Spanish Journal of Agricultural Research
16 (1), e0402, 13 pages (2018)
eISSN: 2171-9292
https://doi.org/10.5424/sjar/2018161-12391
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, O.A, M.P. (INIA)

RESEARCH ARTICLE

OPEN ACCESS

Effect of breed and finishing diet on growth performance, carcass and meat quality characteristics of Mos young hens

Mirian Pateiro[1], Diego Rois[2], Jose M. Lorenzo[1], Jose A. Vazquez[3] and Daniel Franco[1]

[1] *Centro Tecnológico de la Carne de Galicia, Rúa Galicia Nº 4, Parque Tecnológico de Galicia, San Cibrao das Viñas, 32900 Ourense, Spain* [2] *Federación de Razas Autóctonas de Galicia (BOAGA). Fontefiz, 32152 Coles (Ourense), Spain* [3] *Grupo de Reciclado y Valorización de Residuos (REVAL), Instituto de Investigaciones Marinas (IIM-CSIC), R/ Eduardo Cabello 6, 36208 Vigo, Spain*

Abstract

Mos breed is a Spanish authoctonus breed linked to raising and natural food, with a growing market niche in the restoration due to their meat is associated with high quality products. The effect of breed (Mos and Sasso X44) on growth performance, carcass characteristics and meat quality of breast and drumsticks was examined in young hens reared 20 weeks in free-range system. The effect of finishing feeding (fodder, corn and linseed) was also evaluated on the aforementioned parameters. The Sasso group grew faster and the maximum weights were higher (p<0.001), but there was no effect of genotype or feed on final weight or growth efficiency. With the exception of breast piece, the highest percentages of commercial cuts were achieved in Mos birds, when breed was the studied effect. On the other hand, color parameters were not affected by breed. However, significant differences were found among feeding, since animals fed with corn achieved the highest redness values in drumstick (11.94 *vs.* 10.09 for corn and fodder, respectively; p<0.05). Regarding chemical composition, intramuscular fat (IMF) displayed significant differences between breeds (p<0.05), showing higher values in Sasso X-44. On the contrary, with the exception of IMF, significant differences (p<0.05) on chemical composition were observed among feeding groups. Finally, fatty acid profile was significantly affected by breed and feeding since animals fed with linseed presented better nutritional indices (lower SFA, n-6/n-3 ratio and higher PUFA and P/S ratio). The results show the suitability of Mos breed to produce high quality poultry products.

Additional keywords: poularde; genotype; free range; carcass traits; nutritional quality.

Abbreviations used: a* (redness); AI (atherogenic index); b* (yellowness); CL (cooking loss); FA (fatty acid); G (animal live-weight, kg); G_m (maximum animal live-weight, kg); h/H (hypocholesterolemic/hypercholesterolemic ratio); IMF (intramuscular fat); L* (lightness); LW (live weight); ME (metabolized energy); MUFA (monounsaturated FA); NV (nutritional value); PUFA (polyunsaturated FA); SFA (saturated FA); SD (standard deviation); SEM (standard error of the mean); t (animal age, weeks); TI (thrombogenic index); t_m (time required to achieve the maximum animal live-weight phase, weeks); TPA (texture profile analysis); UFA (unsaturated FA); WHC (water holding capacity); WB (Warner-Bratzler); τ (time required to achieve the half of the maximum animal live-weight, weeks); μ_m (specific maximum animal live-weight, weeks^{-1}); λ (lag phase, weeks); v_m (animal maximum rate of live-weight, kg/weeks).

Authors' contributions: Conceived, designed and performed the experiments: DR, JML and DF. Animals rearing: DP. Analyzed the data: MP, JAV and DF. Contributed reagents/materials/analysis tools: MP. Wrote the paper: MP, JML, JAV and DF. All authors read and approved the final manuscript.

Citation: Pateiro, M.; Rois, D.; Lorenzo, J. M.; Vazquez, J. A.; Franco, D. (2018). Effect of breed and finishing diet on growth performance, carcass and meat quality characteristics of Mos young hens. Spanish Journal of Agricultural Research, Volume 16, Issue 1, e0402. https://doi.org/10.5424/sjar/2018161-12391.

Received: 06 Oct 2017. **Accepted:** 22 Mar 2018.

Funding: Xunta de Galicia-Consellería de Medio Rural (Regional Government) (FEADER 2012/46).

Competing interests: The authors have declared that no competing interests exist.

Correspondence should be addressed to Daniel Franco: danielfranco@ceteca.net

Introduction

The term Poularde is used to define a young hen that has not laid eggs yet, traditionally reared in free-range conditions and especially primed for consumption, obtaining high quality products. However, to our knowledge there are scarce information about meat quality from Poularde that contrasts these opinions (Sokołowicz *et al*., 2016). This poultry meat product is consumed in several Mediterranean countries, particularly in France, cooked for special occasions, as Christmas day. In addition, consumers require poultry production linked to upbringing and natural food, obtained with local breeds, better adapted to the environment because they associate meat from these birds with high quality products.

Mos chicken breed is a native breed of Galicia (NW Spain) classified as an autochthonous endangered breed (BOE, 2008), characterized by a great rusticity that allows a perfect ability to adapt to the extreme conditions of the region, especially to the harshest temperatures existing in winter. Furthermore, are closely related to the environment and growing up outdoors lets contribute to the maintenance of biodiversity and sustainable agricultural production. The feed is complemented with concentrates and food generated on the farms. This breed is used for the production of eggs, roosters, chickens, capons and poulardes in outdoor breeding systems framed in quality poultry production. Apart of several research with roosters (Franco *et al*., 2012a, 2013) or capons (Díaz *et al*., 2010, 2013), there are few studies about this type of product, so this new information could be useful for the research community, meat poultry retailers, chefs and final consumers.

It is widely accepted that carcass and meat quality can be influenced by several factors, such feed (Puchała *et al*., 2015), age (Touraille *et al*., 1981) and genotype (Wattanachant *et al*., 2004; Jaturasitha *et al*., 2008). Indeed, factors related to meat sensory characteristics (color, cooking losses and tenderness) and meat quality (intramuscular fat and fatty acid (FA)) could be affected. These parameters are considered important as quality indicators and they have an impact on consumer acceptability (Andersen *et al*., 2005). Furthermore, through feeding strategy we can change the FA profile. The type of cereal used in the birds diet (Quentin *et al*., 2003; Lyon *et al*., 2004) had an impact on the amount of fat deposited and the FAs proportion (Kavouridou *et al*., 2008). Thereby, the quality of the FA could be improved increasing the unsaturated fatty acids content (greater proportion of components from the α-linolenic FA family) respect to saturated acids (Crespo & Esteve, 2002).

Therefore, the aim of this study was to evaluate the effect of breed on growth performance, carcass composition and meat quality in breast and drumstick cuts from birds of Mos and Sasso X44 genotypes slaughtered at 20 weeks, as well as the effect of finishing feeding (fodder, corn and linseed) on birds of Mos breed.

Material and methods

Experimental design and animal management

This study was conducted in the experimental facilities of Centro de Recursos Zoogenéticos de Galicia (Fontefiz, Ourense). A total of 60 birds (n = 19 of Sasso X44 and n = 41 of Mos breed) were used to carry out the study by separating the birds according to breed and feeding. Breed treatment consisted of 19 birds of Sasso X44 line (Sasso X44/Fodder) and 19 of Mos breed (Mos/Fodder); whereas feeding treatment consisted of 41 birds of Mos breed separated in three groups, 19 fed with a commercial fodder (Mos/Fodder), 11 with corn (Mos/Corn) and the last 11 with linseed (Mos/Linseed).

Animals were housed under traditional free-range conditions according to Commission Regulation 543/2008 (OJ, 2008). Mos breed birds were obtained from incubations performed of the existing breeder hens in the centre, while Sasso chicks (Sasso, France) were purchased from a local dealer (day 0). At hatch, the chicks were housed in a pen provided with a central hallway, several departments and natural ventilation with a density of 12 birds/m^2. At the 4th week of life, birds were sexed and accommodated in departments of second age with a density of 8 birds/m^2. As heat source, heaters of 250 W at the ratio of 1 per 40 chicks were used. Heaters were partially removed at 4 weeks and completely after 6 weeks. From the 8th week of life until the slaughter, the chicks were moved to the definitive installation, with an indoor and outdoor density of 4 and 6 birds/m^2, respectively. With this type of management we aimed to reproduce the most common system used in poultry outdoors.

Birds were fed "ad libitum" with a starter commercial feeding (21% protein and 12.56 MJ/kg ME) up to 4 weeks. From 4 to 16 weeks, birds were fed with a growth standard commercial feeding (19% protein and 12.14 MJ/kg ME). From 16 weeks to slaughter, a finishing commercial feeding (17% protein and 11.93 MJ/kg ME) was used.

To study the feeding effect, cereals (corn and linseed) were introduced in the diet in last month in order to complete their feeding. Table 1 shows the ingredients, chemical composition and oil FA composition of commercial fodder, corn and linseed. Intakes of compound feed based on a whole group and live weight (LW) of birds in all treatment groups were recorded at birth and biweekly from 2 to 20 weeks.

The birds, at 20 weeks of age, were placed in crates and transported to an accredited abattoir, a journey time of approximately 2 h. The birds were weighed (LW), hung on shackles on a slaughter line, killed by manual exsanguination, plucked and eviscerated. The carcasses were chilled in a 4°C cool room for 24 h. At this moment, the carcasses were weighed and the left side of the carcass was quartered according to Jensen (1984). Carcass portions were obtained as follows: the breast muscle was dissected from the carcass and weighed. The legs were disarticulated at the hip and knee joints and the drum and thigh portions were weighed. The head, neck and feet were also obtained and weighed. Carcass weight was determined as sum of head, neck, legs, drumstick, thigh, wing and breast. Dressing percentage was calculated as the relation between

Table 1. Composition of the experimental diets (dry matter basis)

	Diet		
	Fodder[1]	**Corn**	**Linseed**
Ingredients (%)			
Corn	35.07		
Toasted soybean flour	15.78		
Wheat	14.98		
Barley	11.97		
Extruded soybeans	10.25		
Calcium carbonate	10.11		
Dicalcium phospate	0.94		
Salt	0.25		
Calcium bicarbonate	0.10		
Corn		100	75
Linseed			25
Chemical composition (%)			
Dry matter	90.53	89.31	90.18
Fat	5.52	3.83	12.23
Protein	14.02	7.57	10.65
Ash	7.51	1.30	1.75
Carbohydrates	63.48	76.61	65.55
Energy (MJ/100 g)	1.50	1.55	1.75
Oil fatty acid composition (%)			
C16:0	34.99	14.13	11.90
C18:0	4.33	1.88	2.26
C18:1*n9 cis*	31.06	28.52	25.33
C18:2*n6 cis*	26.77	52.38	43.34
C18:3*n3*	1.39	1.49	14.94
n6/n3	19.26	35.15	2.90

[1]Fodder additives: vitamin A, 10,000 IU/kg; vitamin D3, 2,500 IU/kg; vitamin E, 9 IU/kg; Fe, 60 mg/kg; Zn, 50 mg/kg; Cu, 5 mg/kg; Mn, 60 mg/kg; Co, 0.05 mg/kg; Se, 0.20 mg/kg; I, 0.40 mg/kg; Fe, 425 mg/kg; methionine, 0.33%; lysine, 0.85%; and P, 0.59%.

carcass weight and live weight. Specifically, the *pectoralis major* and *peroneous longus* muscles were excised from breast and drumstick, respectively, for analysis. Breast was used to measure pH, color parameters, water-holding capacity (WHC), and textural traits, whereas drumstick was minced and used only for chemical composition determinations, due to the limited availability of sample.

Meat quality attributes

Physicochemical parameters and chemical composition

The pH of the samples was measured using a digital portable pH-meter (Hanna Instruments, Eibar, Spain) equipped with a penetration probe. A portable colorimeter (Konica Minolta CM-600d, Osaka, Japan) with the next settings machine (pulsed xenon arc lamp, angle of 0° viewing angle geometry, standard illuminant D65 and aperture size of 8 mm) was used to measure the meat color in the CIELAB space (CIE, 1976). Moisture, protein and ash were quantified according to the ISO recommended standards 1442:1997, 937:1978 and 936:1998, respectively. The intramuscular fat (IMF) was extracted according to the AOCS Official Procedure Am 5-04 (AOCS, 2005). Collagen content was determined according to AOAC official method 990.26 (AOAC, 2000). Heme iron was determined following Hornsey (1956).

Breast cuts (*pectoralis major muscle*) were cooked according Pateiro *et al*. (2013). All samples were cut perpendicular to the muscle fibre direction and were measured in a texture analyser (TA.XT.plus of Stable Micro Systems, Vienna Court, UK). Warner Bratzler and TPA-test were conducted following Pateiro *et al*. (2013).

WHC was measured by cooking loss (CL) in breast, and was calculated by measuring the difference in weight between the cooked and raw samples.

Analysis of fatty acid methyl esters

The FA profile was determined following the procedure described by Franco *et al*. (2013). The proportion of polyunsaturated (PUFA), monounsaturated (MUFA), unsaturated (UFA) and saturated (SFA) fatty acid contents were calculated. To assess nutritional properties of IMF, the PUFA/SFA, *n6/n3* hypocholesterolemic/hypercholesterolemic (h/H) ratios, nutritional value (NV) and atherogenic (AI) and thrombogenic index (TI) were determined according to Pateiro *et al*. (2013).

Statistical analysis

Modelling of bird growths

The experimental data of animal growths (G) were modelled by means of logistic equation (Vázquez *et al*., 2012):

$$G = \frac{G_m}{1 + \exp\left[2 + \frac{4v_m(\lambda - t)}{G_m}\right]} \quad [1]$$

Other formulas can be defined in order to obtain more parameters describing the different phases of rooster growth (Vázquez *et al*., 2012):

$$\mu_m = \frac{4v_m}{G_m} \quad [2]$$

$$\tau = \lambda + \frac{2}{\mu_m} \quad [3]$$

$$t_m = \tau + \frac{G_m}{2v_m} \quad [4]$$

where, G is the animal live-weight (kg), t is the animal age (weeks), G_m is the animal maximum live-weight (kg); τ is the time required to achieve the half of the animal maximum live-weight (weeks); v_m is the animal maximum rate of live-weight (kg/week); μ_m is the specific animal maximum live-weight (weeks^{-1}); t_m is the time required to achieve the animal maximum live-weight phase (G_m) (weeks) and λ is the lag phase (weeks).

Numerical methods and statistical analysis

The animal growths data were fitted by minimisation of the sum of quadratic differences between observed and predicted values, using the non-linear least-squares (quasi-Newton) method 'Solver' of the Microsoft Excel spreadsheet. Confidence intervals from the parametric estimates (Student's t test) and consistence of mathematical models (Fisher's *F* test) were evaluated by "SolverAid" macro (http://www.bowdoin.edu/~rdelevie/excellaneous).

For the statistical analysis of the results of carcass characteristics and meat quality, an analysis of variance (ANOVA) of one way using SPSS package (SPSS 19.0, Chicago, IL, USA) was performed for all variables considered in the study. The analysis was done using a GLM procedure, where the characteristics of the carcass, physicochemical parameters, and fatty acids are fixed as dependent variables, and breed and finishing feed was included in the model as fixed factors. The models used were:

$$Y = \mu + B + \varepsilon$$

$$Y = \mu + F + \varepsilon$$

where Y is the observation of dependent variables, μ is the overall mean, B is the effect of breed, F is the effect of finishing feed, and ε is the residual random error associated with the observation. The least squares mean (LSM) were separated using Duncan's t-test. All statistical test of LSM were performed for a significance level $p<0.05$. Standard error of the mean (SEM) were obtained as the standard deviation (SD) divided by the square root of the sample size. Correlations between variables ($p<0.05$) were determined by correlation analyses using the Pearson´s linear correlation coefficient.

Results

Growth performance

Figure 1 shows the experimental data of animal live-weight together with the profiles fitted by using Eq. [1]. As observed, the concordance between experimental and predicted data was very high and statistically significant (Table 2). The goodness of fit was in all cases superior to 0.993 and the robustness of equation (F-Fisher test) was always confirmed ($p<0.001$).

All kinetic parameters were statistically significant in all animal growths (t-Student test). The best growth (evaluated as G_m) was achieved by Sasso (fed with fodder) compared with Mos variety for the different types of feeding studied (fodder, corn and linseed). Maximum live-weight rate (v_m) was also faster in Sasso but for the rest of parameters no significant differences were obtained between the four growths assessed ($p>0.05$). The final weight of Mos rooster fed with fodder was higher than the other ones fed with corn and linseed. Nevertheless, the differences between them were not significant ($p>0.05$). Furthermore, the values of the average growth rates (kg/week) for the complete growth kinetics were: 0.162, 0.115, 0.108 and 0.102 for Sasso X44/fodder, Mos/fodder, Mos/corn and Mos/linseed, respectively (Table 2).

On the other hand, the feed conversion ratio for Sasso X44 was lower (slope values, b= 0.174±0.015 kg of fodder consumed/kg per week) than Mos (b= 0.181±0.020, 0.184±0.014 and 0.188±0.016 kg of fodder, corn and linseed consumed/kg per week, respectively) (Fig. 1). However, no effect of genotype and type of feeding was found in the feed conversion rate because no significant differences were observed (p>0.05).

Slight differences (not significant, p<0.05) can be observed between the live weight data at 20 weeks (Table 3) and the predicted values by the logistic equation at plateau/asymptotic phase (G_m) in Table 2. The experimental data of live weight are included in the own error (as interval of confidence) associated to the numerical determination of G_m. The prediction of this parameter was good but in some

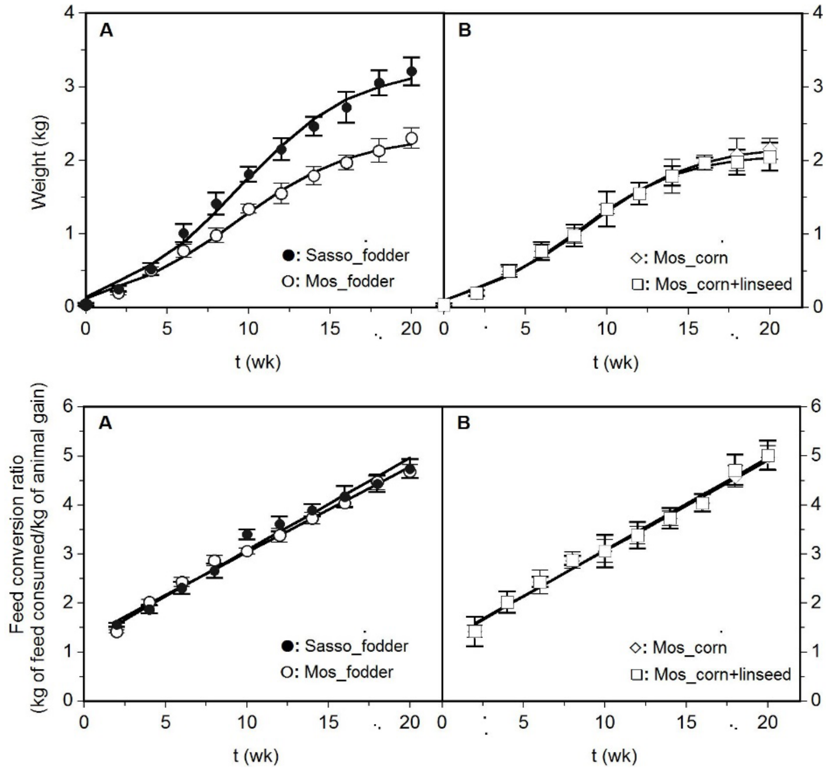

Figure 1. Live-weight kinetics (upper part) and feed conversion ratios (lower part) of young hens. In all cases, experimental data of growth (points) were fitted to Eq. [1] (continuous lines). Feed conversion ratio values were fitted to linear equation. Error bars are the 95% confidence intervals.

Table 2. Parametric estimations and 95% confidence intervals corresponding to the Eqs. [1], [2], [3] and [4] applied to predict the growth data of Mos and Sasso varieties showed in Figure 1.

	Sasso X44/Fodder	Mos/Fodder	Mos/Corn	Mos/Linseed	p-value		SEM
	(n=19)	(n=19)	(n=11)	(n=11)	Breed	Feed	
Gm	3.27 ± 0.31[a]	2.34 ± 0.22[b]	2.21 ± 0.15[b]	2.09 ± 0.13[b]	0.001	0.07	0.11
v_m	0.231 ± 0.037[a]	0.159 ± 0.024[b]	0.162 ± 0.022[b]	0.165 ± 0.023[b]	0.001	0.08	0.012
λ_m	2.38 ± 1.16	1.88 ± 1.15	1.87 ± 0.97	1.86 ± 0.92	0.08	0.26	0.26
μ_m	0.282 ± 0.063	0.272 ± 0.058	0.294 ± 0.053	0.315 ± 0.055	0.14	0.17	0.019
τ	9.47 ± 1.09	9.24 ± 1.09	8.68 ± 0.80	8.21 ± 0.69	0.15	0.08	0.13
t_m	16.56 ± 1.90	16.60 ± 1.95	15.49 ± 1.43	14.55 ± 1.22	0.23	0.07	0.15
G_{av}	0.162 ± 0.015	0.115 ± 0.011	0.108 ± 0.007	0.102 ± 0.006	0.001	0.07	0.008
R^2	0.993	0.993	0.995	0.995	-	-	-
p-value*	4×10^{-10}	3×10^{-10}	1×10^{-10}	1×10^{-10}	-	-	-

R^2: coefficient of multiple determination. p-value* for the robustness of equation were obtained from Fisher´s F test (α=0.05). [a-b] Means followed by different letters in the same row, only within a variable, are significantly different by Fisher´s F test (α=0.05).

Table 3. Effect of breed (Mos *vs.* Sasso X44) and finishing feed (weeks 16 to 20) on carcass quality from pulardas slaughtered at an age of 20 weeks.

	Sasso X44/Fodder (n=19)	Mos/Fodder (n=19)	Mos/Corn (n=11)	Mos/Linseed (n=11)	*p*-value Breed	*p*-value Feed	SEM [2]
Carcass quality							
Live weight (kg)	3.21	2.30[a]	2.16[b]	2.05[b]	<0.001	0.001	0.07
Carcass weight (kg)	2.55	1.80[a]	1.65[b]	1.56[b]	<0.001	<0.001	0.06
Dressing percentage (%)	83.88	81.01[a]	79.47[ab]	78.81[b]	0.001	0.021	0.39
Remainder of carcass (%) [1]	36.49	32.13[a]	30.78[ab]	29.51[b]	<0.001	0.007	0.46
Commercial cuts (% respect to carcass)							
Weight drumstick	10.59	11.82	12.21	12.03	<0.001	0.356	0.12
Skin drumstick	1.21	0.98[a]	0.76[b]	0.75[b]	0.008	0.001	0.04
Lean drumstick	7.03	8.11[b]	8.68[a]	8.61[a]	<0.001	0.013	0.11
Bone drumstick	2.25	2.66	2.70	2.62	0.001	0.848	0.05
Lean/Bone drumstick	3.18	3.11	3.25	3.32	0.647	0.413	0.06
Thigh	14.05	15.65	15.74	15.97	<0.001	0.583	0.16
Drumstick + thigh	24.65	27.47	27.95	28.00	<0.001	0.403	0.24
Wing	8.69	9.70	9.91	10.05	0.030	0.310	0.16
Breast	18.75	17.39	17.91	18.30	0.009	0.273	0.21
Head	2.57	3.20	3.24	3.40	<0.001	0.331	0.06
Neck	5.71	6.02	5.98	6.27	0.140	0.492	0.08
Legs	3.15	4.10[b]	4.24[ab]	4.47[a]	<0.001	0.039	0.08

[1] Remainder of carcass: differences between carcass weight and commercial cuts. [2] SEM: standard error of the mean. [a-b] Means followed by different letters in the same row, only to diet differences within the Mos breed, are significantly different by the Duncan's test (*p*<0.05).

cases (Sasso and Mos fodder), the plateau phase was not completely reached by the experimental data of growth.

Carcass characteristics

Carcass characteristics of Mos and Sasso X44 young hens are shown in Table 3. All carcass parameters, with the exception of neck, presented significant differences (*p*<0.05) respect to breed and feeding. These differences were especially significant (*p*<0.001) for live and carcass weight, carcass and the commercial cuts drumstick (weight and lean), thigh, head, legs, and the sum of drumstick and thigh. As expected, the results of live and carcass weight as well as carcass yield were higher in the commercial breed. However, the average percentages achieved in value commercial cuts reflected higher values in Mos breed. The sum of drumstick and thigh presented higher percentage in Mos breed (27.47 *vs.* 24.65; *p*<0.001). On the contrary, breast percentages were significantly higher for Sasso X44 breed (18.75 *vs.* 17.39; *p*=0.009).

The young hen groups with different feeding regime were differed in terms of live (*p*=0.001) and carcass weight (*p*<0.001), as well as carcass yield (*p*=0.007) (Table 3). The obtained values were higher in the birds fed with fodder followed by those fed with cereals.

Chemical composition and physicochemical parameters

The mean values of the physicochemical parameters and chemical composition are shown in Table 4. Regarding pH values, there were no significant differences between breeds for drumstick samples, whereas breast cuts were significantly affected by breed (*p*<0.001), reaching higher pH values in the commercial breed (5.69 *vs.* 5.81 for Mos and Sasso X44, respectively).

Concerning to color parameters, only in breast samples the luminosity showed significant differences between breeds (*p*=0.007), reaching higher values in Mos breed (Table 4). However, finishing feeding was a factor that affected meat color. Birds fed with fodder achieved the highest L* values in breast cut and the lowest a* values in drumstick cut. Within cereals feeding regime, animals fed with corn presented the highest redness values in drumstick pieces (11.94 *vs.* 10.86).

The results obtained for chemical composition showed that the highest moisture values (*p*<0.05) were found in birds fed with commercial fodder for both pieces. On the other hand, IMF content displayed significant differences (*p*<0.001) between breeds (Table 4), since Sasso X44 breed presented the highest values in both cuts, breast (0.40 *vs.* 0.17; *p*<0.001) and drumstick (2.49 *vs.* 1.89; *p*=0.018). When linseed was present in the diet, the IMF decreased significantly ($p<0.05$) in the drumstick cut (1.39 *vs.* 1.90%). For both genotypes, breast piece achieved the higher protein contents (23.5% and 20.8% for breast and drumstick, respectively). Feeding treatment had significant ($p<0.05$) effect on muscle development (protein content of drumstick and breast), achieving the highest values in birds fed with cereals.

Table 4. Effect of breed (Mos *vs.* Sasso X44) and finishing feed (weeks 16 to 20) on meat quality (chemical composition and colour parameters) of *peroneous longus* (drumstick) and *pectoralis major* (breast).

	Sasso X44/Fodder	Mos/Fodder	Mos/Corn	Mos/Linseed	*p*-value		SEM [2]
	(n=19)	(n=19)	(n=11)	(n=11)	Breed	Feed	
Drumstick							
pH	5.93	5.87^{b}	6.29^{a}	6.25^{a}	0.149	<0.001	0.03
Lightness (L*)	46.75	46.75^{a}	44.00^{b}	47.04^{a}	0.998	0.031	0.38
Redness (a*)	10.28	10.09b	11.94^{a}	10.86^{ab}	0.739	0.016	0.22
Yellowness (b*)	14.58	15.32	14.66	14.45	0.249	0.379	0.24
Moisture (%)	74.64	75.21^{a}	74.64^{b}	74.64^{b}	0.075	0.015	0.11
Intramuscular fat (%)	2.49	1.89^{a}	1.90^{a}	1.39^{b}	0.018	0.050	0.10
Protein (%)	21.50	20.03^{b}	21.44^{a}	21.18^{a}	<0.001	<0.001	0.11
Ashes (%)	1.28	1.32	1.33	1.34	0.071	0.812	0.01
Collagen (%)	0.70	0.61^{b}	0.45^{c}	0.72^{a}	0.008	<0.001	0.02
Fe heme [1]	0.84	0.83^{b}	0.93^{a}	0.95^{a}	0.843	0.012	0.02
Breast							
pH	5.81	5.69^{b}	5.93^{a}	5.92^{a}	0.001	<0.001	0.02
Lightness (L*)	52.78	55.15^{a}	48.46^{c}	50.88b	0.007	<0.001	0.47
Redness (a*)	1.87	1.08	1.81	1.32	0.059	0.212	0.15
Yellowness (b*)	15.98	17.09^{a}	13.54^{b}	13.17^{b}	0.152	<0.001	0.33
Moisture (%)	73.33	74.03^{a}	72.81^{b}	72.90^{b}	0.007	<0.001	0.10
Intramuscular fat (%)	0.40	0.17	0.10	0.16	<0.001	0.135	0.02
Protein (%)	23.46	23.53^{b}	25.84^{a}	25.36^{a}	0.849	<0.001	0.18
Ashes (%)	1.33	1.28^{b}	1.41^{a}	1.34^{ab}	0.206	0.002	0.01
Collagen (%)	0.40	0.38	0.35	0.38	0.687	0.508	0.01
Fe heme[1]	0.23	0.19^{b}	0.26^{a}	0.23^{ab}	0.086	0.026	0.02

[1] Fe heme expressed as (mg/g wet meat). [2] SEM: standard error of the mean. a-c Means followed by different letters in the same row, only to diet differences within the Mos breed, are significantly different by the Duncan's test ($p<0.05$).

Table 5. Effect of breed (Mos *vs.* Sasso X44) and finishing feed (weeks 16 to 20) on water holding capacity and textural parameters of *pectoralis major* (breast).

	Sasso X44/Fodder	Mos/Fodder	Mos/Corn	Mos/Linseed	*p*-value		SEM[1]
	(n=19)	(n=19)	(n=11)	(n=11)	Breed	Feed	
Cooking loss (%)	9.11	8.59	9.59	9.00	0.301	0.294	0.20
Textural parameters							
Firmness (N/s)	5.61	5.46^{b}	7.00^{a}	4.93^{b}	0.752	0.005	0.20
Total work (N/mm)	72.61	71.77^{b}	166.32^{a}	90.22^{b}	0.959	0.003	8.91
Shear force (N/cm^{2})	15.64	14.83^{b}	26.52^{a}	17.60^{b}	0.679	0.001	1.02
TPA-test							
Hardness (N)	40.51	35.53^{b}	58.31^{a}	54.32^{a}	0.052	<0.001	1.77
Springiness (mm)	0.50	0.53	0.53	0.51	0.061	0.327	0.01
Cohesiveness	0.42	0.42^{c}	0.53^{a}	0.50^{b}	0.805	<0.001	0.01
Gumminess (N)	17.11	15.14^{b}	31.18^{a}	27.30^{a}	0.138	<0.001	1.11
Chewiness (N mm)	8.73	8.16^{b}	17.03^{a}	13.94^{a}	0.477	<0.001	0.65

[1] SEM: standard error of the mean. a-c Means followed by different letters in the same row, only to diet differences within the Mos breed, are significantly different by the Duncan's test ($p<0.05$).

Table 6. Effect of breed (Mos *vs.* Sasso X44) and finishing feed (weeks 16 to 20) on fatty acid profile (g/100 g of fat) of *peroneous longus* (drumstick).

Fatty acids [1]	Sasso X44/Fodder (n=19)	Mos/Fodder (n=19)	Mos/Corn (n=11)	Mos/Linseed (n=11)	*p*-value Breed	*p*-value Feed	SEM [3]
C14	0.84	0.87[a]	0.65[b]	0.62[b]	0.309	<0.001	0.02
C16	26.28	26.42[a]	23.11[b]	21.32[c]	0.724	<0.001	0.32
C16:1	4.47	3.07[a]	2.80[ab]	2.45[b]	<0.001	0.019	0.13
C18	7.13	8.28[b]	10.01[a]	9.95[a]	<0.001	<0.001	0.18
C18:1n9c	36.39	32.77[a]	31.39[b]	29.89[c]	<0.001	<0.001	0.40
C18:1n7c	2.12	1.86[b]	2.16[a]	2.06[a]	<0.001	<0.001	0.03
C18:2n6c	17.65	20.54	20.90	21.27	<0.001	0.687	0.34
C18:3n6	0.15	0.15	0.13	0.13	0.590	0.252	0.01
C18:3n3	0.80	0.94[b]	0.71[b]	2.93[a]	0.006	<0.001	0.12
C20:3n6	0.27	0.30[b]	0.36[a]	0.33[a]	0.122	<0.001	0.01
C20:4n6	2.10	3.03[b]	5.54[a]	5.50[a]	0.001	<0.001	0.22
C22:5n3	0.21	0.29[c]	0.49[b]	1.13[a]	0.021	<0.001	0.05
C22:6n3	0.29	0.38[c]	0.62[b]	1.10[a]	0.009	<0.001	0.04
SFA	34.26	35.57[a]	33.76[b]	31.89[c]	0.011	<0.001	0.26
MUFA	42.98	37.70[a]	36.34[a]	34.40[b]	<0.001	<0.001	0.52
PUFA	21.48	25.62[c]	28.75[b]	32.38[a]	<0.001	<0.001	0.60
UFA	64.45	63.32[c]	65.09[b]	66.78[a]	0.030	<0.001	0.26
PUFA/SFA	0.63	0.72[c]	0.86[b]	1.02[a]	0.001	<0.001	0.02
n3	1.30	1.61[b]	1.82[b]	5.15[a]	0.001	<0.001	0.20
n6	20.18	24.01[b]	26.93[a]	27.23[a]	<0.001	0.001	0.48
Nutritional indices [2]							
n6/n3	15.80	15.20[a]	15.08[a]	5.56[b]	0.355	<0.001	0.57
AI	0.46	0.47[a]	0.40[b]	0.36[c]	0.240	<0.001	0.01
TI	0.97	1.00[a]	0.91[b]	0.69[c]	0.170	<0.001	0.02
h/H	2.22	2.21[c]	2.63[b]	2.96[a]	0.929	<0.001	0.05
NV	0.50	0.51[a]	0.46[b]	0.43[b]	0.430	<0.001	0.01

[1] SFA=∑ (C14:0+ C16:0+ C18:0); MUFA=∑ (C16:1+ C18:1*n*9c+ C18:1*n*7c); PUFA=∑ (C18:2*n*6c+C18:3*n*6+ C18:3*n*3+ C20:3*n*6 +C20:4*n*6+ C22:5*n*3+ C22:6*n*3); UFA=∑ MUFA+PUFA. [2] *n6/n3*: ratio between the sum of n6 and n3 fatty acids; AI: atherogenic index; TI: thrombogenic index; h/H: ratio hypocholesterolemic/hypercholesterolemic fatty acids; NV: nutritional value. [3] SEM: standard error of the mean. [a-c] Means followed by different letters in the same row, only to diet differences within the Mos breed, are significantly different by the Duncan's test ($p<0.05$).

Collagen content was significantly affected by breed ($p=0.008$) and feeding ($p<0.001$) in drumstick cuts (Table 4). However, its content did not influence by any effect in breast piece.

Statistical analysis did not find any effect of breed and feeding ($p>0.05$) on WHC of breast expressed as CL (Table 5). Textural parameters and TPA-test showed that no significant differences ($p>0.05$) were found between genotypes (Table 5). In relation to the texture of the breast meat, no significant effect on the WB test values were observed between breeds. Regarding TPA-test, the Mos breed presented the lowest hardness values (35.53 *vs.* 40.51 N for Mos and Sasso genotypes, respectively).

On the other hand, statistical analysis displayed significant differences on textural parameters by diet effect, obtaining the lowest hardness and shear force values in samples from animals fed with commercial fodder. The highest shear force values were noticed in animals from corn treatment (26.52 *vs.* 17.60 *vs.* 14.83 N cm^{-2} for corn, linseed and fodder treatments, respectively). In addition, the lowest hardness values were found in animals fed with fodder (35.53 *vs.* 58.31 *vs.* 54.32 N for fodder, corn and linseed groups, respectively).

Fatty acid profile

The FA profile of breast and drumstick is shown in Table 6 and 7, respectively. When the effect of genotype was evaluated, the FA profile showed that the predominant FAs were MUFA (ranged between 37.7% and 43.23%);

Table 7. Effect of breed (Mos *vs.* Sasso X44) and finishing feed (weeks 16 to 20) on fatty acid profile (g/100g of fat) of *pectoralis major* (breast).

Fatty acids [1]	Sasso X44/Fodder (n=19)	Mos/Fodder (n=19)	Mos/Corn (n=11)	Mos/Linseed (n=11)	*p*-value		SEM [3]
					Breed	Feed	
C14	0.74	0.75[a]	0.46[b]	0.51[b]	0.649	<0.001	0.02
C16	27.57	27.37[a]	23.98[b]	22.77[c]	0.601	<0.001	0.30
C16:1	3.63	3.10[a]	1.82[b]	1.48[b]	0.013	<0.001	0.13
C18	7.35	7.50[b]	10.06[a]	10.40[a]	0.350	<0.001	0.19
C18:1n9c	37.50	35.10[a]	28.88[b]	26.66[b]	0.015	<0.001	0.64
C18:1n7c	2.10	1.93[b]	2.71[a]	2.55[a]	0.128	<0.001	0.06
C18:2n6c	15.68	17.15	16.44	15.73	0.043	0.278	0.28
C18:3n6	0.15	0.14[a]	0.11[b]	0.11[b]	0.171	0.008	0.01
C18:3n3	0.68	0.76[b]	0.48[c]	1.79[a]	0.124	<0.001	0.06
C20:3n6	0.28	0.33[c]	0.56[a]	0.50[b]	0.014	<0.001	0.02
C20:4n6	2.35	3.43[b]	10.59[a]	10.91[a]	0.002	<0.001	0.52
C22:5n3	0.27	0.36[c]	1.17[b]	2.44[a]	0.036	<0.001	0.11
C22:6n3	0.37	0.56[c]	1.48[b]	2.36[a]	0.002	<0.001	0.11
SFA	35.65	35.63[a]	34.50[b]	33.68[b]	0.953	0.002	0.20
MUFA	43.23	40.13[a]	33.40[b]	30.69[c]	0.009	<0.001	0.74
PUFA	19.78	22.74[c]	30.83[b]	33.84[a]	0.009	<0.001	0.81
UFA	63.01	62.87[b]	64.23[a]	64.53[a]	0.772	0.005	0.20
PUFA/SFA	0.56	0.64[c]	0.90[b]	1.01[a]	0.014	<0.001	0.03
n3	1.33	1.69[c]	3.12[b]	6.59[a]	0.011	<0.001	0.27
n6	18.46	21.05[b]	27.71[a]	27.26[a]	0.011	<0.001	0.61
Nutritional indices [2]							
n6/n3	14.44	13.13[a]	9.05[b]	4.34[c]	0.173	<0.001	0.58
AI	0.49	0.48[a]	0.40[b]	0.39[b]	0.960	<0.001	0.01
TI	1.03	1.00[a]	0.86[b]	0.69[c]	0.299	<0.001	0.02
h/H	2.10	2.13[c]	2.56[b]	2.72[a]	0.530	<0.001	0.04
NV	0.53	0.54	0.54	0.55	0.644	0.766	0.01

[1] SFA=∑ (C14:0+ C16:0+ C18:0); MUFA=∑ (C16:1+ C18:1*n*9c+ C18:1*n*7c); PUFA=∑ (C18:2*n*6c+C18:3*n*6+ C18:3*n*3+ C20:3*n*6 +C20:4*n*6+ C22:5*n*3+ C22:6*n*3); UFA=∑ MUFA+PUFA. [2] *n6/n3*: ratio between the sum of n6 and n3 fatty acids; AI: atherogenic index; TI: thrombogenic index; h/H: ratio hypocholesterolemic/hypercholesterolemic fatty acids; NV: nutritional value. [3] SEM: Standard error of the mean; [a-c] Means followed by different letters in the same row, only to diet differences within the Mos breed, are significantly different by the Duncan's test ($p<0.05$).

followed by order decrease by SFA and PUFA, with mean values of 35.3% and 22.4%, respectively. The use of linseed in the diet significantly ($p<0.001$) decreased the SFA and MUFA content and significantly ($p<0.001$) increased the PUFA content in both cuts (drumstick and breast).

Within MUFA, the highest values were always observed in Sasso breed, since oleic and palmitoleic acids were the most abundant. The breast samples showed the highest oleic contents (37.50 *vs.* 35.10%, $p=0.015$, for Sasso and Mos genotypes, respectively) whereas the drumstick samples presented the highest palmitoleic acid (4.47 *vs.* 3.07%, $p<0.001$, for Sasso and Mos breed, respectively). Regarding SFA, both diet and breed effects showed significantly ($p<0.05$) differences in drumstick samples, whereas only diet effect presented significantly ($p<0.05$) differences in breast samples. Finally, the highest PUFA content was found in Mos genotype, since arachidonic and linolenic acids were the most important.

In relation to the nutritional indices, only significant differences ($p=0.001$) were found for PUFA/SFA ratio between breeds, since the highest ratios were observed in drumstick from Mos breed (0.72 *vs.* 0.64 in drumstick and breast samples, respectively). The use of linseed in the diet significantly ($p<0.001$) increased the PUFA/SFA ratio in both pieces (drumstick and breast), whereas the *n6/n3* ratio significantly ($p<0.001$) decreased in both cuts. Regarding h/H ratio, the use of linseed in the finishing diet significantly ($p<0.001$) increased in breast and drumstick samples, from 2.13 to 2.72 and from 2.21 to 2.96 for commercial fodder and linseed groups, respectively. Finally, the lowest AI and TI indices were observed in samples of animals fed with linseed.

Discussion

Growth performance

Similar highlights of animal growths were reported by other authors for Mos and Sasso genotypes slaughtered at 24 weeks (Franco *et al*., 2013). Indeed, the values of *Gm* were, in all cases, lower than those reached by the same birds slaughtered at 32 weeks (Franco *et al*., 2012a).

Compared to other birds studied, the results found by Muriel *et al*. (1999) with females from Redstar Shaver breed were higher than those observed in our study. These authors obtained live weights of 2.42 kg at 11 weeks *vs.* 1.99 kg for Sasso and 1.44 kg for Mos at the same time. Lower growths were reached with Spanish native genotypes slaughtered at 20 weeks: 1.39 kg, 1.50 kg and 1.49 kg for Valenciana de Chulilla, Menorca and Sobrarbe breeds, respectively (Grimal & Gómez, 2007; Cajal, 2008).

Regarding growth efficiency, Muriel *et al*. (1999) observed an efficiency of 4.84 kg of food consumed/kg of Redstar Shaver at 11 weeks *vs.* 3.26 kg of fodder consumed/kg of Sasso and 3.21 kg of fodder consumed/kg of Mos.

Carcass characteristics

The findings of carcass characteristics are consistent with those reported by Franco *et al*. (2012a) who found the same pattern in roosters of the same breeds.

Again, the sum of drumstick and thigh is consistent with those of other studies with the same breed (rooster slaughter at 6 months) and suggests that Mos breed provided high yield of noble parts, with the exception of breast, which satisfies the industry and consumer demands. This outcome is in agreement with data reported by Miguel *et al*. (2008) in chickens of another native Spanish breed (26.89 *vs.* 27.47%, respectively).

The findings of the current study do not support the previous research, observed in roosters of the same breeds fed with a concentrate and corn (Franco *et al*., 2012a). However, when animals from Mos breed were castrated, higher values of carcass weight were found in capons fed with a commercial diet *vs.* capons fed with cereals (Díaz *et al*., 2013).

Chemical composition and physicochemical parameters

The lowest pH values found in breast could be due to the different activity of each muscle, in this way the muscles that had lower pH values could be related to the existence of a higher concentration of glycogen and less activity in the muscle (Lorenzo *et al*., 2013) in accordance with those results reported for other native Spanish chickens (Miguel *et al*., 2008). Regarding feeding, the pH values in birds fed with cereals were higher than those obtained by Díaz *et al*. (2013) in capons fed with cereals and similar than those observed by Franco *et al*. (2012a) in roosters fed with corn. On the other hand, the pH values obtained in the drumstick from birds fed with fodder are in disagreement with data reported by Díaz *et al*. (2010) (5.87 *vs.* 6.40).

Breed is not a factor that affects poultry meat color (Franco *et al*., 2012a, 2013), which is in agreement with data reported by the present research. The highest redness values found in drumstick could be due to the breast is a muscle mainly consisting of white fibers, while drumstick is formed by several muscles with an important proportion of red fibers (Díaz *et al*., 2010). However, finishing feeding affected meat color. These findings seem to be consistent with other researches that found that the use of different cereals may influence the color of meat (Quentin *et al*., 2003; Lyon *et al*., 2004). Numerically, the values obtained for L* were similar than those reported by Franco *et al*. (2012a) and higher than those found by Díaz *et al*. (2013), while redness values were higher than those noticed by other authors (Díaz *et al*., 2010, 2013) in capons fed with commercial diet and cereals.

Despite having statically differences in moisture content for the effects studied in the present research, we can note that the ranged values were similar to those reported by other authors (De Marchi *et al*., 2005; Díaz *et al*., 2010; Franco *et al*., 2012a).

The significant differences found for IMF content could be related with the type of muscle and its composition, since the drumstick is composed by an important proportion of red fibers, which had higher lipid content than white fibers (Cassens & Cooper, 1971). These findings are in disagreement with data reported by other authors (Miguel *et al*., 2008; Díaz *et al*., 2010; Franco *et al*., 2012a) who found higher IMF values in native Spanish breeds. The effect of diet on IMF must be interpreted with caution because energy to protein ratio was no equal for the three feeding treatments, but it seems that our results agree with other studies (Crespo & Esteve, 2002) showing that the polyunsaturation level of the diet may easily influence fat deposits.

In agreement with Wattanachant *et al*. (2004), protein content achieved the highest values in breast piece and within the range obtained by both cuts (breast (21.0-26.2%) and drumstick (18.7-22.2%)) by several authors in other autochthonous breeds (De Marchi *et al*., 2005; Miguel *et al*., 2008; Díaz *et al*., 2010; Franco *et al*., 2012a).

The ashes content were similar than those observed in earlies studies for this breed (Franco *et al*., 2012a), but were slightly higher than those achieved in other studies (De Marchi *et al*., 2005; Miguel *et al*., 2008; Díaz *et al*., 2013). However, the findings for collagen content are in disagreement with data reported by other authors (Jaturasitha *et al*., 2008; Franco *et al*., 2012a) who noticed lower collagen contents in indigenous breeds.

The lack of effect of breed and feeding on WHC is in agreement with those reported by Franco *et al*. (2012a,b; 2013) in entire roosters slaughtered at different ages or in castrated roosters (Amorim *et al*., 2016; Franco *et al*., 2016). However, our cooking loss values were lower than others reported for autochthonous breeds (12.2% *vs.* 13.1% *vs.* 13.7% *vs.* 15.32% *vs.* 15.59% for Mos, Castellana Negra, Padovana, Pedrés and Amarela breeds cited in Franco *et al*. (2013), Miguel *et al*. (2008), De Marchi *et al*. (2005) and Amorim *et al*. (2016), respectively). In addition, these results were similar or even higher than others previously reported in studies carried out with Mos breed in entire (Franco *et al*., 2012a) and castrated roosters (Franco *et al*., 2016). Apart of other factors as breed and different rearing conditions, a possible explanation for these contradictory results could be due to the cooking methodology (temperature). Indeed, Lepetit *et al*. (2000) reported that CL was higher as the temperature increased and in the range of 70-80 ºC. In this regard, they found an increase in CL from 20 to 32%, working with cooked meat from Friesian cull cows. This situation could explain how small differences in the control of cooking temperature over a long time could affect the final result. Therefore, a rigorous control of temperature is necessary.

The no significant effects of genotype on WB test is in agreement with those reported by Díaz *et al*. (2010) who noticed similar values of shear force among breeds (34.2 *vs.* 33.2 *vs.* 34.6 N/cm^2 for Mos, Sasso T-44 and Sasso X-44 genotypes, respectively). However, Wattanachant *et al*. (2004) and Jaturasitha *et al*. (2008) observed significant differences on shear force values among different breeds.

TPA-test showed significant differences between different diets. This result is in agreement with those published by Lyon *et al*. (2004) who observed that meat from corn fed broilers required significantly less force to shear than meat from birds fed wheat. On the contrary, Franco *et al*. (2012a) and Díaz *et al*. (2013) did not find effect of finishing diet on textural parameters.

Fatty acid profile

The effect of genotype on FA profile of breast and drumstick was similar than those found in other native Spanish breeds (Franco *et al*., 2012a; Díaz *et al*., 2013). In contrast, Jaturasitha *et al*. (2008) and Amorim *et al*. (2016) noticed that SFA were the predominant FAs and MUFA less abundant in Thai and Portuguese chicken indigenous, respectively. Accordingly with Wattanachant *et al*. (2004) and Díaz *et al*. (2012), a significantly lower oleic acid content was found in samples from Mos.

The PUFA content depends on the process of elongation/desaturation and the mechanism implicated in the incorporation of long PUFA in the muscles which it is more efficient in native breeds. In this sense, Franco *et al*. (2012a) observed higher arachidonic and docosahexaenoic acids content in Mos genotype than those obtained in commercial line. Statistical analysis displayed significant differences on FA profile by diet effect. To this regard, Cortinas *et al*. (2004) noticed that the PUFA content in chicken tissues depends more on the variation in dietary FA content than the SFA and MUFA contents in these tissues. Our results were in agreement with those reported by Díaz *et al*. (2013) who observed significant effects of feeding in some FA of the breast and drumstick meat.

Regarding nutritional indices, the ratio PUFA/SFA were within the optimal values (0.5-0.7) recommended in the Mediterranean diet (Ulbricht & Southgate, 1991). On the contrary, the *n6/n3* ratio exceed the nutritional recommendations of FAO (2010) for the human diet, established in 4.0. Contemporary changes in human nutrition are characterized by increasing consumption of fat and vegetable oils rich in *n6* PUFA together with decrease in *n3* PUFA rich foods, resulting in an *n6/n3* ratio of 10–20/1 in Western diet for a ratio around 1/1 respect to the diet of our ancestors. In this sense, the ratio n-6/n3- was always under 20 for all cases. The animals fed with linseed, especially in breast samples, showed values very close to these recommendations. Finally, the values obtained for the h/H ratio in animals fed with fodder were within the values considered as favorable (h/H ≥ 2.5), whereas animals fed with cereals (corn or linseed) showed values higher than the recommended values.

As expected, the comparison between genotypes revealed the greater growth of Sasso breed. Although, the hybrid line showed higher carcass weight, Mos breed had a significantly higher percentage of drumstick, thigh and wing. Meat color was modified by finishing diet; since young hens fed with corn presented the highest redness values, which is important for consumer preference. On the other hand, the highest IMF contents were observed in samples from Sasso breed, although breast from Mos breed were tendered than those obtained from Sasso breed. From nutritional viewpoint, Mos breed showed higher content of PUFA and *n3* content respect to Sasso breed. Finishing with cereals increased PUFA content in both pieces; linseed showed higher *n3* values and corn *n6* contents. Linseed-based finishing diet is beneficial due to result in a meat with better nutritional indices (lower SFA and *n6/n3* ratio and higher PUFA and P/S ratio).

References

Amorim A, Rodrigues E, Pereira E, Valetim R, Teixeira A, 2016. Effect of caponisation on physicochemical and sensory characteristics of chickens. Animal 1: 1-9. https://doi.org/10.1017/S1751731115002876

Andersen HA, Oksbjerg N, Yung JF, Therkildsen M, 2005. Feeding and meat quality - A future approach. Meat Sci 70: 543-554. https://doi.org/10.1016/j.meatsci.2004.07.015

AOAC, 2000. AOAC official method 990.26. Hydroxyproline in meat and meat products. 39.1.27. In: Official methods of analysis. Assoc Offic Anal Chem, Arlington, VA, USA.

AOCS, 2005. AOCS Official Procedure Am 5-04. Rapid determination of oil/fat utilizing high temperature solvent extraction. Am Oil Chem Soc, Urbana, IL, USA.

BOE, 2008. Real Decreto 2129/2008, de 26 de diciembre, por el que se establece el Programa Nacional de Conservación, Mejora y Fomento de las Razas. Ministerio de Medio Ambiente, Medio Rural y Marino, Boletín Oficial del Estado n°23, 27 de enero de 2009, Spain. pp: 9211-9242.

Cajal JR, 2008. Caracterización productiva de la gallina raza Sobrarbe. Proc Expoaviga II, Congreso de Etnología Avícola, Barcelona (España). pp: 65-72.

Cassens RG, Cooper CC, 1971. Red and white muscle. Adv Food Res 19: 1-74. https://doi.org/10.1016/S0065-2628(08)60030-0

CIE, 1976. Colorimetry: Official recommendations of the International Commission on Illumination, CIE No. 15 E-1.3.1. Int Commiss on Illum, Paris.

Cortinas L, Villaverde C, Galobart J, Baucells MD, Codony R, Barroeta AC, 2004. Fatty acid content in chicken thigh and breast as affected by dietary polyunsaturation levels. Poult Sci 83: 1155-1164. https://doi.org/10.1093/ps/83.7.1155

Crespo N, Esteve E, 2002. Nutrient and fatty acid deposition in broilers fed different dietary fatty acid profiles. Poult Sci 81: 1533-1542. https://doi.org/10.1093/ps/81.10.1533

De Marchi M, Cassandro M, Lunardi E, Baldan G, Siegel PB, 2005. Carcass characteristics and qualitative meat traits of the Padovana breed of chicken. Int J Poult Sci 4: 233-238. https://doi.org/10.3923/ijps.2005.233.238

Díaz O, Rodríguez L, Torres A, Cobos A, 2010. Chemical composition and physico-chemical properties of meat from capons as affected by breed and age. Span J Agric Res 8: 91-99. https://doi.org/10.5424/sjar/2010081-1147

Díaz O, Rodríguez L, Torres A, Cobos A, 2012. Fatty acid composition of the meat from Mos breed and commercial strain capons slaughtered at different ages. Grasas Aceites 63: 296-302. https://doi.org/10.3989/gya.011312

Díaz O, Rodríguez L, Torres A, Cobos A, 2013. Composition and physico-chemical properties of meat from capons fed cereals. J Integr Agric 12: 1953-1960. https://doi.org/10.1016/S2095-3119(13)60633-4

FAO, 2010. Fat and fatty acid requirements for adults. Fats and fatty acids in human nutrition. Food and Agriculture Organization of the United Nations, Rome. pp: 55-62.

Franco D, Rois D, Vázquez JA, Purriños L, González R, Lorenzo JM, 2012a. Breed effect between Mos rooster (Galician indigenous breed) and Sasso T-44 line and finishing feed effect of commercial fodder or corn. Poult Sci 91: 487-498. https://doi.org/10.3382/ps.2011-01546

Franco D, Rois D, Vázquez JA, Lorenzo JM, 2012b. Comparison of growth performance, carcass components and meat quality, between Mos rooster (Galician indigenous breed) and Sasso T-44 line slaughtered at 10 months. Poult Sci 91: 1227-1239. https://doi.org/10.3382/ps.2011-01942

Franco D, Rois D, Vázquez JA, Lorenzo JM, 2013. Carcass morphology and meat quality from roosters slaughtered at eight months affected by genotype and finishing feeding. Span J Agric Res 11: 382-393. https://doi.org/10.5424/sjar/2013112-3094

Franco D, Pateiro M, Rois D, Vazquez JA, Lorenzo JM, 2016. Effects of caponization on growth performance, carcass and meat quality of Mos breed capons reared in free-range production system. Ann Anim Sci 16: 909-929. https://doi.org/10.1515/aoas-2016-0009

Grimal A, Gómez EA, 2007. Descripción y caracterización de una población de la Comunidad Valenciana: la Gallina de Chulilla. Arch Zootec 56: 523-528.

Hornsey HC, 1956. The colour of cooked cured pork. I. Estimation of the nitric oxide-haem pigments. J Sci Food Agric 7: 91-97. https://doi.org/10.1002/jsfa.2740070804

Jaturasitha S, Srikanchai T, Kreuzer M, Wicke M, 2008. Differences in carcass and meat characteristics between chicken indigenous to Northern Thailand (Black-Boned and Thai Native) and imported extensive breeds (Bresse and Rhode Island Red). Poult Sci 87: 160-169. https://doi.org/10.3382/ps.2006-00398

Jensen JF, 1984. Method of dissection of broiler carcasses and description of parts. World Poult Sci Assoc, Working group V, Frederiksberg C, Denmark.

Kavouridou K, Barroeta AC, Villaverde C, Manzanilla EG, Baucells MD, 2008. Fatty acid, protein and energy gain of broilers fed different dietary vegetable oils. Span J Agric Res 6: 210-218. https://doi.org/10.5424/sjar/2008062-312

Lepetit J, Grajales A, Favier R, 2000. Modelling the effect of sarcomere length on collagen thermal shortening in cooked meat: Consequence on meat toughness. Meat Sci 54: 239-250. https://doi.org/10.1016/S0309-1740(99)00086-8

Lorenzo JM, Pateiro M, Franco D, 2013. Influence of muscle type on physicochemical and sensory properties of foal meat. Meat Sci 94: 77-83. https://doi.org/10.1016/j.meatsci.2013.01.001

Lyon BG, Smith DP, Lyon CE, Savage EM, 2004. Effects of diet and feed withdrawal on the sensory descriptive and instrumental profiles of broiler breast fillets. Poult Sci 83: 275-281. https://doi.org/10.1093/ps/83.2.275

Miguel JA, Ciria J, Asenjo B, Calvo JL, 2008. Effect of caponization growth and on carcass and meat characteristics in Castellana Negra native Spanish chickens. Animal 2: 305-311. https://doi.org/10.1017/S1751731107001127

Muriel A, Martín M, Pascual MR, 1999. Producción de pollos criados en libertad en Extremadura. Secretaria General Técnica. Consejería de Agricultura y Medio Ambiente, Junta de Extremadura, Badajoz.

OJ, 2008. Commission Regulation (EC) No 543/2008 laying down detailed rules for the application of Council Regulation (EC) No 1234/2007 as regards the marketing standards for poultry meat. Official Journal of the European Union L 157 17/06/2008.

Pateiro M, Lorenzo JM, Díaz S, Gende JA, Fernández M, González J, García L, Rial FJ, Franco D, 2013. Meat quality of veal: discriminatory ability of weaning status. Span J Agric Res 11: 1044-1056. https://doi.org/10.5424/sjar/2013114-4363

Puchała M, Krawczyk J, Sokołowicz Z, Utnik-Banaś K, 2015. Effect of breed and production system on physicochemical characteristics of meat from multi-purpose hens. Ann Anim Sci 15: 247-261. https://doi.org/10.2478/aoas-2014-0082

Quentin M, Bouvarel I, Berri C, Le Bihan-Duval E, Baéza E, Jégo Y, Picard M, 2003. Growth, carcass composition and meat quality response to dietary concentrations in fast-, medium- and slow-growing commercial broilers. Anim Res 52: 65-77. https://doi.org/10.1051/animres:2003005

Sokołowicz Z, Krawczyk J, Świątkiewicz, 2016. Quality of poultry meat from native chicken breeds-A review. Ann Anim Sci 16: 347-368. https://doi.org/10.1515/aoas-2016-0004

Touraille C, Kopp J, Valin C, Ricard FH, 1981. Chicken meat quality. Influence of age and growth rate on physicochemical and sensory characteristics of the meat. Archiv Für Geflügelkunde 45: 69-76.

Ulbricht TLV, Southgate DAT, 1991. Coronary heart disease: Seven dietary factors. Lancet 338: 985-992. https://doi.org/10.1016/0140-6736(91)91846-M

Vázquez JA, Lorenzo JM, Fuciños P, Franco D, 2012. Evaluation of non-linear equations to model different animal growths with mono and bi-sigmoid profiles. J Theor Biol 314: 95-105. https://doi.org/10.1016/j.jtbi.2012.08.027

Wattanachant S, Benjakul S, Ledward DA, 2004. Composition, color, and texture of Thai indigenous and broiler chicken muscles. Poult Sci 83: 123-128. https://doi.org/10.1093/ps/83.1.123