Effect of Selection for Lean Tissue Growth on Body Composition and Physiological State of the Pig at Birth

Patrick Herpin, Jean Le Dividich, and Nuno Amaral

INRA, Station de Recherches Porcines, 35590 Saint-Gilles, France

ABSTRACT: The effects of selection for lean tissue growth on the metabolic and physiological state (i.e., level of maturity) of the pig at birth have been examined on newborns from three breeds that markedly differ with respect to birth weight and postnatal muscle growth potential: a primitive Chinese breed (Meishan, MS), a European breed (Large White, LW), and a composite line (CL) highly selected for high rate of gain. Within each breed, 40 pigs from eight litters were used for whole carcass and tissue sampling, blood sampling, and for a fat tolerance test at 2 h of age. The CL pigs were heavier \((P < .001)\) than the LW and MS pigs at birth but exhibited lower percentages of carcass protein, fat, mobilizable fat, and ash than the MS pigs \((P < .05)\). In addition, MS pigs had larger adipose tissue adipocytes than pigs from the two other breeds \((P < .001)\). Despite their 31% higher RNA capacity in longissimus muscle (higher RNA:protein ratio, \(P < .05)\), CL pigs exhibited a lower percentage of muscle protein \((P < .05)\) than did MS pigs. Relative liver weight was higher for LW than for CL pigs \((P < .05)\), which had the lowest percentage of liver phospholipids \((P < .01)\). The CL pigs exhibited lower hematocrit \((P < .01)\), glucose \((P < .01)\), albumin \((P < .01)\), cortisol \((P < .01)\), and thyroxine \((P < .05)\) levels than the MS pigs. Finally, CL pigs had the lowest ability to clear and metabolize circulating triglycerides, as illustrated by their lower triglyceride clearance rate \((P < .07)\), lipoprotein lipase \((P < .07)\), and cytochrome oxidase \((P < .01)\) activities in rhomboideus muscle. Our results suggest that selection for lean tissue growth may have effects on body and tissue composition, metabolic and hormonal state, and fat metabolism that lead to heavier but less mature pigs at birth. This may affect survival rate.

Key Words: Pigs, Genotype, Maturity, Metabolism

Introduction

Neonatal mortality still plagues the swine industry despite the improving knowledge in pig physiology, nutrition, thermoregulation, health, and management (Varley, 1992). In France, for instance, total preweaning losses including stillbirth have remained constant at 17.8% throughout the last 15 yr (ITP, 1990). A possible explanation for this high postnatal mortality in well-controlled nutritional, environmental, and hygienic conditions is a change in the physiological state of the pig at birth. This physiological state depends mainly on the genetic origin of the pig, and during the past years the genetic background of conventional, modern pigs has changed considerably. In this respect, in France (Sellier, 1989), selection for lean tissue growth largely accounts for the increase in muscle percentage in the carcass at slaughter, from 49.5% in 1977 to 55.0% in 1987.

However, the effects of this genetic improvement on body composition and physiological state of the newborn pig are not known. Studies performed on pigs born from the primitive Chinese Meishan breed (Le Dividich et al., 1991b), the genetically obese and slow-growing Ossabaw line (Kasser et al., 1981; Hoffman et al., 1983), or from dams selected for high backfat thickness (Mersmann et al., 1984; Stone et al., 1985) indicated that, despite their smaller birth weight, these pigs usually possessed a higher percentage of body lipids, were more resistant to cold and starvation, and suffered fewer postnatal losses than pigs from conventional, modern breeds. In addition, the activity of lipoprotein lipase, a key enzyme in the control of tissue lipid uptake, was found to be affected by the genetic origin of the animals in utero (McNamara and Martin, 1982). These modifications were associated with metabolic and endocrine differences that can reflect a difference in physiological maturity at birth. This would suggest that during...
development, genetic selection alters nutrient partitioning and growth, which may be associated with marked differences in body composition and physiological state at birth. Therefore, selection for lean tissue growth may affect some biochemical and metabolic factors associated with the ability of the newborn to adapt physiologically after birth.

Although there is no clear definition of physiological maturity at birth, it is well-known that immediate and optimal development of thermoregulation is necessary to ensure maximal neonatal survival, and depends on the physiological state and maturity of the newborn (Hakkarainen, 1975). Using pigs from three different breeds, including the primitive Chinese Meishan (MS) breed, the conventional, modern Large White (LW) breed, and a composite line (CL) highly selected for lean tissue growth, the aims of the present study were to determine the effects of selection for lean tissue growth on the physiological state (i.e., level of maturity) of the pig at birth. Physiological state was characterized by measurements of 1) body and tissue composition, 2) level of plasma hormones and metabolites, and 3) ability to clear and utilize circulating lipids as assessed by a fat tolerance test and the measurement of enzyme activities at the tissue level.

Materials and Methods

Animals

One hundred twenty newborn pigs from three different breeds that differ markedly with respect to birth weight and postnatal muscle growth potential, a primitive Chinese breed (Meishan, MS), a European breed (Large White, LW), and a composite line (CL) highly selected for lean tissue growth, were used. According to Noblet et al. (1991) lean tissue gain of MS, LW, and CL pigs represents 25, 44, and 50% of the live weight gain between 20 and 95 kg, respectively. Corresponding muscle percentages in the carcass at 95 kg live weight are 35, 50, and 60%, whereas fat content averages 44, 23, and 15%, for MS, LW, and CL pigs, respectively (Noblet, personal communication). The MS and LW pigs were born from sows that originated in the INRA herd (St-Gilles, France), whereas CL pigs were obtained from the nucleus herd of a breeding company. Data obtained from this company indicated that their pigs suffered 23.6% preweaning mortality rate, which was higher than the 17.1 and 10.9% reported in LW and MS breeds, respectively (Legault and Caritez, 1982).

Within each breed, 40 pigs from eight litters were used. Throughout gestation, the sows were fed approximately 2.5 kg of standard gestation diet per day. Farrowings occurred naturally and all were attended and supervised. Colostrum samples were collected manually from most udder sections during farrowing and stored at -65°C until they were analyzed. Within each litter, five pigs were selected according to birth weight for blood and tissue sampling and for a fat tolerance test (FTT).

To study the effect of birth weight within each breed, blood samples were collected in heparinized tubes at birth after umbilical cord rupture, using three pigs per litter that were classified as light, medium, and heavy with regard to the expected mean birth weight of the litter. Two other medium-birth weight pigs were used for tissue sampling and FTT. The killed pig was anaesthetized by halothane inhalation, weighed, and exsanguinated within 5 min after birth. The digestive tract and liver (without gall bladder) were removed and weighed. Samples (from 1 to 2 g) of liver, muscles including the white longissimus and the red interscapular rhomboideus (RH) muscles, and s.c. adipose tissue were removed from each pig, frozen in liquid N2, and stored at -65°C until they were analyzed. Dissectable amounts of white adipose tissue were only found subcutaneously, in the interscapular region. The carcasses without the liver and the digestive tract were also frozen in liquid N2 for subsequent mincing and homogenization.

Blood Analysis

After measurement of hematocrit, samples were centrifuged at 5,200 × g for 4 min, and the plasma was stored at -65°C. Plasma samples were analyzed for glucose by the glucose oxidase method using a commercial kit (Biomerieux, Lyon, France), for free fatty acids (FFA) by an enzymatic method (NEFA-C, Wako Chemicals, Neusse, FRG), and for albumin, insulin, thyroxin, and cortisol by RIA using commercial kits (CEA, Gif, France) or specific methods (Herbert et al., 1965, for insulin; Prunier et al., 1993, for cortisol).

Tissue, Carcass, and Colostrum Composition

Samples of colostrum, carcass, liver, and longissimus muscle were freeze-dried and analyzed for dry matter, nitrogen (Kjeldahl procedure), and ash. Gross energy of colostrum was also determined using an adiabatic bomb calorimeter. Total lipids were determined by the method of Rose-Gottlieb (AOAC, 1975) in colostrum, and the method of Folch et al. (1957) in muscle, liver, and carcass samples. Carcass and liver lipid extracts were also analyzed for phospholipids from phosphorus determination (Bartlett, 1959). The DNA and RNA contents were assessed on longissimus muscle according to the fluorimetric and spectrophotometric methods of Labarca and Paigen (1980) modified by Lefaucheur and Ecolan (1990) and Munro and Fleck (1969), respectively. The RNA capacity (i.e., RNA:protein ratio) was calculated because it is proportional to the protein fractional synthesis rate (Attaix et al., 1988).
Adipocyte Cellularity

Adipose cell sizes were determined according to the method of Hirsh and Gallian (1968) and urea was used to liberate osmium tetroxide-fixed adipocytes from the connective tissue matrix. For each sample, the diameters and volumes of 120 cells were determined in an aqueous suspension (NaCl 0.9%, Triton X-100 0.05%) by optic microscopy using a computer-based image analysis system developed by Folmer (INRA, Le Magnéraud, France). Diameter distributions were calculated and plotted as a histogram with each bar representing the average percentage of adipocytes present in a 5-μm diameter range.

Fat Tolerance Test

The FTT was performed as described by Carlson and Rosner (1972) on one pig per litter. Just after birth, the pig was fitted with a catheter in one umbilical artery as previously described (Le Dividich et al., 1991a) and maintained in a control box under a heating lamp for approximately 2 h before the test was performed. Sterile Intralipid solution (Intralipid 20%, Kabivitrum SA, Noisy, France) was injected into the umbilical artery at the rate of 0.5 mL/kg of BW and the catheter was flushed through twice with 2.0 mL of non-heparinized saline. Blood (.8 mL) was withdrawn before and 5, 10, 20, 30, and 40 min after Intralipid administration. After each sampling the catheter was carefully flushed with .5 mL of non-heparinized saline. Blood samples were cooled on ice to 4°C and then successively centrifuged at 60 × g and 1,000 × g for 10 min. Samples of plasma were stored at −20°C and later analyzed for total triglycerides (TG) (kit, Biomerieux, Lyon, France) by an enzymatic method. As reported by Carlson and Rosner (1972), Intralipid-TG elimination approximated to a first-order exponential decay during the first 30 to 40 min after injection and can be linearized by a semi-logarithmic transformation. The TG biologic half-life (T₀.5) and disappearance rate (k₀, percentage/minute) were calculated from these curves; k₀ = .693/T₀.5, and T₀.5 was the time for the TG concentration to decrease by 50%. At the end of the FTT, the catheter was removed and the pig was placed with the sow.

Enzyme Analysis

Samples of red RH muscles were analyzed for lipoprotein lipase (LPL) activities (EC 3.1.1.34) as previously described (Herpin et al., 1987) and results were expressed in microequivalents of fatty acids released per hour per gram of tissue. In colostrum, LPL activity was measured according to the method of Chilliard and Fehr (1976). Assay of cytochrome oxidase (CO; EC 1.9.3.1.), the final enzyme of the respiratory chain in mitochondrial membranes, was performed polarographically in RH muscle and liver at 25°C using a Clark oxygen electrode according to the procedure described by Barré et al. (1987). Cytochrome oxidase activity is commonly used as an index of the overall oxidative capacities of mitochondria or organs (Jansky, 1973). Its activity was expressed in nanoatoms of O₂ consumed per minute per milligram of tissue.

Experimental Design and Analysis

This experiment was designed as a randomized complete block, with breed as main effect, litter within breed as the block, and with five pigs per litter as the experimental unit. Orthogonal contrasts were used to test the effect of selection for lean tissue growth (CL vs MS and LW pig) on LPL activity and the FTT. The relationship between birth weight and each plasma trait within breed was studied by linear regression analysis. Finally, distribution of adipocyte diameter was tested by chi-square analysis.

Results

Length of gestation (113.6 ± 3.1 d) and percentage of live-born pigs (92.3 ± 4.7%) were not different among breeds, but pigs born from MS sows were (P < .001) more numerous (total born/litter 17.4 ± 1.6) than from sows in the two other breeds (10.9 ± 0.7 and 12.1 ± .8 for LW and CL, respectively). Body weight at birth was significantly different (P < .001) among breeds: 814 ± 28, 1,289 ± 57, and 1,451 ± 44 g for all MS, LW, and CL pigs, respectively.

Composition of colostrum during farrowing (Table 1) was similar in the three breeds despite the slightly higher lipid content observed in MS sow colostrum.

Body, Liver, and Muscle Composition at Birth

Chemical carcass composition was highly influenced by breed in that MS pigs had higher percentages of carcass protein, fat, and ash (Table 2) than CL pigs (P < .05) and lower percentages of phospholipids (P < .01) than LW pigs. However, no significant differences were observed among breeds on fatty acid composition of the total lipid extract (data not shown) and on carcass DM content (Table 2), which suggests that the glycogen content of the carcass was different in the three breeds.

Liver weight (Table 2) was positively related to BW (P < .001) and, therefore, the absolute weight of the liver was lowest in newborn MS pigs (P < .01). However, relative to BW, liver weights were similar for MS and LW pigs, whereas CL pigs exhibited lower liver weights (P < .05) than LW pigs. All breeds had similar liver protein and total lipid contents. However, MS pigs differ largely from the two other breeds with regard to the percentage of phospholipids (54.8 vs
Table 1. Effect of breed on colostrum composition during farrowing

<table>
<thead>
<tr>
<th>Item</th>
<th>Breed</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS</td>
<td>LW</td>
</tr>
<tr>
<td>Dry matter, g/kg</td>
<td>26.6</td>
<td>25.4</td>
</tr>
<tr>
<td>Crude protein (N x 6.38), %</td>
<td>16.7</td>
<td>16.8</td>
</tr>
<tr>
<td>Total fat, %</td>
<td>4.72</td>
<td>3.88</td>
</tr>
<tr>
<td>Gross energy, kcal/g</td>
<td>1.36</td>
<td>1.32</td>
</tr>
<tr>
<td>LPL activity</td>
<td>20.7</td>
<td>33.2</td>
</tr>
</tbody>
</table>

- MS = Meishan; LW = Large White; CL = composite line.
- Values are means (n = 8). Means are not significantly different.
- Lipoprotein Lipase (LPL) activity is expressed in microequivalents of fatty acids released per hour per milliliter of colostrum.

Table 2. Body and liver composition* of newborn Meishan (MS), Large White (LW), and composite line (CL) pigs

<table>
<thead>
<tr>
<th>Item</th>
<th>Breed</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS</td>
<td>LW</td>
</tr>
<tr>
<td>Body composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter, %</td>
<td>20.3</td>
<td>20.6</td>
</tr>
<tr>
<td>Protein (N x 6.25), %</td>
<td>12.0</td>
<td>11.9</td>
</tr>
<tr>
<td>Lipids, %</td>
<td>1.87</td>
<td>1.68</td>
</tr>
<tr>
<td>Phospholipids, %</td>
<td>37.5</td>
<td>44.9</td>
</tr>
<tr>
<td>Ash, %</td>
<td>4.45</td>
<td>4.20</td>
</tr>
<tr>
<td>Liver composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver wt, g</td>
<td>23.6</td>
<td>38.4</td>
</tr>
<tr>
<td>Relative liver wt, %</td>
<td>2.80</td>
<td>2.98</td>
</tr>
<tr>
<td>Protein, %</td>
<td>7.99</td>
<td>6.79</td>
</tr>
<tr>
<td>Lipids, %</td>
<td>3.41</td>
<td>3.62</td>
</tr>
<tr>
<td>Phospholipids, %</td>
<td>54.8</td>
<td>34.3</td>
</tr>
</tbody>
</table>

*Values are means for eight pigs in each breed and are expressed as percentage of wet carcass or liver.

Table 3. Longissimus muscle composition* in newborn Meishan (MS), Large White (LW), and composite line (CL) pigs

<table>
<thead>
<tr>
<th>Item</th>
<th>Breed</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS</td>
<td>LW</td>
</tr>
<tr>
<td>Lipids, %</td>
<td>2.03</td>
<td>1.79</td>
</tr>
<tr>
<td>Protein, %</td>
<td>6.80</td>
<td>6.75</td>
</tr>
<tr>
<td>RNA, µg/g</td>
<td>589</td>
<td>684</td>
</tr>
<tr>
<td>DNA, µg/g</td>
<td>671</td>
<td>750</td>
</tr>
<tr>
<td>Protein:DNA ratio (×10^3)</td>
<td>.102</td>
<td>.097</td>
</tr>
<tr>
<td>RNA:DNA ratio</td>
<td>.883</td>
<td>.928</td>
</tr>
<tr>
<td>RNA:Protein ratio</td>
<td>8.77</td>
<td>10.25</td>
</tr>
</tbody>
</table>

*As percentage of wet tissue. Values are means for eight pigs in each breed.
Longissimus muscle composition is presented in Table 3. As for body composition data, CL pigs had a lower protein percentage \((P < .05)\) than MS and LW pigs but no differences were observed among breeds in DM, total lipid, and RNA and DNA contents. However, RNA capacity (i.e., RNA:protein ratio) was 31% higher in longissimus muscle from CL than from MS pigs \((P < .05)\); intermediate values were obtained in the LW pigs.

**Plasma Hormones and Metabolites**

Mean birth weight of light, medium, and heavy pigs used for blood sampling were 575, 810, and 965 g in the MS breed, 985, 1,340, and 1,542 g in the LW breed, and 1,178, 1,457, and 1,656 g in the CL pigs, respectively. Circulating levels of hormones and metabolites were highly influenced by breed (Table 4). Hematocrits differed among breeds \((P < .01)\) and decreased from 38.4 \(\pm 6\) to 36.5 \(\pm 7\) and 33.4 \(\pm 7\)% for MS, LW, and CL pigs, respectively. Glucose level was greater in LW (54.5 \(\pm 4.5\) mg/100 mL) than in MS and CL pigs but no differences were observed among breeds in DM, total lipid, and RNA and DNA contents. However, RNA capacity (i.e., RNA:protein ratio) was 31% higher in longissimus muscle from CL than from MS pigs \((P < .05)\); intermediate values were obtained in the LW pigs.

**Lipid Metabolism**

**Adipose Tissue Cellularity.** Adipose tissue adipocytes had similar cell diameters (24.95 \(\pm 1.06\), 23.67 \(\pm 0.60\), and 24.25 \(\pm 0.53\) \(\mu\)m for MS, LW, and CL pigs, respectively) and volumes (9.52 \(\pm 0.8\), 8.45 \(\pm 0.53\), and 8.83 \(\pm 0.60\) \(\mu\)m\(^3\) for MS, LW, and CL pigs, respectively) in the three breeds. However, breed had a significant effect on diameter (Figure 2) in that MS pigs exhibited a greater number of cells in the two highest ranges (diameter \(\geq 25\) \(\mu\)m) than did the other pigs.

**Fat Tolerance Test.** The curves depicting TG disappearance were linear \((r \geq .98)\) after semilogarithmic transformation. Data for TG clearance rate \((k_F)\) and biologic half-life \((T_{1/2})\) are presented together with basal TG levels in Table 5. Initial TG

---

**Table 4. Plasma hormones and metabolites** in newborn Meishan (MS), Large White (LW), and composite line (CL) pigs

<table>
<thead>
<tr>
<th>Item</th>
<th>Breed</th>
<th></th>
<th></th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MS</td>
<td>LW</td>
<td>CL</td>
</tr>
<tr>
<td>Hematocrit, %(^b)</td>
<td></td>
<td>38.4</td>
<td>36.5</td>
<td>33.4</td>
</tr>
<tr>
<td>Glucose, mg/100 mL(^c)</td>
<td></td>
<td>43.7</td>
<td>56.4</td>
<td>37.8</td>
</tr>
<tr>
<td>Free fatty acids, (\mu)Eq/L(^d)</td>
<td></td>
<td>23.0</td>
<td>33.2</td>
<td>28.8</td>
</tr>
<tr>
<td>Albumin, mg/mL(^e)</td>
<td></td>
<td>1.65</td>
<td>1.30</td>
<td>1.20</td>
</tr>
<tr>
<td>Insulin, (\mu)IU/mL(^f)</td>
<td></td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Thyroxine, ng/mL(^g)</td>
<td></td>
<td>80.5</td>
<td>85.6</td>
<td>71.6</td>
</tr>
<tr>
<td>Cortisol, ng/mL(^h)</td>
<td></td>
<td>150.6</td>
<td>114.4</td>
<td>127.0</td>
</tr>
</tbody>
</table>

\(^a\)Values are means for 21 to 25 pigs in each breed (except for hematocrit values, \(n = 30\)).

\(^b\)MS vs LW, \(P < .05\); MS vs CL, \(P < .01\); LW vs CL, \(P < .01\).

\(^c\)LW vs MS, CL, \(P < .01\).

\(^d\)MS vs LW, \(P < .05\).

\(^e\)MS vs LW, CL, \(P < .01\).

\(^f\)Below the sensitivity of the assay (3 \(\mu\)IU/mL).

\(^g\)MS vs CL, \(P < .05\); LW vs CL, \(P < .01\).
Results of the present study clearly indicate an effect of selection for lean tissue growth on body and tissue composition, concentrations of plasma metabolites and hormones, and fat metabolism of the newborn pig.

**Effect of Breed on Body Composition at Birth**

Although composition of the fetal pig has been shown to be less affected by manipulating sow diet, some differences have been evidenced according to the genetic origin of the animals. For instance, selection for high backfat thickness is associated with an increased percentage of body fat in fetus near term (Hoffman et al., 1983; Stone et al., 1985). In the present study and relative to BW, CL pigs had less total fat, mobilizable fat, and ash than those from the primitive MS breed; intermediate values were observed for LW pigs. The absolute differences between CL and MS pigs for the percentage of fat (−0.28%) and mobilizable fat (−3.1%) are small, but taken together they represent a 23% decrease in the total amount of mobilizable fat per kilogram of birth weight. This may be of great importance with regard to postnatal energy metabolism and survival of the animals. These results reflecting fat deposition during fetal life are consistent with the observed differences in adipocyte size (Hausman et al., 1983): larger adipocytes are more numerous in subcutaneous adipose tissue from MS than from CL pigs. In addition, CL pigs exhibited a higher capacity for protein synthesis than did MS pigs, as assessed by their higher RNA:protein ratio in longissimus muscle. Despite this, they had the lowest percentage of protein in the carcass as well as in the muscle. In other words, selection of parents for lean tissue growth results in pigs that have less body fat and a higher protein synthesis potential at birth. However, this potential is not overtly expressed yet.

One can speculate that the differences observed among breeds can be related to differences in birth levels were significantly \((P < .05)\) higher in MS than in LW pigs, CL pigs had intermediate values. The CL pigs exhibited a lower ability to clear the Intralipid emulsion as shown by a 38% higher \(T_5\) and a 30% lower \(k_F\) than LW and MS pigs (CL vs MS and LW, orthogonal contrasts, \(P < .07\)).

**Enzyme Activities.** The LPL and CO activities are presented in Table 6. The lowest LPL activity was found in the muscle of CL pigs \((8.36 \pm 1.07 \, \mu\text{Eq of FA released-h}^{-1}\cdot\text{g}^{-1} \text{of tissue}); it was approximately 30% lower than in the two other breeds (orthogonal contrasts, \(P < .07\)). Similar effects were observed for muscle CO activity with values decreasing from 19.05 \(\pm\) 1.70 to 13.40 \(\pm\) 1.31 and 11.81 \(\pm\) 0.76 nAtoms of \(O_2\) consumed-min\(^{-1}\cdot\text{mg}^{-1}\) of tissue for MS, LW, and CL pigs, respectively \((P < .01)\). No differences were observed on CO activity in the liver.

Table 5. Triglyceride clearance rate \((k_F)\) and biologic half-life \((T_5)\) during a fat tolerance test \(^a\) (FTT) in unfed Meishan [MS], Large White [LW], and composite line [CL] pigs aged 2 hours

<table>
<thead>
<tr>
<th>Breed</th>
<th>MS</th>
<th>LW</th>
<th>CL</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triglycerides, mg/L</td>
<td>153.3</td>
<td>52.0</td>
<td>81.4</td>
<td>28.8</td>
</tr>
<tr>
<td>(T_5), min</td>
<td>5.58</td>
<td>5.32</td>
<td>7.51</td>
<td>0.85</td>
</tr>
<tr>
<td>(k_F), mg %/min</td>
<td>14.56</td>
<td>14.98</td>
<td>10.33</td>
<td>1.88</td>
</tr>
</tbody>
</table>

\(^a\)Values are means for eight pigs in each breed. Procedure for the FTT (administration of .5 mL of Intralipid emulsion per kilogram of BW in the umbilical artery) and \(T_5\) and \(k_F\) calculations are described in Materials and Methods.

\(^b\)Triglyceride levels are basal levels before Intralipid administration.

\(^c\)MS vs LW, \(P < .05\).

\(^d\)MS, LW vs CL, \(P < .07\).
weight. De Passillé and Hartsock (1979) reported a small but significant effect of birth weight on body composition traits, within as well as between litters, in that carcasses from the heaviest newborns had higher DM and protein percentages, but the differences in fat content were not significant. In the present study, there was no significant within-breed effect of BW on body and muscle composition. In addition, relative to BW, CL newborns had lower amounts of chemical components in the carcass as well as in the muscle and they were 78 and 58% heavier than MS and LW pigs, respectively, which confirms the existence of a main effect of breed.

Table 6. Lipoprotein lipase (LPL) and cytochrome oxidase (CO) activities\textsuperscript{a} in rhomboideus muscle and liver of newborn Meishan (MS), Large White (LW), and composite line (CL) pigs\textsuperscript{b}

<table>
<thead>
<tr>
<th>Breed</th>
<th>Item</th>
<th>MS</th>
<th>LW</th>
<th>CL</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Muscle LPL, Eq fatty acids h\textsuperscript{-1}.g\textsuperscript{-1c}</td>
<td>11.79</td>
<td>12.20</td>
<td>8.36</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>Muscle CO, natoms O\textsubscript{2} min\textsuperscript{-1}.mg\textsuperscript{-1d}</td>
<td>19.05</td>
<td>13.40</td>
<td>11.81</td>
<td>1.31</td>
</tr>
<tr>
<td></td>
<td>Liver CO, natoms O\textsubscript{2} min\textsuperscript{-1}.mg\textsuperscript{-1'}</td>
<td>8.19</td>
<td>6.16</td>
<td>8.43</td>
<td>1.60</td>
</tr>
</tbody>
</table>

\textsuperscript{a}CO activity was significantly higher in rhomboideus muscle than in the liver in each breed (MS, P < .01; LW, P < .001; CL, P < .05).

\textsuperscript{b}Values are means for seven or eight samples in each breed.

\textsuperscript{c}MS, LW vs CL, P < .07.

\textsuperscript{d}MS vs LW, CL, P < .01.

Effect of Breed on Metabolic and Hormonal State

Together with the lower plasma cortisol and thyroxine levels, the lower hematocrit of CL pigs is likely indicative of their reduced ability to develop metabolic and physiological adaptations associated with optimal postnatal survival. The hematocrit is closely related to blood hemoglobin and erythrocyte population (Miller et al., 1961) and the lower value found in CL newborns can reflect a reduced oxygen-carrying capacity that could impair the effectiveness of their thermogenic response to cold stress, as reported by Seerley et al. (1972) and Mayfield et al. (1987). The greater cortisol levels in MS than in LW and CL pigs confirm previous observations on MS pigs of various ages (Morméde et al., 1984) and the specificity of the MS breed with regard to glucocorticoid metabolism. Cortisol is involved in the stress response and the initiation of parturition by swine fetus (First and Bosc, 1979). With regard to postnatal survival, one can postulate that a higher responsiveness of the adrenal system would be of benefit to the newborn pig during the stress of parturition and during the first few critical hours after birth. In addition, thyroid hormones are known to have an effect on oxidative metabolism at the tissue and mitochondrial levels (Dauncey, 1990) and to control the postnatal development of thermogenesis in the pig (Slebodzinski, 1988; our unpublished observations). As illustrated here by the 14% lower plasma thyroxine level and the lower CO activity in skeletal muscle, CL newborns do exhibit a lower potential for fatty acid oxidation that is likely to be associated with a lower ability to withstand and survive a cold stress.

Within breed, overall fetal growth is reported to be positively related to plasma concentration of albumin (Stone and Christenson, 1982). Our within-breed data on birth weight are consistent with these results except that no relationship was found between plasma concentration of albumin and BW in CL pigs. In addition, CL pigs exhibited the lowest absolute levels of plasma albumin and were the heaviest. In fact, the level may have been lowest because they were heavier and the albumin synthesis similar, resulting in more dilution in plasma albumin. Nevertheless, these results are in agreement with the lower albumin levels reported by Stone (1984) and Stone et al. (1985) in pigs from lean lines than in pigs from obese lines. Furthermore, as suggested by Stone (1984), albumin synthesis by the liver and its level at birth are indicative of the physiological state of the newborn. Therefore, the lower level of plasma albumin and the absence of relationship between birth weight and albumin levels in CL pigs could reflect both the lower relative weight and the delayed maturation of the liver.

Effect of Breed on Lipid Metabolism of the Newborn

Postnatal enhancement of lipid metabolism is a major factor involved in the development of glucose and thermal homeostasis, and therefore pig survival, during the 1st d of life (Herpin et al., 1992). Consequently, lipid utilization could be a pertinent index of metabolic maturity at birth. In our study, it is noticeable that CL pigs had a lower ability to metabolize lipids during the early neonatal period. Using the assumption that the TG clearance rate (k\textsubscript{F}) determined during the FTT reflects endogenous plasma TG fractional removal rate (Carlson and
Assessment of Physiological Maturity

As previously stated by Hakkarainen (1975), there is no doubt that physiological state and survival rate are correlated at birth, but characterization of pig development and maturity is very difficult. However, on the basis that the most pronounced changes in body composition traits and plasma hormones and metabolites during later stages of pregnancy are an increase in body lipid and protein (Hakkarainen, 1975; Hoffman et al., 1983), an increased liver weight (Padalikova and Jezkova, 1984), and liver phospholipids (Mersmann et al., 1984; Stone et al., 1985), circulating lipids and is consistent with the data obtained when comparing obese and lean lines of pigs (Hoffman et al., 1983; Mersmann et al., 1984; Stone et al., 1985).

Implications

Taken together our results shown that selection for lean tissue growth in pigs has a negative effect on several factors that may affect survival at birth. These factors include body and tissue composition, metabolic and hormonal state, and fat metabolism at birth. In other words, one can postulate that selection for lean tissue growth could generate heavier but less mature pigs at the moment of birth, and this can affect survival rate.

Literature Cited


regulatory aspects of thermogenesis in cold exposed piglets. Comp. Biochem. Physiol. 87A:1073.


