Effect of the proportion of Duroc genes in crosses with Large White and Landrace pigs on the characteristics of seasoned Parma ham

Alberto Sabbioni, Valentino Beretti, Alessio Zanon,
Paola Superchi, Claudia Sussi, Alberto Bonomi

Dipartimento di Produzioni Animali, Biotecnologie Veterinarie, Qualità e Sicurezza degli Alimenti.
Università di Parma, Italy.

Corresponding author: Prof. Alberto Sabbioni. Dipartimento di Produzioni Animali, Biotecnologie Veterinarie, Qualità e Sicurezza degli Alimenti. Facoltà di Medicina Veterinaria. Via del Taglio 8, 43100 Parma, Italy - Tel. +39 0521 032625 - Fax: +39 0521 032611 - Email: alberto.sabbioni@unipr.it

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ABSTRACT

The aim of this study was to estimate the linear and quadratic effects of the proportion of Duroc genes on the characteristics of seasoned Parma hams by means of a covariance model. The study was carried out on 167 pigs (87 castrated males, 80 females) from different crosses among Duroc (D), Large White (LW) and Landrace (L) breeds, slaughtered at 300 d of age (live weight 170 kg). All pigs were raised under similar conditions. The curing period was 380 days. The proportion of Duroc genes was 0% (LWxL; n. 33), 25% [(LWx(DxL); n. 31 and Lx(DxLW); n. 35)] and 50% [Dx(LWx(LWxL)); n. 68]. The increase in the proportion of Duroc genes had a positive linear effect (P<0.01) and a negative quadratic effect (P=0.01) on the yield of deboned ham while ham fat thickness decreased linearly (P=0.07) and increased quadratically (P<0.01). A higher proportion of Duroc genes was also linearly associated with a lower lightness (P<0.01) and a less yellow color (P=0.09) of the *biceps femoris* muscle; positive quadratic coefficients have been shown for lightness (P<0.01), yellowness (P=0.01) and hue (P=0.03). The chemical composition of the *semitendinosus* muscle featured a linear increase in moisture (P<0.01) and decrease in fat (P=0.03) and non protein nitrogen (P=0.01) content, in addition to significant quadratic effects with an increase in the proportion of Duroc genes. In conclusion, crossbreeding with the Duroc breed (up to 50%) makes it possible to obtain positive quality characteristics of cured Parma ham.

Key words: Swine, Duroc, Ham, Crossbreeding.

RIASSUNTO

INFLUENZA DELLA PERCENTUALE DI GENI DELLA RAZZA DUROC, NELL'INCROCIO CON LE RAZZE LARGE WHITE E LANDRACE, SULLE CARATTERISTICHE DEL PROSCIUTTO DI PARMA STAGIONATO.

Sono stati valutati, attraverso l'applicazione di un modello di analisi della covarianza, gli effetti lineari e quadratici dell'aumento della percentuale di geni della razza Duroc sulle caratteristiche dei prosciutti stagionati (durata della stagionatura tipo Parma: 380 giorni), provenienti da 167 suini (87 maschi castrati, 80 femmine), appartenenti a diversi incroci, alla cui formazione hanno partecipato le razze Duroc (D), Large White (LW) e Landrace (L), macellati a circa 300 d di età (peso di macellazione 170 kg). La quota di geni della razza Duroc è risultata pari a 0% (LWxL; n.=33), a 25% [(LWx(DxL); n.=31 e Lx(DxLW); n.=35)] e a 50% [Dx(LWx(LWxL)); n.=68]. L'aumento della proporzione di geni della razza Duroc porta ad un aumento lineare (P<0,01) e ad una riduzione quadratica (P=0,01) della resa in prosciutto disossato, mentre lo spessore del grasso di copertura presenta una riduzione lineare (P=0,07) ed un aumento quadratico (P<0,01). Il colore del m. biceps femoris presenta una minore luminosità (P<0,01) e una riduzione lineare della compo-

nente del giallo (P=0,09) con l'aumentare della percentuale di geni Duroc; sono stati poi messi in evidenza effetti quadratici negativi per luminosità (P<0,01), componente del giallo (P=0,01) e tinta (P=0,03). La composizione chimica del m. semitendinosus ha messo in evidenza un aumento lineare del tenore di umidità (P<0,01) e una riduzione del tenore di grasso (P=0,03) e di azoto non proteico (P=0,01), accanto ad effetti quadratici significativi all'aumentare della quota di geni della razza Duroc. Le variazioni riscontrate permettono di valutare positivamente il contributo della razza Duroc, fino al 50%, sulle caratteristiche del prosciutto di Parma stagionato.

Parole chiave: *Suini, Duroc, Prosciutto, Incrocio.*

Introduction

Pig production in Italy is mainly oriented towards the breeding of heavy pigs for industrial transformation. High slaughtering weights must be associated with the production of high quality lean meat. To this aim, pig breeders have traditionally employed Large White and Landrace breeds, that in Italy are submitted to a selection scheme which takes into account several meat quality traits, such as ham weight loss after the first salting step. Other breeds are frequently employed for crossbreeding, and "hybrid pigs" currently represent the most frequently used genotype in sire lines (Istituto Parma Qualità, 2003). Among the breeds used in the sire lines, the Duroc breed is of particular importance; the proportion of Duroc genes normally does not exceed 50%, in order to avoid problems such as deep seated hairs or marbling.

The effect of the Duroc breed has been extensively studied, in particular with regard to growth performance, carcass and meat quality for light (Simpson *et al.*, 1987; Edwards *et al.*, 1992; Liu *et al.*, 1999; Blanchard *et al.*, 1999) and heavy pig production (Fabbri and Bergonzini, 1979; Santoro *et al.*, 1981; Geri *et al.*, 1983; Bittante *et al.*, 1989; Caleffi and Broccaioli, 1990; Bittante *et al.*, 1990; Bonomi *et al.*, 1991; Franci *et al.*, 1994 a; Franci *et al.*, 1994 b; Bittante *et al.*, 1993; Sabbioni *et al.*, 2002 a), fat composition (Franci *et al.*, 1995; Sabbioni *et al.*, 2002 b) and cured ham characteristics (Bittante *et al.*, 1991; Bonomi *et al.*, 1992; Gallo *et al.*, 1994; Franci *et al.*, 1996).

All studies concerning cured ham production have been conducted in Italy, due to the high quality characteristics that are guaranteed, associated also with higher market prices. There are currently 19 swine meat products in Italy with the European Protected Designation of Origin, 7 of which are referred to as cured hams.

The aim of the present study was to evaluate the effect of the percentage of Duroc gene on several characteristics of cured Parma ham.

Material and methods

The trial was conducted by evaluating hams from 167 heavy pigs, 87 castrated males and 80 females, belonging to different crosses, among Duroc (D), Large White (LW) and Landrace (L) breeds, bred from 26 sows mated to 15 unrelated boars (6 LW, 4 L, 5 D). The percentage of the Duroc breed was equal to 0% (LWxL; n. 33), to 25% [(LWx(DxL); n. 31 and Lx(DxLW); n. 35)] and to 50% [Dx(LWx(LWxL)); n. 68]. The presence of a group of Dx(Lx(LxLW)) was initially foreseen in the experimental protocol to mediate the effects of the other breeds in the 50% Duroc genes group. However, it was not included due to technical causes. This absence could have determined a slightly different estimation of the other breeds, limitedly to such group.

Animals were submitted to the same rearing and feeding conditions, as reported elsewhere (Sabbioni *et al.*, 2002a); they were slaughtered at 298 ± 6 d of age, during three different sessions; in each session a representative number of animals from all the genetic types were slaughtered.

The right ham of all pigs was weighed at slaughtering, after 24 hours of air-cooling at 4°C and then after trimming. Cooling and trimming losses were calculated and referred to as percentage of raw or cooled ham weight, respectively. The curing period, according to the official "Prosciutto di Parma" production protocol, lasted

380 d. At the end of the curing period, each ham was weighed and seasoning losses were calculated and referred in percentage to cold trimmed ham weight. Seasoned hams were measured, according to Fabbri *et al.* (1983). Briefly, length was measured from the proximal epiphysis of the femur to the tarsal bones, width and circumference were measured at their maximum point; compactness index was calculated as weight/length and conformation index as (width/length) x 100, according to Franci *et al.* (1997). Ham fat thickness was measured by ultrasound with a 3.5 MHz probe on the external side, at the intersection between the length line and the width line.

On the *biceps femoris*, after removal of 1 cm of muscle, the color was recorded with a Minolta Chromameter Reflectance II CR100/08, set at channel 1, containing a calibration with a Standard Gardner pink tile no.CG6625 (Y=45.97; x=0.3658; y=0.3250). Color values were expressed as CIE L* a* b* (Novelli *et al.*, 1991). The values of hue and chrome were calculated, respectively, as arctg(b*/a*) and $\sqrt{(a^{*2}+b^{*2})}$.

Table 1. Mean values (±SD) of ham parameters for each genotype.

Genotype		LWxL	LWx(DxL)	Lx(DxLW)	Dx(LWx(LWxL))
		mean ± SD	mean ± SD	mean ± SD	mean ± SD
Weight at slaughter	kg	17.27 ± 1.51	15.75 ± 1.28	16.73 ± 1.49	15.98 ± 1.49
Weight after cooling	"	16.76 ± 1.37	15.42 ± 1.31	15.96 ± 1.48	15.69 ± 1.48
Weight after trimming	"	13.57 ± 1.00	12.44 ± 1.17	12.74 ± 1.09	12.76 ± 1.29
Weight after seasoning	"	10.06 ± 0.83	9.13 ± 0.95	9.54 ± 0.83	9.41 ± 0.95
Weight after deboning	"	9.13 ± 1.22	7.78 ± 0.61	8.65 ± 0.84	8.17 ± 0.88
Cooling losses	%	2.89 ± 2.11	2.13 ± 0.65	4.63 ± 1.96	1.77 ± 0.85
Trimming losses	"	18.89 ± 2.19	19.34 ± 2.07	20.05 ± 2.77	18.72 ± 1.81
Seasoning losses	"	26.56 ± 2.42	26.75 ± 3.94	25.94 ± 1.76	26.92 ± 2.79
Deboned ham yield	"	88.38 ± 1.17	88.06 ± 0.39	89.28 ± 0.71	88.45 ± 0.69
Length	cm	51.47 ± 1.50	51.39 ± 2.05	51.44 ± 2.02	51.93 ± 2.05
Width	"	32.12 ± 1.57	30.59 ± 1.19	31.44 ± 1.47	31.21 ± 1.87
Circumference	"	77.08 ± 2.77	74.06 ± 2.84	76.17 ± 2.59	75.37 ± 3.02
Thickness	"	14.10 ± 0.87	13.65 ± 0.84	13.95 ± 0.83	13.73 ± 0.97
Compactness index (§)	g/cm	195.39 ± 15.28	177.49 ± 15.64	185.54 ± 14.72	181.05 ± 14.45
Conformation index (§§)		62.43 ± 3.06	59.57 ± 2.12	61.17 ± 2.92	60.16 ± 3.81
Fat thickness	cm	1.12 ± 0.16	1.13 ± 0.05	1.17 ± 0.30	1.34 ± 0.30
L*		45.03 ± 1.27	44.41 ± 1.20	44.38 ± 0.21	45.74 ± 1.07
a*		11.18 ± 1.13	10.79 ± 0.60	10.62 ± 1.64	9.96 ± 1.14
b*		5.75 ± 0.50	4.92 ± 0.51	5.81 ± 0.28	5.26 ± 0.45
Hue		0.48 ± 0.03	0.43 ± 0.03	0.51 ± 0.05	0.49 ± 0.03
Chrome		12.58 ± 1.16	11.87 ± 0.68	12.12 ± 1.55	11.27 ± 1.17
Moisture	%	58.20 ± 0.99	59.02 ± 0.21	58.61 ± 0.30	58.03 ± 0.91
Protein	"	26.93 ± 1.33	27.40 ± 0.77	27.59 ± 1.32	27.55 ± 1.30
Fat	"	8.09 ± 1.31	6.23 ± 0.51	7.03 ± 1.51	7.33 ± 2.09
Ash	"	6.78 ± 0.55	7.35 ± 0.24	6.77 ± 0.47	6.89 ± 0.62
NaCl	"	5.29 ± 0.46	5.74 ± 0.21	5.16 ± 0.42	5.30 ± 0.51
NPN/total N	"	21.38 ± 1.19	22.22 ± 1.86	19.90 ± 1.69	20.78 ± 2.00

(§) : weight/length *LW = Large white* *D = Duroc*
(§§) : (width/length) x 100 *L= Landrace*

Table 2. Weights, technological losses and measurements after seasoning of hams (least-squares means ± SE). Linear (b_1±SE) and quadratic (b_2±SE) effects of percentage of Duroc genes increase by 10%.

		Overall mean ± SE	b_1 ± SE	P	b_2 ± SE	P	RSD
Weight at slaughter	kg	16.37 ± 0.06	-0.221 ± 0.120	0.07	0.031 ± 0.022	ns	0.744
Weight after cooling	"	15.89 ± 0.02	0.012 ± 0.033	ns	0.000 ± 0.006	ns	0.207
Weight after trimming	"	12.83 ± 0.03	-0.049 ± 0.052	ns	0.012 ± 0.010	ns	0.326
Weight after seasoning	"	9.50 ± 0.03	0.038 ± 0.063	ns	-0.005 ± 0.012	ns	0.371
Weight after deboning	"	8.37 ± 0.03	-0.338 ± 0.072	0.00	0.058 ± 0.014	0.00	0.333
Cooling losses	%	2.80 ± 0.10	-0.008 ± 0.197	ns	-0.012 ± 0.036	ns	1.233
Trimming losses	"	19.21 ± 0.17	0.393 ± 0.340	ns	-0.080 ± 0.062	ns	2.128
Seasoning losses	"	26.63 ± 0.22	-0.693 ± 0.467	ns	0.125 ± 0.086	ns	2.738
Deboned ham yield	"	88.47 ± 0.06	0.463 ± 0.141	0.00	-0.072 ± 0.027	0.01	0.651
Length	cm	51.62 ± 0.14	0.266 ± 0.298	ns	-0.014 ± 0.055	ns	1.750
Width	"	31.33 ± 0.11	-0.271 ± 0.230	ns	0.052 ± 0.042	ns	1.349
Circumference	"	75.63 ± 0.16	-0.075 ± 0.330	ns	0.033 ± 0.061	ns	1.935
Thickness	"	13.83 ± 0.06	0.097 ± 0.127	ns	-0.014 ± 0.023	ns	0.748
Compactness index (*)	g/cm	183.9 ± 0.6	-0.215 ± 1.256	ns	-0.046 ± 0.230	ns	7.366
Conformation index (**)		60.7 ± 0.3	-0.832 ± 0.542	ns	0.117 ± 0.100	ns	3.182
Fat thickness	cm	1.25 ± 0.02	-0.086 ± 0.047	0.07	0.027 ± 0.009	0.00	0.214

ns : P>0.10.
(*) : weight/length
(**) : (width/length) x 100

Twenty-six seasoned hams of each genetic type were submitted to deboning and chemical composition (AOAC, 1999), salt content and extractable non protein nitrogen (NPN) (Bellatti *et al.*, 1983) were evaluated on a sample from the *semitendinosus* muscle, obtained during deboning.

Raw data were elaborated according to the least squares method (SPSS, 2002), using the following model of covariance analysis:

$$y_{ijk} = m + S_i + M_j + b_1X_{1ijk} + b_2X_{1\,ijk}^{2} + b_3X_{2ijk} + e_{ijk}$$

where:
y_{ijk} = individual observation;
m = overall mean;
S_i = fixed effect of sex (i = 1,2);
M_j = fixed effect of session of slaughtering (j =1,..,3);

b_1, b_2 = regression coefficients with percentage of Duroc breed genes (X_1) in linear and quadratic form, respectively; for the independent variable a scale was used so that the regression coefficients were expressed as the variation of the dependent each 10% more genes of the Duroc breed;

b_3 = regression coefficient with carcass or raw ham weight (X_2, kg), respectively, for data concerning raw ham weight, or data concerning ham weight during curing, losses, linear measures and indexes, color and chemical composition;

e_{ijk} = error term.

With the aim to better evaluate the lack of linearity, least squares means were obtained for some parameters by means of GLM analysis, following a model with sex, slaughtering session and percentage of Duroc breed inclusion as fixed factors and raw ham weight as covariate.

Results and discussion

The mean values (±SD) of ham parameters for each genotype are reported in Table 1. All values lay between the ranges reported in literature for "Prosciutto di Parma" production from heavy pigs (Bonomi *et al.*, 1992; Gallo *et al.*, 1994).

The effects of an increase in the percentage of Duroc genes on ham weights and losses during curing and on ham measurements are reported in Table 2. Although raw ham weight was slightly reduced with increasing percentages of Duroc genes (P=0.07), as reported elsewhere (Sabbioni *et al.*, 2002 a), weights and losses after cooling, trimming and curing were not affected by the percentage of Duroc genes (P>0.10). Deboned ham yield, as percent of cured ham, was linearly increased (P<0.01) with the increase in Duroc genes, likely due to a lower bone content; also a negative quadratic effect was shown (P=0.01). Least squares means of deboned ham yield reported values of 88.22%, 88.43% and 88.42% at percentages of Duroc genes of 0%, 25% and 50, respectively (data not tabulated). The absence of linearity, in this case as in other cases, is not easily explainable if not assuming a specific heterosis effect in some breed combinations. Bittante *et al.* (1991) noted that pigs from Duroc boars have higher deboned ham yields (about 3.5%), while Franci *et al.* (1997) reported a deboning loss of less than 3.7% in Duroc derived pigs compared to LW pigs.

Duroc breed rate did not affect the measures of seasoned ham, the compactness index and the conformation index (P>0.10); Franci *et al.* (1997) have shown a negative effect of the Duroc breed, compared to LW, on compactness and conformation indexes, varying from 2% to 2.2%; Bittante *et al.* (1991) noted that Duroc-derived pigs, compared to LW pigs, showed higher length and lower width, higher compactness index and lower conformation index.

Seasoned ham fat thickness linearly decreased with the increase in Duroc genes (P=0.07), as the quadratic effect was positive (P<0.01). Least squares means of fat thickness were cm 1.11, 1.15 and 1.45 at 0%, 25% and 50% Duroc breed inclusion, respectively (data not tabulated). Higher fat thickness with the increase in the percentage of Duroc genes has previously been reported by Bonomi *et al.* (1992) and by Blanchard *et al.* (1999); actually Duroc breed selection in Italy is aimed to contrast carcass fatness and, in particular, intramuscular fat by means of an appropriate selection index (ANAS, 2003).

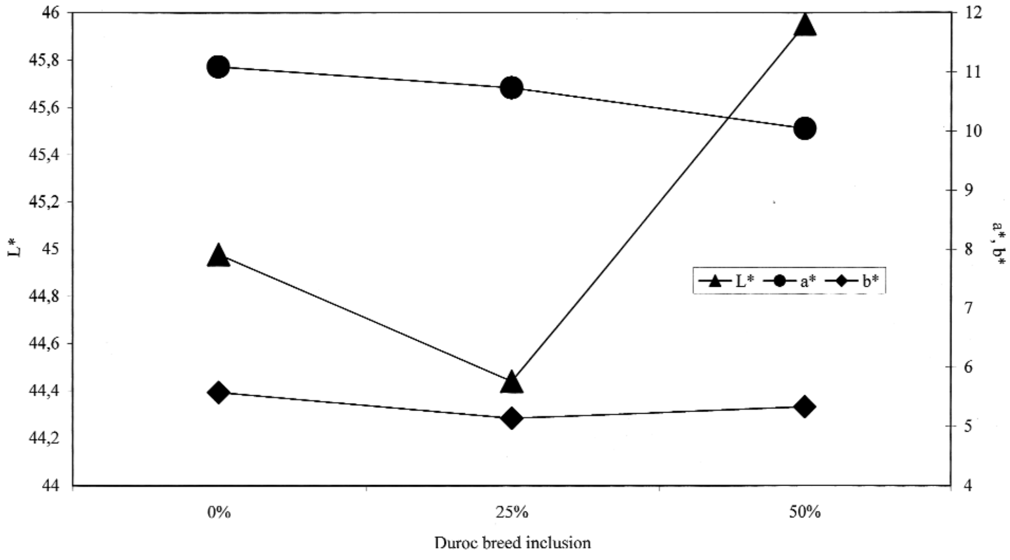
Table 3 summarizes the results of *biceps femoris* muscle color from cured hams. Contrary to what has been shown in raw hams at 24 h *post mortem* (Sabbioni *et al.*, 2002 a), the linear effect of the percentage of Duroc breed on seasoned ham lightness (L*) was negative (P<0.01) and the quadratic effect positive (P<0.01). Moreover, redness (a*) was not affected (P>0.10) and yellowness (b*) linearly reduced (P=0.09) and quadratically increased (P=0.01). The hue was positively affected in a quadratic form (P=0.03) by the percentage of Duroc breed genes, while chrome was not affected (P>0.10). Plots of least squares means for some color parameters are reported in Figure 1. The drop of L* values at 25% Duroc breed inclusion

Table 3. Color of *biceps femoris* muscle of seasoned hams (least-squares means ± SE). Linear (b_1±SE) and quadratic (b_2±SE) effects of Duroc genes percentage increase by 10%.

	Overall mean ± SE	b_1 ± SE	P	b_2 ± SE	P	RSD
L*	45.23 ± 0.10	-0.716 ± 0.201	0.00	0.165 ± 0.038	0.00	0.928
a*	10.49 ± 0.11	-0.176 ± 0.248	ns	0.001 ± 0.047	ns	1.142
b*	5.40 ± 0.04	-0.146 ± 0.085	0.09	0.042 ± 0.016	0.01	0.394
Hue	0.478 ± 0.003	-0.003 ± 0.007	ns	0.003 ± 0.001	0.03	0.032
Chrome	11.81 ± 0.11	-0.215 ± 0.247	ns	0.019 ± 0.047	ns	1.138

ns : P>0.10.

Figure 1. LS means of L*, a* and b* parameters in relation to Duroc breed inclusion.



could be better attributed to specific breed combinations than to breed effect. Franci *et al.* (1996) noted that Tuscany hams from Duroc derived pigs showed higher values of L*, b* and chrome than LW, L, Belgian Landrace and Cinta Senese derived pigs. No significant effect of Duroc breed on seasoned ham color was reported by Gallo *et al.* (1994). Blanchard *et al.* (1999) reported darker muscle color in fresh meat for 25% and 50% Duroc crosses compared with 0%.

The chemical composition of the *semitendinosus* muscle is reported in Table 4. As moisture increased linearly (P<0.01), fat (P=0.03) content decreased linearly with the increasing of Duroc breed inclusion; as expected, the quadratic effects were negative for moisture (P<0.01) and positive for fat (P=0.02). Protein, ash and salt were not linearly influenced by Duroc genes percentage (P>0.10), while ash and salt showed a significant and negative quadratic effect (P<0.01, P=0.08 and P=0.10, respectively). NPN content was significantly influenced by Duroc breed inclusion, with a negative linear effect (P=0.01) and a slightly positive quadratic effect (P=0.09). Plots of least

Table 4. Chemical composition of *semitendinosus* muscle of seasoned hams (least-squares means ± SE). Linear (b_1±SE) and quadratic (b_2±SE) effects of Duroc genes percentage increase by 10%.

		Overall mean ± SE	b_1 ± SE	P	b_2 ± SE	P	RSD
Moisture	%	58.28 ± 0.07	0.777 ± 0.161	0.00	-0.163 ± 0.031	0.00	0.744
Protein	"	27.41 ± 0.12	0.198 ± 0.255	ns	-0.019 ± 0.048	ns	1.178
Fat	"	7.25 ± 0.16	-0.776 ± 0.341	0.03	0.150 ± 0.065	0.02	1.574
Ash	"	6.93 ± 0.05	0.079 ± 0.099	ns	-0.033 ± 0.019	0.08	0.459
NaCl	"	5.35 ± 0.04	0.018 ± 0.022	ns	-0.024 ± 0.015	0.10	0.377
NPN/total N	"	21.17 ± 0.13	-0.748 ± 0.293	0.01	0.095 ± 0.056	0.09	1.351

ns : P>0.10.

Figure 2. LS means of chemical composition in relation to Duroc breed inclusion.

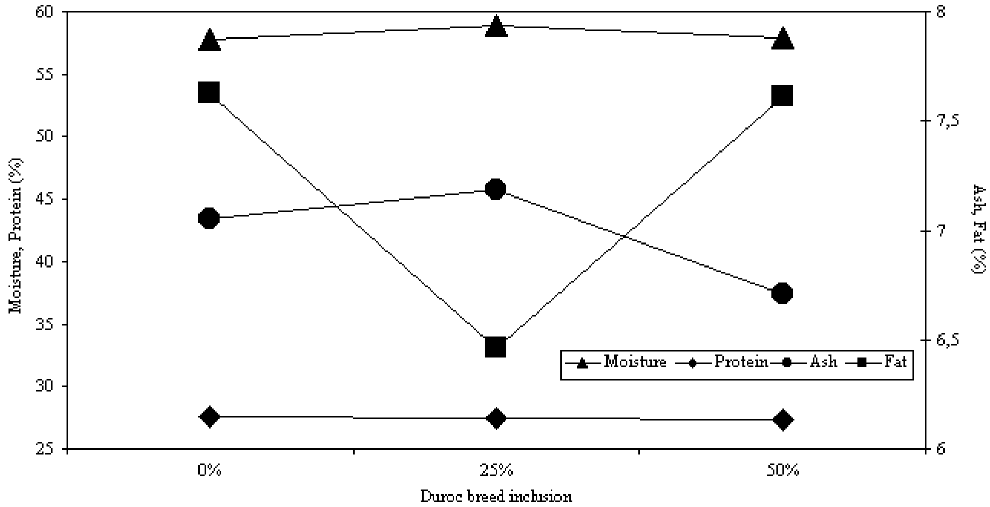
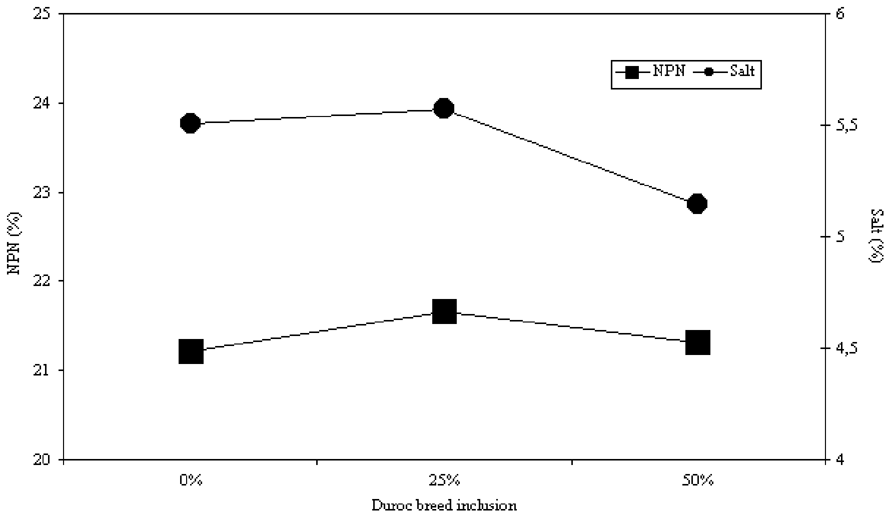


Figure 3. LS means of salt and NPN content in relation to Duroc breed inclusion.



squares means for chemical composition are reported in Figures 2 and 3. Gallo *et al.* (1994) noted a significant effect of Duroc breed on chemical composition of seasoned hams; in particular, Duroc breed inclusion increased dry matter and sodium chloride content and decreased crude protein percentage. Our study puts in evidence a reduction of salt content with the increase of Duroc genes percentage, that could be related to the higher ham fat thickness seen above, in agreement with that seen by Franci *et al.* (1996) in Tuscany ham, and a reduction of NPN content. Indeed, a reduction of NaCl levels in ham samples is important in determining sensory properties of Parma ham (Toscani *et al.*, 2000), while a reduction of NPN values indicates less proteolysis and a better curing technique.

Conclusions

The use of the Duroc breed for the production of heavy pigs for industry seems justified from the results of the present study, carried out with the aim to evaluate the effects of an increase in Duroc breed genes on the characteristics of Parma ham after curing. The main effects associated with an increase in Duroc breed genes include an improvement of deboned ham yield, ham fat thickness after curing and a reduction of salt and non protein nitrogen content.

Variations relevant to chemical composition of cured hams regard the improvement of the organolectic properties, in line with the aim of "Prosciutto di Parma" production protocol. Attention must be paid to color variations, characterized by a reduction of lightness and yellow that could have a negative impact on Parma ham production at Duroc breed inclusion levels above 50%.

When considering the conclusions of previous studies on the effects of the percentage of Duroc breed genes on growth characteristics, carcass, meat and fat quality (Sabbioni *et al.*, 2002 a; 2002 b), it is possible to conclude that the Duroc breed can be used in crosses with LW and L breeds up to a 50% blood percentage, thereby offering a positive contribution for the production of typical, long seasoning, air dried, salt cured hams, as well.

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