

PAPER

Productive response of Duroc x Large White and Commercial Hybrid x Large White crosses fed high and low protein diets

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Abstract

Thirty five Duroc x Large White (DUxLW) and 43 Commercial Hybrid x Large White (CHxLW) were fed two diets differing for the content of crude protein (CP), with the aim to evaluate the effects of these diets on growth, carcass and thigh traits. Pigs were allotted to two groups and fed high protein (HP) and low protein (LP) diet. Within each dietary group, 3 diets were formulated, for the initial phase of growth (from 79 to 112 days, 17.3% and 15.4% CP as fed basis for the HP and LP diet, respectively), for the intermediated phase of growth (from 113 to 196 days, 15.1% and 13.7% CP as fed basis for the HP and LP diet, respectively) and for the finishing period (from 197 to 272 days, 13.4% and 11.4% CP as fed basis for the HP and LP diet, respectively). HP diets were supplemented with Lysine, LP were supplemented also with Methionine and Threonine. Pigs were slaughtered at nine months of age. Body weight (BW), average daily gain, total feed intake and feed conversion ratio were not affected by diet. Carcass weight, thigh weight, backfat and lean thickness and lean percentage (Fat-O-Meater, FOM) were not affected by dietary treatments, whilst backfat thickness and FOM were significantly higher ($P < 0.01$) in DUxLW and CHxLW pigs genotype respectively. A reduction of about 15% (12% to 17%) of the dietary CP recommended by nutritional requirements does not affect the main productive performances and carcass characteristics of pigs slaughtered at around 160 kg of BW.

Introduction

Nutrition is the main factor of impact on the productive and reproductive livestock performances. One of the more important aspects in livestock is to give rations that provide all the

nutrients designed to meet the needs of animals in different stages of growth and production. In swine breeding dietary protein primarily affects the amount and quality of the products, animal health and environmental pollution, so that must precisely be adjusted to the animal body weight (BW) and genetic (Le Bellego *et al.*, 2002; Mordenti *et al.*, 1995). The Italian production of pigs is mainly devoted to heavy pig breeding, slaughtered at 160-170 kg BW, for industry transformation (about 163 kg; Faravelli, 2009). In practice, throughout the production cycle of heavy pigs two or three different diets are fed, with a progressive reduction of protein content in the finishing period, when the share of nitrogen (N) retained by animals are smaller than those retained from animals slaughtered at lower weights.

In this regard, the information about the efficiency of protein utilization in pigs over 110 kg is limited. Usually, in the case of production of heavy pigs, the protein is often supplied in excess with respect to the actual needs. In fact, diets are formulated so as to meet the demands of few specific essential amino acids, but this commonly leads to high and wasteful levels of other amino acids. The need of pigs for the essential amino acids was widely studied and the researches confirm their inefficacy in satisfying the non-specific N requirements (Adkins *et al.*, 1966; Allen and Baker, 1974; Featherstone, 1976); furthermore the essential amino acids must be supplied with the diet in certain amounts and proportions to obtain optimum efficiency of utilization of the proteins. Several authors report values of efficiency of dietary protein utilization between 18-40 % (de Lange *et al.*, 1999; Della Casa, 2006; Dourmad *et al.*, 1994; Monteiro *et al.*, 2010; Mordenti *et al.*, 1995; Rossi *et al.*, 2005); according to Dourmad *et al.* 2007, in pigs fed diets based on cereals and soybean flour during breeding-fatening, the N retention is of about 32%. The different protein utilization depends on several factors: composition of the diet, physiological state, growth intensity of the animals, breed and genotype, sex and slaughter weight (Bittante *et al.*, 1990). Since the '90s, several studies have been conducted to evaluate the odds of a restricted protein supply, but balancing the amino acid profile by adding on synthetic amino-acids to the diet. These studies showed that under this condition crude protein (CP) could be reduced without negative impact on the performances. The present study intended to evaluate the effects of diets differing for protein content on growth, carcass and thigh traits of crossbred pigs obtained from Duroc (DU) or Commercial Hybrid (CH) boars and Large White (LW) sows.

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Materials and methods

For the trial, 12 LW sows 2 DU boars and 2 CH boars were used. The Duroc boars and the Large White females were from the genetic pure lines selected by National Association of Pig Breeders, Roma, Italy (ANAS, 2011). Sows were synchronized using orally active progestagen. Three sows were randomly mated with each boar on the same day and the parturition occurred in an interval of 5 days. Newborns were ear tagged for individual identification and males were castrated. At weaning 4 males and 4 females were randomly selected within each litter and kept in separated boxes until 9 weeks of ages. During the preliminary adaptation phase, pigs received a compound medicated feed for 10 days (doxycycline mg 300 and colistin SO₄ mg 300), under the prescription of the veterinarian responsible for the farm of the animal health and welfare. The reason was related to the change of stable and to unexpected very cold weather conditions that could have led to respiratory disease. After the treatment, 35 DUxLW, (24 females and 11 castrates) and 43 CHxLW piglets (25 females and 18 castrates) were considered available for the trial. Piglets were separated in two groups and allotted to the experimental isoenergetic diets, differing for CP content.

Thirty seven piglets were fed the high protein (HP) diet and four one piglets the low protein (LP) diet. Within each dietary group, 3 diets were formulated, the first for the initial phase of growth (from 79 to 112 days, Growing A), the second for the intermediated phase of growth (from 113 to 196 days, Growing B) and the third for the finishing period (from 197 to 272 days, Finishing). For the three phases, the CP of the HP diet was equal to 17.3%, 15.1% and 13.4% as fed basis and for the LP group to 15.4%, 13.7% and 11.4% as fed basis. HP diets were supplemented with lysine, LP were supplemented also with methionine and threonine (Table 1). For each dietary treatment, pigs were allotted to 3 boxes (13, 12 and 12 pigs for HP diet and 14, 14 and 13 pigs for LP diet). Animals were not separated, but their number in each box was balanced for genotype and sex. During the trial, the animals were fed *ad libitum* with the experimental diets and had free access to water distributed with automatic watering systems. The amount of feed offered and refused was weighted daily for each box. The HP diets were formulated on the basis of recommendations provided by ANAS (2011) for LW pigs and by National Research Council (NRC, 1988). All the ingredients complied the prescription for the production of San Daniele ham Protected Designation Origin (PDO) (Bosi and Russo, 2004).

Within each genetic type, pigs of both genders were randomly assigned to the HP and LP diets, providing a similar initial average BW and allocated in 4 boxes from days 79 to 154 and in 6 boxes from day 154 until the end of the trial. Rations were offered twice a day and the orts collected daily and weighted. The animals were weighed before the morning meal at 79, 112, 154, 196 and 272 days of age. Proximate analysis, neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined on compounds weekly sampled during the trial (AOAC, 1990; van Soest, 1982). At nine months of age, pigs were slaughtered in a slaughterhouse by electrical stunning, exsanguinated, scalded at 65°C, skinned, eviscerated, and split down the center of the vertebral column according to standard commercial procedures. On the day of slaughtering, all pigs were delivered to the commercial slaughterhouse where they rested for a minimum of 12 hours prior to slaughtering. Fat and loin muscle thickness (backfat thickness and loin thickness) were measured using a Fat-O-Meater instrumentation, inserting the probe between the third and fourth last rib on the left hot carcass at 8 and 10 cm off the dorsal midline. The carcass lean percentage was cal-

culated and hot carcass weight was recorded for each selected pig. The EC weight (EC-W) is the cold weight of carcass and is defined by the Council Regulation (EC) n. 1234/2007, Annex V, Part B. Following the classification manual of pig carcasses edited by Ministry of Agricultural, Food and Forestry Policies and by the Istituto Nord-Est Qualità editing (INEQ, 2011), the carcasses were classified according to their weight in heavy (H, >110.1 kg) and light (L, <110.1 kg). Backfat thickness was used to grade the carcass in the EUROP grid. According to the Consortium of San Daniele ham belonging to light carcasses (L) and E (>=55% lean meat) and P (<40% lean meat) carcasses are excluded from the seasoning. For PDO production only the H carcasses (H,

>110.1 kg) and U, R, O carcasses (from 40% to 54.9% lean meat) are suitable.

Statistical analysis

Data of productive performances were analyzed with the general linear model implemented in the SPSS package using the Type III sequential Sum of Square (1997):

$$Y_{ijklm} = \mu + D_i + G_j + B(D_i)_k + S_l + D_x G_{ij} + D_x S_{jl} + \beta_0 (BW_{79})_{ijklm} + \epsilon_{ijklm}$$

where:

Y_{ijklm} are the observations, μ is the overall mean, D_i is the fixed effect of the diet ($i = 1$ to 2), G_j is the fixed effect for genotype ($j = 1$ to

Table 1. Formulation, chemical composition and nutritive value of the diets (% as fed basis).

	HP Growing A	HP Growing B	HP Finishing	LP Growing A	LP Growing B	LP Finishing
Corn	41.68	47.82	47.57	47.39	52.76	51.94
Soybean meal SE	17.82	13.86	10.89	11.07	8.91	4.46
Barley	16.83	16.83	19.80	17.04	17.82	21.29
Bran	8.99	9.39	10.40	9.62	9.78	11.88
Germ flour	3.96	3.47	2.97	3.52	1.98	1.98
Molasses	3.96	3.96	3.96	4.02	3.96	3.96
Ca carbonate	1.68	1.68	1.68	1.70	1.68	1.68
Palm oil	1.49	1.19	1.19	1.51	0.99	0.99
Beet pulp	1.49			1.51		
Dicalcium phosphate	0.50	0.50	0.35	0.51	0.50	0.35
Vitamins Mix	0.50	0.50	0.40	0.51	0.50	0.40
Sodium chloride	0.30	0.30	0.30	0.30	0.30	0.30
Lactic-formic acid	0.30			0.30		
Lignosulphite	0.30	0.30	0.30	0.30	0.30	0.30
Lysine	0.12	0.12	0.10	0.41	0.30	0.28
Bredol® emulsifier	0.05	0.05	0.05	0.05	0.05	0.05
Phytase	0.05	0.05	0.05	0.05	0.05	0.05
Methionine				0.09	0.07	0.05
Threonine				0.10	0.06	0.06
Dry matter	88.25	87.93	88.52	88.28	87.85	88.58
Concentrate feed	4.58	4.00	3.75	4.54	3.85	3.58
Nx6.25	17.25	15.10	13.35	15.38	13.71	11.35
Ether extracts	4.42	3.95	3.94	4.47	3.91	4.05
Ash	7.16	6.06	5.69	6.65	5.66	5.37
Nitrogen-free extract	66.59	58.81	61.78	68.96	60.73	64.23
Neutral detergent fibre	16.61	14.04	14.63	16.23	14.97	15.07
Acid detergent fibre	5.46	4.46	4.29	5.10	4.20	3.98
Acid detergent lignin	1.61	1.33	1.24	1.51	1.15	1.10
Lysine	1.67	1.46	1.24	1.67	1.37	1.07
Methionine	0.51	0.47	0.46	0.51	0.51	0.43
Digestible energy°, kcal/kg	3190	3184	3151	3170	3211	3194

Growing A: initial phase of growth, from 79 to 112 days; integration/kg: Vit. A U 9800; Vit. D₃ U 950; Vit. E mg 6; Cu mg 18; Fe mg 150; I mg 0.5; Mn mg 50, Zn mg 120; Se mg 0.1. Growing B: intermediated phase of growth, from 113 to 196 days; integration/kg: Vit. A U 9800; Vit. D₃ U 950; Vit. E mg 6; Cu mg 18; Fe mg 150; I mg 0.5; Mn mg 50, Zn mg 120; Se mg 0.1. Finishing phase, from 197 to 272 days; integration/kg: Vit. A U 8000; Vit. D₃ U 800; Vit. E mg 4; Cu mg 16; Fe mg 120; I mg 0.3; Mn mg 40, Zn mg 100; Se mg 0.08. °Estimate based on NRC values (1998).

2), B is the random effect of the box ($k = 1$ to 3) within the diet D, S_i is the fixed effect for sex ($l = 1$ to 2). Covariate for the body weight recorded at the beginning of the trial (BW_{79}) was used for the dependent variables BW and average daily gain (ADG). Covariate was omitted for the initial BW. Data of carcass characteristics were analyzed with the same model, without covariate. Data of carcass classification, expressed as percentage, were analyzed using the chi square test. Considering that for total feed intake (TFI) and feed conversion ratio (FCR) only 3 observations for diet were available, a ONEWAY model was used, with the fixed effect of treatment (HP vs LP).

Results and discussion

The trial aimed at determining the protein content of the diet required to attain entirely exploited the growth potential of crossbreed pigs of different genetic type, in particular of LW sows mated with DU or CH boars. Therefore the diets have been formulated so as to ensure protein levels generally recommended to livestock farming of heavy pigs (ANAS, 2011). These dietary guidelines are based on the standards proposed for fattening pigs with good potential for muscle growth at least up to about 120 kg of BW (NRC, 1988), with a stair

step reduction of 10% during the breeding and the finishing period.

Live weight changes and feed intake

The controls at 79 (beginning), 112, 154, 196 and 272 (end) days were used to calculate the individual ADG. Diet, genotype and the interaction diet x genotype did not significant affected BWs (Table 2). The ADG during the whole experimental period did not differ between diets and averaged 0.719 kg/d (Table 2). No significant differences between genotypes and diets were recorded for the ADG between 79 and 112 days, 112 and 154 days,

Table 2. Body weights and average daily gain of pigs during the experiments.

	Diet		Genotype		Sex		Significance					SEM
	HP	LP	DUxLW	CHxLW	FE	CA	D	G	S	DxG	DxS	
Number of observations	37	41	35	43	49	29						
Body weights at												
79 d, kg	27.55	26.48	27.04	26.94	26.27	27.77	ns	ns	*	ns	ns	1.315
112 d, kg	41.95	40.04	41.50	40.49	41.02	40.97	ns	ns	ns	ns	ns	0.909
154 d, kg	71.13	70.01	71.27	69.87	70.35	70.80	ns	ns	ns	ns	ns	1.649
196 d, kg	103.58	99.35	101.49	101.45	101.62	101.32	ns	ns	ns	ns	ns	2.279
272 d, kg	167.69	163.48	164.46	166.71	166.68	164.49	ns	ns	ns	ns	ns	2.865
ADG, kg/d	0.73	0.70	0.71	0.72	0.72	0.71	ns	ns	ns	ns	ns	0.015

HP, high protein diets; LP, low protein diets; DUxLW, Duroc x Large White crosses; CHxLW, Commercial Hybrid x Large White crosses; FE, females; CA, castrated males; D, diet; G, genotype; S, sex; ADG, average daily gain. * $P < 0.05$; ns, not significant.

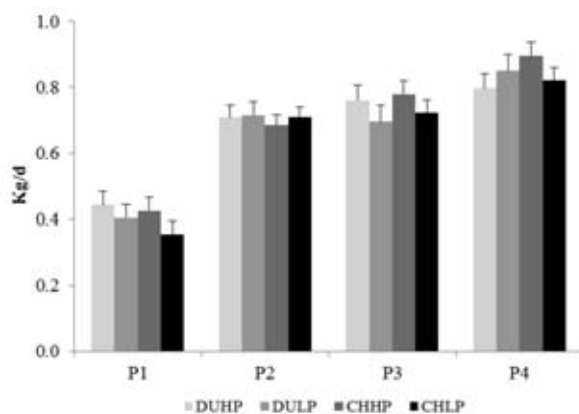


Figure 1. Average daily gain (ADG) of Duroc x Large White and Commercial Hybrid x Large White crosses fed diets with high and low protein content. P1, growing period 79-112 days; P2, growing period 113-154 days; P3, growing period 155-196 days; P4, finishing period 196-272 days; DUHP, Duroc x Large White crosses, high protein diets; DULP, Duroc x Large White crosses, low protein diets; CHHP, Commercial Hybrid x Large White crosses, high protein diets; CHLP, Commercial Hybrid x Large White crosses, low protein diets.

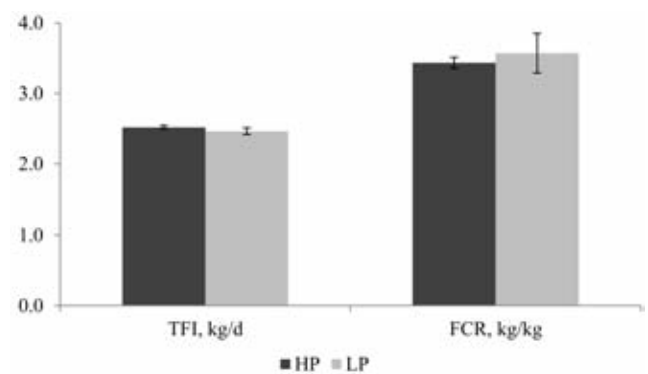


Figure 2. Total feed intake and total feed conversion ratio of pigs fed with the two experimental diets. TFI, total feed intake; FCR, feed conversion ratio; HP, high protein diets; LP, low protein diets.

154 and 196 days and 196 and 272 days (Figure 1). The ADG recorded in the present trial is higher than that reported by Pastrello (2011) and by Stefanon *et al.* (2004) for commercial hybrids (0.65 kg/d and 0.64 kg/d, respectively). Bosi and Russo (2004) and Fabbri *et al.* (2009) reported higher ADG for heavy pig crosses reared to fit the Parma ham PDO product specification (0.77 kg/d and 0.75 kg/d, respectively). Variable results of ADG are reported in the literature for crossbred pigs derived from DU boars. In a previous research, Sgorlon *et al.* (2012) reported that DUxLW crosses grew faster than CHxLW crosses (0.70 kg/d and 0.68 kg/d, respectively) and the ADG for all the pigs was lower to that reported in this paper. Comparable results were also obtained by Bonomi *et al.* (2002, 2003) from LW x Landrace, Du x (LW x Landrace) and CH crosses kept under control from 30 up to 160 kg BW. In those studies, the CP contents of control diets were gradually reduced at 60 and 100 kg BW from 17% to 15% and to 13% and not statistically effect on BW gains and FCR were observed for diet and genotypes. Similarly, Piva *et al.* (1993a) did not report a significant effect on daily gain of dietary CP restriction in hybrid pigs from 60 to 160 kg BW. These data confirm the odds of reducing the protein content of the diet given during the final period of growth, if an adequate amount of lysine and methionine is ensured. The findings of the present experiment can further help to elucidate the major effect of the contents of essential amino acids over the protein level. The lysine and methionine were added to the LP growing and finishing diets to raise their concentration higher than recommended threshold values (NRC, 1998). Studies on N retention in swine have shown that the addition of crystalline amino acids, *e.g.* lysine and DL-methionine hydroxyl

analog to meet amino acids ideal ratio, reduces N excretion by increasing the retained N (Honeyman, 1993; Piva *et al.* 1993b). It can be considered that the protein content of the LP diet, within the formulation proposed, was not limiting the growth of heavy pigs, thus ensuring for these hybrids to attain the production performances required for PDO Italian hams. The TFI and FCR during the trial were not affected by diet (Figure 2). It must be underlined that pigs were not feed individually and, consequently, the effect on FCR has to be considered with caution, probably reflecting the BW changes of pigs. The average FCR was lower than that reported for commercial hybrids by Bosi *et al.* (1999), Romanzin (2010)

and Pastrello (2011), who report FCR greater than 4. Sabbioni *et al.* (2002) measured the linear effects of the proportion of Duroc genes with respect to ADG, FCR, carcass and meat quality in heavy pigs deriving from LW and Landrace sows. The increase proportion of DU genes negatively affected the BW at the different ages, but not the weight at slaughtering.

Slaughter performances

The pigs were contemporary and were slaughtered simultaneously as they reached the minimum age specified in the recommendation of the Consortium of San Daniele ham, *i.e.* 9 months. Since the age criteria was adopted, at the slaughterhouse then also came pigs

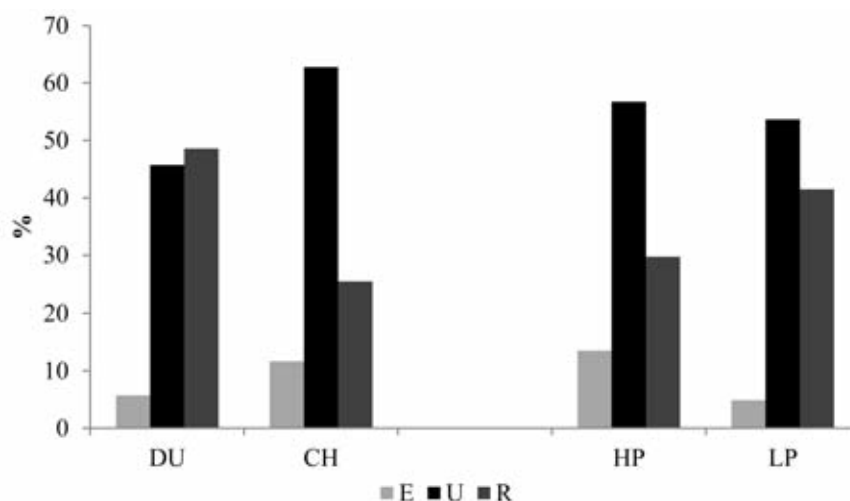


Figure 3. Classification of carcasses based on EUROP system. HP, high protein diets; LP, low protein diets; DU, Duroc x Large White crosses; CH, Commercial Hybrid x Large White crosses; E, lean meat ≥55%; U, lean meat from 54.9% to 50%; R, lean meat from 49.9% to 45%.

Table 3. Characteristics of carcasses of pigs measured at slaughterhouse.

	Diet		Genotype		Sex		Significance					SEM
	HP	LP	DUxLW	CHxLW	FE	CA	D	G	S	DxG	DxS	
Number of observations	37	41	35	43	49	29						
FOM, %	51.12	50.24	49.94	51.42	51.77	49.59	ns	*	**	ns	ns	0.327
Carcass												
EC-W, kg	130.57	126.07	127.27	129.37	127.86	128.78	ns	ns	ns	ns	ns	2.678
Weight, kg	137.43	132.25	133.72	135.96	134.36	135.32	ns	ns	ns	ns	ns	2.993
Fat thickness, mm	25.89	26.68	28.00	24.58	24.48	28.10	ns	**	**	ns	ns	0.547
Lean thickness, mm	72.30	69.34	71.57	70.07	71.60	70.04	ns	ns	ns	ns	ns	0.822
Thigh												
Raw, kg	17.34	16.55	16.73	17.16	17.12	16.77	ns	ns	ns	ns	ns	0.342
Trimmed, kg	14.20	13.68	13.77	14.10	14.17	13.71	ns	ns	ns	ns	ns	0.289

HP, high protein diets; LP, low protein diets; DUxLW, Duroc x Large White crosses; CHxLW, Commercial Hybrid x Large White crosses; FE, females; CA, castrated males; D, diet; G, genotype; S, sex; EC-W, cold weight of carcass as defined by the Council Regulation (EC) n. 1234/2007, Annex V, Part B; FOM, Fat-O-Meat, estimated lean content of the carcass; *P<0.05; **P<0.01; ns, not significant.

weighing less than 155 kg of BW: 6 DUxLW crosses (17%, average 145.5 kg BW), 6 females equally divided between HP and LP diets, and 12 CHxLW crosses (44%, average 142.1 kg BW) 7 barrows and 5 females, 2 HP and 10 LP diets. Out of these animals, 4 only had also a carcass weight of less than 110.1 kg (L), the minimum values defined by the strictest standards for the classification of pig carcasses considered by the Italian Law no. 96, Art. 27 (Italian Regulation, 2010). Under normal conditions, these subjects would have been sent to slaughter two weeks later.

The differences between dietary treatments of the recorded carcass traits were not significant (Table 3). In comparison to CHxLW pigs, DUxLW exhibited significantly lower FOM ($P<0.05$) and higher backfat thickness ($P<0.01$). FOM percentage was lower ($P<0.01$) and backfat thickness higher ($P<0.01$) for castrates in comparison to females. The weight of raw and trimmed thighs were similar in castrates and females. The carcasses in the E class were 11.6% and 5.7% for CH and DU respectively, whilst the percentage in the R class accounted for 25.6% and 48.6% for CH and DU respectively. However, the effect of genotype was not significant ($P>0.05$). Also the dietary treatment did not lead to significant differences, and the percentages of carcasses classified in the E, U and R grid were very similar between HP and LP pigs (Figure 3). According to Ong and Hutagalung (1986) and Kerr *et al.* (1995), the reduction of protein in the diet at slaughter leads to a thinner *longissimus dorsi* and a thicker layer of backfat, in comparison to pigs receiving a higher protein diet. This confirms the assertion of Noblet *et al.* (2003), who in a review concludes that a reduction of protein in comparison to that recommended by the requirements and not balanced by amino acid integrations, depresses production performances and negatively affects the content of fat and muscle of the carcass. However, these data refer to pig slaughtered at about 100 kg of BW, while in the heavy pigs for Italian PDO ham production, reared until a final BW of 160 kg, the protein content of the diet does not seem to significantly affect the carcass quality. The rearing of heavy pig is extended in time by a 50%, and during this period a different protein requirement needs to be considered. In pigs weighting 100 kg, the muscles exceed the 58% of BW, while in the heavy pigs the muscle tissue represents no more than the 50% of the BW. More often, in the heavy pigs production, the protein content of the diet does not seem to significantly affect the carcass quality. Fabbri *et al.* (2009) after a feeding trial carried out using diets with differ-

ent protein levels and similar to those used in this experience on DUxLW females and barrows, did not find any significant differences on thighs characteristics. A similar conclusion was also achieved by Bosi *et al.* (1999) and Bonomi *et al.* (2002) that, in the previously cited experiences, comparing the effect of diets containing different amounts of protein, replaced by an adequate content of synthetic lysine, on different swine crosses and on CH, found out only irrelevant differences on dressing percentage at slaughter and on the qualitative characteristics of the carcass.

Thus, the relationship between ingested and retained protein is less strict for heavy pigs in the finishing phase of growth. Fabbri *et al.* (2009) did not find significant differences on thighs characteristics in DUxLW pigs fed diets with protein contents similar to those used in this study.

Conclusions

The results from this study indicate that a mild reduction of protein in the diet does not affect substantially the performances of the heavy pigs for the crossbreed considered. Also, a thoughtful examination of the data during the intermediated phases confirms that a reduction of CP in the diet does not affect the growth of these crosses. The lack of significant effects of *in vivo* productive performances is confirmed by the recorded carcass traits from the two genotypes.

Finally, it must be underlined that both the genotypes adequately fit to the production of the PDO of San Daniele ham.

References

- Adkins, J.S., Wertz, J.M., Hove, E.L., 1966. Influence of non-essential L-amino acids on growth of rats fed high levels of essential amino acids. *Exp. Biol. Med.* 122:519-523.
- Allen, N.K., Baker, D.H., 1974. Quantitative evaluation of non-specific nitrogen sources for the growing chick. *Poultry Sci.* 53:258-264.
- ANAS, 2011. Alimentazione scrofe e suini. Linee Guida. Available from: <http://geni.anas.it/images/pdf/manuale%20alimentazione.pdf>
- AOAC, 1990. Official methods of analysis. Association of Official Analytical Chemists, Washington, DC, USA.
- Bittante, G., Ramanzin, M., Schiavon, S., 1990. Previsione della ritenzione azotata nei suini in accrescimento. *Riv. Suinicolt.* 4:115-121.
- Bonomi, A., Bonomi, B.M., Quarantelli, A., 2003. La produzione del suino pesante in rapporto ai tipi genetici e all'impiego di diete ipoproteiche integrate con lisina. Effetti sui prosciutti stagionati. *Riv. Suinicolt.* 44:151-154.
- Bonomi, A., Bonomi, B.M., Quarantelli, A., Sabbioni, A., Superchi, P., Sussi, C., Virgili, R., Fusari, A., 2002. La produzione del suino pesante in rapporto ai tipi genetici e all'impiego di diete ipoproteiche integrate con lisina. *Suinicoltura* 4:198-204.
- Bosi, P., Russo, V., 2004. The production of the heavy pig for high quality processed products. *Ital. J. Anim. Sci.* 3:309-321.
- Bosi, P., Mattuzzi, S., Cacciavillani, J.A., Casini, L., 1999. Urea in the diet of finishing Italian heavy pigs. pp 309-321 in *Proc. 13th Nat. Congr. ASPA, Piacenza, Italy.*
- De Lange, K., Nyachoti, M., Birkett, S., 1999. Manipulation of diets to minimize the contribution to environmental pollution. *Adv. Pork Prod.* 19:173-186.
- Della Casa, G., 2006. Con meno azoto nella dieta cala il vincolo ambientale. *Suinicoltura* 8:54-59.
- Dourmad, J.Y., Jondreville, C., 2007. Impact of nutrition on nitrogen, phosphorus, Cu and Zn in pig manure, and on emissions of ammonia and odours. *Livest. Sci.* 112:192-198.
- Dourmad, J.Y., Etienne, M., Pruniera, A., Noblet, J., 1994. The effect of energy and protein intake of sows on their longevity: a review. *Livest. Prod. Sci.* 40:87-89.
- Fabbri, C., Moscatelli, G., Della Casa, G., Poletti, E., 2009. Interventi sulla dieta per ridurre l'azoto escreto nei suini pesanti in fase di finissaggio. *Suinicoltura* 3:124-131.
- Faravelli, E., Basile, C.G., 2009. Il mercato dei suini. Produzione e consumo. Osservatorio agroalimentare lombardo, Quaderno n° 18. ERSAF Publ., Roma, Italy.
- Featherstone, W.R., 1976. Adequacy of glutamic acid synthesis by the chick for maximal growth. *Poultry Sci.* 55:2479-2480.
- Honeyman, M.S., 1993. Environment-friendly swine feed formulation to reduce nitrogen and phosphorus excretion. *Am. J. Alternative Agr.* 8:128-132.
- INEQ, 2011. Manuale Procedure operative e controllo dell'attività di classificazione delle carcasse suine. Available from: http://www.ineq.it/index.php?action=show_folder&folder_id=48
- Italian Regulation, 2010. Provisions for the ful-

- fillment of obligations deriving from Italy's membership of the European Communities, Community Law 2009, LD 96/2010. In: Official Journal No. 146, 25/6/2010, pp 1-51.
- Kerr, B.J., Mckeith, F.K., Easter, R.A., 1995. Effect of performance and carcass characteristics to finisher pigs fed reduced crude protein, aminoacid-supplemented diets. *J. Anim. Sci.* 73:433-440.
- Le Bellego, L., van Milgen, J., Noblet, J., 2002. Effect of high temperature and low protein diets on performance of growing finishing pigs. *J. Anim. Sci.* 80:691-701.
- Monteiro, D.O., Pinheiro, V.M.C., Mourao, J.L.M., Rodrigues, M.A.M., 2010. Strategies for mitigation of nitrogen environmental impact from swine production. *Rev. Bras. Zootecn.* 39:S317-S325.
- Mordenti, A., Piva, G., Salvatori, G., 1995. Efficienza alimentare nel suino all'ingrasso. *Riv. Suinicolt.* 10:19-32.
- National Research Council, 1998. Nutrient requirements of swine, 10th ed. National Academy Press, Washington, DC, USA.
- Noblet, J., Bontems, V., Tran, J., 2003. Estimation de la valeur énergétique des aliments pour le porc. *INRA Prod. Anim.* 16:197-210.
- Ong, H.K., Hutagalung, R.H., 1986. Effect of fibre and protein levels on growth and carcass characteristics of pigs. *Mardi Res. Bull.* 14:170-177.
- Pastrello, A., 2011. Impiego di razioni a basso titolo proteico: effetti sulla qualità delle carcasse, dei tagli commerciali e delle cosce di suino pesante. Degree Diss., Università di Padova, Italy.
- Piva, G., Morlacchini, M., Prandini, A., Cerioli, C., Ferrarini, F., Di Renzi, L., 1993a. Diete convenzionali a basso livello proteico per ridurre l'escrezione azotata nei suini. *Zoot. Nutr. Anim.* 19:81-87.
- Piva, G., Morlacchini, M., Varini, G., Ferrarini, F., Grandini, A., 1993b. Diete a basso livello proteico nella produzione del suino pesante. *Agricoltura Ricerca* 15:73-80.
- Rizzi, N., 2006. Composizione chimica corporea del suino pesante: confronto tra effetti simulati e misurati dovuti al genotipo, al genere e al livello proteico della dieta. Degree Diss., Università di Padova, Italy.
- Romanzin, A., 2010. Effetto dell'impiego di razioni a basso titolo proteico con minime aggiunte di aminoacidi di sintesi sulle performance e sulla qualità della carcassa del suino pesante. Degree Diss., Università di Padova, Italy.
- Rossi, A., De Roest, K., Sardi, L., Mordenti, A., Speroni, M., Della Casa, G., 2005. Quanto azoto assunto con la razione finisce nelle feci e nell'aria. *Inform. Agr.* 31:47-49.
- Sabbioni, A., Superchi, P., Sussi, C., Bonomi, A., 2002. Effect of Duroc genes proportion on growth performance and on carcass and meat quality characteristics in heavy pigs Ital. *J. Anim. Sci.* 1:17-24.
- Sgorlon, S., Guitti, D., Bassi, M., Cadel, G., Stefanon, B., 2012. Genetica dei suini qualificata per la PDO di San Daniele. *Suinicoltura* 2:68-75.
- Stefanon, B., Floris, R., Braglia, S., Davoli, R., Fontanesi, L., Dall'Olio, S., Graziosi, R., Susmel, P., Russo, V., 2004. A new approach in association study of single nucleotide polymorphism of genes for carcass and quality traits in commercial pigs. *Ital. J. Anim. Sci.* 3:177-189.
- Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:3583-3597.

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