PAPER

Effect of sire breed and rearing system on growth, carcass composition and meat traits of Cinta Senese crossbred pigs

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Abstract

The objective of this work was to evaluate, under indoors and outdoors rearing, the effect of crossing Cinta Senese (CS) with Italian Large White (ILW) and Italian Duroc (ID) breeds. Starting from 72 d of age, 9 CS, 8 ILWxCS and 7 IDxCS were reared outdoors (OUT) in 3 paddocks of 2 ha and 8 CS, 10 ILWxCS and 8 IDxCS pigs were reared indoors (IN) in three pens of 20 m^2. All pigs, fed the same commercial diets, were weighed and measured periodically and were slaughtered at a target live weight of 150 kg. Indoor-pigs grew faster than the outdoor ones and crossbred pigs showed higher average daily gain than CS breed (476, 437 and 387 g/d for IDxCS, ILWxCS and CS, respectively). Rearing system had moderate or null effect on carcass and sample cut composition whereas the OUT pigs, when compared to IN ones, showed higher moisture and lower IMF in *Longissimus L.* and *Psoas M.* muscles and higher cooking loss of meat (22.1 *vs* 18.4 %) that resulted also less red (a* 10.94 *vs* 12.04). CS had more fat in carcass and more bone in sample cut than the crossbreeds. ILWxCS showed lower IMF content and higher moisture in muscles and brighter and less red meat than the other breeds, while IDxCS produced the most tender meat after cooking. The use of Italian Duroc could be profitable on Cinta Senese to improve the farming performance without worsening the fresh meat quality.

Introduction

Cinta Senese is an Italian local pig reared mainly in Tuscany. Among the Italian autochthonous swine breeds, it has good chances to be developed due to the fair number of heads and the strong linkage to the ancient typical production and to the territory. At present, the breed represents one of the more interesting examples of a well done safeguard operation of autochthonous germoplasm and it is a witness of the link among rustic breed, territory and typical product. After the severe bottleneck in the eighties when its number dramatically fell at few dozen of animals, the Cinta Senese pig today seems to have recovered a significant market interest linked to the typicality and authenticity of its products, both fresh and seasoned. Averted the danger of extinction, the renewed interest on the breed requires a better understanding of its potential under different management system. In Southern Europe local breeds are often crossed with selected breeds to exploit additive and non-additive genetic effects, as in the production of Iberian pig crossed with Duroc breed (Carrapiso and Garcia, 2005; Ramirez and Cava, 2007). The crossbreeding could counterbalance some limits of Cinta Senese (CS) both *on vita* performances and on carcass traits. Crosses between CS and Large White (LW) were historically produced in the Tuscany Region (Raimondi, 1954) and recent studies have been conducted on this crossbred (Acciaioli *et al*., 2002; Franci *et al*., 2003, 2005), while no information are available concerning the use of Duroc as sire breed on Cinta Senese.

Additionally, swine rearing system alternative to the conventional one has recently attracted interest for animal welfare issue assuring new opportunities in niche retail marketing. The farming system for Cinta Senese and its crosses is the extensive pig-production, typical in the Mediterranean area, where the genotype-environment interaction results in measurable effects on pig performances and meat quality. Many studies compared the effect of rearing system on various pig breeds (Enfalt *et al*., 1997; Honeyman and Harmon, 2003; Pugliese *et al*., 2003; Bee *et al*., 2004; Gentry *et al*., 2004; Pugliese *et al*., 2005; Lebret *et al*., 2006). The objectives of this work were to evaluate, under indoor and outdoor rearing, the effects of cross with two improved breeds (Italian Large White and Italian Duroc) on growth performance and carcass and meat quality of Cinta Senese pigs.

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Materials and methods

Animals and rearing

Animal housing and husbandry procedures followed the norms of the European Council Directive 2008/120 (European Commission, 2008). Experimental pigs were obtained by mating 9 CS sows by 2 Cinta Senese, 2 Italian Large White (ILW) and one Italian Duroc (ID) boars. Birth occurred during a three-month period, in winter-spring season. At the age of three weeks, males were castrated. Castration was performed by a veterinarian under surgical anaesthesia with standard post surgery treatment. For the purpose of this trial, a total of 50 pigs were employed. Nine CS, 8 ILWxCS and 7 IDxCS pigs were reared outdoors (OUT) separately in 3 paddocks of about 2 ha each, where no extra feed was available. Eight CS, 10 ILWxCS and 8 IDxCS pigs were reared indoors (IN) in three distinct pens of 20 m^2. The distribution of the piglets in the two rearing systems occurred at an average weight of 18.2±3.6 kg and at an average age of 72.3±9.7 days, balancing for sex and litter, as possible. Pigs were fed the same commercial diets with 15% of crude protein up to 70 kg of live weight and 12.5% up to slaughter, both with 12.6 MJ/kg of metabolizable energy. Diets were distributed twice a day on a daily basis of 90 g/kg of metabolic weight up to a maximum of 2.8 kg/head/d. Feed consumption was not recorded but no refusals were left in pens and paddocks.

In vivo and *post-mortem* recording

Animals were weighed at birth, at weaning (avg 39 d), at allotment in the experimental groups and, afterwards, every three weeks. The average group weight was used to calculate the ration in the subsequent period. Pigs were slaughtered at a target live weight of 150 kg, on average. Slaughter occurred in three different days in which all the genetic types and rearing systems were adequately represented. After slaughter the following measures on right side were taken: carcass length, backfat thickness (separately for inner and outer layers) at the last thoracic (LT) vertebra and at *Gluteus Medius* (GM) muscle. The right side was dissected following ASPA methodology (ASPA, 1991) and lean cuts (loin, ham with foot, shoulder with foot, neck), fat cuts (backfat, belly, jowl, kidney fat) and bone cut (head), were weighed.

A portion of the loin (sample cut) including the 2nd to the 5th lumbar vertebra, from which subcutaneous fat was removed at side dissection, was dissected into total lean, *Longissimus lumborum* (LL), *Psoas major* (PM), intermuscular fat and bone. The cross sectional area of LL at the 2nd lumbar vertebra was measured.

On LL and PM moisture (by lyophilization), intramuscular fat (ether extract), protein and ash contents were determined (AOAC, 2000). On LL the following determinations were also carried out: i) pH recorded at 45 min (pH45) and 24 h (pH24) *post-mortem*; ii) colour parameters L*, a* and b*, with Minolta chromameter CR200. The hue angle (arctan (b*/a*)) and chroma $((a^*)^2 + (b^*)^2)^{1/2}$ were also computed; iii) water-holding capacity (WHC) determined as: drip loss on slices stored horizontally for 48 h at 4°C; free water by the filter paper press method (Grau and Hamm, 1952); cooking loss in water-bath on sample of 100 g of weight and 3 cm of height and width. Samples were cooked until internal temperature reached 70°C; iv) Warner-Bratzler (WB) shear force on raw and cooked meat, measured using an Instron 1011 apparatus on cylindrical cores of 2.54 cm of diameter (average of two measures).

Statistical analysis

Data were analysed with the SAS software package (2007) using appropriate models for the different traits as following.

For the evolution of live weight:

$$Y_{ijklm} = \mu + B_i + G_j + R_k + I_{ijkl} + (BxR)_{ik} + b_l(X_{ijklm}) + E_{ijklm}$$

where: Y = mth observation of the lth subject of kth rearing system, jth gender and ith breed; B = breed effect (i = 1...3); G = gender effect (j = 1, 2); R = rearing system effect (k = 1, 2); I= subject effect within breed, gender and rearing system; X = independent variable (age) tested up to the third degree; E = error random effect.

For initial and final weight and age:

$$Y_{ijkl} = \mu + B_i + G_j + R_k + (BxR)_{ik} + E_{ijkl}$$

where, besides the above definitions: Y = observation of the lth subject of kth rearing system, jth gender and ith breed.

For carcass and meat traits:

$$Y_{ijklm} = \mu + B_i + G_j + R_k + D_l + (BxR)_{ik} + b(X_{ijklm}) + E_{ijklm}$$

where, besides the above definitions: Y = mth observation of the lth day of slaughter, kth rearing system, jth gender and ith breed; D = day of slaughter effect (l = 1...3); X = independent variable (live weight) tested up to the third degree.

For initial and final weights and ages, and carcass and meat traits, no significant interactions were found (P>0.05) and therefore the model was reduced to main effects only. Similarly, a preliminary analysis did not show significant effect of the initial weight, that therefore was excluded from the final model.

The differences between least squares means (± s.e.) were statistically tested by the Student's *t*-test.

Results and Discussion

Growth performance

Figures 1 and 2 show the trend of body weight and average daily gain (ADG) in relation to age. ADG was calculated as first derivative of the primitive weight-age function. The outdoor system worsened growth performances in all genetic types despite animals fed the same ration, as shown also in Table 1 that reports the initial and final ages and weights and the overall ADG during the experimental period. The results are in agreement with those of other studies (Enfält *et al*., 1997; Acciaioli *et*

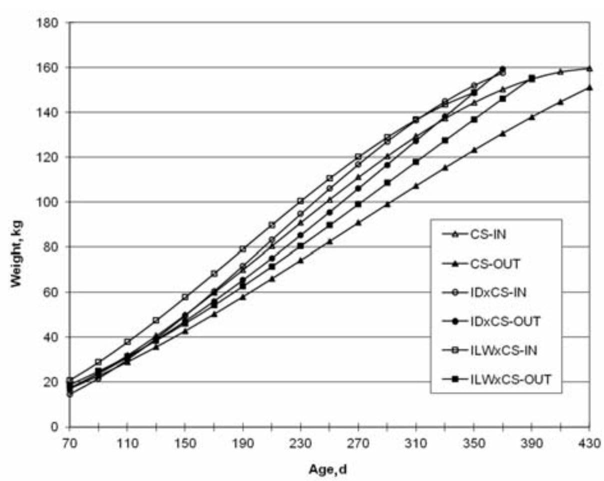

Figure 1. Evolution of live weight of pigs according to breed x rearing system combinations.

Table 1. Live weight, age and average daily gain in trial.

	Breed			Rearing system		RSD
	CS	IDxCS	ILWxCS	IN	OUT	
Initial age, d	78.3^a	75.1^a	62.8^b	71.5	72.6	9.3
Initial weight, kg	20.8^a	16.5^b	17.5^b	18.0	18.5	3.6
Final age, d	430^a	375.4^b	361.5^b	383.9	394.1	33.2
Slaughter weight, kg	154.6	157.8	147.3	155.6	150.9	13.6
Average daily gain, g	387^a	476^c	437^b	449a	418^b	60

RSD, residual standard deviation; CS, Cinta Senese; ID, Italian Duroc; ILW, Italian Large White; ^{a,b,c}within criterion, means with different letters differ (P<0.05).

al., 2002; Guy *et al*., 2002; Pugliese *et al*., 2003; Bee *et al*., 2004; Gentry *et al*., 2004) but disagree with experiments on pigs fed *ad libitum* (Lebret *et al*., 2006; 2011), where outdoor animals grew faster as consequence of higher feed intake. However, present results confirm the reduction of feed efficiency in pigs reared outdoors, due both to physical activity and to climatic conditions since the OUT rearing may contribute to increase energy requirements for spontaneous exercise (Fitts *et al*., 1973; Petersen *et al*., 1998) and for thermoregulation, especially in winter and summer periods (Lopez *et al*., 1991; Bee *et al*., 2004; Gentry *et al*., 2004).

As regard genetic effect, crosses with the improved breeds (Italian Large White and Italian Duroc) showed higher growth performance than the pure Cinta Senese pigs, confirming other works that compared local breeds with improved ones or their crosses (Serra *et al*., 1998; Acciaioli *et al.*, 2002; Serrano *et al*., 2008). As the behaviour of the crosses is concerned, it seems that ILWxCS pigs worsened their growth rate in outdoor system more than IDxCS did and, on overall, showed slightly lower ADG (Table 1). Comparisons for growth rate between Duroc and Large White, always tested in indoor rearing, are widely reported in literature with conflicting results. Better performance in progeny of Duroc boar than in that of LW boar was noted by McGloughlin *et al*. (1988) and Franci *et al*. (1994), up to 85 and 160 kg, respectively; Sabbioni *et al*. (2002) found a negative effect of the contribution of Duroc genes on LW up to 120 kg but positive afterwards; Liu *et al*. (1999) reported no significant differences in growth rate between Duroc and LW, both as pure-bred or crossbred.

Carcass traits

Table 2 reports carcass measurements and composition. As rearing system is concerned, significant differences on carcass measurements were found only on backfat thickness of outer layer at LT, higher in the indoor pigs. Carcass composition was not affected by rearing system, except for the ham percentage that was higher in the outdoor pigs. This result confirms the findings of Enfält *et al*. (1997) that outdoor rearing would induce greater development of glycolytic muscles, particularly muscles of the ham, and it is in agreement with the results obtained on Nero Siciliano pig by Pugliese *et al*. (2003, 2004), which found higher percentage of ham and of lean within ham in outdoor reared pigs. On the contrary, Lebret *et al*. (2002, 2011) did not show any significant effect of housing system on carcass muscle and ham percentage and on carcass

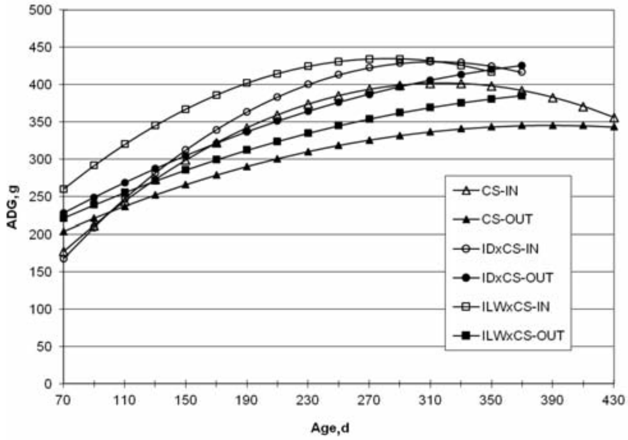

Figure 2. Evolution of average daily gain of pigs, calculated as first derivative of the equations of Figure 1, according to breed x rearing system combinations.

Table 2. Carcass measurements and composition.

	Breed			Rearing system		RSD
	CS	IDxCS	ILWxCS	IN	OUT	
Carcass length, cm	100.9[a]	103.9[b]	103.4[b]	103.0	102.5	3.31
Backfat thickness°, cm						
LT total	4.07[a]	3.24[b]	2.80[c]	3.42	3.32	0.48
LT outer layer	1.56[a]	1.41[ab]	1.22[b]	1.50[a]	1.30[b]	0.26
LT inner layer	2.50[a]	1.83[b]	1.58[b]	1.92	2.02	0.40
GM total	4.28[a]	2.95[b]	2.68[b]	3.36	3.25	0.66
GM outer layer	2.43[a]	1.70[b]	1.52[b]	1.96	1.81	0.47
GM inner layer	1.85[a]	1.25[b]	1.16[b]	1.40	1.44	0.31
Lean cuts, %	61.70[a]	66.46[b]	67.70[b]	64.90	65.68	2.09
Ham + feet, %	26.32[a]	27.44[b]	27.79[b]	26.89[a]	27.48[b]	0.91
Loin, %	14.09[a]	16.64[b]	17.30[b]	15.86	16.16	0.99
Shoulder + feet, %	16.21[a]	16.90[b]	17.06[b]	16.86	16.59	0.70
Neck, %	5.08[a]	5.48[b]	5.54[b]	5.28	5.45	0.39
Fat cuts, %	33.45[a]	28.53[b]	26.90[b]	30.08	29.18	2.36
Belly, %	14.82[a]	12.84[b]	12.66[b]	13.69	13.18	1.01
Backfat, %	8.13[a]	6.94[b]	5.43[c]	6.94	6.72	1.05
Jowl, %	6.69[a]	5.77[b]	6.08[b]	6.29	6.07	0.50
Kidney fat, %	3.81[a]	2.98[b]	2.74[b]	3.15	3.20	0.68
Head, %	4.62[a]	4.76[a]	5.15[b]	4.79	4.89	0.51

Carcass traits estimated at the average live weight of 152 kg; RSD, residual standard deviation; CS, Cinta Senese; ID, Italian Duroc; ILW, Italian Large White; °LT, at last thoracic vertebra; GM, at *Gluteus medius* muscle; [a,b,c]within criterion, means with different letters differ (P<0.05).

Table 3. Sample cut composition.

	Breed			Rearing system		RSD
	CS	IDxCS	ILWxCS	IN	OUT	
Sample cut weight, g	1481.6[a]	1862.5[b]	1833.4[b]	1718.5	1733.1	190.1
Total lean, %	82.76[a]	82.44[a]	85.02[b]	83.26	83.56	2.36
Longissimus lumborum	54.79[a]	52.41[b]	53.66	53.43	53.81	3.10
Psoas major, %	18.55[a]	19.54	20.42[b]	19.27	19.75	1.71
Other muscles, %	9.41[a]	10.49	10.94[b]	10.56	10.00	1.84
Intermuscular fat, %	3.66[a]	4.95[b]	3.94	4.25	4.11	1.59
Bone, %	13.60[a]	12.61	11.04[b]	12.49	12.33	2.67
Lean/bone	6.40[a]	6.96	7.96[b]	7.14	7.08	1.78
Area of LL, cm^2	42.96[a]	53.15[b]	58.53[b]	52.77	50.31	8.12

Sample cut composition estimated at the average live weight of 152 kg; RSD, residual standard deviation; CS, Cinta Senese; ID, Italian Duroc; ILW, Italian Large White; [a,b]within criterion, means with different letters differ (P<0.05).

fatness. Also in the present work the overall fatness of the carcass did not result statistical different between the rearing systems, despite the lower fat cuts content (about 1%) in outdoor pigs, but on this topic the literature is rather controversial since outdoor rearing, in relation to the conventional system, determined both increase (Gentry *et al*., 2004; Lebret *et al*., 2006) and decrease (Enfält *et al*., 1997; Bee *et al*., 2004) of carcass fatness. It is thus confirmed the higher variability in body composition of pigs produced in alternative rearing systems compared to conventional ones (Millet *et al*., 2005; Lebret, 2008).

As genetic type is concerned, the crossbreeds showed longer carcass than CS pure breed in agreement with the result obtained by Franci *et al*. (2003) on LW crossed with CS and by Serrano *et al*. (2008) on Duroc crossed with Iberian strain. Moreover, CS showed the thickest backfat at all the locations, consistent with the highest carcass fatness as showed by their composition in fat and lean cuts. The result confirms the well known higher adipogenetic ability of the unimproved breeds (Labroue *et al*., 2000; Franci *et al*., 2003, 2005; Renaudeau *et al*., 2005, 2007; Serrano *et al*., 2008) and it was expected since the genetic selection in pigs led to the increase of growth rate and to the reduction of body fat, as observed by Wood *et al*. (2004) comparing modern breeds (Duroc and Large White) with the traditional ones (Berkshire and Tamworth).

The comparison between the two crossbreeds indicates that backfat of IDxCS was thicker than that of ILWxCS, irrespective of the location, although the statistical significance is reached only for the total LT location. This result confirms the general higher carcass adiposity of IDxCS, at least in the absolute value of total fat cuts, that became statistical significant only for backfat percentage. In turn, ILWxCS showed higher percentage of head, also in comparison with CS pure breed. When compared as pure or sire breed, Duroc and Large White showed conflicting reciprocal results on carcass composition. Sabbioni *et al*. (2002) found that Duroc genes determined thicker backfat at shoulder level, but had no effect on the carcass composition. Instead, McGloughlin *et al*. (1988) and Channon *et al*. (2004) reported no differences in fat thickness, while for Affentranger *et al*. (1996) and Enfält *et al*. (1997) Duroc sire determined more fat in back and in ham than Large White or Yorksire ones. The variability of these results is confirmed in other researches that assessed the differences among Duroc genetic lines, as it regards carcass fatness (Cilla *et al*., 2006; Ramirez and Cava, 2007) and it must be reminded that Duroc breed employed in the present experiment is the line selected for the typical Italian heavy pig production, where no particular emphasis against the subcutaneous fat is applied (ANAS, 2010).

Sample cut composition and meat traits

Table 3 shows the sample cut traits. Neither for tissue composition nor for the area of LL any effect of rearing system was detected, while the comparison among the breeds showed several differences. It is noteworthy that this sample cut did not include the subcutaneous fat surrounding the loin portion. So, at the same live weight of 152 kg, the weight of sample cut and the area of LL were significant lower in CS than in crossbred pigs, in agreement with the differences found for loin percentage on the carcass (Table 2) and consistent with the results of previous experiments (Pugliese *et al*., 2004; Franci *et al*., 2005). The partition of the main tissues shows that ILWxCS had the highest lean percentage, IDxCS exhibited more intermuscular fat than CS, CS had higher bone percentage than ILWxCS. On overall, the lean/bone ratio was higher in ILWxCS than in CS with the IDxCS pigs in intermediate position. Within the lean portion, CS pig had more LL than IDxCS and less PM than ILWxCS.

As regard chemical composition of the muscles (Table 4), outdoor system determined higher moisture both in LL and in PM and significant lower fat content in PM. Literature is controversial on the influence of alternative housing system on intramuscular fat content, as reviewed by Millet *et al*. (2005). For instance, outdoor rearing, in respect to the indoor one, determined lower IMF content (Enfält *et al*., 1997; Gentry *et al*., 2002); or similar values (Van der Wal *et al*., 1993; Lebret *et al*., 2002); or higher IMF content (Lebret *et al*., 2006, 2011; Trombetta *et al*., 2009). However, in the present trial, even if the three fat compartments (subcutaneous, intermuscular and

Table 4. Chemical composition (percentage on wet basis) of muscles of sample cut.

		Breed		Rearing system		RSD
	CS	IDxCS	ILWxCS	IN	OUT	
Longissimus lumborum						
Moisture	69.87^{a}	69.94^{a}	71.43^{b}	69.87^{a}	70.95^{b}	1.83
Protein	22.94^{a}	22.13^{b}	22.99^{a}	22.78	22.58	0.65
Fat	6.01^{a}	6.72^{a}	4.43^{b}	6.26	5.17	2.16
Ash	1.12	1.08	1.24	1.19	1.11	0.25
Psoas major						
Moisture	72.16^{a}	73.38^{b}	73.84^{b}	72.60^{a}	73.64^{b}	0.87
Protein	22.07^{a}	21.61^{b}	22.13^{a}	22.08	21.79	0.70
Fat	4.13^{a}	3.40^{a}	2.41^{b}	3.75a	2.87^{b}	1.15
Ash	1.26	1.25	1.20	1.24	1.23	0.19

RSD, residual standard deviation; [a,b]within criterion, means with different letters differ (P<0.05).

Table 5. Physical properties of *Longissimus lumborum*.

		Breed		Rearing system		RSD
	CS	IDxCS	ILWxCS	IN	OUT	
pH_{45}	6.51	6.58	6.41	6.46	6.55	0.25
pH_{24}	5.68	5.61	5.61	5.59^{a}	5.67^{b}	0.12
Colour parameters						
L*	45.52^{a}	49.60^{b}	49.14^{b}	47.94	48.24	2.65
a*	12.29^{a}	11.82^{a}	10.35^{b}	12.04^{a}	10.94^{b}	1.60
b*	3.04	3.59	3.33	3.44	3.21	1.02
Chroma	12.69^{a}	12.35^{a}	10.92^{b}	12.56^{a}	11.41^{b}	1.75
Hue	0.24^{a}	0.29^{b}	0.31^{b}	0.28	0.28	0.06
Drip loss, %	1.89^{a}	2.76	3.27^{b}	2.57	2.72	1.55
Cooking loss, %	19.90	19.25	21.51	18.35^{a}	22.09^{b}	4.54
Free water, cm^2	9.46	10.36	9.05	9.66	9.59	2.10
WB on fresh meat, kg	10.16	10.90^{a}	9.72^{b}	10.14	10.38	1.56
WB on cooked meat, kg	11.60^{a}	9.65^{b}	11.32^{a}	10.62	11.09	2.33

RSD, residual standard deviation; CS, Cinta Senese; ID, Italian Duroc; ILW, Italian Large White; WB, Warner-Bratzler shear force; [a,b]within criterion, means with different letters differ (P<0.05).

intramuscular) exhibited analogous behaviour in relation to the rearing system, with a tendency to general higher adiposity for indoor housed pigs, it is noteworthy that only at the muscular level the difference became significant, confirming the high sensibility of this depot to environmental manipulation (Lebret *et al.*, 2011)

The genetic effect appears more important and affected in similar way both muscles. ILWxCS pig exhibited higher moisture and lower fat content than the other two breeds that, in turn, appeared with a similar meat composition with the exception of the protein content, lower in IDxCS pigs, also in respect to ILWxCS. The higher IMF content in the local pig than in the improved one (white breeds) is well known and demonstrated also in recent works (Labroue *et al.*, 2000; Estévez *et al.*, 2003; Franci *et al.*, 2005), as it is also well known the importance of contribution of Duroc genes in increasing the IMF content (Lo *et al.*, 1992; Enfält *et al.*, 1997; Channon *et al.*, 2004; Lebret *et al.*, 2011). On the other hand, Duroc breed, widely employed for crossbreeding with Iberian strain, exhibited important differences in IMF content among its genetic lines (Cilla *et al.*, 2006; Ramirez and Cava, 2007). However, Ventanas *et al.* (2006), Serrano *et al.* (2008) and Juàrez *et al.* (2009) reported lower IMF content in LL or PM of pigs sired by Duroc than in those sired by several Iberian strains. Instead, in the present trial, the crossbreeding of Italian Duroc on Cinta Senese did not decrease the fat content in both tested muscles while, as the other fat depots is concerned, determined an increase of intermuscular fat of loin (Table 3) and, mainly, a marked reduction of carcass fatness (Table 2).

Table 5 shows the results on pH and physical traits of LL. Differences between the rearing systems are evident on some parameters: outdoor-pig exhibited higher pH24, less water holding capacity (statistical significant only for cooking loss) and lower colour intensity (chroma) due to the lower a* value (red component). Other researches indicate that, generally, the outdoor rearing did not determine variation on pH_1 and pH_u of *Longissimus* muscle and increased the drip loss (Gentry *et al.*, 2002; Bee *et al.*, 2004; Lebret *et al.*, 2011). In particular, according with the present trial, Enfält *et al.* (1997), employing the same three methods for WHC determination, found always higher loss in outdoor pigs even if the significance was reached only in drip loss. On the other hand, the same Authors found higher shear force value in meat of the outdoor pigs, in contrast with the present results. Also the influence of rearing system on colour, here found, is not confirmed in the literature which generally did not report differences between the two rearing systems (Gentry *et al.*, 2002; Bee *et al.*, 2004) or, eventually, showed higher b* value in meat of outdoor pigs (Lebret *et al.*, 2006, 2011).

As genetic effect is concerned, ILWxCS had higher drip loss than CS while IDxCS had intermediate value, but no differences were found for the other measures of WHC. The raw meat of Italian Duroc sired pigs was more tough than that of the other breeds (significant vs. ILWxCS) but it became the most tender after cooking. Moreover, for the colour parameters, the Italian Duroc progeny behaved as Italian Large White cross, having higher L* and Hue values than CS, and as CS pure breed showing higher values of a* and Chroma than ILWxCS. The literature on the comparison between local and selected pigs, in relation to physical properties of meat, partially confirms this results. In a previous experiment, Franci *et al.* (2005) found that the meat of CS was more red and tough and had higher WHC than that of LW pure breed but these differences remained only for WHC when the comparison involved the LWxCS cross. French local breeds showed more red meat than the Large White (Labroue *et al.*, 2000). Several strains of Iberian pig exhibited darker and redder meat than commercial (Landrace x Large White) or Iberian x Duroc pig (Estevez *et al.*, 2003; Juàrez *et al.*, 2009). On the other hand, Duroc lines appeared quite different from each other as WHC and colour is concerned (Ramirez and Cava, 2007; Serrano *et al.*, 2008) while the comparison of Duroc with the other improved breeds highlighted only its lower WB shear value (Enfält *et al.*, 1997; Juàrez *et al.*, 2011).

Conclusions

The rearing system had great impact on the growth rate of pure and crossbred Cinta Senese pigs, in controlled feeding conditions, even if, the worst performance due to outdoor rearing seemed attenuated on Italian Duroc crosses. On the contrary, the effect on carcass quality and meat quality was limited to a lower content of intramuscular fat and higher cooking loss in outdoor pigs.

The genetic effect was more evident than the rearing one and, besides the confirmation of the behaviour of the crosses with Large White, it is interesting the evaluation of the employ of the Italian Duroc breed on Cinta Senese, never tested previously. This breed, in fact, improved carcass traits in the reduction of fatness in a similar way as Italian Large White did, but maintained the same level of IMF of Cinta Senese with meat that showed the same redness, similar WHC and even more tenderness after cooking.

The use of Duroc, at least of the line selected for Italian heavy pig here tested, could thus be used profitably in crossing on Cinta Senese to improve aspects of the farming economy (growth, feed efficiency and carcass traits) without negative effects on meat quality.

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