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MEAT QUALITY OF COMMERCIAL CHICKENS REARED IN DIFFERENT PRODUCTION SYSTEMS: INDUSTRIAL, RANGE AND ORGANIC*

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Abstract

Meat is an important part of the human diet since it provides several nutrients. However, the amount of these nutrients can differ according to several factors. With this in mind, the present research was designed with the main objective of evaluating the effect of production system of broiler chickens (industrial, range and organic) on meat quality. The physicochemical, chemical and nutritional characteristics were determined in breast and drumstick meat. The organic chickens presented the lowest amounts of fat and cholesterol and the highest amounts of protein. The colour was also influenced by the production system, where organic and range chickens had the highest values of redness in both cuts (breast and drumstick). In addition, the content of essential fatty acids (C18:2*n-6* and C18:3*n-3*) and other fatty acids with high biological importance, such as eicosapentanoic acid (EPA; C20:5*n-3*), docosapentanoic acid (DPA; C22:5*n-3*) and docosahexanoic acid (DHA; C22:6*n-3*) were higher in organic samples compared to industrial or range chickens. The amino acids content did not vary with the production system. With regard to mineral contents, organic chickens had the highest values of iron in drumstick and significantly lower values of magnesium in both cuts than industrial chickens. On the whole, the meat of the organic chickens showed better nutritional characteristics than those produced in range or industrial conditions.

Key words: poultry meat, chemical composition, fats and fatty acids, amino acids, cholesterol

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Poultry meat production represents approximately 36% of the global meat production, with chicken production being the most common source of poultry meat, representing about 89% of total poultry production (FAOSTAT, 2018). Most of chicken meat production is produced under intensive systems. However, in recent years, an increased consumer interest in chicken production has been shown, especially linked to upbringing and natural food. Meat from these birds is associated with high quality products. Thus, alternative poultry production systems are defined – free-range and organic. These increases in the production were reflected in the organic poultry head numbers, registering almost a 14% yearly increase between 2005 and 2015 in the European Union (European Commission, 2016).

The production and control of free-range and organic poultry are regulated according to European Commission Regulations 543/2008 and 889/2008, respectively (OJ 2008 a, 2008 b). In these regulations, organic poultry production is defined as the production coming from slow-growing breeds or fast-growing raised until a minimum age of 81 days. Animal accommodation conditions must provide a high level of animal welfare, fed on pastures, fodder and food preferably from the farm, and with free access to outdoors spaces. Free-range poultry production is not as restrictive as organic production. Birds also should have free access to outdoor space, which improves the quality of the products obtained and helps to maintain biodiversity and sustainable agricultural production, especially in depressed areas.

Chicken meat is an important source of edible animal protein, phosphorus and other minerals. It also contains less fat than other cuts (e.g. beef and pork), with a higher proportion of unsaturated fatty acids than saturated fatty acids. This ratio makes it a good alternative to red meat [Food and Agriculture Organization (FAO) 2010].

Chicken meat quality can be influenced by several factors, such as the production system (Husak et al., 2008; Puchała et al., 2015), age (Díaz et al., 2010) and genotype (Jaturasitha et al., 2008; Franco et al., 2013). Quality indicators of meat sensory characteristics (colour, cooking losses and tenderness) and meat quality (intramuscular fat and fatty acid profile) could be affected by these parameters, being able to influence the consumer acceptability (Andersen et al., 2005). Rearing system can influence the amount of fat deposited and the fatty acids proportion (Bogosavljević-Bošković et al., 2012), being able to change the fatty acids profile (Kavouridou et al., 2008). The quality of the fatty acids could be improved by including grass as part of the nutrition, which would increase the polyunsaturated fatty acids content (greater proportion of components from the α-linolenic fatty acids family) in relation to saturated acids (Crespo and Esteve-García, 2002; Bessa et al., 2006). These fatty acids have an important role in the prevention and treatment of cardiovascular diseases, and in the normal growth and development (Simopoulus, 2004; Kritchevsky, 2008).

Although consumers increasingly demand meat from chickens raised in a free-range or organic production systems, the relatively little scientific information available focuses primarily on comparing growth parameters. As commented above, other publications regarding meat quality focus on analysing a single factor, such as diet, the rearing system, slaughter age, etc. However, the present research intends to encompass all the factors that differentiate chicken farming systems (diet, genetic line-

ages, rearing system and slaughter age), and verify how these factors, together, affect the composition and quality of meat. In addition, this study presents a complete analysis of the meat of each group of animals, including compositional and physicochemical parameters, fatty acids, amino acids and minerals content, thus contributing to a description of the chemical and nutritional composition of the industrial, range and organic chickens meat.

In summary, the main objective of this work was to evaluate the effect of production system of broiler (industrial, range and organic) on meat characteristics as proximate composition, colour characteristics, mineral content, fatty acid and amino acid profiles in breast and drumstick meat.

Material and methods

Animals management and sampling procedures

This study was conducted with a total of 30 female chickens (broilers) divided according to production system into industrial (n = 10), range (n = 10) and organic (n = 10). Each group of animals used in the present research were reared in a single farm (plot). Therefore, a total of 3 plots (industrial, range and organic farms) were employed. A total of 28,000 birds were reared in the intensive group, 24,000 in the range group and 9,600 in the organic group. From each farm, 10 animals were randomly selected according to their live weight. The weight at which they were sacrificed was fixed before the beginning of the experiment. The sacrifice of all the chickens was performed when they reached approximately 2.7 kg of live weight.

Animals of industrial group were raised in intensive conditions. The broiler lineage used in this group was Ross 308. All animals of this research were housed in a farm, directly on the ground with wood chip or rice husk bed and forced ventilation with a maximum density of 39 kg per m^2. The temperature, humidity and light conditions were controlled throughout the rearing process. The industrial chickens were slaughtered at 45 days. In contrast, range and organic groups were housed under traditional conditions according to Commission Regulations 543/2008 and 889/2008, respectively (OJ 2008 a, 2008 b), aiming to reproduce the most common system used in poultry outdoors. Range chickens, using Sasso XL-44 as lineage, were housed in a farm, directly on the ground with wood chip or rice husk bed and natural ventilation with a density of 27.5 kg per m^2. During at least half of their lives, the birds had access during the day to open air space that includes an area covered with vegetation for the most part, with an area equal to or greater than of 1 m^2 per animal. Range chickens were slaughtered at 57 days. Organic chicken (Sasso T-44) was also produced directly on the ground with wood chip or rice husk bed and natural ventilation with a density of 21 kg per m^2, and with outdoor access with an area equal to or greater than 4 m^2 per animal. Organic chickens were slaughtered at 81 days. All animal management was in accordance with the ethics approval P.CPA.00815 (24/11/2015).

The feed was different depending on the group of animals. In industrial group, birds were fed *ad libitum* with a starter commercial diet up to 8 days. From 9 to

19 days, birds were fed with a standard commercial grower diet. Between days 20 and 42, animals were fed with a commercial finishing diet. In the last step of rearing (three days before slaughter), animals were fed with a commercial finishing diet. On the other hand, range and organic animals were fed *ad libitum* with a commercial starter diet up to 25 days, and since day 26 until slaughter with a commercial finishing diet. Its duration depended on the group of animals, 32 and 56 days for range and organic, respectively. The commercial compound feed for the industrial and range chickens was supplied by Coren Agroindustrial S.A.U. (Ourense, Spain), while the feed for the organic chickens was supplied by Caponcito S.R.L. (Lugo, Spain) with the organic certificate number GA/096/CO. Table 1 shows the chemical composition and fatty acids composition of commercial finishing diet of industrial, range and organic chickens.

Table 1. Chemical composition of the finishing diet

Chemical composition (g/100 g)	Industrial	Range	Organic
1	2	3	4
Protein	20.1	17.3	19.5
Fat	7.7	4.5	4.9
Ash	4.8	5.3	4.1
Fibre	2.6	2.5	4.7
Mineral mix:			
Ca (g 100 g^{-1})	0.70	0.80	0.36
Na (g 100 g^{-1})	0.17	0.17	0.095
Fe (mg kg^{-1})	49.5	49.5	30.0
Cu (mg kg^{-1})	15.0	15.0	3.0
Se (mg kg^{-1})	0.30	0.30	0.10
Zn (mg kg^{-1})	48.0	48.0	40.0
Vitamin mix:			
Vitamin A (IU kg^{-1})	8800	11000	10000
Vitamin D_3 (IU kg^{-1})	3200	4000	2000
Vitamin E (mg kg^{-1})	30.0	35.0	20.0
Amino acids:			
Lysine (g 100 g^{-1})	1.15	1.07	1.33
Methionine (g 100 g^{-1})	0.55	0.52	0.45
Fatty acids (g/100 g of fatty acids):			
C14:0	1.26	0.13	0.07
C14:1*n-5*	0.18	nd	nd
C15:0	0.19	0.02	0.03
C16:0	21.57	12.75	12.10
C16:1*n-7*	3.15	0.13	0.12
C17:0	0.46	0.09	0.10
C17:1*n-7*	0.26	0.05	0.05
C18:0	9.74	2.75	3.38
C18:1*n-9*	31.80	24.72	20.32

Table 1 – contd.

1	2	3	4
C18:1*n-7*	1.87	1.21	1.10
C18:2*n-6*	24.45	52.63	54.24
C20:0	0.17	0.39	0.39
C20:1*n-9*	0.41	0.25	0.22
C18:3*n-3*	2.07	4.03	6.99
C20:2*n-6*	0.18	0.05	0.06
C22:0	0.09	0.31	0.31
C20:5*n-3*	0.08	0.24	0.27
SFA	33.48	16.44	16.38
MUFA	37.67	26.36	21.81
PUFA	26.78	56.95	61.56
n-6	24.63	52.68	54.30
n-3	2.15	4.27	7.26

nd: not detected. Industrial: The feed composition was made with animal fat, flours of corn, wheat, soy and canola and vitamin and mineral supplement in unknown contents.

Range and organic: The feed composition was made only with vegetable ingredients, including flour of corn, wheat and soybean and vitamin and mineral supplement in unknown contents.

Before slaughter (reached 45, 57 and 81 days for industrial, range and organic, respectively), the birds were placed in crates and transported to an accredited abattoir (Centro de Procesado Avícola, COREN, Ourense, Spain). The birds were weighed (2.87±0.06 kg, 2.63±0.27 kg and 2.72±0.16 kg of live weight for industrial, range and organic, respectively), hung on shackles on a slaughter line, killed by mechanical exsanguination, plucked and eviscerated. The carcasses were chilled in a 4°C cool room for 24 h. At this moment, carcasses were transported to the laboratory to carry out the analysis. The carcasses were weighed and the left side of the carcass was quartered according to Jensen (1984). The *pectoralis major* muscle was excised from breast and *iliotibialis* and *sartorius* muscles from drumstick for analysis.

Physicochemical and proximate composition analysis

The pH of the samples was measured after 24 h using a digital portable pH-meter (Hanna Instruments, Eibar, Spain) equipped with a penetration probe. Colour parameters were measured using a portable colorimeter (Konica Minolta CM-600d, Osaka, Japan) with pulsed xenon arc lamp filtered to illuminant D65 lighting conditions, 0° viewing angle geometry and 8 mm aperture size, to estimate meat colour in the CIELAB space (CIE, 1976): luminosity (L*), redness (a*) and yellowness (b*). The colour was measured in three different points of each sample. Before each series of measurements, the instrument was adjusted using a white ceramic tile.

Moisture, protein and ash were quantified according to the ISO recommended standards (ISO 1442:1997, ISO 937:1978 and ISO 936:1998, respectively), while total fat was extracted and quantified according to the American Oil Chemists Society Official Procedure Am 5-04 (AOCS, 2005). For determination of total cholesterol,

2 g of sample were saponified with potassium hydroxide in ethanolic solution and cholesterol was extracted with n-hexane and separated and identified by normal phase-HPLC technique following the procedure described by Domínguez et al. (2018). The content of total cholesterol in chickens' meat was calculated, in duplicate for each muscle sample, based on the external standard technique, from a standard curve of peak area vs. concentration. Results were expressed as mg cholesterol/100 g of meat.

Fatty acid methyl esters analysis

Total fat was extracted from 10 g of sample, according to Bligh and Dyer (1959) procedure. Between 100 and 200 milligrams of fat was used to determine the fatty acid profile. Total fatty acids were transesterified according to Domínguez et al. (2015 a) procedure. Separation and quantification of the FAMEs was carried out using a gas chromatograph (GC-Agilent 7890B; Agilent Technologies Spain, S.L., Madrid, Spain) equipped with a flame ionization detector following the chromatographic conditions described by Domínguez et al. (2015 a). Data regarding FAME composition were expressed in g/100 g of fatty acids.

The atherogenic index (AI) and thrombogenic index (TI) were calculated according to Ulbricht and Southgate (1991):

$$AI=[C12:0+(4*C14:0)+C16:0]/[(\Sigma PUFA)+(\Sigma MUFA)];$$
$$TI=[C14:0+C16:0+C18:0]/[(0.5*\Sigma MUFA)+(0.5*n\text{-}6)+(3*n\text{-}3)+(n\text{-}3/n\text{-}6)]$$

The hypocholesterolemic/Hypercholesterolemic ratio (h/H) was calculated according to Fernández et al. (2007): h/H = [(sum of C18:1*n-9*, C18:1*n-7*, C18:2*n-6*, C18:3*n-6*, C18:3*n-3*, C20:3*n-6*, C20:4*n-6*, C20:5*n-3*, C22:4*n-6*, C22:5*n-3* and C22:6*n-3*)/(sum of C14:0 and C16:0)].

Protein amino acid profile

The hydrolysis of the protein, derivatization, and identification of hydrolysed amino acids were carried out following the procedure described by Domínguez et al. (2015 b). Data regarding amino acid composition were expressed in mg/100 g of meat.

Mineral composition

The quantification of mineral elements (Ca, Fe, K, Mg, Na, P and Zn) was performed by inductively coupled plasma-optical emission spectrometry (ICP-OES), according to the procedure described by Lorenzo et al. (2015). The final value for each element was obtained by calculating the average of three determinations. The results were expressed as mg/100 g of meat.

Statistical analysis

A total of 60 samples (10 animals per production system × 3 production systems × two cuts) were analysed for different parameters. The effect of production system on pH, colour parameters, chemical composition, fatty acids, amino acids and

mineral composition was examined using a one-way ANOVA, where these parameters were set as dependent variables and the rearing system of commercial chickens as fixed effect. The values were given in terms of mean values and standard error (SEM). The least squares mean (LSM) were separated using Duncan's test with a significance level $P<0.05$. All statistical analysis was performed using IBM SPSS Statistics 19 software (IBM, Corp., 2010).

Results

Chemical composition and colour characteristics

The ultimate pH, the chemical composition and the colour parameters of breast and thigh meat of the three commercial chickens are shown in Table 2.

Regarding ultimate pH values, breast cuts were significantly affected by rearing system ($P<0.001$), reaching higher values in the industrial group in relation to the organic and range groups, which presented similar means. Whereas no significant differences were found between the three groups for the ultimate pH values in drumstick samples.

Colour parameters showed significant differences ($P<0.05$) among the three groups studied in both breast and drumstick samples. Regarding luminosity (L*), the behaviour was different depending on the muscle studied. In breast, the differences among samples were not significant. The organic group presented lowest L* values in drumstick samples in relation to the industrial and range groups, which presented similar means.

Regarding redness (a*), the values were higher in range group than the other groups for the breast. In drumstick samples, the groups range and organic presented higher a* values in relation to the industrial. Yellowness (b*) values showed a similar behaviour in both cuts, being observed higher values in the range group when compared to industrial and organic, which presented similar values.

Chemical composition of breast and drumstick of the three groups studied are shown in Table 2. Rearing system had a significant effect on chemical composition. The moisture values were higher in industrial group in both cuts, while range and organic samples showed similar values. Regarding protein, the contents were different among the three commercial types of chickens studied. For the drumstick, the organic group presented higher protein value in relation to the others; for the breast, the organic and range groups had higher averages in relation to the industrial.

Rearing system had a significant effect ($P<0.01$) on fat content. These differences were especially observed in breast samples, where the values found in industrial group were almost four times higher than those found in range and organic chickens. The effects on drumstick samples were similar to breast. Rearing system also had effect on ash content. Organic chickens showed the highest contents in the two cuts studied.

Regarding cholesterol, its contents were different among the group of commercial chicken. Between commercial chickens, industrial group showed the highest values in both cuts.

Table 2. Chemical composition and colour parameters of breast and drumstick meat of three commercial chickens

	Breast					Drumstick				
	Industrial	Range	Organic	SEM	Sig.	Industrial	Range	Organic	SEM	Sig.
pH	6.05 b	5.68 a	5.74 a	0.04	***	6.31	6.22	6.31	0.04	ns
Colour parameters										
L*	54.7	54.0	56.5	0.51	ns	54.1 b	54.1 b	47.2 a	1.11	**
a*	–1.31 a	3.76 c	0.30 b	0.49	***	7.22 a	10.51 b	9.59 b	0.46	*
b*	7.90 a	20.8c	10.0 b	1.12	***	14.1 a	21.1 b	13.1 a	0.76	***
Chemical composition (g/100 g):										
moisture	75.0 b	73.7 a	73.8 a	0.20	**	72.3 b	69.8 a	70.8 a	0.33	**
fat	1.39 b	0.33 a	0.38 a	0.16	**	8.05 a	10.4 b	7.88 a	0.33	***
protein	22.7 a	23.7 b	24.4 b	0.19	***	18.3 a	18.4 a	19.7 b	0.17	***
ash	1.19 a	1.40 b	1.81 c	0.06	***	1.03 a	1.01 a	1.10 b	0.01	**
cholesterol (mg/100 g)	50.3 b	40.9 a	40.7 a	1.16	***	43.0 b	37.4 a	38.5 a	0.95	*

a, b, c – mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly (Duncan's test; $P<0.05$); Sig.: significance: * ($P<0.05$), ** ($P<0.01$), *** ($P<0.001$), ns (not significant); SEM: standard error of the mean.

Table 3. Fatty acids profile of breast and drumstick meat of three commercial chickens

Fatty acids (g/100 g of FAME)	Breast					Drumstick				
	Industrial	Range	Organic	SEM	Sig.	Industrial	Range	Organic	SEM	Sig.
1	2	3	4	5	6	7	8	9	10	11
C14:0	0.83 b	0.47 a	0.52 a	0.04	***	0.87 c	0.50 a	0.63 b	0.03	***
C14:1*n-5*	0.30	0.25	0.30	0.01	ns	0.24 b	0.18 a	0.17 a	0.01	***
C15:0	0.13 c	0.06 a	0.09 b	0.01	***	0.12 c	0.06 a	0.09 b	0.01	***
C16:0	22.6 a	24.4 b	24.0 b	0.22	***	23.2 a	24.1 b	23.3 a	0.17	*
C16:1*n-7*	4.59 b	4.91b	3.19a	0.17	***	5.91 b	5.92 b	4.32 a	0.16	***
C17:0	0.23 c	0.09 a	0.18 b	0.01	***	0.21 c	0.09 a	0.16 b	0.01	***
C17:1*n-7*	0.32 ab	0.25 a	0.38 b	0.02	*	0.23 c	0.10 a	0.13 b	0.01	***
C18:0	7.62 b	6.37 a	7.49 b	0.14	***	6.66 b	5.83 a	6.75 b	0.10	***
9t-C18:1	0.29 b	0.15 a	0.15 a	0.01	***	0.31 b	0.16 a	0.19 a	0.01	***
C18:1*n-9*	35.2 c	32.9 b	28.5 a	0.64	***	38.7 c	36.0 b	33.9 a	0.42	***
C18:1*n-7*	2.90 c	2.49 b	2.20 a	0.07	***	2.47 c	2.17 b	2.02 a	0.04	***
C18:2*n-6*	18.7 a	22.0 b	23.5 b	0.51	***	17.6 a	21.6 b	23.8 c	0.54	***
C20:0	0.07 ab	0.07 a	0.08 b	0.00	*	0.07 a	0.07 a	0.08 b	0.00	***
C18:3*n-6*	0.15	0.17	0.17	0.00	ns	0.15 a	0.17 a	0.20 b	0.01	**
C20:1*n-9*	0.39 c	0.31 b	0.26 a	0.01	***	0.39 b	0.32 a	0.31 a	0.01	***
C18:3*n-3*	1.27 a	1.28 a	1.66 b	0.05	***	1.33 a	1.43a	2.03 b	0.06	***
C20:2*n-6*	0.37	0.32	0.33	0.01	ns	0.19 b	0.16 a	0.20 b	0.01	***
C20:3*n-6*	0.34 a	0.48 b	0.58 b	0.03	**	0.16 a	0.17 a	0.21 b	0.01	***
C20:4*n-6*	2.07 a	2.25 a	3.55 b	0.19	**	0.73 a	0.70 a	1.10 b	0.04	***
C20:5*n-3*	0.23	0.23	0.18	0.01	ns	0.04 b	0.03 a	0.05 c	0.00	***
C22:5*n-3*	0.53 a	0.59 a	0.84 b	0.04	**	0.14 a	0.11 a	0.19 b	0.01	***
C22:6*n-3*	0.30 a	0.33 a	0.65 b	0.04	***	0.07 a	0.07 a	0.12 b	0.01	***

Table 3 – contd.

1	2	3	4	5	6	7	8	9	10	11
SFA	31.6	31.5	32.4	0.21	ns	31.2	30.7	31.1	0.17	ns
MUFA	44.1 c	41.3 b	34.8 a	0.86	***	48.3 c	44.9 b	41.0 a	0.60	***
PUFA	24.4 a	27.2 b	32.8 c	0.83	***	20.6 a	24.4 b	27.9 c	0.64	***
n-3	2.35 a	2.43 a	3.38 b	0.11	***	1.62 a	1.65 a	2.41 b	0.07	***
n-6	22.0 a	25.0 b	29.2 c	0.71	***	18.9 a	22.8 b	25.5 c	0.57	***
n-6/n-3	9.44 b	11.5 c	8.29 a	0.30	***	11.7 b	13.8 c	10.6 a	0.26	***
AI	0.38	0.38	0.39	0.01	ns	0.39	0.38	0.38	0.01	ns
TI	0.77	0.78	0.75	0.01	ns	0.8	0.79	0.76	0.01	ns
h/H	2.66	2.52	2.59	0.03	ns	2.56	2.54	2.66	0.03	ns

a, b, c – mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly (Duncan's test; $P<0.05$); Sig.: significance: * ($P<0.05$), ** ($P<0.01$), *** ($P<0.001$), ns (not significant); SEM: standard error of the mean; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; AI: atherogenic index; TI: thrombogenic index; h/H: hypocholesterolemic/Hypercholesterolemic ratio.

Fatty acid profile

The fatty acid profile of chicken breast and drumstick meat is shown in Table 3. The fatty acid profile was the same in both cuts. The major fatty acid was C18:1*n-9* (oleic acid), followed by C16:0 (palmitic acid), C18:2*n-6* (linoleic acid), C18:0 (stearic acid), C16:1*n-7* (palmitoleic acid) and finally C18:1*n-7* (vaccenic acid), C20:4*n-6* (arachidonic acid) and C18:3*n-3* (linolenic acid) with similar values. The individual content of the other 14 fatty acids identified in the meat samples was in all cases less than 1%.

Although the profile is the same, the content of the fatty acids was different among the three commercial types of chickens studied. Rearing system influenced 18 out of 22 fatty acids in breast and all fatty acids content in drumstick. Saturated fatty acids (SFA) did not show significant differences between three groups in both cuts. Industrial chickens showed the highest content of C14:0, C15:0 and C17:0 in both cuts, while the values of C16:0 were significantly higher in range than the other 2 production systems in drumstick meat and higher than industrial chickens in breast meat. On the contrary, organic chickens showed the highest values of C20:0 compared to range chickens in breast and higher than the other two production systems in drumstick. However, the content of this fatty acid was not very important, since in all cases it represented less than 0.1% of total fatty acids. The lowest values of C18:0 were found in range meat in both cuts, and there are no differences in this fatty acid content between industrial and organic chickens.

Regarding monounsaturated fatty acids (MUFA), animals from industrial group showed the highest values, followed by animals from range group, and by organic group in breast and drumstick. Similar results were observed for C18:1*n-9* (oleic acid), C18:1*n-7* and C20:1*n-9*. Another important fatty acid was C16:1*n-7*, which presented the same values for industrial and range chickens, while organic group showed the lowest values of this fatty acid in both cuts. Regarding MUFA, the other minority fatty acids, such the contents of C14:1*n-5* and C17:1*n-7* in drumstick, or the content of 9t-C18:1 in both cuts were higher in the industrial group than in the animals from the other two production systems.

In contrast, the content of polyunsaturated fatty acids (PUFA) was significantly higher in the meat of organic group chickens, followed by range chickens and by industrial in breast and drumstick. Similar results were reported for *n-6* PUFA. The highest amounts of C18:2*n-6* were found in range and organic groups in breast meat and in organic group in drumstick, while the industrial chickens presented significantly lower values than the other 2 groups in both cuts. In the case of C20:4*n-6* organic chickens had higher values than the other 2 groups of animals in both cuts. The other minority *n-6* fatty acids showed also a similar trend. Drumstick from organic chickens had the highest content of C18:3*n-6*, C20:2*n-6* and C20:3n-6, while in the breast, only the content of C20:3*n-6* showed significant differences, its content being higher in range and organic groups than industrial chickens. In a similar way, the *n-3* PUFA of organic chickens were also higher than the other two groups in both cuts. The contents of C18:3*n-3*, C22:5*n-3* and C22:6*n-3* in both cuts and the content of C20:5*n-3* in drumstick were higher in organic than in the industrial and range chickens.

Table 4. Amino acids composition of breast and drumstick meat of three commercial chickens

Amino acids (mg/100 g)	Breast					Drumstick				
	Industrial	Range	Organic	SEM	Sig.	Industrial	Range	Organic	SEM	Sig.
Aspartic acid	2092	2150	2129	41.3	ns	1670	1672	1690	28.0	ns
Serine	966	947	988	23.5	ns	798	810	798	16.5	ns
Glutamic acid	3264	3306	3309	57.1	ns	2838	2807	2800	46.8	ns
Glycine	973	992	981	18.1	ns	860	805	869	14.5	ns
Alanine	1298	1314	1341	22.3	ns	1041	1039	1063	16.6	ns
Proline	855	904	876	22.8	ns	755	717	818	18.6	ns
Tyrosine	832	849	861	17.5	ns	671	708	707	15.4	ns
Total non-essential	10280	10462	10485	185	ns	8634	8663	8790	136	ns
Histidine	812 a	928 b	1002 b	20.8	***	564	593	614	9.27	ns
Arginine	1696	1695	1789	30.7	ns	1456	1491	1521	27.8	ns
Threonine	984	986	1032	16.2	ns	793	824	842	13.8	ns
Cysteine	245	246	259	5.96	ns	214	215	220	5.0	ns
Valine	1097	1110	1145	18.5	ns	847	868	880	11.5	ns
Methionine	385	399	410	11.3	ns	252	265	286	10.0	ns
Lysine	2031	2074	2043	41.3	ns	1635	1611	1646	29.0	ns
Isoleucine	1126	1143	1166	18.9	ns	876	883	916	11.8	ns
Leucine	1827	1864	1889	32.4	ns	1458	1464	1523	22.7	ns
Phenylalanine	928	937	947	14.5	ns	764	764	802	10.5	ns
Total essential	11131	11380	11681	174	ns	8859	8999	9250	121	ns
Essential/Non-essential	1.09	1.09	1.12	0.01	ns	1.03	1.04	1.06	0.01	ns

a, b – mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly (Duncan's test; $P<0.05$); Sig.: significance: *** ($P<0.001$), ns (not significant); SEM: standard error of the mean.

In order to evaluate the nutritional value of intramuscular fat, *n-6/n-3* ratio, atherogenic index (AI), thrombogenic index (TI) and h/H ratio were calculated. In the present study, only *n-6/n-3* was affected by rearing system. In this case and in both cuts, the highest value of this ratio was observed in meat of range chickens, followed by industrial chickens and by organic chickens. The other nutritional indices did not show differences between the three groups of chickens.

Amino acids composition

The amino acid composition of breast and drumstick of industrial, range and organic chickens is shown in Table 4. The amino acid profile was the same in both cuts. Between all amino acids, only the content of histidine from breast showed differences ($P<0.001$) among the three rearing system. In this regard, organic and range chickens presented higher values of this amino acid than in industrial chickens.

On the other hand, in both cuts, the amino acid that showed the highest content was glutamic acid followed by aspartic acid and lysine with similar values, leucine, arginine and alanine. The sum of these six amino acids represents 57% of the total amino acids. In contrast, the lowest values were found, also in both cuts, for cysteine and methionine.

The essential/non-essential ratio also did not present significant differences between the chicken groups.

Mineral composition

The concentrations of minerals of breast and drumstick of three commercial chickens are presented in Table 5. The most abundant macroelements were potassium (K) and phosphorous (P) with similar amounts, followed by sodium (Na), magnesium (Mg) and calcium (Ca). The lowest values of macroelements were observed for zinc (Zn) and iron (Fe). In the present study, statistical analysis showed that the amounts of Na and Mg in breast and Fe and Mg in drumstick were influenced by rearing system. Chickens of industrial group showed higher values of Na in breast than the other two groups of animals. The content of Mg was also higher in industrial chickens group than in range and organic chickens in both cuts. Finally, the content of Fe was significantly higher in the drumstick of organic chickens than in industrial chickens, while range chickens showed intermediate values.

Table 5. Mineral composition of breast and drumstick meat of three commercial chickens

Minerals (mg/100 g)	Breast					Drumstick				
	Industrial	Range	Organic	SEM	Sig.	Industrial	Range	Organic	SEM	Sig.
Ca	5.79	6.41	6.41	0.30	ns	6.63	6.33	6.19	0.30	ns
Fe	0.34	0.44	0.41	0.02	ns	0.59 a	0.68 ab	0.77 b	0.02	**
K	211	202	201	2.39	ns	186	184	171	3.22	ns
Mg	41.2 b	26.1 a	25.8 a	1.96	***	29.4 b	21.5 a	19.1 a	1.18	***
Na	53.5 b	47.4 a	46.9 a	1.23	*	68.2	68.5	66.1	1.24	ns
P	210	206	210	4.96	ns	176	180	173	4.19	ns
Zn	0.55	0.49	0.48	0.01	ns	1.33	1.40	1.38	0.03	ns

a, b – mean values in the same row (corresponding to the same parameter) not followed by a common letter differ significantly (Duncan's test; $P<0.05$); Sig.: significance: * ($P<0.05$), ** ($P<0.01$), *** ($P<0.001$), ns (not significant); SEM: standard error of the mean.

Discussion

Chemical composition and colour characteristics

The lowest pH values found in breast for range and organic groups could be due to these animals having free access to outdoor space, which means better animal welfare. These conditions reduce the stress pre-slaughter, which leads to less pre-slaughter glycogen breakdown in the muscle and therefore more substrate for post-mortem metabolism (Castellini et al., 2002).

Colour is considered an important quality indicator and has an impact on consumer acceptability (Mennecke et al., 2007). Production system is one of the factors that could influence meat colour (Fanatico et al., 2005). In the present study, the higher values obtained for a* in meat from range chickens could be due to the increase of physical activity associated with access to outdoors (Husak et al., 2008). These trends can also be observed in organic chickens since these animals have access to the outdoors. Some authors concluded that the higher physical activity resulted in an increase of myoglobin content, which is positively related with redness (Fletcher, 1999).

Moreover, the slaughter age could also have influence on colour parameters. Older animals have higher contents of myoglobin and therefore higher a* values (Castellini et al., 2002; Husak et al., 2008). In the present study, younger animals (industrial chickens) were those that obtained the lowest a* values in relation to the range and organic chickens, in both cuts.

An important aspect to take into account is the detection and prevention of PSE meat to obtain quality poultry meat. In this sense, pH and colour are parameters that are related to PSE conditions and therefore could be considered as quality indicators (Barbut,1998; Woelfel et al., 2002). In fact, a significant correlation was obtained between pH and the colour parameters L* and a* ($r= –0.27$, $P<0.05$ and $r=0.46$, $P<0.01$, respectively). These findings were similar to those found by other authors, who described a negative correlation between pH and L* values ($r= –0.636$ and $r= –0.961$; $P=0.0001$) and a positive correlation with a* ($r=0.275$ and $r=0.947$; $P=0.0001$) (Fletcher, 1999; Qiao et al., 2001). According to Trout (1989) the positive correlation between pH and a* values is due to the protective effect of pH on the denaturation of myoglobin pigments.

Production system has been shown to influence the quality of poultry meat (Castellini et al., 2002; Bianchi et al., 2007; Fanatico et al., 2007; Husak et al., 2008). In this way, significant differences ($P<0.05$) were found between the three types of commercial chickens. The effect of rearing system on the chemical composition of chicken meat could be associated with the fact that animals reared under outdoor conditions are submitted to a natural ambient that led to differences in the structural manifestations of tissues and organs, as well as affecting metabolic biochemical processes (Bogosavljević-Bošković et al., 2010 a).

The values found for moisture showed that samples of animals reared outdoors had lower contents in breast and in drumstick. These results agree with those reported in the literature (Castellini et al., 2002; Husak et al., 2008). The differences in this parameter could be related with the slow-growing genotype poultry, which

had poorer water holding capacity than fast-growing ones (Santos et al., 2005). The poor water holding capacity in slow-growing birds is attributed to their tissue being less mature metabolically at harvest than the fast-growing birds (Castellini et al., 2002).

According to Castellini et al. (2002) and Bogosavljević-Bošković et al. (2010 b), organic chickens showed the lowest fat contents. These differences could result from organic and range chickens having more physical activity than industrial chickens, which would favour myogenesis instead of lipogenesis (Castellini et al., 2002; Fanatico et al., 2007). Additionally, other studies have shown that the additional space provided in free-range and organic production increases leanness in poultry, most likely due to activity (Castellini et al., 2002). As occurs in breast, in drumstick organic samples showed the lowest fat contents, although those were very similar to industrial samples. However, in this case range chickens displayed the highest fat values, which could be related with the type of muscle and its activity. Another possible explanation is that the slow-growing genotypes, as we used in the range and organic systems, had lower fat compared with fast-growing genotypes, as Ross used in our industrial system (Wattanachant et al., 2004).

In the same way, organic chickens showed the highest contents of protein, followed by range and industrial animals. This is in accordance with the results found by Husak et al. (2008) and Bogosavljević-Bošković et al. (2010 b). Moreover, in agreement with Wattanachant et al. (2004), protein content achieved the highest values in breast cut. This author also concluded that slow-growing genotypes had higher protein content compared with fast-growing genotypes. The values obtained were similar to those found by other authors in chicken (Castellini et al., 2002; Castellini et al., 2006; Husak et al., 2008). The main reason for the high amounts of protein on range and organic system was possibly related to exercise in an outdoor system contributing to muscle development and therefore higher protein (Fanatico, 2007).

Regarding ashes, organic chicken had higher contents in the pieces studied. The most viable explanation would be that older animals tend to have higher minerals content in the meat, which is related to metabolic growth and development activities (Prändal et al., 1994). This may justify the higher value of ashes in the meat of animals raised in the organic system, since they were slaughtered later.

Regarding cholesterol, production system was a factor that had influence on its contents ($P<0.05$). These values were within the typical values found in poultry meat of 27 to 90 mg/100 g (Chizzolini et al., 1999). In fact, other authors found in breast of broilers amounts of cholesterol between 35.9 and 43.1 mg/100 g and in thigh between 50.9 and 76.1 mg/100 g (Komprda et al., 1999; Komprda et al., 2000 a). The behaviour of cholesterol contents was in agreement with the results found by Pettersson and Aman (1991), and Bragagnolo and Rodríguez-Amaya (2002), who observed that the amounts of cholesterol decrease significantly when the slaughter age increases. Additionally, intramuscular fat (IMF) is another of the parameters that can affect the amount of cholesterol, since pieces with high content of IMF present proportionately less membrane polar lipids and therefore lower amounts of the cholesterol associated with these membranes (Alasnier et al., 1996). However, in the present study only values obtained for drumstick complied with what has been men-

tioned previously, namely range chickens obtaining the highest IMF contents (and therefore the lowest cholesterol contents).

These results were interesting from a nutritional point of view because cholesterol content has been an important aspect in making nutritional decisions. Moreover, poultry meat is considered a recommendable food, which was reflected in the contents found. The levels found in the present study were below the maximum daily recommendations for cholesterol intake; one hundred-gram portion of chicken drumstick meat without skin represents only 14.7% of the upper limit of daily cholesterol intake in breast samples and 13.2% in drumstick (300 mg per day) (American Heart Association, 2008).

On the whole, range and organic chickens presented more favourable cholesterol contents in both commercial cuts from the viewpoint of healthy human nutrition.

The aforementioned results allow us to affirm that chicken produced under organic conditions would be a good alternative to industrial systems, since outdoor access could improve meat quality reducing fat and cholesterol contents as well as favour the higher contents of protein and ashes.

Fatty acids composition

As commented in the results section, in the present study, both cuts showed the prevalence of MUFA followed by SFA and PUFA. This profile was previously reported by Geldenhuys et al. (2015) in goose hunted in summer season, by Gálvez et al. (2018) in turkey and by Komprda et al. (1999, 2000 a, b) in chickens. In contrast, Kuttappan et al. (2012) found similar contents of SFA, MUFA and PUFA (30–35%) in broiler breast, while Geldenhuys et al. (2015) in goose, Komprda et al. (2002) in turkey and Zhao et al. (2011) in broilers found that PUFA were the major fatty acids (between 37 and 50% of total FAME). Husak et al. (2008) found differences in fatty acid profile among organic, free-range and conventional broilers. These authors observed that organic broilers presented PUFA as major fatty acids while MUFA were the most important fatty acids in conventional and free-range broilers.

It was evident that the production system significantly affected the fatty acids content of the chicken meat. As commented above, in both cuts, organic chickens present the highest values of PUFA (both *n-3* and *n-6* PUFA), while the highest values of MUFA were found in industrial chickens. Range chickens presented intermediate values of MUFA and PUFA. In contrast, the content of total SFA were not influenced by production system. These findings are in accordance with the results obtained by Husak et al. (2008), who described higher MUFA and lower PUFA (especially *n-3*) values in conventional broilers than free-range and organic broilers.

Therefore, organic and range productions are clearly different from industrial production system. These differences are related to the diets received in each production system. It is well known that the main factor influencing the fatty acid composition of the meat is the variation in the diet of the animals (Wood and Enser, 1997; Geldenhuys et al., 2015). This fact is particularly evident in monogastric animals where the dietary fatty acids are incorporated directly into the tissue lipids (Domínguez et al., 2015 c; McRae et al., 2005). This theory coincides with the findings of our study, where the diet of industrial production had higher contents of C18:1*n-9* (31.8

vs. 20–24%) and lower amounts of C18:2*n-6* (24.45 vs. 52–54%) and C18:3*n-3* (2.07 vs. 4–7%) than the other two production systems. In addition, access to a grass (with high amounts of C18:3*n-3*) in range and organic production could also explain the high content of C18:3*n-3* in breast and drumstick meat in comparison with industrial production system (Husak et al., 2008). Therefore, the differences observed in C18:2*n-6* and C18:3*n-3* amount could presumably be due to the increased uptake of dietary fatty acids in adipocytes in the range and organic chickens.

In this regard, Komprda et al. (2002) also observed that fatty acids from the diet strongly influenced the final amounts of fatty acids in turkey meat. These authors found that turkeys fed with a diet that contained sunflower oil (54.7% of C18:2*n-6*) and other feeds with linseed oil (36.5% of C18:3*n-3*) present higher amounts of these fatty acids in meat (thigh and breast). This is due to animals being incapable of synthesizing PUFA, and C18:2*n-6* and C18:3*n-3* must be supplied by the diet (Kuttappan et al., 2012).

Furthermore, since C18:3*n-3* is the precursor of the C20:5*n-3*, C22:5*n-3* and C22:6*n-3* (Wood and Enser, 1997), it is expected that the concentration of these also increase. However, in the present research only the content of C22:5*n-3* and C22:6*n-3* in organic chickens showed higher amounts than industrial chickens. This fact could be related with the high amounts of *n-6* PUFA in the diet. According to Gerster (1998), the *n-6* rich diets decreased the conversion of C18:3*n-3* to the other long-chain *n-3* PUFA. In this regard, other authors argue that the most important factor to the conversion of C18:3*n-3* in long-chain *n-3* PUFA was probably not C18:2*n-6* amount itself, but C18:2*n-6*/C18:3*n-3* ratio (Komprda et al., 2000*b*; Domínguez et al., 2015 c). With this in mind, it is easy to understand why there are no significant differences in C20:5*n-3*, C22:5*n-3* and C22:6*n-3* between industrial and range chickens. In the present study the C18:2*n-6*/C18:3*n-3* ratio of industrial (11.8) and range (13.1) diets is so similar, while this ratio in organic diet is lower (7.7). In addition, we also confirm the dependence of C20:4*n-6* content in meat on the C18:2*n-6* amount in the diet.

Finally, nutritional indices were calculated according to the fatty acids values. These indices show the ratio between the healthy and unhealthy fatty acids, and they give us information about the health of the fat composition and therefore the influence they can exert on various diseases. The values of atherogenic index (AI), thrombogenic index (TI) and h/H ratio did not show significant differences between industrial, range and organic chickens in both cuts. Other authors reported values of 0.48 of AI and 0.74–0.88 of TI in chicken (Castellini et al., 2006) and 0.45 of AI, 0.88–0.98 of TI and 2.3–2.5 of h/H ratio in turkey meat (Galvez et al., 2018). The *n-6/n-3* ratio is another vital aspect with regards to human health. It is well known that the high proportion of PUFA in itself is not necessarily healthy if it is not balanced in relation to the *n-6/n-3* ratio, which should not exceed 4 (Simopoulos, 2004). Excessive amounts of *n-6* PUFA and very high *n-6/n-3* PUFA ratios promote several kinds of pathogenesis, whereas increased levels of *n-3* PUFA (and low *n-6/n-3* PUFA ratios) exert suppressive effects (Simopoulos, 2004). In this case, organic chickens showed the lowest and range chickens showed the highest values of this ratio. However, all of the samples analysed presented values higher than the recommended values.

On the whole, organic chickens with high amounts of essential fatty acids (C18:2*n-6* and C18:3*n-3*), other fatty acids with high biological importance as long-chain *n-3* PUFA and lower *n-6/n-3* ratio presented more favourable meat from the viewpoint of human nutrition.

Amino acids composition

Considering the human requirements of amino acids [World Health Organization (WHO) 2007], the lean poultry is a valuable source of dietary essential amino acids (Dillon, 2013; Pereira and Vicente, 2013). In this study, arginine was included in the essential amino acids, as done by Hoffman et al. (2005), because arginine is considered a conditionally essential amino acid (Arienti 2003).

Multiple studies in poultry meat showed similar results to ours. The amino acid profile obtained in the present research, in which the major amino acid is glutamic acid, followed by aspartic acid, lysine and leucine with similar amounts, and then arginine and alanine were previously reported in chicken (Zhao et al., 2011; Fu et al., 2016), turkey (Ribarski and Oblakova, 2016; Gálvez et al., 2018;) and goose (Geldenhuys et al., 2015).

On the other hand, analysis of amino acid composition showed no great difference among production systems. In fact, only histidine in breast meat showed differences between the production systems. Additionally, the two lineages used in the present study also did not influence the amino acid composition. In the same way, the values of essential/non-essential ratio did not show differences among production systems and range between 1.03 and 1.12. These values agree with those described by Gálvez et al. (2018) in turkey meat.

In accordance with our results, Zhao et al. (2011) did not find differences in amino acids content between two broiler breeds. In the same way, Ribarski and Oblakova (2016) did not find differences between the amino acids amount in turkey breast. This suggests that the amino acid content is scarcely influenced by factors such as diet, production system or slaughter age. According to De Smet and Vossen (2016), the low differences found in amino acids are due to the amino acid profile of muscle tissue being relatively conserved.

Mineral composition

The composition of minerals is another important aspect for human health (Ribarski and Oblakova, 2016). In this regard, several factors could be responsible for the variation of some minerals content in meat. According to Geldenhuys et al. (2015) the main factors that can vary meat minerals are genetic, sex, environmental and diet. However, in this research, although older animals tend to have higher ashes content, the mineral composition did not reflect this aspect. We only observed slight differences in 3 out of 7 minerals studied.

Our mineral contents agree with those reported by Geldenhuys et al. (2013, 2015) who found that P was the most abundant mineral followed by K in goose meat.

On the other hand, the differences obtained in Fe amounts in drumstick meat between organic, range and industrial chickens could be due to the differences in myoglobin content. The high level of Fe in organic and range chickens is attributed

to elevated myoglobin content because the drumstick muscle of these chickens endures a high level of physical activity (extensive system) in comparison with industrial chickens (intensive system). Therefore, the chickens produced in an extensive system have a high myoglobin content for oxygen supply. This aspect was probed by Geldenhuys et al. (2013), who concluded that the metabolic capacity and fibre composition of the muscle is the main factor that affects the amount of Fe. Additionally, meat is considered to be a good source of Fe because 50–60% is in the heme form and is therefore more readily adsorbed (Luciano, 2009).

With the results obtained in the present study it is possible affirm that chicken meat is an excellent source of some minerals such as Fe, Zn and P. The chicken meat contains all the minerals essential for human consumption [Food and Agricultural Organization (FAO), 2001] and the increased bioavailability of certain minerals such as Fe or Zn (Geldenhuys et al., 2015) is also beneficial for human health.

As a general conclusion, the production system had high influence on chemical and nutritional characteristics of meat. In all cases, organic chickens showed higher amounts of essential fatty acids (C18:2*n-6* and C18:3*n-3*) and other fatty acids with high biological importance as long-chain *n-3* PUFA and lower *n-6/n-3* ratio, fat and cholesterol content. In addition, organic chickens had the highest values of Fe in drumstick meat. With this in mind, we can concluded that organic production system presented more favourable meat from the viewpoint of human nutrition.

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References

Alasnier C., Rémignon H., Gandemer G. (1996). Lipid characteristics associated with oxidative and glycolytic fibres in rabbit muscles. Meat Sci., 43: 213–224.

American Heart Association (2008). Dietary guidelines for healthy American adults. Cholesterol. Fat, in: Heart and Stroke Encyclopedia Dallas, USA.

American Oil Chemist Society (AOCS) (2005). AOCS Official Procedure Am 5-04. Rapid determination of oil/fat utilizing high temperature solvent extraction. Urbana, IL.

Andersen H.J., Oksbjerg N., Young J.F., Therkildsen M. (2005). Feeding and meat quality – a future approach. Meat Sci., 70: 543–554.

Arienti G. (2003). Le basi molecolari della nutrizione. 2nd ed. Piccin Nuova Libraria S.p.A., Padova, Italy.

Barbut S. (1998). Estimating the magnitude of the PSE problem in poultry. J. Muscle Foods, 9: 35–49.

Bessa R.J.B., Alves S.P., Figueiredo R., Teixeira A.J.R., Rodrigues A.I.P., Janeiro A., Costa M., Santos-Silva J., Prates J.A.M. (2006). Discrimination of production system and origin of animal products using chemical markers. In: Animal Products from the Medi-

terranean Area. EAAP Publication No. 119, Ramalho Ribeiro M.C., Horta A.E.M., Mosconi C., Rosati A. (Eds). Academic Publishers, Netherlands, pp. 231−240.

Bianchi M., Petracci M., Sirri F., Folegatti E., Franchini A., Meluzzi A. (2007). The influence of the season and market class of broiler chickens on breast meat quality traits. Poultry Sci., 86: 959–963.

Bligh E.G., Dyer W.J. (1959). A rapid method of total lipid extraction and purification. Can. J. Biochem. Phys., 37: 911–917.

Bogosavljević-Bošković S., Mitrovic S., Djokovic R., Doskovic V., Djermanovic V. (2010 a). Chemical composition of chicken meat produced in extensive indoor and free range rearing systems. Afr. J. Biotechnol., 9: 9069–9075.

Bogosavljević-Bošković S., Pavlovski Z., Petrović M.D., Dosković V., Rakonjac S. (2010 b). Broiler meat quality: Proteins and lipids of muscle tissue. Afr. J. Biotechnol., 9: 9177–9182.

Bogosavljević-Bošković S., Rakonjac S., Dosković V., Petrović M.D. (2012). Broiler rearing systems: a review of major fattening results and meat quality traits. World Poultry Sci. J., 68: 217–228.

Bragagnolo N., Rodríguez-Amaya D.B. (2002). Simultaneous determination of total lipid, cholesterol and fatty acids in meat and backfat of suckling and adult pigs. Food Chem., 79: 255–260.

Castellini C., Mugnai C., Dal Bosco A. (2002). Effect of organic system on broiler carcass and meat quality. Meat Sci., 60: 219–225.

Castellini C., Dal Bosco A., Mugnai C., Pedrazzoli M. (2006). Comparison of two chicken genotypes organically reared: oxidative stability and other qualitative traits of the meat. Ital. J. Anim. Sci., 5: 29–42.

Chizzolini R., Zanardi E., Dorigoni V., Ghidini S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci. Technol., 10: 119–128.

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

Crespo N., Esteve-García E. (2002). Nutrient and fatty acid deposition in broilers fed different dietary fatty acid profiles. Poultry Sci., 81: 1533–1542.

De Smet S., Vossen E. (2016). Meat: The balance between nutrition and health. A review. Meat Sci. 120: 145–156.

Díaz O., Rodríguez L., Torres A., Cobos A. (2010). Chemical composition and physicochemical properties of meat from capons as affected by breed and age. Span. J. Agric. Res., 8: 91–99.

Dillon E.L. (2013). Nutritionally essential amino acids and metabolic signalling in aging. Amino Acids, 45: 431–441.

Domínguez R., Crecente S., Borrajo P., Agregán R., Lorenzo J.M. (2015 a). Effect of slaughter age on foal carcass traits and meat quality. Animal., 9: 1713–1720.

Domínguez R., Borrajo P., Lorenzo J.M. (2015 b). The effect of cooking methods on nutritional value of foal meat. J. Food Compos. Anal., 43: 61–67.

Domínguez R., Martínez S., Gómez M., Carballo J., Franco I. (2015 c). Fatty acids, retinol and cholesterol composition in various fatty tissues of Celta pig breed: Effect of the use of chestnuts in the finishing diet. J. Food Compos. Anal., 37: 104–111.

Domínguez R., Barba F.J., Centeno J.A., Putnik P., Alpas H., Lorenzo J.M. (2018). Simple and rapid method for the simultaneous determination of cholesterol and retinol in meat using normal-phase HPLC technique. Food Anal. Method., 11: 319–326.

European Commission (2016). Facts and figures on organic agriculture in the European Union. European Union: Farm accountancy data network, Agriculture and Rural Development, Unit Economic Analysis of EU Agriculture.

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 Sci., 84: 1785–1790.

Fanatico A.C., Pillai P.B., Emmert J.L., Owens C.M. (2007). Meat quality of slow-and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access. Poultry Sci., 86: 2245–2255.

FAOSTAT 2018. On-line and multilingual database currently covering international statistics [Online]. Available: http://faostat.fao.org/faostat/default.jsp [18 July 2018].

Fernández M.J., Ordóñez A., Cambero I., Santos C., Pin C., De La Hoz L. (2007). Fatty acid compositions of selected varieties of Spanish dry ham related to their nutritional implications. Food Chem., 101: 107–112.

Fletcher D.L. (1999). Broiler breast meat color variation, pH and texture. Poultry Sci., 78: 1323–1327.

Food and Agriculture Organization (FAO) (2010). Agribusiness handbook. Poultry meat and eggs. Rome: Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization (FAO) (2001). Human vitamin and mineral requirements [Online]. Available. http://www.fao.org/3/a-y2809e.pdf [18 February 2019]

Franco D., Rois D., Vázquez J.A., Lorenzo J.M. (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.

Fu Q., Leng Z.X., Ding L.R., Wang T., Wen C., Zhou Y.M. (2016). Complete replacement of supplemental dl-methionine by betaine affects meat quality and amino acid contents in broilers. Anim. Feed Sci. Technol., 212: 63–69.

Gálvez F., Domínguez R., Pateiro M., Carballo J., Tomasevic I., Lorenzo J.M. (2018). Effect of gender on breast and thigh turkey meat quality. Brit. Poultry Sci., 59: 408–415.

Geldenhuys G., Hoffman L.C., Muller N. (2013). Aspects of the nutritional value of cooked Egyptian goose (*Alopochen aegyptiacus*) meat compared with other well-known fowl species. Poultry Sci., 92: 3050–3059.

Geldenhuys G., Hoffman L.C., Muller N. (2015). The fatty acid, amino acid, and mineral composition of Egyptian goose meat as affected by season, gender, and portion. Poultry Sci., 94: 1075–1087.

Gerster H. (1998). Can adults adequately convert a-linolenic acid (18:3*n-3*) to eicosapentaenoic acid (20:5*n-3*) and docosahexaenoic acid (22:6*n-3*)? Int. J. Vitam. Nutrit. Res., 68: 159–173.

Hoffman L.C., Kritzinger B., Ferreira A.V. (2005). The effects of region and gender on the fatty acid, amino acid, mineral, myoglobin and collagen contents of impala (*Aepyceros melampus*) meat. Meat Sci., 69: 551–558.

Husak R.L., Sebranek J.G., Bregendahl K. (2008). A survey of commercially available broilers marketed as organic, free-range, and conventional broilers for cooked meat yields, meat composition, and relative value. Poultry Sci., 87: 2367–2376.

IBM Corporation (2010). IBM SPSS Statistics for Windows, version 19.0. New York: IBM Corporation.

ISO 937. (1978). Determination of nitrogen content, in: International standards meat and meat products. Geneva: International Organization for Standardization.

ISO 1442. (1997). Determination of moisture content, in: International standards meat and meat products. Geneva: International Organization for Standardization.

ISO 936. (1998). Determination of ash content, in: International standards meat and meat products. Geneva: International Organization for Standardization.

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). Poultry Sci., 87: 160–169.

Jensen J.F. (1984). Method of dissection of broiler carcasses and description of parts. Denmark: World Poultry Science Association, Working group V.

Kavouridou K., Barroeta A.C., Villaverde C., Manzanilla E.G., Baucells M.D. (2008). Fatty acid, protein and energy gain of broilers fed different dietary vegetable oils. Span. J. Agric. Res., 6: 210–218.

Komprda T., Zelenka J., Tieffova P., Stohandlova M., Foltyn J. (1999). Effect of the growth intensity on cholesterol and fatty acids content in broiler chicken tissues. Archiv fur Geflugelkunde, 63: 36–43.

Komprda T., Zelenka J., Tieffova P., Štohandlová M., Foltýn J., Fajmonova E. (2000 a). Effect of age on total lipid, cholesterol and fatty acids content in tissues of fast and slow growing chickens. Archiv fur Gefluegelkunde, 64: 121–128.

Komprda T., Zelenka J., Tieffová M., Štohandlová M., Foltýn J., Fajmonova E.

(2000 b). Meat quality of broilers fattened deliberately slow by cereal mixtures to higher age: 1. Growth and sensory quality. Archiv fur Gefluegelkunde, 64: 167-174.

Komprda T., Zelenka J., Bakaj P., Kladroba D., Blazkova E., Fajmonova E. (2002). Cholesterol and fatty acid content in meat of turkeys fed diets with sunflower, linseed or fish oil. Archiv fur Geflugelkunde, 67: 65–75.

Kritchevsky D. (2008). Fats and oils in human health. In: Food Lipids. Chemistry, Nutrition, and Biotechnology, Akoh C.C., Min D.B. (Eds). CRC Press, Boca Raton, FL, pp. 499–511.

Kuttappan V.A., Brewer V.B., Apple J.K., Waldroup P.W., Owens C.M. (2012). Influence of growth rate on the occurrence of white striping in broiler breast fillets. Poultry Sci., 91: 2677–2685.

Lorenzo J.M., Bermúdez R., Domínguez R., Guiotto A., Franco D., Purriños L. (2015). Physicochemical and microbial changes during the manufacturing process of dry-cured lacón salted with potassium, calcium and magnesium chloride as a partial replacement for sodium chloride. Food Control, 50: 763–769.

Luciano F.B. (2009). The impacts of lean red meat consumption on human health: A review. CyTA–J. Food., 7: 143–151.

McRae J., O'Reilly L., Morgan P. (2005). Desirable characteristics of animal products from a human health perspective. Livest. Prod. Sci., 94: 95–103.

Mennecke B.E., Townsend A.M., Hayes D.J., Lonergan S.M. (2007). A study of the factors that influence consumer attitudes toward beef products using the conjoint market analysis tool. J. Anim. Sci., 85: 2639–2659.

OJ (2008 a). 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.

OJ (2008 b). Commission Regulation (EC) No 889/2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. Official Journal of the European Union L 250 18/09/2008.

Pereira P.M.D.C.C., Vicente A.F.D.R.B. (2013). Meat nutritional composition and nutritive role in the human diet. Meat Sci., 93: 586–592.

Pettersson D., Aman P. (1991). Production results, serum cholesterol concentration and carcass composition of broiler chickens fed diets based on bran or inner endosperm from oats with and without enzyme supplementation. J. Sci. Food Agric., 57: 273–286.

Prändal O., Fischer A., Schmidhofer T., Sinell H. (1994). Tecnología e higiene de la carne. Editorial Acribia. Zaragoza, Spain.

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.

Qiao M., Fletcher D.L., Smith D.P., Northcutt J.K. (2001). The effect of broiler breast meat color on pH, moisture, water-holding capacity, and emulsification capacity. Poultry Sci., 80: 676–680.

Ribarski S., Oblakova M. (2016). Slaughter yield and quality of meat from wild turkey (*Meleagris gallopavo silvestris vieillot*) reared in hunting reserve in south Bulgaria. Trakia J. Sci., 14: 135.

Santos A.L., Sakomura N.K., Freitas E.R., Fortes C.M.L.S., Carrilho E.N.V.M., Fernandes J.B.K. (2005). Growth, performance, carcass yield and meat quality of three broiler chickens strains. Rev. Bras. Zootec., 34: 1589–1598.

Simopoulos A.P. (2004). Omega-6/omega-3 essential fatty acid ratio and chronic diseases. Food Rev. Int., 20: 77–90.

Trout G.R. (1989). Variation in myoglobin denaturation and color of cooked beef, pork, and turkey meat as influenced by pH, sodium chloride, sodium tripolyphosphate, and cooking temperature. J. Food Sci., 54: 536–540.

Ulbricht T.L.V., Southgate D.A.T. (1991). Coronary heart disease: seven dietary factors. Lancet., 338: 985–992.

Wattanachant S., Benjakul S., Ledward D.A. (2004). Composition, color, and texture of Thai Indigenous and broiler chicken muscles. Poultry Sci., 83: 123–128.

Woelfel R.L., Owens C.M., Hirschler E.M., Martinez-Dawson R., Sams A.R. (2002). The characterization and incidence of pale, soft, and exudative broiler meat in a commercial processing plant. Poultry Sci., 81: 579–584.

Wood J.D., Enser M. (1997). Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. Brit. J. Nutr., 78: S49–S60.

World Health Organization (WHO) (2007). Protein and amino acid requirements in human nutrition: Report of a joint FAO/WHO/UNU expert consultation. Available: https://apps.who.int/iris/handle/10665/43411. [18 February 2019].

Zhao G.P., Cui H.X., Liu R.R., Zheng M.Q., Chen J.L., Wen J. (2011). Comparison of breast muscle meat quality in 2 broiler breeds. Poultry Sci., 90: 2355–2359.

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