Influence of rearing system, diet and gender on performance, carcass traits and meat quality of Polish Landrace pigs

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Forty-eight Polish Landrace pigs (initially 32.43 ± 0.70 kg live weight) were assigned to a 2 × 2 × 2 factorial arrangement in order to assess the effects of the rearing system (outdoor v. indoor), diet (with corn grain silage v. without corn grain silage) and gender (barrows v. gilts) on performance, carcass traits, meat quality and intramuscular collagen (IMC) characteristics. During the trial period of 14 weeks, each group was housed in a pen of 12 m², and the outdoor-reared animals had access to a paddock of 24 m². Pigs were fed a diet computed according to standard requirements and supplied on a basis of 9% of metabolic weight (live weight⁴⁻⁵). Pigs were slaughtered at 110.69 ± 0.85 kg. The rearing system did not significantly affect growth, hot and cold dressing, meat quality of m. longissimus lumborum or IMC. Outdoor pigs had less (P < 0.05) backfat thickness, slightly higher (P < 0.082) lean percent and a meat with lower pH and fat than the conventional system. In light of these results, alternative pig rearing systems with indoor space and free outdoor access could be an interesting production system for the pigs. Compared with the pigs fed diets with corn grain silage, those fed diets without corn had higher (P < 0.05) lean, ham percentage and IMC content, lower (P < 0.05) neck percentage but similar main tissue components of the ham and meat quality. Compared with the gilts, barrows were fatter and showed a meat with different physico-chemical traits, which was slightly more tender and had similar IMC properties.

Keywords: pig, rearing system, diet, gender, carcass and meat quality

Implications

Compared with conventional production systems, outdoor pig production systems are often perceived to be more environmentally friendly and better for animal welfare and, moreover, have relatively low capital investment. This study shows that intensive outdoor pigs had less backfat thickness, slightly higher lean percent and a meat with lower fat content than the conventional system. Therefore, alternative pig rearing systems with indoor space and free outdoor access could be an interesting production system for the pig. In addition, the use of diets with or without corn grain silage to pigs is compared.

Introduction

Conventional production systems are generally associated with negative environmental impact (pollution, offensive odors), and poor animal welfare, due to high animal densities and bad housing conditions, and are perceived to result in reduced meat quality (reviewed in Bonneau and Lebret, 2010). Intensive outdoor pig production systems have been put into practice (pigs housed in an open building with outside access) in recent years in some parts of the world (Bonneau and Lebret, 2010). Interest in outdoor pig production is also growing in Poland. These alternatives to traditional indoor systems may also become more common as environmental or animal welfare regulations become more intense. In addition, outdoor pig production systems often have relatively low capital investment, and the ability to be readily expanded.

The effects of pig rearing conditions on production and quality of pork are conflicting. Some studies have determined that pigs finished outdoors had less backfat than pigs finished indoors (Enfält et al., 1997; Sather et al., 1997). Other studies (Gentry et al., 2002; Lebret et al., 2006) have reported to the contrary. In addition, Lebret et al. (2006) found lower lean meat content in pigs reared outdoors, but other authors (Högborg et al., 2004) did not report any effect between indoor and outdoor systems on intramuscular fat.
content and lean percentage. The influence of rearing systems on other quality parameters, such as ultimate pH, tenderness and drip loss of meat, is also controversial (reviewed in Lebret, 2008 and Bonneau and Lebret, 2010). However, outdoor access is likely to increase the level of physical exercise of the animals, which may have an effect on intramuscular collagen (IMC) characteristics (Maiorano et al., 2003), responsible for the background toughness of meat (McCormick, 2009), and on yield from a technological point of view (Bouten et al., 2000).

Very often, an outdoor rearing system is associated with the supplementation of commercial diet mixtures along with farm-grown feedstuff, such as different green forage. Climatic conditions in Poland are not conducive to cultivation of corn for dry feed. Therefore, some farmers use wet corn crops as silage for fattener pig feeding. Some authors have reported that limited doses of silaged corn should be used in pig diets during the whole fattening period (Grabowicz et al., 2006; Millet et al., 2006) because inclusion of high rate of corn cob mix in the pig ration may affect immunocompetence (Millet et al., 2006).

The aim of the present study was to evaluate the effects of rearing system (outdoor v. indoor), diet (with corn grain silage v. without corn grain silage) and gender on growth performance, carcass characteristics, meat quality and IMC properties of Polish Landrace pigs.

Material and methods

Animals

Animal handling followed the recommendations of European Union directive 86/609/EEC. The trial was carried out in a pig farm located in the Kujawy-Pomorze region of Poland. Forty-eight Polish Landrace pigs (an average age of 80 ± 2.1 days old) were individually marked, weighed (initially 32.43 ± 0.70 kg live weight) and randomly distributed into four groups of twelve pigs, each group comprising six barrows and six gilts. The two groups were kept outdoors and the other two indoors. The first two groups were reared outdoors. One of the two groups reared outdoors was fed a diet with corn grain silage, whereas the second did not receive such supplement. In the case of the group kept indoors, as previously, one received diet with corn grain silage, whereas the second did not receive this addition. During the trial period of 14 weeks (from the last week of May to August, with sporadic maximal temperature not passing 26°C to 28°C), pigs were housed in 24 pens of 6 m² (indoor environmental temperature: 20.6 ± 2.6°C) with two pigs per pen (three pens per treatment), and the outdoor-reared animals had access to a paddock of 24 m² (average temperatures were: 16°C for June, 19°C to 20°C for July and 17°C for August). During the trial, pigs were fed a diet computed according to the standard requirements and supplied on a basis of 9% of metabolic weight (live weight1/3). The animals were fed twice daily and during the experimental period had free access to water. Composition and chemical components of the diets are given in Table 1.

To calculate the food amount to be administered and the average daily weight gain (ADG), pigs were individually weighed (in the morning after an overnight fast) at the beginning of the trial, monthly and at slaughter.

Slaughter surveys

All the animals were slaughtered the same day at 180 ± 2.1 days of age according to standard procedures (Poland PN-86/A-82002-1) in a commercial slaughterhouse located 2 km from the experimental farm. The animals were transported with straight-deck trailers constructed of aluminium punched sides and were gently moved to a small room where they remained overnight with access to water, but not to feed. Pigs were electrically stunned and following exsanguination, the carcasses were scalded, dehaired and eviscerated. Hot and cold carcasses were weighed and dressing percentages were calculated. Dressing and jointing procedures were the same as applied at Slaughter Performance Testing Stations (Różycyki, 1996). Meat of primal cuts was calculated according to the equation elaborated by Różycyki (1996) and divided by the half carcass weight to obtain the percentage carcass lean content as follows:

\[
Y = 1.745x_1 + 0.836x_2 + 0.157x_3 - 1.884
\]

where \(Y\) = meat of primal cuts (kg); \(x_1\) = ham without backfat and skin (with shank; kg); \(x_2\) = loin without backfat and skin + tenderloin (kg); \(x_3\) = (2× width + height) of loin eye area (cm²). Carcass lean content (%) = \((Y/\text{half carcass weight} \times 100)\).

Backfat depth was measured with electronic calipers up to 1 mm accuracy. From 5 measurements (above the shoulder in thickest area, between the last thoracic vertebra and the first lumbar vertebra, Sacrum I, Sacrum II, Sacrum III) of backfat thickness the arithmetic mean was calculated (Różycyki, 1996). The hot carcass was split into two sides. At 24 h post mortem, the left side was weighed and dissected into the main commercial cuts. Ham, loin, tenderloin, neck and shoulder cuts were weighed and expressed as percentages of the cold carcass weight. The loin was cut behind the last thoracic vertebra, on the frontal surface loin eye area was determined using a computer analysis system LUCIA (System for Image Processing and Analysis, version 4.82.2004). The ham was dissected into the main tissue components (lean, fat, skin and bone).

Meat quality measures

The following determinations were carried out on longissimus lumborum (LL) muscle between the 2nd and 5th lumbar vertebra. The \(pH_{\text{45}}\) was recorded 45 min post mortem using a portable pH-meter equipped with a glass electrode (R. Matthäus, Pöttmes, Germany). At 48 h post mortem, the meat \(pH\) was measured in freshly minced and water-suspended meat tissue. At the same time the water holding capacity (WHC) was determined using filter paper (Whatman No. 1) press method (Grau and Hamm, 1957) and was expressed as free water in meat.
The drip loss was measured (Honikel, 1987) on LL chops (2.0 to 2.5 cm thick). Immediately after cutting off and weighing, the sample with fascia was put into double polythene bags, where the inner bag was perforated to allow the exudate leaks. Meat samples were collected from the carcasses at 24 h post mortem and then stored for 48 h at 4 °C. Drip loss was expressed as the percentage sample weight loss during storage.

For the determination of meat tenderness instrumental analysis was performed using an INSTRON 3342 (Norwood, MA, USA), with Warner–Bratzler shear force device (Szalata et al., 1999). The LL chops (2.5 to 3.0 cm thick) were kept in a frozen state at −25 °C until analysis. After thawing for 24 h at 4 °C, the chops were wrapped with gauze cloth and cooked in 0.85% NaCl at 70 °C for 45 min. Then, the samples were cooled overnight at 4 °C before Warner–Bratzler shear values were determined. Three cores were cut parallel to the muscle fibers and each core was sheared four times. The average of 12 shears was expressed in N/cm.

### Meat chemical characteristics

The LL muscle samples were collected (after 24 h at 2 °C to 4 °C), between the 2nd and 5th lumbar vertebra, vacuum packaged and stored frozen (−40 °C) until chemical composition and IMC analyses.

### Proximate analysis

On LL samples, moisture (method no. 950.46), fat (method no. 991.36), protein (method no. 981.10) and ash (method no. 920.153) were assessed according to AOAC procedures (Association of Official Analytical Chemists, 1999, Ch. 39), after 24 h thawing at 4 °C.

### Collagen analysis

Approximately 100 g of muscle (wet weight) was thawed at room temperature, trimmed of fat and epimysium, lyophilized for 48 h, weighed and hydrolyzed in Duran tubes in 5 ml 6N HCl at 110 °C for 18 to 20 h for determination of hydroxyproline (Woessner, 1961) and cross-linking. All analyses were carried out using the methods described in the literature.

### Table 1 Mean values of composition and chemical components of the diets

<table>
<thead>
<tr>
<th>Dietary component</th>
<th>With corn</th>
<th>Without corn</th>
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<tbody>
<tr>
<td></td>
<td>Fattening period</td>
<td>Fattening period</td>
</tr>
<tr>
<td>Ground wheat (%)</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>Ground triticale (%)</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>Ground barley (%)</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>Corn grain silage (%)</td>
<td>24</td>
<td>38</td>
</tr>
<tr>
<td>Wheat bran (%)</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Ground soybean (%)</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Protein concentrate PT-121 (%)</td>
<td>15</td>
<td>9</td>
</tr>
</tbody>
</table>

**Dry matter (%)**

- 80.98 (With corn) 80.82 (Without corn)

**Composition of dietary dry matter**

- Crude ash (%)
- CP (%)
- Crude fat (%)
- Crude fiber (%)
- N-free extractives (%)
- Starch (%)
- Carbohydrate (%)
- ADF (%)
- NDF (%)
- Metabolizable energy (MJ/kg)
- Vitamin–mineral premix

**Vitamins and minerals**

- Vitamin A as retinyl acetate, 11 128 IU; vitamin D₃ as cholecalciferol, 2204 IU; vitamin E as α-tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfate, 1.42 mg; thiamine as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B₁₂, 0.03 mg; o-panthenolic acid as o-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

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*Composition of protein PT-121: metabolizable energy, 9.04 MJ; Net energy, 6.46 MJ; CP, 32.70% to 33.70%; Crude fiber, 8.50%; Crude ash, 22% to 24%; Crude fat, 2.5% to 4.5%; Ca, 5.85%; P-digestible, 1.48%; Na, 1.25%; Lysine, 4.12%; Methionine, 0.70%; Methionine + Cystine 1.27%.

Tryptophan, 0.41%; Threonine, 1.41%.

The vitamin–micronutrient premix provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A as retinyl acetate, 11 128 IU; vitamin D₃ as cholecalciferol, 2204 IU; vitamin E as α-tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfate, 1.42 mg; thiamine as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B₁₂, 0.03 mg; o-panthenolic acid as o-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.
out in duplicate. Collagen content was calculated by multiplying the measured weight of hydroxyproline by 7.25. Hydroxylysylpyridinoline (HLP) concentration, the principal non-reducible cross-link of muscle collagen (McCormick, 2009), was determined using a modified HPLC procedure developed by Eyre et al. (1984). The HPLC was equipped with a Kontron 450 MT2 (Kontron Instruments, Milan, Italy) data system and with an Altex (Beckman Instruments, Fullerton, CA, USA) Ultrasphere-ODS (C-18; small pore; 4.6 × 250 mm) column. The HLP was expressed as moles of HLP per mole of collagen and also as μg of HLP per mg of lyophilized tissue.

**Statistical analysis**

Data were performed using SPSS package (SPSS/PC + Statistics 17.0, SPSS Inc., Chicago, IL, USA, 2008). Data were evaluated by factorial ANOVA where rearing system, diet and gender were the main factors. Pen was the experimental unit for growth performances and each individual pig was considered as the experimental unit for carcass characteristics and meat quality. BW at slaughter was included as a covariant. The interaction between the main factors was not significant and is not reported in the results. Relationships between shear force and IMC variables were evaluated with simple linear correlations using the same statistical package.

**Results and discussion**

**Growth and slaughter performance**

The rearing system, diet and gender did not significantly affect final weight (ranging from 109.82 to 111.56 kg) and ADG (ranging from 779.65 to 806.57 g/day), as well as hot and cold carcass weight, and dressing percentage (Table 2). There has been considerable work comparing the performance of outdoor with indoor finishing pigs in Europe, but such studies are scarce in Poland. The influence of outdoor rearing on pig performances varies according to many factors, such as housing, genetics, climatic conditions, space allowance and feeding regimen (Lebret et al., 2006). Gentry et al. (2002) did not find any effect on pig growth and carcass weight of rearing environment (indoors on slats or outdoors fed alfalfa pasture). Lebret et al. (2006) reported that pigs reared in an outdoor system (sawdust bedding with free access to an outdoor area, 2.4 m²/pig) exhibited better growth rate due to their greater feed intake, especially during the finishing period, and heavier carcasses compared with pigs reared in the conventional system (fully slatted floor, 0.65 m²/pig).

Compared with indoor animals, outdoor animals had less (P < 0.05) backfat thickness, slightly higher but not statistically significant (P = 0.082) lean meat percentage, and similar loin eye area (Table 2) and percentage of tenderloin, loin, neck, shoulder and ham (Table 3). In addition, the weight of the ham was similar between outdoor and indoor pigs. The tissue dissection indicated that pigs reared indoors had only a slightly higher but not statistically significant (P = 0.078) proportion of fat and skin compared with the pigs reared outdoors (Table 3). Previous studies (Enfält et al., 1997; Sather et al., 1997) reported that pigs reared outdoors had less backfat than those reared indoors. These findings and those in the current study are not consistent with the findings of Lebret (2008). Pigs reared in the outdoor system exhibited higher backfat depth. Compared with conventional indoor rearing, Lebret et al. (2006) reported that pigs reared with free access to an outdoor area had thicker mean backfat, independent of carcass weight, although the proportions of carcass cuts (except to backfat) were unaffected.

Compared with the corn grain silage diet, diet without corn grain silage had a higher percentage of both triticale and barley and also had a higher percentage of dry matter and lower percentage of fat (Table 1). Diet did not affect slaughter performance, except the lean meat percentage that was higher (P < 0.05) in pigs fed without corn than in the pigs fed with corn (Table 2). It should be stressed that carcass lean content in our experiment was relatively high ranging from 58.90% in the control group to 57.23% in the corn group. In a previous study, Różycki (2003) found an average carcass lean content of 57.6% in the Polish Landrace pigs (n = 625). The lower musculature of pigs fed the diet with corn grain silage is likely an effect of lower conversion rate of CP from mixture

<table>
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<th>Table 2 Mean values for carcass traits</th>
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with maize grain as reported by Grabowicz et al. (2006). A tendency towards lower weight gains with large doses of maize silage, especially with low content of or without cobs in pig feeding was observed by several authors (Rajic et al., 1988; Burgstaller, 1995).

Carcass weight, dressing out and loin eye area were not affected by gender. Barrows had fatter carcasses than gilts ($P < 0.001$), which agrees with the findings of Correa et al. (2008) and Fernández-Duena et al. (2008). The lean meat content was higher ($P < 0.001$) in gilts than in barrows (Table 2), in agreement with the earlier study (Fernández-Duena et al., 2008).

Compared with pigs fed diets containing corn grain silage, animals fed diets without corn grain silage had a higher ($P < 0.001$) proportion of lean and a lower ($P < 0.001$) adiposity compared with the barrows; the bone percentage was not affected by gender.

### Meat quality

Results on meat quality traits (pH, WHC, drip loss and shear force) in the LL muscle are reported in Table 4. The diet did not significantly affect any meat quality traits. The rearing system also did not affect meat quality traits, except for pH value, which was slightly lower in the meat of pigs reared outdoors than in pigs reared indoors (5.38 v. 5.41, respectively; $P = 0.052$). Differences in pH could be due to the variation in muscle glycogen content: outdoor-reared pigs could have higher glycolytic store, indicating more glycogen in the muscle at slaughter, which then results in more lactate in the post-mortem process (Bonneau and Lebret, 2010). However, ultimate pH value is also dependent on the ante-mortem stress, type of breed and the genetic variation within breeds (Terlouw, 2005). There is some conflict regarding the differences between pigs raised outdoors and conventionally with respect to pre-slaughter stress and its impact on pork quality (reviewed in Bonneau and Lebret, 2010).

Even though initial pH was not significantly affected by gender, ultimate (48 h) pH of barrows was lower ($P < 0.05$) than gilts.

### Table 3 Mean value for cuts and lean, fat and bone content of the ham

<table>
<thead>
<tr>
<th></th>
<th>RS</th>
<th>D</th>
<th>G</th>
<th>Significance</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Outdoor</td>
<td>Indoor</td>
<td>With corn</td>
<td>Without corn</td>
</tr>
<tr>
<td>Remarks on left side</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tenderloin (%)</td>
<td>1.15</td>
<td>1.27</td>
<td>1.18</td>
<td>1.23</td>
</tr>
<tr>
<td>Loin (%)</td>
<td>21.47</td>
<td>21.57</td>
<td>22.61</td>
<td>21.51</td>
</tr>
<tr>
<td>Neck (%)</td>
<td>13.55</td>
<td>13.44</td>
<td>13.80</td>
<td>12.60</td>
</tr>
<tr>
<td>Shoulder (%)</td>
<td>13.50</td>
<td>12.91</td>
<td>13.11</td>
<td>13.61</td>
</tr>
<tr>
<td>Ham (%)</td>
<td>20.60</td>
<td>20.32</td>
<td>20.17</td>
<td>20.67</td>
</tr>
<tr>
<td>Ham (kg)</td>
<td>8.99</td>
<td>8.94</td>
<td>8.81</td>
<td>9.12</td>
</tr>
<tr>
<td>Lean (%)</td>
<td>77.16</td>
<td>76.09</td>
<td>76.03</td>
<td>77.23</td>
</tr>
<tr>
<td>Fat and skin (%)</td>
<td>15.25</td>
<td>16.47</td>
<td>16.40</td>
<td>15.32</td>
</tr>
<tr>
<td>Bone (%)</td>
<td>7.58</td>
<td>7.44</td>
<td>7.57</td>
<td>7.45</td>
</tr>
</tbody>
</table>

RS = rearing system; D = diet; G = gender.
*Twenty-four pigs for treatment.
$P < 0.05$, *** $P < 0.001$.

### Table 4 Mean value for pH, WHC, drip loss and shear force of Longissimus lumborum muscle

<table>
<thead>
<tr>
<th></th>
<th>RS</th>
<th>D</th>
<th>G</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outdoor</td>
<td>Indoor</td>
<td>With corn</td>
<td>Without corn</td>
</tr>
<tr>
<td>pH 45</td>
<td>6.49</td>
<td>6.55</td>
<td>6.60</td>
<td>6.44</td>
</tr>
<tr>
<td>pH 48</td>
<td>5.38</td>
<td>5.41</td>
<td>5.40</td>
<td>5.39</td>
</tr>
<tr>
<td>WHC (%)</td>
<td>23.12</td>
<td>23.18</td>
<td>23.02</td>
<td>23.28</td>
</tr>
<tr>
<td>Drip loss (%)</td>
<td>5.02</td>
<td>4.58</td>
<td>4.87</td>
<td>4.72</td>
</tr>
<tr>
<td>Shear force (N)</td>
<td>45.91</td>
<td>43.67</td>
<td>44.22</td>
<td>45.36</td>
</tr>
</tbody>
</table>

RS = rearing system; D = diet; G = gender; WHC = water holding capacity.
*Twenty-four pigs for treatment.
$P < 0.05$, *** $P < 0.001$.
Collagen chemical composition (%)
does not influence pH45 and pH 24 values (Corino et al.,
gender (Table 4). Other authors have reported that sex
tissue characteristics and rate of tenderization (Huff-Lonergan
tions, sarcomere length, pH, temperature, fat, connective
variety of factors, such as, differences in fiber type propor-
percentage of intramuscular lipid was less in thelongissimus
and gilts. In addition, these authors observed that the per-
HLP/IMC (mol/mol) 0.11 0.11 0.12 0.10 0.11 0.11 0.01 ns ns ns
HLP (µg/mg²) 3.05 3.13 3.17 2.97 3.13 3.01 0.17 ns ns ns

IMC = intramuscular collagen; RS = rearing system; D = diet; G = gender; HLP = hydroxylysylpyridinoline.

Comparison of the sexes revealed no differences in IMC characteristics, a finding in accord with literature (Corino et al., 2008).

Conclusion
The results of the present study indicate similar hot and
cold dressing percentages, physico-chemical traits of LL
muscle and IMC properties of Polish Landrace pigs for both a
conventional rearing system and an alternative pig rearing
system, with indoor space and free outdoor access. Outdoor
pigs had less backfat thickness and slightly higher lean

than that of gilts. In addition, compared with barrows, gilts
had lower (P < 0.05) WHC and their meat was less tender
(P < 0.001). Drip loss was not significantly affected by
gender (Table 4). Other authors have reported that sex
does not influence pH24 and pH34 values (Corino et al.,
2008; Rodríguez-Sánchez et al., 2009), WHC and drip loss
(Rodríguez-Sánchez et al., 2009) in longissimus muscle.
Regarding shear force values, similar findings were reported
by Fernández-Dueñas et al. (2008), who found that meat
from gilts had greater shear force values than barrows.
Stoller et al. (2003) reported similar Warner–Bratzler shear
force values for the longissimus muscle between barrows
and gilts. In addition, these authors observed that the per-
centage of intramuscular lipid was less in the longissimus
muscle from the gilts than barrows (2.27% v. 2.70%,
respectively), which concurs with the results of the present
study (Table 5). Differences in toughness can be caused by
a variety of factors, such as, differences in fiber type propor-
tions, sarcomere length, pH, temperature, fat, connective
structure and rate of tenderization (Huff-Lonergan et al.,
2000).

Chemical composition and IMC properties of LL are shown
in Table 5. The rearing system and diet did not significantly
affect the chemical composition of the meat. These findings
were partially supported by Enfält et al. (1997), who observed
no effect of the rearing system in intramuscular fat and ash of longissimus dorsi muscle; conversely, these authors reported a higher amount of protein in outdoor pigs than in indoor pigs. Other authors (Lebret, 2008) reported higher intramuscular fat in the m. longissimus in pigs reared outdoors; conversely, Sather et al. (1997) found that the longissimus thoracis muscle of pigs reared indoors had higher fat content compared with pigs reared outdoors.

No differences between sexes were detected for protein
and ash percentages. However, barrows had more (P < 0.05)
intramuscular fat than gilts, which is in line with the higher
carcass fat content observed for castrates, and greater
(P < 0.05) dry matter, a finding in accord with the literature
(Stoller et al., 2003; Fernández-Dueñas et al., 2008). These
findings are not surprising because castration favours intra-
muscular fattening of meat (Barton-Gade, 1987).

Collagen concentration and degree of collagen matura-
tion, expressed as HLP cross-link concentration, were not
influenced by the rearing system. In a previous work,
Maiorano et al. (2003) did not find any effect of rearing
system on longissimus muscle collagen content, but these
authors report an increase of HLP content and HLP/IMC ratio
in m. semimembranosus of outdoor pigs than their confine-
ment-reared counterparts. Differences in IMC amount and
cross-linking among muscles could be due to functional
and structural differences between locomotor and postural
muscles (McCormick, 2009).

Diet had a minimal influence on IMC properties. IMC
concentration decreased (+7.5%) with corn supplement
(P < 0.05), but there was no significant effect of diet on cross-
linking (µg/mg of HLP) and collagen maturity, as indicated by
the HLP/IMC ratio. In the present study, a positive correlation
(r = 0.334; P < 0.05) was found between shear force values
of cooked meat and collagen concentration values. Toughness
measurements made with a Warner–Bratzler shear are believed
to reflect both the myofibrillar and connective tissue compo-
nents of muscle (Harris and Shorthose, 1988). Connective
structure is believed to contribute to the initial toughness of
meat as well as the sensation of chewiness (Duizer et al., 1996).

Comparison of the sexes revealed no differences in
IMC characteristics, a finding in accord with literature (Corino
et al., 2008).

Conclusion
The results of the present study indicate similar hot and
cold dressing percentages, physico-chemical traits of LL
muscle and IMC properties of Polish Landrace pigs for both a
conventional rearing system and an alternative pig rearing
system, with indoor space and free outdoor access. Outdoor
pigs had less backfat thickness and slightly higher lean

Table 5  Mean value for chemical composition and IMC properties of Longissimus lumborum muscle

<table>
<thead>
<tr>
<th></th>
<th>RS°</th>
<th>Outdoor</th>
<th>Indoor</th>
<th>With corn</th>
<th>Without corn</th>
<th>Barrows</th>
<th>Gilts</th>
<th>s.e.</th>
<th>RS</th>
<th>D</th>
<th>G</th>
<th>Significance</th>
</tr>
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<tbody>
<tr>
<td>Chemical composition (%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Dry matter (%)</td>
<td>25.54</td>
<td>25.63</td>
<td>25.43</td>
<td>25.74</td>
<td>25.76</td>
<td>25.41</td>
<td>0.09</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
<td></td>
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<tr>
<td>Protein (%)</td>
<td>22.97</td>
<td>22.91</td>
<td>22.86</td>
<td>23.01</td>
<td>22.97</td>
<td>22.91</td>
<td>0.07</td>
<td>ns</td>
<td>ns</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fat (%)</td>
<td>1.43</td>
<td>1.59</td>
<td>1.45</td>
<td>1.57</td>
<td>1.65</td>
<td>1.37</td>
<td>0.07</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash (mg/g)</td>
<td>1.13</td>
<td>1.12</td>
<td>1.11</td>
<td>1.13</td>
<td>1.14</td>
<td>1.11</td>
<td>0.01</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collagen</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>IMC (µg/mg²)</td>
<td>18.92</td>
<td>19.58</td>
<td>18.50</td>
<td>20.00</td>
<td>19.18</td>
<td>19.32</td>
<td>0.35</td>
<td>ns</td>
<td>*</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLP/IMC (mol/mol)</td>
<td>0.11</td>
<td>0.11</td>
<td>0.12</td>
<td>0.10</td>
<td>0.11</td>
<td>0.11</td>
<td>0.01</td>
<td>ns</td>
<td>ns</td>
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<td></td>
<td></td>
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<tr>
<td>HLP (µg/mg²)</td>
<td>3.05</td>
<td>3.13</td>
<td>3.17</td>
<td>2.97</td>
<td>3.13</td>
<td>3.01</td>
<td>0.17</td>
<td>ns</td>
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</table>
percent, as well as a meat with lower pH and fat content than from the conventional system. In light of these results, alternative pig rearing systems with indoor space and free outdoor access could be an interesting production system for the Polish Landrace pig. However, additional studies are required to determine the benefits to the commercial producer and to the consumer. Compared with the pigs fed a diet with corn grain silage, those fed a diet without corn grain silage had lower neck percentage, higher lean and ham percentage, as well as higher IMC amount. Diet did not affect the main tissue components (lean, fat, skin and bone) of the ham and physico-chemical characteristics of meat. Compared with the gilts, barrows were fatter and showed a meat with different physico-chemical traits, which was slightly more tender and had similar IMC properties.

References


