew faster (p<0.01) than the gilts. The live weight was the same in both sexes, but M% was lower (p<0.01) and F% higher (p<0.01) in castrated males than in gilts (Table 1). Also, the CSA_loin was larger (p<0.01) in gilts than in castrated males. Similarly, in their study of German
Table 2. Correlation coefficients between histochemical parameters and growth and between histochemical and carcass parameters.

| Age L | LW  | ADG | CW  | pH₁ | pH₂ | CSA_loin | F%  | M%  |
|-------|-----|-----|-----|-----|-----|----------|-----|-----|
| I% number | .041 | .200 | .046 | .187 | .087 | .135     | .134 | .055 | -.079 |
| IIA% number | -.085 | -.178 | -.020 | -.209 | .059 | .052     | -.034 | -.138 | .128 |
| IIB% number | .035 | -.035 | -.061 | .005 | -.133 | -.183   | -.099 | .073 | -.042 |
| I% area | .025 | .159 | .052 | .157 | .122 | .060     | .020 | .074 | -.125 |
| IIA% area | -.052 | -.071 | .038 | -.113 | .065 | .070     | .015 | -.164 | .161 |
| IIB% area | .020 | -.096 | -.076 | -.052 | -.185 | -.116   | -.029 | .073 | -.028 |
| CSA₁ | .141 | .028 | .090 | .103 | .038 | -.070    | -.071 | .088 | -.178 |
| CSA₁IA | .173 | .331 | .175 | .341 | -.004 | .072    | .160 | .019 | -.019 |
| CSA₁IB | .222 | .148 | .045 | .202 | .046 | .060    | .114 | .060 | -.143 |
| CSA fibre | .235 | .160 | .062 | .223 | .023 | .038    | .092 | -.090 | -.169 |
| Num fibre | -.103 | .008 | -.005 | .046 | -.012 | .001    | .493 | -.305 | .391 |

* = significant, p<0.05; *** = significant, p<0.001

CSA₁₀₀₀ = cross-sectional area of fibre
Num fibre = CSA₁₀₀₀/CSA fibre
ADG = average daily gain (g) during test period adjusted to weight of 25-100 kg
CSA₁₀₀₀ = cross-sectional area of loin
M% = percentage of high value cuts in carcass with head
F% = percentage of fat in back and loin

Landrace Nürnberg and Ender (1990) found that carcass meat content was lower, fat content higher and the cross-sectional area of loin smaller in castrated males than in gilts at the same live weight.

The pH₁ value of Landrace was lower (p<0.01) than that of Yorkshire pigs (Table 1.) On the basis of pH₁ values (<5.8), there were only two PSE carcasses among the pigs studied, one in each breed. This is a very low number (1.3%), due possibly to the fact that the pigs were always allowed to rest overnight before slaughter. The pH₁ value found here was lower and the CSA₁IB larger in Landrace than in Yorkshire pigs.

A large fibre CSA may result in limited diffusion of muscle lactate into blood in stress situations. Lactate can thus rapidly accumulate in the muscle and give rise to low pH values. In porcine longissimus, glycogen is normally stored in type IIB fibres (Swatland 1975, Karlsson et al. 1994). If the content of type IIB fibres is high and that of type I fibres in longissimus low, there is also a high glycogen content, and thus more lactate may be formed. In dark porcine muscles with a high content of type I fibres it is impossible for the ultimate pH value to go as low as in light muscles because of the lower glycogen stores in dark muscles. Neither in this study nor
in the work of Nürnberg and Ender (1990) were any significant differences found in pH₁ or pH₂ values between the sexes.

The relation of histochemical properties to growth and carcass parameters

The correlation coefficients for growth and carcass traits and for the histochemical parameters measured for porcine *longissimus* are listed in Table 2. The finding of Sosnicki (1987) that a negative correlation exists between the percentage of BR fibres and age was not confirmed here (p>0.05). Nor was our study able to confirm the finding of Miller et al. (1975) that faster growing pigs appeared to possess more, but smaller, fibres in *longissimus* than did slower growing pigs at the same live weight. We did, however, find a positive correlation between I%<sub>number</sub> and LW (p<0.05) and between CSA<sub>IIB</sub> and LW (p<0.001), and between CSA<sub>IIB</sub> and CW (p<0.001) and between CSA<sub>IIB</sub> and CW (p<0.05). We also found a negative correlation between HIA%<sub>number</sub> (p<0.05) and CW. The positive correlation between live weight and ADG (r=.414, p<.001) makes it difficult to come to any definite conclusion regarding the relationship between histochemical parameters and growth rate. Some researchers have found a positive correlation between the percentage of type IIB fibres in *longissimus* and the CSA of pork loin (Bader 1981, Fiedler and Otto 1982, Wegner and Ender 1990, Fewson et al. 1993), but we could not confirm this finding (p>0.05). Our findings were, however, consistent with those of Staun (1972) and Miller et al. (1975), namely that a positive correlation exists between the Num<sub>fibre</sub> and CSA<sub>loin</sub> and between the Num<sub>fibre</sub> and M%. A negative correlation was found between Num<sub>fibre</sub> and F%.

Conclusions

Comparisons of all histochemical traits reveal significant variance between animals. Landrace *longissimus* shows a lower number of type IIB fibres with a larger fibre CSA than does Yorkshire *longissimus*. The CSA of type IIB fibres is larger in gilts than in castrates. There are differences in growth and carcass parameters between the sexes. The large variation in histochemical and other traits between animals suggests that it should be possible to select animals with the desired characteristics for breeding. Further investigations are needed to establish the criteria for good meat quality parameters and the heritability of these properties.

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Tutkimuksessa verrattiin maatiais- ja yorkshire-sika-rotuja keskenään määrittämällä histokemiallisesti *longissimus*-lihaksen lihassolutyyppien ominaisuuksia. Lisäksi selvitettiin histokemiallisten ominaisuuksien suhdetta eläimen kasvuun ja ruohon laatun. Käsiteltyäkinä muuttujina olivat ikä, päiväkasvu, elopaino, teuraspaino, pH1- ja pH2-arvot, ulkofileen poikkipinta-ala sekä ruohon liha- ja rasvaprosentit. Lihassolut määritettiin histokemiallisesti myosin ATPasimenetelmällä ja luokiteltiin kolmeen ryhmään: I, IIA ja IIB. Lihassolujen lukumäärä laskettiin jakamalla fileen poikkipinta-ala keskimääräisellä lihassolun poikkipinta-alalla. Maatiaisen *longissimus*-lihaksessa oli tyypin I lihassolujen poikkipinta-ala pienempi ja tyypin IIB lihassolujen poikkipinta-ala suurempi kuin yorkshiren *longissimus*-lihaksessa. Leikkojen *longissimus*-lihaksissa tyypin IIB lihassolut olivat suurempia kuin imisten *longissimus*-lihaksessa. Rotu ja sukupuoli eivät vaikuttaneet ulkofileen lihassolujen määriin. Maatiaisessa pH1-arvot olivat alhaisemmat kuin yorkshiressa. Imisissä oli ruohon lihamäärä suurempi ja rasvamäärä pienempi kuin leikoissa. Myös ulkofileen poikkipinta-ala oli imissä suurempi kuin leikoissa. Eri eläinryhmöiden histokemiailiset, kasvu ja ruohon laatuominaisuudet vaihtelivat paljon. Histokemialliset ominaisuudet eivät vaikuttaneet eläimen kasvuun ja ruohon laatuominaisuuuksiin.