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To cite this article: Maria Federica Trombetta, Simona Mattii, Marina Pasquini & Adalberto Marina (2009) Influence of diet and rearing system on heavy pig performance, carcass and meat quality, Italian Journal of Animal Science, 8:1, 23-35, DOI: 10.4081/ijas.2009.23

To link to this article: http://dx.doi.org/10.4081/ijas.2009.23

Influence of diet and rearing system on heavy pig performance, carcass and meat quality

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ABSTRACT

Identifying alternative dietary protein sources and new types of outdoor rearing techniques that enhance animal welfare, thus optimising costs and production performance, are among the main objectives of nutritionists and breeders. The aim of this study was to compare two types of rations where pea and potato concentrate completely substituted soybean in intensively and extensively bred swine.
Forty Large White × Duroc piglets weighing about 40 kg were divided into 4 groups of 10 sex- and weight-matched individuals: Indoor rearing + Control diet, Indoor rearing + Experimental diet, Outdoor rearing + Control diet, Outdoor rearing + Experimental diet. Different diets were formulated for the growing phase (40-100 kg) and the fattening period (100-slaughter); pigs, weighed individually every 40 days to estimate the average daily gain and feed conversion rate, were slaughtered when they reached the weight for Italian ham production. The following measurements were obtained: carcass weight, slaughtered yield, weight of lean cuts, pH 45 minutes and 24 hours *post mortem*. 40 *semimembranosus* muscle samples were analysed for colour parameters (L*, a* and b*), moisture, fat, protein and ash while the energy values were calculated. *Semimembranosus* intramuscular fat and ham backfat were analysed for fatty acid profile.
Statistical analysis of performances data was conducted using design with repeated measures and the slaughterhouse, meat and fat composition data were subjected to ANOVA. The results show that soybean can be completely substituted with other protein crops. Rearing and slaughterhouse performances were not affected by the diet, whereas significant differences emerged with the rearing system. Diet composition significantly affected lean meat proportion (50.0 *vs* 48.2) and fat thickness of 3/4 Thoracic Vertebra (25.3 *vs* 28.3 mm), while the rearing system significantly affected all carcass quality measures. Some parameters were better in outdoor-than indoor-subjects. Meat colour was also significantly influenced by the rearing effect, being less light and yellow in the former subjects (L* 49.9 *vs* 37.3; b* 3.7 *vs* 2.3). Chemical analysis demonstrated that the meat of outdoor-reared subjects was leaner (1.96% *vs* 1.38% fat) and had a lower water content (72.8% *vs* 71.8%).
The complete replacement of soybean is thus compatible with a strong characterization and an enhancement of the value of swine products. In addition, the rearing system can result in distinctive quality features, such as ham colour and fat content, allowing products from outdoor rearing to be clearly recognized from those obtained from intensive rearing.

Key words: Pig, Diet, Rearing, Performance, Quality.

RIASSUNTO

INFLUENZA DELLA DIETA E DELLA TECNICA DI ALLEVAMENTO DEL SUINO PESANTE
SULLE PERFORMANCE E SULLA QUALITÀ DELLA CARCASSA E DELLE CARNI

La ricerca di fonti proteiche alternative e l'applicazione di nuove tipologie di allevamento all'aperto o con spazi più ampi a disposizione degli animali per un migliore benessere sono oggi aspetti di grande interesse sia per il nutrizionista sia per l'allevatore.

A tale scopo, sono stati utilizzati 40 suini Large White x Duroc del peso iniziale medio di 40 kg, che sono stati divisi omogeneamente in 4 gruppi: Allevamento in box + dieta controllo; Allevamento in box + dieta sperimentale; Allevamento open air + dieta controllo; Allevamento open air + dieta sperimentale. Sono state formulate due diverse diete per il periodo di accrescimento (40-100 kg) e per il periodo d'ingrasso (100 kg-macellazione). I suini, ogni 40 d, erano sottoposti a controlli ponderali per aggiustare la razione e calcolare l'AMG. In occasione delle pesate si prelevavano campioni di mangime per controllarne la composizione. Al raggiungimento del peso richiesto per la produzione del suino pesante i soggetti sono stati portati al macello 24 ore prima della macellazione; i gruppi sono stati tenuti separati e al macello si è rilevato il peso vivo, il peso della carcassa, il peso dei tagli magri e si è controllato il pH a 45' e a 24 ore. Dopo 24 ore di raffreddamento i prosciutti sono stati sottoposti alla rifilatura ed è stato registrato il peso, si è determinato il pH e il colore sul muscolo semimembranosus; *40 campioni di muscolo* semimembranosus *sono stati analizzati per proteine, grasso e ceneri. I campioni di carne e di grasso del prosciutto sono stati analizzati per la composizione acidica.*

I dati di allevamento sono stati sottoposti all'analisi statistica per dati ripetuti mentre quelli di macellazione e della qualità sono stati analizzati mediante ANOVA. L'analisi statistica non ha evidenziato, per i parametri analizzati, effetti dovuti al tipo di dieta. Solo la percentuale di carne magra (50% vs 48,2%) e lo spessore di lardo alla 3/4 vertebra toracica (25,3 vs 28,3 mm) sono stati influenzati dall'effetto dieta. Il tipo di allevamento invece ha influenzato in maniera significativa le performance di accrescimento che sono state migliori per i soggetti indoor, *tutte le caratteristiche qualitative della carcassa (carne magra 47,9% vs 50,3%, spessore del grasso alla 3/4 vertebra lombare 31,2 vs 24,3 mm e 3/4 vertebra toracica 29,3 vs 24,1) e della qualità (contenuto di grasso 1,96 vs 1,38%) sono risultate migliori per i suini allevati* outdoor. *I risultati ottenuti con questa prova sperimentale ci indicano che la soia può essere sostituita con altre proteaginose nella formulazione delle diete per suini e che la tipologia di allevamento influenza significativamente sia le performance di allevamento che di macellazione.*

Parole chiave: *Suino, Dieta, Allevamento, Performance, Qualità.*

Introduction

Finding alternative dietary protein sources and new types of outdoor rearing techniques that enhance animal welfare, thus optimising costs and production performance, are priorities for nutritionists and breeders. The provenance of soybean, at present the main protein crop in the diet of monogastric animals, largely from genetically modified plants is prompting its replacement with other protein sources (Sundrum *et al.*, 2005).

Low protein diets without amino acid integration give negative consequences on the performances of monogastric animals.

Therefore in swine rearing the protein supply must be adjusted in amino acids content (which are essential for body protein biosynthesis). The optimum amino acid levels in swine diet have been extensively studied, taking into account genetic type, age, physiological state and sex (INRA, 1984; D'Mello, 1994; Lyczynski *et al.*, 2003). Most researchers concur in considering lysine as the major limiting amino acid, whose supply in the ration needs to be indicated explicitly, because any variation in its absolute content affects the utilization of other amino acids (Sundrum *et al.*, 2005).

Soybean, whose high biological value is due to its excellent amino acid profile, can be

replaced by leguminous seeds such as peas, faba beans and lupin. Most seed legumes are used both in human and animal diets; their protein contents range from 28.5% in *Vicia faba* to 36% in *Lupinus albus*. All leguminous plants are high in lysine but low in sulphurated amino acids; for instance, peas have a higher lysine content than soybeans (7 g/16 gN *vs* 6.2 g/16 gN), but only 2.4 g/16 gN sulphurated amino acids compared with 3.4 g/16 gN of soybean (Sundrum *et al.*, 2005). Factors that have an adverse effect on digestibility also need to be taken into account, such as high lecithin content (in peas); lecithin can bind to sugars forming glycoproteins that limit intestinal absorption (de Lange *et al.*, 2000). Treatments like seed decortication, expansion, extrusion, and toasting can address these problems (de Lange *et al.*, 2000; Sundrum *et al.*, 2005).

The rearing mode can also affect performances. The few available data for heavy pigs production about the substitution of soybean with legume seeds during growth and fattening, and the equally scanty information on the performances and meat quality of subjects bred outdoors (Petersen *et al.*, 1998; Pugliese *et al.*, 1999; Bonomi, 2005; Franci *et al.*, 2005; Stein *et al.*, 2006) prompted us to compare two types of rations, where pea and potato concentrate completely substituted soybean in intensively and extensively bred swine.

Material and methods

Forty Large White × Duroc piglets weighting about 40 kg at purchase were bred at the teaching-experimental farm "Pasquale Rosati" of the Polytechnic University of Marches, Ancona, Italy. They were divided into 4 groups of 10 sex-and weight-matched individuals according to the scheme:

    indoor rearing + control diet
    indoor rearing + experimental diet
    outdoor rearing + control diet
    outdoor rearing + experimental diet.

The experimental design started in May and ended in November for indoor rearing (187 day) and December for outdoor rearing (204 day). The mean temperature of the May-August period was 20.9°C and that of September-November was 14.2°C. Indoor-bred pigs were housed in pens (1.5 sqm/head) with a rest area and an external area for moving and feeding. Outdoor-bred swine were kept in one of two 300 sqm paddocks, divided by diet. The paddocks, bordered by an electric fence, were endowed with huts for rest and shelter and with a pool for cooling in the summer. There were 5 water troughs; dry feed was placed in mangers allowing simultaneous feeding by all 10 subjects. The difference in rearing system was due to available area for each pig: 1.5sqm/head in the indoor system *vs* 30sqm/head in the outdoor system.

The diet formulations are reported in Table 1. There were two diets for each group, one for the growing phase from 40 kg to 100 kg, and another for the fattening phase from 100 kg to slaughter. In the two experimental diets, soybean was completely substituted by peas and potato concentrate. The chemical characteristics of each feed was checked monthly and the mean values are reported in Table 2. The fatty acid composition of fattening diets (Table 3) was very similar except for $C_{20:0}$ in the experimental ration compared with the control fattening ration (0.32% *vs*, n.d). The feed, accounting for 8% of metabolic body weight (Ricci Bitti *et al.*, 1975), was administered twice daily and without supplement of diet for pigs reared open air. Subjects were weighed individually every 40 days after 12 h feed restriction using an Omega electronic scale to adjust feed rations and estimate the average daily gain (ADG) of the period and the feed conversion rate (FCR) of the whole experiment.

Table 1.   Diet formulation (%).

	Growing phase		Fattening phase	
	Control	Experimental	Control	Experimental
Barley	13.0	16.0	16.6	16.6
Corn	37.6	37.6	40.0	40.0
Wheat flour middling	7.0	7.0	7.0	7.0
Bran Wheat	17.0	14.0	17.0	17.0
Soybean meal 44	18.0	-	14.0	-
Pea	-	10.0	-	8.0
Potato concentrate	-	8.0	-	6.0
Molasses of beet	4.0	4.0	3.0	3.0
Animal fat	1.0	1.0	-	-
$CaCO_3$	1.0	1.0	1.0	1.0
NaCl	0.5	0.5	0.5	0.5
$CaHPO_4$	0.5	0.5	0.5	0.5
Vit.-min. supplement	0.4	0.4	0.4	0.4

Table 2.   Chemical composition of growing and fattening diets (% as fed).

	Growing phase		Fattening phase	
	Control	Experimental	Control	Experimental
DM	87.0	87.0	87.5	87.5
Crude protein	15.0	15.0	14.1	14.1
Ether extract	3.7	3.7	2.8	2.8
Crude fibre	4.8	3.9	4.6	4.4
Ash	6.3	4.9	5.4	5.6
Phosphorus*	0.50	0.50	0.40	0.40
Calcium*	0.60	0.60	0.45	0.45
Lysine**	0.80	0.80	0.71	0.76
Methionine**	0.25	0.27	0.29	0.30
Threonine**	0.58	0.45	0.53	0.44
Digestible Energy** kcal/kg	3110	3235	3065	3125

*According to NRC, 1998.
**Estimated value.

Table 3.   Fatty acid composition (%) of diets.

	Fattening diets	
	Control	Experimental
C14	0.26	0.29
C16	13.98	14.08
C16:1	0.22	0.22
C18	1.56	1.54
C18:1	19.42	19.06
C18:2	53.39	51.39
C18:3	5.05	5.63
C20:0	nd	0.32
C20:1	0.091	0.091
C22:0	nd	0.036

nd=not detectable value.

When they reached the required weight for Italian heavy pig production (about 150 kg), they were moved to a slaughterhouse 24 hours before slaughtering and housed so as to maintain group identification. The outdoor and indoor groups were slaughtered on different dates.

After slaughtering the carcasses were weighed and the proportion of lean meat and fat thickness at 3/4 Lumbar vertebra (LV) and 3/4 Thoracic vertebra (TV) were assessed with Fat O' Meater (FOM SFK Technology), then the carcasses were dissected and the following data were obtained: slaughter yield, weight of lean cuts (ham, loin, shoulder); pH at 45 minutes and at 24 hours *post mortem* was assessed using a pH meter with an Ingold needle in the *semimembranosus* muscle of the right hindleg. After a 24 h cooling period, the ham was trimmed and the ham weighed again.

The 40 *semimembranosus* muscle samples were analysed for colour parameters (L*, a* and b*) with a Minolta Chroma Meter CR200 with D65 light; chroma ($(a^2+b^2)^{½}$)

and hue (arctang b/a) were also computed. Moisture was determined by lyophilisation and intramuscular fat as ether extract; protein content (Kijehldal), ash (muffle at 550°C) were analysed while the energy values were calculated.

Semimembranosus intramuscular fat and ham backfat were analysed for fatty acid profile. Fatty acid methyl esters were prepared by esterification according to Rodriguez *et al.* (1998) and analysed by gas chromatography using a Chrompack CP9001 apparatus equipped with a flame ionisation FID. Fatty acid separation occurred in a silica-coated capillary column (length 50 m and internal diameter 25 mm). The detector's initial temperature was 150°C, reaching a final temperature of 250°C with 3°C/min increases. The carrier gas was nitrogen. Individual methyl esters were identified by their retention time compared with the retention time of standard methyl ester.

A repeated measure analysis was applied to data according to the model:

$$Y_{ijk}=\mu+T_i+P_j+D_k+(TxD)_{ik}+(TxP)_{ij}+(DxP)_{kj}+ +(TxDxP)_{ijk}+ \varepsilon_{ijk}$$

Where Y_{ijk} is the response variable, μ is the overall mean of the population, T_i is the mean of dietary treatment (i=1 to 2), P_j is the mean effect of sampling (j=1 to 6) with sampling as a repeated factor, D_k is the fixed effect for "rearing system" (k=1 to 2), $(TxD)_{ik}$, $(TxP)_{ij}$ and $(TxDxP)_{ijk}$ are the interaction and ε_{ijk} is the unexplained residual element assumed to be independent and normally distributed. Data computations were performed using the repeated measure statement of the SPSS (1997), which corresponds to the PROC MIXED procedure of SAS (1999). To test partial interaction of sampling between diets, simple contrast were used, comparing 50 d and 35 d *vs* 20 d sampling time.

The slaughtering data were analysed using analysis of variance within GLM procedure (JMP 3.1.5 package, SAS Institute, 1995) using diets, rearing system as factors, interaction (diet* rearing system) was eliminated from the model because it was not significant.

Results and discussion

The initial and final live weights in relation to diet and rearing mode effects are reported in Table 4. The rearing system did affect results, with a significantly (P<0.01) higher weight at slaughter (177.95 *vs* 159.95 kg) achieved in a slightly shorter time in intensively bred pigs (187 *vs* 204 days) and also ADG_T (0.726 *vs* 0.586) was better; while the substitution of soybean did not induce significant differences. This is less than the times reported by Falaschini *et al.* (1995) for hybrid pigs with a similar initial weight bred intensively and by Falaschini *et al.* (2000) for subjects bred outdoors. The ADG data (Figure 1) showed significant differences (P<0.01) due to the rearing mode, while the diet effect was not significant. Our average figures are higher than those described by Falaschini *et al.* (1995) for intensively bred hybrids, and those for our outdoor-bred animals are better than those of Falaschini *et al.* (2000) for outdoor

heavy pigs. As expected, growth rates were better in animals bred indoors than those bred outdoors. In particular, at the first time point the average daily gain of the outdoor subjects (ADG_1) was markedly lower than that of their counterparts (Figure 1). This is to be ascribed to physiological adaptation to the rearing system, as piglets came from a traditional farm. The opposite effect was noted for ADG_3, probably due to the fact that this time point fell in the summer, when greater feed waste and greater water intake may have accelerated intestinal transit times in relation to less favourable environmental conditions (temperature, air velocity) among indoor-bred animals. At the next check, the weight of indoor-bred individuals recovered and remained high until the last check. The overall FCR (Table 4) is acceptable, but is significantly better for the indoor group. The higher index calculated for the outdoor group confirmed the data obtained by Falaschini *et al.* (2000) for heavy pigs bred in a similar way, indicating that a part of the energy supplied by the ration is spent on motor activity. However, our FCR was similar in absolute terms to those reported by Suzuki *et al.* (2003) for Duroc and Berkshire subjects weighing 70 to 105 kg.

Performance parameters at slaughter are listed in Table 5. Carcass weight was significantly heavier (P<0.01) in subjects

Table 4.   Live weight, Average Daily Gain and Feed Conversion Rate (mean ± SE).

		Diet (D)		Rearing system (RS)		Level of significance	
		Control	Experimental	Indoor	Outdoor	D	RS
Initial weight	kg	40.50 ± 0.82	42.15 ± 0.82	42.17 ± 0.82	40.87 ± 0.82	ns	ns
Final weight	"	166.8 ± 2.2	171.0 ± 2.3	177.9 ± 2.8	159.9 ± 2.3	ns	P<0.01
ADGt	"	0.649 ± 0.01	0.663 ± 0.01	0.726 ± 0.01	0.586 ± 0.01	ns	P<0.01
FCR		4.3 ± 0.08	4.8 ± 0.09	3.8 ± 0.08	4.6 ± 0.09	ns	P<0.01

ns=not significant.

Figure 1.   Average daily gain.
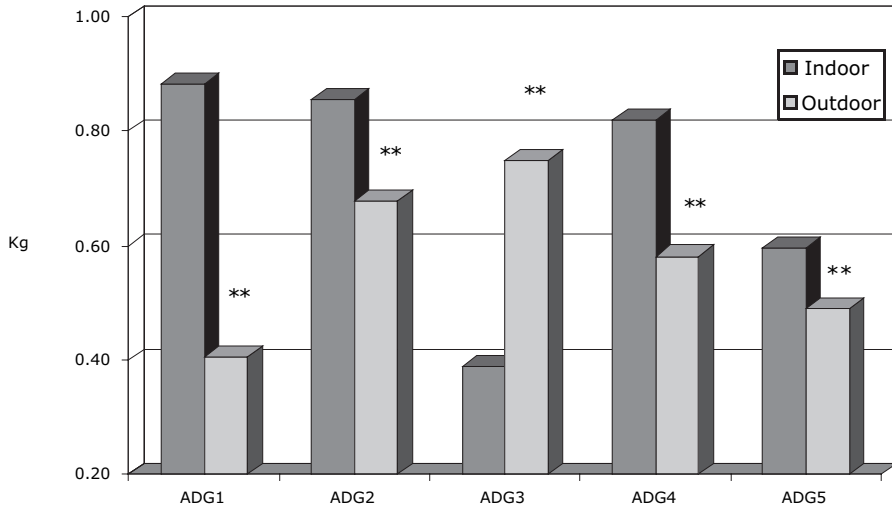
Diet Wilk's Lambda (F>0.310); Rearing system Wilk's Lambda (F>0.000).

raised indoors, whereas yield at slaughter was not affected by rearing system and was similar to that described by Campodoni *et al.* (1999) for Large White × Cinta Senese (LW×CS) pigs bred indoors. Similarly, the percentage of shoulder, ham and loin on carcass weight was not significantly influenced by either effect.

The pH values 45 minutes and 24 hours *post mortem*, determined on the *semimembranosus* muscle of ham, showed a normal reduction in this important parameter of meat quality. The diet gave similar results for both groups, whereas the outdoor rearing system gave a slightly lower pH than the indoor-bred even if significant (P<0.01). The pH of outdoor-bred animals was similar to those reported by Franci *et al.* (2005) for Cinta Senese pigs and by Pugliese *et al.* (1999) for outdoor-bred Large White and hybrids; 24 hour pH was similar in all groups and also similar to the values reported in previous experiments on heavy pigs (Trombetta *et al.*, 1995; Pugliese *et al.*, 1999; Franci *et al.*, 2005).

FOM values (Table 6) showed the proportion of lean meat to be significantly influenced both by the diet effect (P<0.01) and by the rearing technique (P<0.05), as the control diets and outdoor breeding yielded carcasses with a greater proportion of lean meat.

The FOM values obtained in this study were lower than those reported by Affentranger *et al.* (1996) in crosses receiving rations with different energy contents, by Falaschini *et al.* (1995) in hybrid pigs and by Stein *et al.* (2006) for pigs fed with peas. Lumbar fat thickness (LV) was significantly affected only by the rearing technique (P<0.01); it was greater in indoor-bred animals than those reared outdoors (31.2 mm *vs* 24.3 mm) and was similar to that described by Falaschini *et al.* (1995) in heavy pigs.

3/4 thoracic vertebra fat thickness was influenced both by diet (P<0.01) and by breeding mode (P<0.01); it was greater in the group receiving the experimental diet compared with the control diet and lower in outdoor-reared pigs.

Table 5.   Performance at slaughter, weight of lean cuts and pH (mean ± SE).

		Diet (D)		Rearing System (RS)		Level of significance	
		Control	Experimental	Indoor	Outdoor	D	RS
Carcass weight	kg	139.4 ± 0.9	142.7 ± 0.9	145.6 ± 0.9	138.9 ± 0.9	ns	P<0.01
Yield	%	82.9 ± 1.2	81.9 ± 1.2	83.4 ± 1.2	81.4 ± 1.2	ns	ns
Shoulder % Carcass weight		6.3 ± 0.14	6.3 ± 0.14	6.1 ± 0.14	6.4 ± 0.14	ns	ns
Ham % Carcass weight		12.1 ± 0.28	12.2 ± 0.28	12.1 ± 0.28	12.2 ± 0.28	ns	ns
Loin % Carcass weight		13.8 ± 0.25	13.6 ± 0.25	13.8 ± 0.25	13.6 ± 0.25	ns	ns
45 min pH		6.5 ± 0.06	6.4 ± 0.06	6.6 ± 0.06	6.3 ± 0.06	ns	P<0.01
24 h pH		5.6 ± 0.02	5.6 ± 0.02	5.6 ± 0.02	5.6 ± 0.02	ns	ns

Table 6.   Fat O' Meater parameters (mean ± SE).

		Diet (D)		Rearing system (RS)		Level of significance	
		Control	Experimental	Indoor	Outdoor	D	RS
Lean	%	50.0 ± 0.40	48.2 ± 0.40	47.9 ± 0.40	50.3 ± 0.40	P<0.01	P<0.05
3/4 LV	mm	26.5 ± 1.14	29.0 ± 1.14	31.2 ± 1.14	24.3 ± 1.14	ns	P< 0.01
3/4 TV	"	25.3 ± 0.77	28.3 ± 0.77	29.3 ± 0.77	24.1 ± 0.77	P<0.01	P<0.01

LV: Lumbar Vertebra; TV: Thoracic Vertebra.

Table 7.   Weight and colour parameters of trimmed ham (mean ± SE).

		Diet (D)		Rearing system (RS)		Level of significance	
		Control	Experimental	Indoor	Outdoor	D	RS
Ham	kg	16.8 ± 0.34	17.0 ± 0.34	17.6 ± 0.34	16.2 ± 0.34	ns	P<0.01
Trimmed ham	"	13.6 ± 0.28	13.7 ± 0.28	13.9 ± 0.28	13.5 ± 0.28	ns	ns
L*		43.6 ± 0,90	43.7 ± 0,90	49.9 ± 0, 90	37.3 ± 0.90	ns	P<0.01
a*		9.6 ± 0.50	10.2 ± 0,51	9.3 ± 0,51	10.5 ± 0,50	ns	ns
b*		2.7 ± 0.25	3.4 ± 0.25	3.7 ± 0.25	2.3 ± 0.25	P<0.05	P<0.01
Chroma		10.1 ± 0.48	10.9 ± 0.48	10.1 ± 0.48	10.8 ± 0.48	ns	ns
Hue		0.29 ± 0.032	0.36± 0.033	0.44 ± 0.033	0.21 ± 0.032	ns	P<0.01

The weight of trimmed ham and the values of colour parameters (L*, a*, b*), Chroma and Hue are shown in Table 7. Trimmed ham weight was not significantly affected by either variable, while the meat of indoor-bred subjects was significantly lighter (L*) (P<0.01). The L* value obtained by the two diets was lower than that reported by Suzuki *et al.* (2003) for different genetic types and by Bonomi (2005) for pigs fed with peas, while that of the indoor-bred group was similar to the one described by Franci *et al.* (2005) for Cinta Senese pigs; L* in outdoor-bred subjects was lower than that reported by Gentry *et al.* (2004) and by Pugliese *et al.* (1999) in pigs reared with the same technique.

The redness (a*) parameter was not influenced by either effect and values were lower than those reported by Bonomi (2005) and similar to those reported by Franci *et al.* (2005) for Large Whites and by Pugliese *et al.* (1999) for outdoor-reared subjects, while they were higher than those of Gentry *et al.* (2004) for outdoor-reared pigs.

In contrast, the yellowness (b*) parameter was significantly affected by both effect (D=P<0.05; RS=P<0.01), showing lower values than those reported by Suzuki *et al.* (2003) and Franci *et al.* (2005) for different genetic types and by Gentry *et al.* (2004) and Pugliese *et al.* (1999) for outdoor-bred pigs.

Chroma was not influenced by either effect; its value was higher than that described by Pugliese *et al.* (1999) in outdoor-bred subjects and lower than those reported by Franci *et al.* (2005) for different genetic types.

Hue was influenced only by the breeding technique (P<0.01) and exhibited higher values (less intense hue) in indoor-reared pigs. The values of subjects fed the experimental diet and of those bred indoors were similar to those of the indoor and outdoor groups of Pugliese *et al.* (1999) and to those described by Franci *et al.* (2005) for different genetic types.

The chemical composition of *M. semimembranosus* is reported in Table 8. Significant differences due to the rearing system were found for moisture (P<0.01), fat (P<0.01), ash (P<0.05) and energy (P<0.01). The moisture value found in this study was generally lower than the one reported by Pugliese *et al.* (1999) for heavy pigs bred indoors and outdoors and by Franci *et al.* (2005) for different genetic types. The protein level was similar to the one described by Nilzen *et al.* (2001) for pigs raised indoors and outdoors. Extensively reared subjects exhibited a significantly smaller amount of intramuscular fat compared with those bred indoors, as also reported Pugliese *et al.* (1999).

Table 8.   Chemical composition of meat as fed (mean ± SE).

		Diet (D)		Rearing system (RS)		Level of significance	
		Control	Experimental	Indoor	Outdoor	D	RS
Moisture	%	72.3 ± 0.08	72.3 ± 0.08	72.8 ± 0.08	71.8 ± 0.08	ns	P<0.01
Protein	"	21.0 ± 0.37	20.6 ± 0.37	21.1 ± 0.37	20.4 ± 0.37	ns	ns
Fat	"	1.61 ± 0.12	1.74 ± 0.12	1.96 ± 0.12	1.38 ± 0.12	ns	P<0.01
Ash	"	1.16 ± 0.025	1.13 ± 0.025	1.18 ± 0.025	1.10 ± 0.025	ns	P<0.05
Energy	kcal/g	4.17 ± 0.006	4.18 ± 0.006	4.19 ± 0.006	4.16 ± 0.006	ns	P<0.01

Table 9. Fatty acid composition of intramuscular fat (mean ± SE).

	Diet (D)		Rearing system (RS)		Level of significance	
	Control	Experimental	Indoor	Outdoor	D	RS
C14:0	2.2 ± 0.12	2.1 ± 0.12	2.00 ± 0.12	2.3 ± 0.12	ns	ns
C16:0	29.0 ± 0.984	27.3 ± 0.984	28.7 ± 0.984	27.6 ± 0.984	ns	ns
C16:1	3.3 ± 0.23	3.1 ± 0.23	3.2 ± 0.23	3.2 ± 0.23	ns	ns
C18:0	15.1 ± 1.04	12.0 ± 1.04	14.0 ± 1.04	13.1 ±1.05	P<0.05	ns
C18:1	37.5 ± 1.03	40.2 ± 1.03	39.0 ± 1,03	38.7 ± 1.03	ns	ns
C18:2	6.3 ± 1.04	9.5 ± 1.04	7.9 ± 1.04	7,9 ±1,04	P<0.05	ns
C18:3	1.1 ± 0.16	0.647 ± 0.16	0.680 ± 0.16	1.1 ± 0.16	P<0.05	ns
C20:1	1.36 ± 0.18	1.19 ± 0.18	1.25 ± 0.18	1.29 ± 0.18	ns	ns
C20:2	0.48 ± 0.06	0.63 ± 0.06	0.46 ± 0.06	0.65 ± 0.06	ns	P<0.05
SFA	46.3 ± 1.56	41.4 ± 1.56	44.7 ± 1.56	43.0 ± 1.56	P<0.05	ns
MUFA	42.2 ± 1.1	44.6 ± 1.1	43.5 ± 1.1	43.2 ± 1.1	ns	ns
PUFA	8.0 ± 0.98	10.8 ± 0.98	9.07 ± 0.98	9.67 ± 0.98	P<0.05	ns
S/U	0.94±0.06	0.79 ± 0.06	0.88 ± 0.06	0.84 ± 0.06	ns	ns

S/U: Saturated/Unsaturated.

The samples from outdoor-bred pigs contained significantly less ash (P<0.05) than those from the indoor group; similar values have been obtained by Pugliese *et al.* (1999) and Nilzen *et al.* (2001) in subjects reared with the same techniques. Calculation of the energy content yielded a significantly lower value (P<0.01) in the outdoor group, due to a smaller proportion of fat.

The fatty acid composition of intramuscular fat is reported in Table 9. Significant differences (P<0.05) due to the diet effect were found for stearic acid (C18:0), linoleic acid (C18:2), linolenic acid (C18:3), and the sum of saturated and polyunsaturated fatty acids. In particular, stearic acid was higher in the group fed the control diet; these values were also higher than those reported by Nilzen *et al.* (2001) in pigs receiving a feed containing soybean and by Leskanic *et al.* (1997) for ω_3-supplemented diets. C18:2 was higher in

pigs fed the experimental diet, levels were lower than those described by Leskanic *et al.* (1997), and similar to those described by Nilzen *et al.* (2001). Linolenic acid was significantly higher in subjects receiving the control diet, even though this feed contained a slightly lower proportion of linolenic acid than the experimental diet (5.05 *vs* 5.6).

The sum of saturated acids was significantly greater in animals receiving the control diet, whereas PUFA were higher in those fed the experimental diet containing peas than those fed the control diet (soybean) and was of better quality from the nutritional standpoint. Intramuscular fat was not affected by the breeding system.

The fatty acid composition of the ham backfat (Table 10) was significantly affected both by effects with regard to $C_{14:0}$ (D=P<0.05, RS=P<0.01) and $C_{20:2}$ (D=P<0.01, RS=P<0.05); by the sole rearing mode for $C_{20:0}$ (P<0.01)

Table 10.   Fatty acid composition of fat (mean ± SE).

	Diet (D)		Rearing system (RS)		Level of significance	
	Control	Experimental	Indoor	Outdoor	D	RS
C14:0	1.5 ± 0.04	1.6 ± 0.04	1.4 ± 0.04	1.6 ± 0.04	P<0.05	P<0.01
C16:0	23.8 ± 0.33	24.7 ± 0.33	24.0 ± 0.33	24.7 ± 0.33	P<0.05	ns
C16:1	2.1 ± 0.07	2.1 ± 0.07	2.0 ± 0.07	2.2 ± 0.07	ns	ns
C18:0	14.2 ± 0.32	13.9 ± 0.32	13.9 ± 0.32	14.1 ± 0.32	ns	ns
C18:1	39.3 ± 0.47	39.0 ± 0.47	39.6 ± 0.47	38.6 ± 0.47	ns	ns
C18:2	14.6 ± 0.42	14.6 ± 0.42	14.4 ± 0.42	14.7 ± 0.42	ns	ns
C18:3	1.8 ± 0.04	1.7 ± 0.04	1.7 ± 0.04	1.8 ± 0.04	ns	ns
C20:0	0.30 ± 0.02	0.28 ± 0.02	0.26 ± 0.02	0.32 ± 0.02	ns	P<0.01
C20:2	0.84 ± 0.017	0.77 ± 0.017	0.77 ± 0.017	0.83 ± 0.017	P<0.01	P<0.05
C20:3	0.26 ± 0.026	0.34 ± 0.026	0.30 ± 0.026	0.30 ± 0.026	P<0.05	ns
SFA	39.7 ± 0.53	40.5 ± 0.53	39.7 ± 0.53	40.5 ± 0.53	ns	ns
MUFA	41.3 ± 0.49	41.1 ± 0.49	41.6 ± 0.49	40.8 ± 0.49	ns	ns
PUFA	17.5 ± 0.44	17.4 ± 0.44	17.2 ± 0.44	17.6 ± 0.44	ns	ns
S/U	0.67 ± 0.015	0.69 ± 0.015	0.67 ± 0.015	0.67 ± 0.015	ns	ns

and by the sole diet effect for $C_{16:0}$ and $C_{20:3}$ (P<0.05). $C_{14:0}$ content was greater for both effects than those reported by Nilzen *et al.* (2001) for pigs fed a diet containing soybean (indoor *vs* outdoor) and by Franci *et al.* (2005) for Cinta Senese, Large White and Large White x Cinta heavy pigs and was similar to that reported by Bonomi A. (2005).

Palmitic acid ($C_{16:0}$) was significantly (P<0.05) higher in subjects receiving the diet containing peas, with values similar to those reported by Leskanic *et al.* (1997) for subjects fed diets with different fat sources integrated with vitamin E, by Franci *et al.* (2005) for different breeds and by Bonomi (2005) for pigs fed with peas.

$C_{20:0}$ was significantly greater in the outdoor group, while arachidic acid in this group was similar to that reported by Leskanic *et al.* (1997) in pigs fed a control diet containing

swine fat. $C_{20:2}$ was higher in the animals receiving the control diet and in those bred outdoors, and also higher than that described by Franci *et al.* (2005) for Cinta Senese, Large White and Large White x Cinta pigs. $C_{20:3}$ was significantly different (P<0.05), and higher among subjects fed the experimental diet, with higher values compared with those reported by Leskanic *et al.* (1997) in subjects receiving ω_3-supplemented diets.

The sum of saturated, mono- and polyunsaturated fatty acids was not influenced by the effects investigated and values were similar in the different groups.

Conclusions

The results obtained in this experiment prompt the following considerations:

- complete substitution of soybean with

other protein crops did not adversely affect rearing or slaughterhouse performances and appears to be feasible, checking the amino acid level;

 - the rearing system affects rearing and slaughter performance more than the diet; even though the present data indicate that outdoor rearing can be adopted without strong adverse effects on performances;

 - 45 minutes pH values were lower in the outdoor group, though still in the recommended range;

 - the rearing technique significantly affected the quality characteristics of the carcass (% of lean meat, fat thickness) and of the meat. The L* parameter was lower in the outdoor compared with the indoor group. Less light meat can result in less aqueous film on the cut surface;

 - the chemical composition was also influenced by the breeding technique; these findings confirmed the analysis of carcass quality parameters and the colour evaluation (L*), since the muscle of outdoor-reared subjects had a smaller moisture and fat content;

 - finally, the fatty acid composition of intramuscular fat evidenced a greater amount of unsaturated fatty acids in pigs fed the experimental diet, while the backfat composition was affected both by diet and by rearing mode.

Complete replacement of soybean is thus compatible with strong characterization and enhancement of the value of swine products. The data carcass and meat quality were better in outdoor- than indoor-reared pigs independently of the diet, yielding leaner meat with a more intense hue. In addition, the rearing system can result in distinctive quality features, such as ham colour and fat content, allowing products from outdoor rearing to be clearly recognized from those obtained from intensive rearing.

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