Growth, carcass and meat quality of Casertana, Italian Large White and Duroc x (Landrace x Italian Large White) pigs reared outdoors

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Abstract

To compare growth, skeletal development, carcass traits and meat quality of different genotypes, 10 Casertana (CT), 10 Italian Large White (LW) and 10 Duroc x (Landrace x Italian Large White) (DU) crosses, barrows of 90 days of age, were allotted to the same outdoor rearing and feeding conditions. Live weight was recorded and average daily gain (ADG) was calculated. At slaughter (330-day-old) dressing and lean percentages were determined; backfat thickness and loin eye depth were measured; carcasses were dissected into commercial cuts. Water holding capacity, pH and colour (45 min and 24 h post-mortem) were measured. Longissimus lumborum muscle samples were collected for cholesterol, α-tocopherol and intramuscular collagen (IMC) analyses. CT compared to DU and LW had the lowest growth rate and skeletal development.

Casertana showed higher backfat thickness, lower lean cut/fatty cut ratio and less lean meat (P<0.05). Loin eye depth differed among genotypes with LW>DU>CT (P<0.05). CT showed higher red colour of the meat than DU and LW (P<0.05). CT compared to LW had the highest hydroxylysylpyridinoline (HLP) crosslink concentration and HLP/IMC ratio, and a lower IMC amount (P<0.05). Casertana pigs produced meat that could be tougher than that from the improved breed, but more acceptable from the technological point of view.

At eleven months of age bone weight, length and diameter were clearly genetic type-related; differently, the bone maturity was similar among the genotypes studied.

Introduction

The conventional pig production systems, suited for improved breeds, are generally thought to be associated with negative environmental impact and poor animal welfare, and is perceived to result in reduced meat quality (Bonneau and Lebret, 2010). Thus, in the near future, the pork industry has to pose pig production systems that satisfy consumer and citizen demands for lower environmental impact, improved animal welfare, and better meat quality (Edwards, 2005; Lebret, 2008). The use of native breeds, some of which are free range raised, apart from allowing a wider and more rational exploitation of marginal areas and avoiding the environmental problems of intensive farming, could provide products more acceptable to some consumers (Edwards, 2005). The general belief of a greater consumer acceptance of meat from unimproved pigs, particularly when reared outdoors, has been experimentally supported, in some European breeds: Iberian (Cava et al., 2000; Carrapio et al., 2003) and Corsican (Coutron-Gambotti et al., 1998). Nevertheless, for a better knowledge of their potential, it is advisable to evaluate their performance and meat quality in comparison to selected breeds under outdoor management.

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 (Pietrolà et al., 2006; Bonneau and Lebret, 2010; Maiorano et al., 2013). Interest in intensive outdoor pig production is also growing in Italy (Maiorano et al., 2007; Pietrolà et al., 2006). 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 prior to low capital investment, and the ability to be readily expanded.

Casertana (CT) is one of the few Italian local pig breeds that has survived despite the introduction of higher performing breeds. The CT pig is medium-small sized, the coat is bright black and mostly hairless, the standard type exhibits wattles. In the past, the breed was reared in Southern Italy for its productive performance, particularly as regards the fattening tendency (Pietrolà et al., 2006). Compared to pig lines highly selected for lean growth efficiency, the CT breed is characterized by slower growth rate and greater fatness (Pietrolà et al., 2006), nevertheless there is an increasing interest in Italy for the valorisation of its typical products, for its relevance as genetic reserve and for its usefulness for marginal rural area preservation and exploitation. Recently investigations were performed in order to better characterize genes involved in fattening (Dal Monego et al., 2007; D’Andrea et al., 2008; Daniele et al., 2008). However, very few data are available on growth and carcass composition of the CT breed (Fortina et al., 2005; Pietrolà et al., 2006; Maiorano et al., 2007). In addition, some studies on skeletal development of pig reported that the genotype influences the evolution of the metacarpal growth plate and, consequently, the development of long bones strictly related to composition of gain (muscle/fat/bone ratio) and therefore carcass quality (Field et al., 1990a; Filetti et al., 2003). Due to lack of interest in this breed in the past, few recent papers on meat and fat characteristics are available (Zullo et al., 2003; Maiorano et al., 2007; Salvatori et al., 2008) and some knowledge (Maiorano et al., 2007) exists on CT intramuscular collagen (IMC), responsible for the background toughness of meat (McCormick, 1999) and on yield from a technological point of view (Boutten et al., 2000). The purpose of this study was to increase knowledge regarding Casertana meat quality and also to compare growth, slaughter performance, meat quality and skeletal development of the CT breed to that of Italian Large White and Duroc x (Landrace x Italian Large White) crosses (one of the most widely used commercial crossbreeds), raised in an intensive outdoor farming system.
Materials and methods

Animals
Animal handling followed the recommendations of European Union directive 86/609/EEC and Italian law 116/92 concerning animal care.

The trial was carried out in Molise (Italy), on an experimental farm situated near the Abruzzi, Lazio and Molise National Park at 800 m asl. Ten Casertana, ten Italian Large White and ten Duroc x (Landrace x Italian Large White) barrows of 90±3-day-old, with an average starting live weight of about 22±0.8, 35±1.0 and 43±1.1 kg, respectively, were used. The CT pigs were randomly chosen among the progeny of 6 boars and 16 gilts collected from the different breeding areas. Animals belonged to different litters. The LW and DU pigs were purchased in commercial farms avoiding relatives. Parents of LW were recorded in the official methods of the Animal Science and Production Association (Martillotti et al., 1987). To calculate the food amount to be administered and the overall average daily weight gain, pigs were individually weighed (in the morning after an overnight fast) at the beginning of the trial, monthly and at slaughter. Weight gains were divided into 3 periods according to each feeding phase: growing phase (initial weight-60 kg of live weight), fattening phase (60-100 kg of live weight) and finishing phase (100- final live weight).

Slaughter surveys
After an on-farm fasting period of 8 h, the pigs were individually weighed and transported for 35 min to the abattoir. The pigs were hold in lairage for 4 h with free access to water. All the animals were slaughtered the same day at 330±3 days of age, according to procedures described by the Animal Science and Production Association (ASPA, 1991). Hot carcass weights were recorded. Backfat and loin eye depth were measured with Fat-O-Meater press method (Grau and Hamm, 1952).

Table 1. Pig performances and carcass traits during the trial.

|                       | CT | Genotype | DU | LW | SEM | P   |
|-----------------------|----|----------|----|----|-----|-----|
| No. of pigs           | 10 | 10       | 10 |    |      |     |
| Growth performances   |    |          |    |    |      |     |
| ADG (90-330 days), g/d| 478a | 674b | 729b | 0.21 | 0.009 |
| Final live weight, kg | 140.1a | 202.4b | 207.8b | 5.99 | 0.001 |
| Carcass traits        |    |          |    |    |      |     |
| Carcass weight, kg    | 112.0a | 161.9b | 168.6b | 4.90 | 0.001 |
| Dressing out, %       | 80.2 | 80.0 | 81.1 | 0.50 | 0.771 |
| Backfat thickness, cm | 5.1a | 3.4a | 3.1a | 0.21 | 0.001 |
| Loin eye depth, cm    | 5.2a | 8.3a | 9.3a | 0.36 | 0.001 |
| Lean meat yield, %    | 47.1a | 51.3b | 52.8b | 0.63 | 0.001 |
| Remarks on left side  |    |          |    |    |      |     |
| Ham, %                | 29.2 | 29.1 | 29.6 | 0.35 | 0.476 |
| Shoulder, %           | 13.8a | 16.5b | 17.0b | 0.39 | 0.026 |
| Loin, %               | 8.2a | 11.8b | 12.2b | 0.38 | 0.016 |
| Neck, %               | 5.3a | 6.5b | 6.9b | 0.16 | 0.021 |
| Lean cuts yield, %    | 56.5a | 63.9b | 65.8b | 0.90 | 0.012 |
| Fatty cuts yield, %   | 31.4a | 24.7a | 23.8a | 0.75 | 0.016 |
| Lean to fat cut ratio | 1.81 | 2.60b | 2.78b | 0.09 | 0.036 |

CT, Casertana; DU, Duroc x (Landrace x Italian Large White); LW, Italian Large White; ADG, average daily gain. *Ham, shoulder, loin, neck; **backfat, belly, jowl, kidney fat. a-cDifferent superscript indicate statistical differences (P<0.05).

Meat quality
Longissimus lumborum (LL) muscle samples were collected (after 24 h at 2 to 4°C), between the 2nd to the 5th lumbar vertebra, vacuum packaged and stored frozen (−40°C) until cholesterol, vitamin E (alpha-tocopherol) and intramuscular collagens (IMC) analyses.

pH, colour and water holding capacity
On LL the following determinations were carried out: i) pH was recorded 45 min (pH45) and 24 h (pH24) post-mortem using a portable HI 9625 pH meter (Hanna Instruments, Padova, Italy); ii) colour parameters L*, a* and b*, with a Minolta chromameter CR300. The Hue angle (tan−1 (b*/a*)) and Chroma (a*2 + b*2)1/2 were also computed. Reflectance measurements were performed after the samples had oxygenated in air for at least 30 min by which time measurements were stable (Škrlep and Čandek-Potokar, 2006). The temperature (T45 min and T24 h), measured at approximately 5 cm depth in the muscle, was from 38.9 to 39.5 °C and 3.2 to 3.4 °C at 45 min and 24 h post-mortem, respective-ly; iii) water-holding capacity (WHC) was determined as free water by the filter paper press method (Grau and Hamm, 1952).

Cholesterol analysis
Cholesterol was extracted using the method of Maraschiello et al. (1996) and then quantified by HPLC. A Kontron HPLC (Kontron Instruments, Milano, Italy) model 535 equipped with a C18 reverse-phase column (250x4.6 mm x 5 µm) (Phenomenex, Torrance, CA, USA) was used. The mobile phase was acetonitrile/2-propanol (55:45 v/v) at a flow rate of 1.2 mL/min. The detection wavelength was 210 nm and retention time was 13.89 min.

Alpha-tocopherol analysis
The levels of Vitamin E in the meat were determined and quantified according to the method described by Zapel and Csallany (1983) and then quantified by HPLC model 535 (Kontron Instruments) equipped with a C18
Collagen analysis

In order to study IMC properties, approximately 100 g of muscle (wet weight) were thawed, trimmed of fat and epimysium, lyophilized for 48 h, weighed, and hydrolyzed in Duran tubes in 6 N HCl at 110°C for 18 to 20 h (Etherington and Sims, 1981) for determination of hydroxyproline (Woessner, 1961) and crosslinking. All analyses were carried out in duplicate. IMC concentration was calculated, assuming that collagen weighed 7.25 times the measured hydroxyproline weight (Eastoe and Leach, 1958) and expressed as μg hydroxyproline/mg of lyophilized tissue. Hydroxylysylpyridinoline (HLP) concentration, the principal non-reducible crosslink of muscle collagen (McCormick, 1999), was determined using the high pressure liquid chromatography (HPLC) procedure developed by Eyre et al. (1984). Hydroxylysylpyridinoline was expressed as moles of HLP per mole of collagen and also as μg HLP/mg of lyophilized tissue.

Bone analysis

Distal portion of bones of anterior legs were collected from each carcase and the 3rd and 4th metacarpal (MC) bones were taken. Bones were cleaned of all connective tissue, measured for length, diaphyseal diameter and weighed. Dry weight of the 4th MC was recorded after 7 d at 100°C in a drying oven for moisture determination. Growth plate width on the distal end of the 3rd MC was measured after silver nitrate staining (Maiorano et al., 1999) of 4 longitudinal slices 2 mm thick cut on the sagittal plane. Three width measurements on bone slice were made on different anatomical locations 1/4, 1/2 and 3/4 the distance across the bone slice with microscopic examination. Therefore, the 12 measurements on each MC growth plate were averaged.

Statistical analyses

One way analysis of variance (ANOVA) was performed for all variables considered in the study (SPSS, 2010). Scheffe’s test was applied to compare the mean values of the genotype. Simple correlations were calculated among ultimate pH and colour variables using the same statistical package. Each individual pig was considered as the experimental unit.

Results and discussion

Growth and slaughter performance

In this trial, slaughter weight in LW and DU were higher than that recommended by the Italian pig industry because it was necessary to approach to the minimum slaughter weight (140 kg) for CT pigs. Growth performance and carcase traits are shown in Table 1. In agreement with the recent findings of Pietrola et al. (2006), CT pigs had lower (P<0.05) average daily gain (ADG) than the other two genotypes. The lower growth rate of the unimproved breed confirms the findings found in other Italian (Acciaioli et al., 2002; Filetti et al., 2003; Franci et al., 2003) and European (Legault et al., 1996; Serra et al., 1998; Alfonso et al., 2005) native breeds.

As a consequence of the differences in growth rates and in initial live weight among genetic types studied, the slaughter and carcase weights in CT were lower than those of the LW and DU (P<0.05) pigs. No statistical differences (P>0.05) in slaughter and carcase weights were detected between LW and DU pigs. No genetic type differences were found for dressing out. Comparisons involving CT and other breeds are scarce in literature, but in contrast with the present results, Pietrola et al. (2006) found some significant differences in dressing percentage between CT (81.4%) and Italian Large White (79.8%) pigs slaughtered at 151 and 179 kg of live weight, respectively. This different trend may be due to both different slaughter weight and fat deposition between pigs used in this experiment and those of Pietrola et al. (2006). Differently and in agreement with our findings, Alfonso et al. (2005) did not detect any difference in dressing percentage between Basque and Large White pigs. However, contradictory data regarding the dressing percentage comparison

Table 2. Average value for physical traits of Longissimus lumborum muscle.

|                  | CT       | Genotype | DU     | SEM  | P      |
|------------------|----------|----------|--------|------|--------|
| pH6              | 6.17a,b  | 6.13c    | 5.94e  | 0.05 | 0.020  |
| pH4              | 5.51     | 5.41     | 5.49f  | 0.02 | 0.271  |
| WHC, %           | 15.9     | 17.5     | 17.5   | 0.59 | 0.444  |
| Colour 45 min post-mortem | 35.47 | 35.53    | 37.82  | 0.33 | 0.514  |
| *                | 6.01     | 5.69     | 5.47   | 0.26 | 0.705  |
| *                | 1.22     | 0.86     | 1.19   | 0.22 | 0.770  |
| Chroma           | 6.12     | 5.74     | 5.60   | 0.30 | 0.662  |
| Hue              | 11.48    | 8.61     | 12.26  | 1.36 | 0.143  |
| Colour 24 h post-mortem | 39.60 | 43.43    | 42.24  | 1.94 | 0.320  |
| L*               | 9.26     | 7.34     | 8.35   | 0.42 | 0.415  |
| Chroma           | 13.13b   | 22.66b   | 20.34c | 1.54 | 0.042  |

Table 3. Average value for cholesterol and α-tocopherol content, and intramuscular collagen properties of Longissimus lumborum muscle.

|                  | CT       | Genotype | DU     | SEM  | P      |
|------------------|----------|----------|--------|------|--------|
| Cholesterol, mg/100g | 66.24   | 65.10    | 61.03  | 1.37 | 0.271  |
| α-tocopherol, μg/g   | 2.96     | 3.42     | 2.99   | 0.19 | 0.369  |
| IMC, μg/mg           | 19.88    | 26.72a   | 24.90c | 1.17 | 0.018  |
| HLP, μg/mg          | 5.30c    | 4.24a    | 2.60   | 0.41 | 0.004  |
| HLP/IMC, mol/mol     | 0.187b   | 0.113c   | 0.081e | 0.15 | 0.001  |
of native and improved pigs exist (Legault et al., 1996; Serra et al., 1998; Franci et al., 2003).

As expected, CT were fatter than DU and LW pigs, both for backfat thickness and fatty cut yield (P<0.05), while LW and DU pigs had higher (P<0.05) lean meat, and shoulder, loin and neck percentages, as well as lean cut yield and lean cuts/fatty cuts ratio. Comparable measurements for backfat thickness were found by Fortina et al. (2005) and Pietroš et al. (2006) on CT pigs and by Franci et al. (2005) on Cinta Senese pigs, slaughtered at different ages and weights. Moreover, significant differences (P<0.05) were detectable among genetic groups with regard to loin eye depth with LW>DU>CT. These findings confirm the general higher fat deposition of native breeds compared to improved pigs (Serra et al., 1998; Franci et al., 2005), and in addition, they confirm a large amount of variation in the genetic capacity to deposit lean tissue that exists among pigs. Ham percentage did not differ significantly (P>0.05) between the three genetic groups, although the hams of the commercial pigs were markedly (P<0.01) heavier (LW=24.9 kg, DU=23.6 kg) than those of the CT (16.3 kg), because ham weights are related to slaughter weight (Alfonso et al., 2005).

**Meat quality**

The results for pH, WHC and colour are reported in Table 2. It is well known that the ultimate pH of the muscle is an important contributing factor to meat quality; it is in turn dependent on the stress ante-mortem, the type of breeds and the genetic variation within breeds (Tarlouw, 2005). Genetic type influenced pH45 (P<0.05), but pH24 values were not significantly (P>0.05) affected and they are in acceptable range (5.5 to 5.8). Compared to CT and DU, LW showed the lowest pH45 value (5.94), indicating a faster rate of post-mortem glycolysis (Murray et al., 1989). Local breeds are less susceptible to stress ante-mortem factors than improved pigs (Alfonso et al., 2005).

Genetic type did not affect WHC or colour measurements, except for red and hue indexes which recorded 24 h post-mortem. Compared to the meat from improved pigs, the meat from CT pigs exhibited a redder colour (higher a* value; P<0.05) and lower hue value (P<0.05). The literature (Franci et al., 2005; Estévez et al., 2006) reports a meat more red in native breeds than in improved ones; this might also be explained at least in part by the growth of pigs and in part by the ultimate pH. In fact, Latorre et al. (2008) reported a negative correlation between daily growth and a* value in three different pig genotypes. In addition, DeVol et al. (1988) revealed a high positive correlation between Longissimus muscle colour and pH. On the other hand, in the present study was found a negative correlation (P<0.01) between pH45 and L* (r=–0.587), a* (r=–0.482) and b* (r=–0.463) values. Meat colour is the most important factor affecting consumer acceptance, purchasing decisions and satisfaction of meat products (Muchenje et al., 2009). Colour of pork is strongly associated with expected meat quality (Bredahl et al., 1998). Meat purchasing decisions are influenced by colour more than any other quality factor because consumers use discolouration as an indicator of freshness and wholesomeness (Mancini and Hunt, 2005).

Cholesterol content in carcasses of animals has long been identified as the single most important characteristic of overall meat quality (Newman, 1993) and limitation in cholesterol intakes, as well as fat intakes, is thought to be an important measure to prevent obesity and hypercholesterolaemia, conditions that are considered to predispose to various chronic diseases of the circulatory system (Chizzolini et al., 1999; Jiménez-Colmenero et al., 2001).

Genetic type did not significantly influenced the cholesterol content in LL muscle (Table 3). Similarly, Harris et al. (1993) found no effect of breed on cholesterol content of Longissimus and Semitendinosus muscles. Conversely, Lan et al. (1993) comparing muscle cholesterol content of several genetic types observed significant differences, but not among all breed studied. There are limited information in literature on the cholesterol content of the meat from CT pigs but the values detected in the present study for all the studied samples were quite high than that found by Maiorano et al. (2007) and Salvatori et al. (2008). The cholesterol content of pork reported in the literature varies. The discrepancy can be attributed to a number of factors, such as muscle type, age/weight of animal, environmental factors, feeding, and rearing system (Bragagnolo and Rodriguez-Amaya, 2002), as well as the use of different methodologies for cholesterol quantification or for sampling (Bragagnolo and Rodriguez-Amaya, 2002). All these factors make it very difficult to establish fair comparison, however cholesterol amount found in this experiment generally agrees with reported values (Harris et al., 1993; Lan et al., 1993; Chizzolini et al., 1999).

Muscle α-tocopherol concentration was similar among genotypes (Table 3), according to Nilsén et al. (2001). Similar values of α-tocopherol concentration have been noted in muscle from female, castrated male and entire male pigs (Högberg et al., 2004). Vitamin E is a powerful lipid-soluble antioxidant in biological systems, capable of breaking the chain of lipid oxidation in the cell membranes, thereby preventing the formation of rancid flavour during storage (Buckley et al., 1995).

**IMC characteristics are shown in Table 3. Genetic type clearly influenced IMC properties. IMC amount was lower (P<0.05) for CT in comparison to DU and LW, while DU and LW did not differ (P>0.05). Muscle HLP concentration (µg/mg) and collagen maturation (HLP/collagen) were higher (P<0.05) for CT in comparison to LW, with intermediate (P>0.05) values for DU. We supposed that these findings could be related both genotype and growth rate. In fact, this result partially confirms our previous research (Maiorano et al., 2003), reporting a higher collagen maturation (0.251 moles of HLP per mole of collagen) in native pigs (Cinta Senese breed) than in improved breeds. Other authors have reported a marked genetic effect on collagen properties in pigs (Lebret et al., 2001), beef (Campo et al., 2000) and lamb (Heinze et al., 1986). In addition, the literature documents growth rate-dependent differences (P<0.05).**
shifts in muscle collagen amount and/or crosslinking (Aberle et al., 1981; McCormick, 1994; Harper, 1999; Maiorano et al., 2007).

During rapid growth, newly synthesized collagen dilutes older collagen and is less crosslinked than the pre-existing collagen (Etherington, 1987), with a positive effect on meat tenderness (McCormick, 1994). An increase in IMC crosslinking leads to an increased IMC thermal stability, which has been related to undesirable changes in eating quality of meat (McCormick, 1999). On the other hand, Boutten et al. (2000) showed a positive relationship between collagen crosslinking and technological yield, demonstrating that collagen characteristics are also indicators of technological behaviour.

Metacarpal bone characteristics are shown in Table 4. Bone weight, length and diameter were clearly genetic type-related; CT pigs possessed smaller and lighter bones than other genotypes (P<0.05). Nevertheless, bone moisture and growth plate width (the site of genetic lines (P<0.05). Nevertheless, bone were smaller and lighter bones than other genotypes (P<0.05). Nevertheless, bone moisture and growth plate width (the site of genetic type-related characteristics of Basque and Large White pigs. Anim. Res. 54:33-42.

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Conclusions

In this work, new data describing productive performance, meat quality and skeletal development of the CT breed are reported. The CT pig was prone to adipogenesis and showed lower growth rate, lean cuts yield and skeletal development when compared to IW and DU pigs. This considerable difference is likely to be due to the fact that the CT was never submitted to modern selecting schemes and with the goals of fast growth rate and lean meat production. In addition, it should be emphasized the overall high values for HLP in the CT pigs, responsible for the positive effect on yield from a technological point of view. The productive aptitude of this Italian native pig suggests that the breed could be used for typical products.

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