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Composition and Physico-Chemical Properties of Meat from Capons Fed Cereals

Olga Díaz, Luisana Rodríguez, Alexandr Torres and Ángel Cobos

Food Technology Division, Department of Analytical Chemistry, Nutrition and Food Science, Faculty of Sciences, University of Santiago de Compostela, Lugo 27002, Spain

Abstract

Chemical composition, physico-chemical properties and fatty acid composition of breast and drumstick meat from capons (castrated male cockerels) fed cereals were studied. Three groups of capons were reared. One group was fed *ad libitum* the same commercial diet until the 4th mon of life. The last month of its life, the capons of this group were fed corn. The second and third group of capons were fed the same diet from caponization. The second group was fed mixture of corn (50%) and wheat (50%). The third group of capons was fed 2/3 corn and 1/3 mixture of corn (50%) and barley (50%). Capons were reared under free-range conditions and slaughtered at 150 d of age. Caponization was performed at 48 d. No significant effects of feeding in chemical composition, pH, water holding capacity, drip and cooking losses and texture of the meat were observed. The meat of the third group (capons fed 83% corn) was more yellow and showed higher content of C18:2 than that of the other capons.

Key words: castrated male cockerel, feeding, meat quality, fatty acids

INTRODUCTION

Capons are castrated male cocks that are consumed in several European countries, such as France, Hungary and Spain. Their meat is very appreciated by consumers and it reaches high prices due to its quality. In northwestern Spain (Galicia), capons were traditionally reared in free range conditions and their diet was only supplemented with cereals or potatoes. Nowadays, the capons are fed commercial diet until the last month and then they are only fed corn. Previous studies on chemical and fatty acid composition and physico-chemical properties of meat from capons have been carried out feeding animals with commercial diet with or without free range conditions (Tor *et al.* 2005; Miguel *et al.* 2008; Sirri *et al.* 2009; Díaz *et al.* 2010, 2012). There is no information about composition and properties of meat from capons only fed cereals, mainly corn. Consumers demand products of high quality and they, specially people who like gourmet foods, are very interesting in meat and meat products from animals that were fed all their life in the traditional way. Consumers associate these meats with high quality products because the animals are fed without additives that are usually included in the commercial diets. However, the feeding of capons with corn could influence the meat quality, such as it has been observed in the increase of polyunsaturated fatty acid content and colour parameters of rooster meat (Franco *et al.* 2012a, b). Because of the high cost of corn, the use of other cheaper cereals, such as barley and wheat, in capon

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Correspondence Ángel Cobos, Tel: +34-982-824070, Fax: +34-982-285872, E-mail: angel.cobos@usc.es

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diets could be very interesting. However, the use of these cereals at high levels can cause negative effects on the growth of broilers (Nahas and Lefrancois 2001).

The objective of this study was to determine the chemical and fatty acid composition and physico-chemical properties of the breast and drumstick meat of capons fed corn the last month on their life or fed different cereals (corn and wheat or corn and barley) from caponization until slaughter.

RESULTS AND DISCUSSION

The carcass weights of capons fed corn in their last month of life (CDC batch), of those fed corn and wheat (CW batch) and of those fed corn and barley (CB batch) are shown in Table 1. Significant differences between the CDC batch and the other two batches were found. The capons fed corn in their last month of life showed higher carcass weight than the other ones due to they were fed commercial diet until the 4th mon of life. This diet included different ingredients and additives that probably provided better nutritional balance than the feeding with cereals. The formulation of commercial poultry diets considers the essential nutrients and they are provided by animal and vegetable proteins and fats, minerals, vitamin premixes, and cereals. Each separate type of ingredient provides a specific quantity and quality of nutrients to the diet that is formulated for maximum animal growth (Hui and Guerrero-Legarreta 2010). The growth of these capons in this period was higher than those of capons fed cereals (Fig.). No increase of the capon weight was observed in CDC batch from the 4th mon of life until slaughter. This could be due to the capons were fed only corn; however, it is more possible that the 4-mon-old animals of this batch nearly reached the maximum development. Díaz *et al.* (2010) only observed capons with carcass weights higher than 4 kg in 8-mon animals. There are no studies about growth of capons or chickens that they were only fed cereals in free range conditions. Under extensive indoor conditions, Franco *et al.* (2012a, b) observed that the feeding in the last month with corn *vs*. commercial fodder did not modify growth parameters of roosters. No significant differences were found in the capon carcass weight between CW (50% corn, 50% wheat) and CB (83% corn and 17% barley) batches. In broilers, Brake *et al.* (1997) observed that barley could be fed up to 30% of the diet without adversely affecting body weight gain. Nahas and Lefrancois (2001) reported that broilers fed diets containing up to 15% barley and up to 20% wheat showed similar body weights than those fed corn-soybean diet. Negative effects of the inclusion of whole wheat at a high level in broiler diets on performance have been reported due to the activity of pentosans (Choct and Annison 1992); however, the high levels of wheat in feeding of CW batch did not decrease the capon growth in comparison to CB batch.

The chemical composition of breast and drumstick meat of the capons is shown in Table 1. The values of dry matter, protein and ash were similar to those observed by Díaz *et al.* (2010) in capons fed commercial diet slaughtered at 5 mon. However, the lipid contents were lower than those reported in that manuscript. This is probably related to those capons were fed commercial diet (with higher lipid content than cereals) until slaughter. However, fat content was not lower than 3%. When lipid content is under 3%, palatability declines below an acceptable level (Miller 1994). Dry matter, protein, lipids and ash contents of breast and drumstick meat were not influenced by the feeding. Franco *et al.* (2012a, b) also observed that the finishing diet (corn *vs*. commercial fodder) did not cause important changes in chemical composition of the rooster meat.

The physico-chemical properties of breast meat and drumstick meat of the different types of capons are shown in Tables 2 and 3, respectively. The pH, the wa-

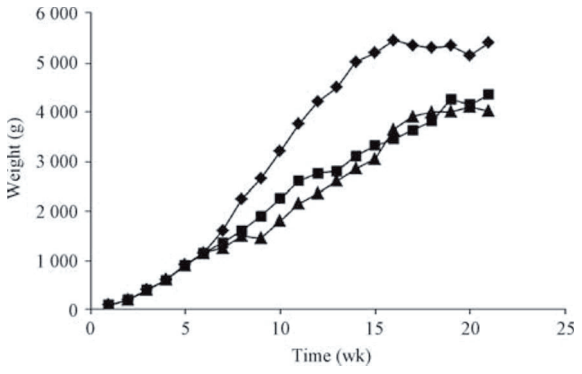

Fig. Growth of capons slaughtered at 5th mon using the three diets. Capons fed commercial diet and corn in the last month (♦); capons fed corn and wheat (■); capons fed corn and barley (▲).

Table 1 Effect of feeding of capons in the carcass weight and chemical composition of breast meat and drumstick meat

	CDC	CW	CB	*P* value
Carcass weight (g)	4 165.20±227.21 a	3 348.80±240.94 b	3 355.80±239.21 b	<0.001
Breast meat (%)				
Dry matter	27.07±0.23	27.09±0.30	26.94±0.76	0.861
Protein	22.84±1.34	22.65±0.19	22.36±0.85	0.716
Lipids	3.01±1.10	3.23±0.17	3.36±0.45	0.728
Ash	1.12±0.05	1.10±0.09	1.12±0.07	0.894
Drumstick meat (%)				
Dry matter	26.80±2.26	26.61±0.69	26.76±1.20	0.981
Protein	19.34±1.71	19.35±0.54	19.25±1.03	0.989
Lipids	6.29±0.98	6.11±0.57	6.29±0.86	0.925
Ash	1.06±0.05	1.05±0.07	1.11±0.05	0.210

CDC, capons fed commercial diet and corn in the last month; CW, capons fed corn and wheat; CB, capons fed corn and barley.
Values within the same row followed by different letters differ significantly (P<0.05). The same as below.

ter holding capacity (WHC), the drip loss and the cooking loss were not significantly influenced by the feeding of the capons. These results were similar to those observed in T-44 capons fed commercial diet slaughtered at 5 mon (Díaz *et al.* 2010). Other authors in chickens (Du and Ahan 2002; Quentin *et al.* 2003) and roosters (Franco *et al.* 2012a, b) have also observed that the pH was not significantly influenced by the diet. Cooking loss was not affected by the diet in broilers (Adams *et al.* 1994) and roosters (Franco *et al.* 2012a, b).

As far as colour parameters are concerned, lightness (L*) of breast meat and drumstick meat was not significantly influenced by the feeding of the capons. However, the feeding significantly influenced (P<0.05) the redness values (a*) of drumstick with skin and yellowness values (b*) of skinless breast. The batch CB (capons fed corn and barley) showed significantly higher a* values in drumstick with skin than the batch CW (capons fed corn and wheat). It has been also observed (Smith *et al.* 2002; Lyon *et al.* 2004) that the a* values of meat from broilers fed wheat-based diets were lower than those of birds fed corn-based diets. The batch CB showed significantly higher b* values in skinless breast than the other batches. It has been already reported that the diet is a factor that affects poultry meat colour (Fletcher 2002). However, the effect of the diet on the colour of the meat is not clear. Franco *et al.* (2012b) observed that meat from roosters fed corn showed significantly lower luminosity (P<0.001) and significantly higher redness and yellowness (P<0.001) in breast than cocks fed commercial diet whereas Franco *et al.* (2012a) observed that meat from roosters fed corn showed a slightly higher luminosity and yellowness and significantly lower redness (P<0.001) in breast than cocks fed commercial diet. According to these results, the yellowness is the value more influenced by the feeding with corn. The capons fed more corn from caponization until slaughter (batch CB) also

Table 2 Effect of feeding of capons on physico-chemical properties of breast meat

	CDC	CW	CB	*P* value
pH	5.64±0.02	5.57±0.11	5.62±0.03	0.205
WHC (%)	23.57±1.42	23.33±0.76	23.44±1.85	0.964
Drip loss (%)	2.88±0.50	2.95±0.89	2.98±0.44	0.968
Cooking loss (%)	18.74±1.36	18.24±0.97	18.83±1.53	0.750
Breast with skin				
L*	60.66±3.15	63.14±1.12	60.66±1.72	0.158
a*	3.54±1.88	2.38±0.83	2.32±0.92	0.283
b*	32.38±6.59	28.12±4.13	30.68±1.96	0.373
Skinless breast				
L*	50.55±5.35	50.75±8.89	48.84±6.49	0.896
a*	0.33±0.98	0.17±0.58	0.03±0.51	0.815
b*	5.12±1.44 a	6.41±2.28 ab	8.72±1.40 b	0.021
Breast meat				
L*	46.19±4.34	46.90±6.68	44.18±2.61	0.663
a*	0.54±0.87	0.37±0.93	0.77±1.06	0.802
b*	8.35±2.02	8.90±1.82	10.49±3.00	0.356
Compression (N cm^{-2})	67.24±2.84	68.73±2.23	67.35±1.45	0.522
Shear force (N cm^{-2})	33.00±4.29	33.22±3.66	33.14±2.80	0.995

Table 3 Effect of feeding of capons on physico-chemical properties of drumstick meat

	CDC	CW	CB	*P* value
pH	5.93±0.06	5.98±0.09	5.98±0.19	0.783
WHC (%)	24.00±2.52	24.35±2.73	25.02±1.87	0.794
Drumstick with skin				
L*	63.10±1.93	61.96±2.17	61.18±1.52	0.308
a*	0.97±0.88 ab	0.52±0.53 a	1.81±0.51 b	0.028
b*	24.97±5.69	21.54±7.16	25.52±3.50	0.503
Skinless drumstick				
L*	53.77±3.71	55.71±3.60	56.16±3.25	0.539
a*	2.48±2.75	0.98±0.83	1.84±1.52	0.471
b*	8.10±2.55	8.12±2.29	12.32±3.82	0.069
Drumstick meat				
L*	47.04±6.57	52.62±6.40	53.15±2.46	0.191
a*	2.83±2.77	1.00±1.83	1.32±1.62	0.380
b*	9.33±2.32	10.24±2.79	13.54±2.76	0.061

showed higher values of yellowness. The yellowness values were higher to those observed in T-44 birds fed commercial diet slaughtered at 5 mon (Díaz *et al.* 2010). These results were probably due to the feeding of the animals with corn. Lyon *et al.* (2004) also observed that meat from broilers fed corn-based diet was significantly more yellow than meat from birds fed wheat-based diet. The high b* values of birds fed corn are due to the natural carotenoid pigment xanthophyll present in the corn (Brown *et al.* 2008) It has also been reported that the meat from birds with access to the outdoors is more yellow; this may be related to the feeding of plant material (Fanatico *et al.* 2005). The b* values of the meat of our study were higher than those observed by Miguel *et al.* (2008) in capons housed under free-range conditions fed commercial diet. This result was probably due to the higher amount of plants ingested by the capons of our study.

In relation to the texture of the breast meat (Table 2), no significant effects of the feeding on the compression test values were observed. In the shear test, no significant differences were found among batches. These results were in agreement with Franco *et al.* (2012a, b) who found no effects of finishing feeding treatment on textural parameters. However, these results were different of those reported by Lyon *et al.* (2004); these authors observed that meat from corn-fed broilers required significantly less force to shear than meat from birds fed wheat. The compression test values were similar to those observed in capons fed commercial diet slaughtered at 5th mon (Díaz *et al.* 2010). However, the shear force values of capon meat were higher than those observed by Díaz *et al.* (2010) in capons slaughtered at 5th mon. This fact could be attributed due to the differences in the lipid content of the meat. The meat with higher contents of lipids is more tender than the meat with lower lipid concentration (Komprda *et al.* 2000).

The fatty acid compositions of breast meat and drumstick meat of the different types of capons are shown in Tables 4 and 5, respectively. In breast meat and drumstick meat, the main fatty acid was oleic (33-34%) followed by palmitic (25-26%), linoleic (16-20%), stearic (7-8%) and arachidonic (3-5%) acids. Monounsaturated fatty acids (MUFA) were the main group (41-43%) followed by saturated fatty acids (SFA) (33-35%) and polyunsaturated fatty acids (PUFA) (22-25%). These results were similar to those observed in T-44 capons fed commercial diet slaughtered at 5 mon (Díaz *et al.* 2012). Significant effects of feeding were observed in some fatty acids of the breast meat and drumstick meat. In both meats, capons fed cereals from caponization (batches CW and CB) showed significantly higher content of C14:1 and C16:1n-7 than capons fed corn in their last month of life (batch CDC). Capons fed corn and barley (batch CB) showed significantly higher content of C18:2n-6 than capons of the other two batches in drumstick meat and than capons of batch CW (animals fed corn and wheat) in breast meat. Other authors have reported that the PUFA content in chicken tissues depends more on the variation in dietary fatty acid content than the SFA and MUFA contents in these tissues (López-Ferrer *et al.* 2001; Cortinas *et al.* 2004). Our results were in agreement with these authors. The differences in C14:1 and

C16:1 are not related to the fatty acid content of the diets because these are not essential fatty acids. The differences in C18:2 among batches could be attributed to the lipid content and fatty acid composition of the different feeding regimen of the birds (Table 6) because this is an essential fatty acid (it cannot be synthesized by animals). Corn showed a high content of linoleic acid (56.5%). Although wheat and barley presented higher content of linoleic acid (62.0 and 57.6%, respectively) than corn, the lipid content of corn (3.8%) was higher than that of wheat and barley (1.6 and 2.1%). The batch CB showed higher linoleic content than batch CW due probably to the higher amount of linoleic acid of its diet. The batch CDC also showed lower linoleic content than batch CB although the capons fed only corn the last month. The commercial diet presented lower linoleic content than corn. The feeding only with corn the last month did not increase the content of this fatty acid in the meat. The linoleic content of meat of capons from batch CDC was similar to that observed by Díaz *et al.* (2012) in breast and drumstick meat of capons T-44 fed commercial diet (16.86 and 19.04%, respectively).

Table 4 Effect of feeding of capons on the fatty acid composition of breast meat

Item[1)]	CDC	CW	CB	*P* value
C14:0	0.75±0.08	0.73±0.05	0.71±0.07	0.579
C14:1	0.11±0.02 a	0.15±0.02 b	0.16±0.03 b	0.010
C15:0	0.09±0.02	0.10±0.01	0.10±0.02	0.814
C16:0	26.32±0.54	26.42±1.41	26.04±1.46	0.882
C16:1n-9	0.49±0.14	0.60±0.17	0.52±0.14	0.469
C16:1n-7	3.37±0.49 a	4.62±0.47 b	4.52±0.71 b	0.008
C17:0	0.16±0.02	0.14±0.02	0.14±0.01	0.046
C17:1	0.11±0.02	0.11±0.03	0.10±0.01	0.551
C18:0	8.13±0.68	7.76±1.85	7.34±1.06	0.638
C18:1n-9	33.93±1.55	34.40±1.26	32.82±1.89	0.304
C18:1n-7	2.70±0.53	3.06±0.56	2.64±0.60	0.461
C18:2n-6	16.61±0.87 ab	15.70±1.99 a	18.49±1.49 b	0.037
C18:3n-3	0.65±0.03	0.71±0.14	0.76±0.17	0.420
C20:1	0.33±0.11	0.37±0.08	0.38±0.02	0.549
C20:4n-6	4.72±0.80	3.87±0.44	3.73±0.56	0.055
C22:4n-6	0.65±0.24	0.52±0.08	0.70±0.16	0.289
C22:5n-3	0.32±0.11	0.31±0.01	0.36±0.10	0.676
C22:6n-3	0.58±0.31	0.43±0.08	0.51±0.13	0.516
SFA	35.45±1.02	35.14±2.40	34.32±1.54	0.586
MUFA	41.03±2.34	43.32±1.75	41.12±1.76	0.157
PUFA	23.52±2.00	21.54±2.24	24.56±2.35	0.130
Σn-6	21.97±1.57	20.08±2.18	22.92±2.04	0.103
Σn-3	1.55±0.43	1.45±0.16	1.63±0.35	0.698
n-6/n-3	14.82±2.80	13.92±1.75	14.33±1.82	0.812
PUFA/SFA	0.66±0.06	0.62±0.10	0.72±0.09	0.214

[1)] SFA, MUFA, PUFA mean saturated, monounsaturated and polyunsaturated fatty acids, respectively. The same as below.

CONCLUSION

The capons fed commercial diet except the last month of their life that they were fed corn showed higher carcass weight that the capons fed cereals from caponization until slaughter; however, no significant effects of feeding were observed in chemical composition, pH, water holding capacity, drip and cooking losses and texture of the meat.

The meat of the capons fed higher amount of corn during fattening was more yellow and showed higher concentration of linoleic acid than the meat from the other capons. This latter fact could mainly be explained by the high linoleic acid content of the corn.

MATERIALS AND METHODS

Animals and diet

Sixty 1-d-old male chicks of Sasso T-44 slow growing strain (Sasso, Sabres, France) were used in the experiments. The animals were divided into three groups (twenty animals each one). They were housed separately in three indoor pens (24 m^2 each one) with access to grass paddocks (333 m^2 each one) in free range conditions. They grew contemporarily in order to avoid the influence of different environment

Table 5 Effect of feeding of capons on the fatty acid composition of drumstick meat

	CDC	CW	CB	*P* value
C14:0	0.86±0.07	0.80±0.05	0.79±0.05	0.178
C14:1	0.14±0.02 a	0.17±0.01 b	0.17±0.02 b	0.015
C15:0	0.10±0.02	0.10±0.01	0.10±0.01	0.758
C16:0	25.18±0.69	25.40±0.95	24.63±0.88	0.370
C16:1n-9	0.65±0.17	0.81±0.10	0.66±0.14	0.165
C16:1n-7	4.29±0.46 a	5.42±0.36 b	5.41±0.97 b	0.026
C17:0	0.17±0.02	0.15±0.01	0.15±0.02	0.040
C17:1	0.14±0.01	0.13±0.02	0.12±0.01	0.119
C18:0	8.09±0.76	7.07±0.54	7.11±0.80	0.071
C18:1n-9	33.47±1.17	33.77±0.85	32.91±2.04	0.643
C18:1n-7	2.85±0.85	2.82±0.35	2.55±0.41	0.682
C18:2n-6	18.73±1.21 a	17.83±1.31 a	20.08±1.28 b	0.047
C18:3n-3	0.80±0.04	0.82±0.11	0.93±0.23	0.367
C20:1	0.36±0.05	0.39±0.06	0.40±0.03	0.427
C20:4n-6	2.89±0.24	3.01±0.27	2.67±0.59	0.420
C22:4n-6	0.74±0.13	0.70±0.14	0.76±0.10	0.705
C22:5n-3	0.21±0.04	0.24±0.04	0.22±0.06	0.690
C22:6n-3	0.34±0.06	0.37±0.06	0.33±0.07	0.606
SFA	34.40±1.13	33.52±1.49	32.78±1.01	0.155
MUFA	41.89±2.06	43.51±1.03	42.22±2.08	0.352
PUFA	23.71±1.25	22.97±1.34	25.00±1.97	0.154
Σn-6	22.36±1.22	21.54±1.31	23.51±1.74	0.135
Σn-3	1.35±0.09	1.43±0.19	1.48±0.31	0.607
n-6/n-3	16.65±1.20	15.28±1.93	16.22±2.48	0.540
PUFA/SFA	0.69±0.03	0.69±0.06	0.76±0.07	0.094

Table 6 Lipid content (%) and fatty acid composition of cereals and commercial diet

	Corn	Wheat	Barley	Commercial diet
Lipids	3.8	1.6	2.1	4.2
C14:0	0.09	0.10	0.15	0.71
C15:0	0.03	0.12	0.06	0.70
C16:0	10.65	15.60	14.40	17.82
C16:1n-7	0.10	0.12	0.08	0.91
C17:0	0.07	0.09	0.04	0.25
C17:1	0.04	0.06	0.03	0.17
C18:0	1.41	0.77	1.60	7.35
C18:1n-9	29.73	15.86	22.95	32.93
C18:2n-6	56.47	62.05	57.58	36.06
C18:3n-3	1.06	4.44	2.44	2.39
C20:1	0.35	0.81	0.68	0.70
SFA	12.25	16.68	16.24	26.83
MUFA	30.21	16.84	23.74	34.71
PUFA	57.54	66.48	60.02	38.46

conditions. Caponization was performed at 48 d of age. All birds were caponised bilaterally using the surgical method described by López-Beceiro *et al.* (1992) and in accordance with EU regulations. The absence of testicular regeneration was determined by visual assessment in live animals and also after slaughtering.

One group of castrated cockerels was fed *ad libitum* commercial diet until the 4th mon of life. This diet was mainly composed of corn, soybean meal and wheat dried distiller grains with solubles and contained 200 g kg^{-1} crude protein, 40 g kg^{-1} cellulose fiber, 42 g kg^{-1} crude fat and 60 g kg^{-1} ash. The lipid content and fatty acid composition of this diet are shown in Table 6. The last month of their life, the capons of this group were fed corn (CDC batch). The second and third groups of capons were fed commercial diet before caponization and only cereals from caponization. The second group was fed mixture of corn (50%) and wheat (50%) (CW batch). The third group of capons (CB batch) were fed 2/3 corn and 1/3 mixture of corn (50%) and barley (50%) (i.e., 83% corn and 17% barley). The lipid content and fatty acid composition of cereals are also shown in Table 6. When the animals reached the predetermined age for sampling (at 5th mon, i.e., at 150 d), five animals of each group were randomly selected and they were stunned, killed by manual exsanguination, plucked, completely eviscerated (obtaining the ready-to-cook carcass) and weighed. Then, they were refrigerated at 4°C for 24 h until analyses. A total of fifteen animals (five of each batch) were analysed.

Sampling and qualitative meat traits determinations

The left breast and drumstick of each carcass were excised for analyses. The samples were immediately analysed for physico-chemical properties, and part of the meat was vacuum packed and kept at -20ºC until the later chemical analyses were carried out.

For chemical analyses, the meat samples were finely minced in a blender (Polytron PT 10-35). AOAC (1995) methods were used for the dry matter, protein and ash determinations. Lipids were extracted and purified from the former homogenate with a chloroform:methanol mixture (1:1, v/v) according to the method of Hanson and Olley (1963). The total lipids were gravimetrically determined. All analyses were made in duplicate.

The pH of the meat was determined introducing a penetration pH electrode in the sample and the measurement was carried out in triplicate with a pH meter GLP 21 (Crison Instruments, S.A., Barcelona, Spain). Water holding capacity, determined as expressible juice, was studied using a modification of the filter paper press method (Hamm 1960). A piece of (300±5) mg of intact meat was placed between two pieces of Whatman filter paper No. 1 (11 cm diameter), previously desiccated and weighed, and was placed between two plexiglass plates and pressed by a weight of 2 kg for 5 min. The outline areas of the expressible juice and the meat film were traced, and the sizes of the two areas were measured (in cm^2) after digital acquisition with a scanner using the UTHSCSA Image Tool program (ver. 2.0, University of Texas Health Science Center, San Antonio, Texas). Water-holding capacity (WHC) was expressed as percentage of the meat area related to the juice area.

The drip loss was measured in accordance with Honikel and Hamm (1994). A slice of breast meat was cut parallel to the fiber direction, 30 g weight, was suspended inside a polyethylene bag and sealed under atmospheric pressure. The sample was held at 2°C for 72 h and then reweighed. The drip loss was expressed as a percentage of the initial sample weight.

Cooking loss was evaluated according to Boccard *et al.* (1981). A slice of breast meat weighing approximately 70 g was placed in a plastic pouch and sealed under moderate vacuum. The pouch was introduced into water at 70°C for 50 min and then placed in cold water for 20 min. After that the meat sample was taken from the bag, mopped dry and weighed. Cooking loss was expressed as the ratio (×100) of the difference in weight between the cooked and the raw meat relative to the weight of the raw meat. Water-holding capacity, drip loss and cooking loss determinations were made in duplicate.

Colour measurements were taken on the surfaces of breast and drumstick with skin, skinless breast and skinless drumstick, and on the transverse cut of the *pectoralis major* and *peroneus longus* muscles and were made in triplicate. Colour was recorded using a Spectro-Color Dr. Lange chromameter (Dr. Bruno Lange GmbH & Co., Düsseldorf, Germany). All measurements were made in the CIE L*a*b* colour space (CIE 1976) using the D65 illuminant and the 10º standard observer. The instrument was standardized with the white and black tiles provided by the manufacturer before sample measurements. The colour values were expressed as L* (lightness), a* (redness/greenness) and b*

(yellowness/blueness).

Texture analyses were done on breast meat samples cooked as described above, using a Hounsfield Material Testing Machine (Model H10KM, Hounsfield Test Equipment Limited, UK). A compression test was carried out on small pieces of 1 cm×1 cm and 2 cm along the fiber axis, using a cylindrical 10 mm diameter probe. The sample was placed under the probe (with muscular fibers almost parallel to the force direction) that moved downwards at a constant speed of 180 mm min^{-1} (pre-test) and 60 mm min^{-1} (test). The thickness of the sample was recorded when the probe first came in contact with it. The probe continued downwards to a pre-fixed percentage (75%) of the sample thickness. The results were expressed in N cm^{-2}.

Warner-Bratzler shear tests of cooked meat were made on samples of rectangular cross section, 1 cm×2 cm and 2 cm along the fiber axis. The samples were sheared at a right angle to the fiber axis using a Warner-Bratzler shear blade, which moved down with a constant speed of 60 mm min^{-1}. The razor blade shear force (N cm^{-2}) was calculated. The determinations of texture analyses were made in triplicate.

The fatty acid composition of lipids was determined by gas liquid chromatography of methyl esters prepared in basic conditions (KOH:methanol). The gas chromatograph was a Hewlett-Packard apparatus (HP 5890) equipped with a dual flame ionization detector. The capillary column (30 m, internal diameter 0.25 mm) was packed with OV-225 (0.1 μm) on fused silica. Hydrogen was used as the carrier gas under constant pressure (110 kPa). Analysis was performed using an initial isothermic period (150°C, 2 min); thereafter the temperature was increased to 210°C at an increasing rate of 4°C min^{-1}, and finally an isothermic period (210°C, 15 min) was established. The injector and detector were maintained at 250°C. A Hewlett-Packard HP3394A integrator was used for quantitative analyses. The identification of different fatty acid methyl esters was performed by comparison of the retention times with those of authentic standards (Sigma, USA). The amounts of fatty acids were expressed as a percent of total area of injected methyl esters. All analyses were made in duplicate.

Statistical analyses

Data were evaluated statistically using the SPSS ver. 12.0 for Windows (2004) program. A one-way ANOVA was used to analyze the effects of the feeding on the parameters determined and the means were compared using the Tukey *F*-test with significance at $P<0.05$.

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References

Adams M H, Watkins, S E, Waldroup A L, Waldroup P W. 1994. Utilization of high-oil corn in diets for broiler chickens. *Journal of Applied Poultry Research*, **3**, 146-156.

AOAC. 1995. *Official Methods of Analysis*. 15th ed. AOAC, Washington, D.C, USA.

Brake J D, Brann D E, Griffey C A. 1997. Barley without enzyme supplementation in broiler grower and finisher diets. *Journal of Applied Poultry Research*, **6**, 422-431.

Boccard R, Buchter L, Casteels E, Cosentino E, Dransfield E, Hood D E, Joseph R L, Macdougall D B, Rhodes D N, Schön I, *et al*. 1981. Procedures for measuring meat quality characteristics in beef production experiments. Report of Working group in the commission of the european communities' (CEC) beef production research programme. *Livestock Production Science*, **8**, 358-397.

Brown S N, Nute G R, Baker A, Hughes S I, Warriss P D. 2008. Aspects of meat and eating quality of broiler chickens reared under standard, maize-fed, free-range or organic systems. *British Poultry Science*, **49**, 118-124.

Choct M, Annison G. 1992. Anti-nutritive effect of wheat pentosans in broiler chickens: roles of viscosity and gut microflora. *British Poultry Science*, **33**, 821-834.

CIE. 1976. Official recommendations of the International Commission on Illumination, Colorimetry. Publication CIE No. 15 (E-1.3.1). Commission International de l'Eclairage, Paris, France.

Cortinas L, Villaverde C, Galobart J, Baucells M D, Codony R, Barroeta A C. 2004. Fatty acid content in chicken thigh and breast as affected by dietary polyunsaturation levels. *Poultry Science*, **83**, 1155-1164.

Díaz O, Rodríguez L, Torres, A, Cobos A. 2010. Chemical composition and physico-chemical propoerties of meat from capons as affected by breed and age. *Spanish Journal of Agricultural Research*, **8**, 91-99.

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 y Aceites*, **63**, 296-302.

Du M, Ahn D. 2002. Effect of dietary conjugated linoleic acid on the growth rate of live birds and on the abdominal fat content and quality of broiler meat. *Poultry Science*, **81**, 428-433.

Fanatico A C, Cavitt L C, Pillai P B, Emmert J L, Owens C M. 2005. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: meat quality. *Poultry Science*, **84**, 1785-1790.

Fletcher D L. 2002. Poultry meat quality. *World's Poultry Science Journal*, **58**, 131-145.

Franco D, Rois D, Vazquez J A, Lorenzo J M. 2012a. Comparison of growth performance, carcass components, and meat quality between Mos rooster (Galician indigenous breed) and Sasso T-44 line slaughtered at 10 months. *Poultry Science*, **91**, 1227-1239.

Franco D, Rois D, Vazquez J A, Purrinos L, Gonzalez R, Lorenzo J M. 2012b. Breed effect between Mos rooster (Galician indigenous breed) and Sasso T-44 line and finishing feed effect of commercial fodder or corn. *Poultry Science*, **91**, 487-498.

Hamm R. 1960. Biochemistry of meat hydration. *Advances in Food Research*, **10**, 355-463.

Hanson S W F, Olley J. 1963. Application of the bligh and dyer method of lipid extraction to tissue homogenates. *Biochemical Journal*, **89**, 101P-102P.

Honikel K O, Hamm R. 1994. Measurement of water-holding capacity and juiciness. In: Pearson A M, Dutson T R, eds., *Quality Attributes and Their Measurement in Meat*, *Poultry and Fish Products*. Blackie Academic and Professional, London, UK. pp. 125-161.

Hui Y H, Guerrero-Legarreta I. 2010. Poultry biology, classification, and trade descriptions. In: Guerrero-Legarreta I, Hui Y H, eds., *Handbook of Poultry Science and Technology*. John Wiley & Sons, Hoboken, NJ, USA. pp. 3-18.

Komprda T, Zelenka J, Fajmonová E, Jarošová A, Kubiš I. 2000. Meat quality of broilers fattened deliberately slow by cereal mixtures to higher age. 1. Growth and sensory quality. *Archive für Geflügelkunde*, **64**, 167-174. (in Spanish)

López Beceiro A M, Pereira Espinel J L, Barreiro Lois A. 1992. *The Castration of Domestic Poultry: Chicken Castration*. Servicio de Publicaciones. Diputación Provincial, Lugo, Spain. (in Spanish)

López-Ferrer S, Baucells M, Barroeta A C, Grashorn M A. 2001. N-3 enrichment of chicken meat. 1. Use of very long chain fatty acids in chicken diets and their influence on meat quality: fish oil. *Poultry Science*, **80**, 741-752.

Lyon B G, Smith D P, Lyon C E, Savage E M. 2004. Effects of diet and feed withdrawal on the sensory descriptive and instrumental profiles of broiler breast fillets. *Poultry Science*, **83**, 275-281.

Miguel J A, Ciria J, Asenjo B, Calvo J L. 2008. Effect of caponisation on growth and on carcass and meat characteristics in Castellana Negra native Spanish chickens. *Animal*, **2**, 305-311.

Miller R K. 1994. Quality characteristics. In: Kinsman D M, Kotula A W, Breidenstein B C, eds., *Muscle Foods: Meat*, *Poultry*, *and Seafood Technology*. Chapman and Hall, NY, USA. pp. 296-332.

Nahas J, Lefrancois M R. 2001. Effects of feeding locally grown whole barley with or without enzyme addition and whole wheat on broiler performance and carcass traits. *Poultry Science*, **80**, 195-202.

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. *Animal Research*, **52**, 65-77.

Sirri F, Bianchi M, Petracci M, Meluzzi A. 2009. Influence of partial and complete caponization on chicken meat quality. *Poultry Science*, **88**, 1466-1473.

Smith D P, Lyon C E, Lyon B G. 2002. The effect of age, dietary carbohydrate source, and feed withdrawal on broiler breast fillet color. *Poultry Science*, **81**, 1584-1588.

SPSS. 2004. SPSS for Windows Version 12.0. SPSS Inc., Chicago, Illinois, USA.

Tor M, Estany J, Francesch A, Cubiló M D. 2005. Comparison of fatty acid profiles of edible meat, adipose tissues and muscles between cocks and capons. *Animal Research*, **54**, 413-424.

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