Physicochemical composition and sensory quality evaluation of capon and rooster meat

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ABSTRACT The aim of the present study was to evaluate the effect of caponization on the physicochemical and sensory characteristics of rooster and capon meat (2 Portuguese autochthonous chicken breeds of roosters: *Amarela* and *Pedrês*), raised under the same production. The birds were castrated at 9 wk of age and bred until 140 d of age. Forty *Amarela* (20 roosters and 20 capons—castrated male) and 40 *Pedrês Portuguesa* (20 roosters and 20 capons) breed chickens, 5 free-range chickens, and 5 broilers were used. From the breast, leg, and wing muscles, physicochemical parameters such as pH, water activity (a_w), physical color, moisture content, ash, CP, pigments, collagen, and total fat and fatty acids profile, were analyzed according to standard procedures. Caponization did not affect pH, a_w, lightness (L^*), yellowness (b^*), ash, protein, collagen, saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA), and the ratio of unsaturated fatty acids (UFA)/SFA. Results show that caponization decreased ($P \leq 0.05$) moisture content and increased ($P \leq 0.05$) pigments and intramuscular fat content. Capons showed higher ($P \leq 0.001$) redness (a^*) and chroma (C^*), and lower ($P \leq 0.001$) hue (H^*) compared to roosters. Caponization increased ($P \leq 0.05$) monounsaturated fatty acids content and PUFA/SFA. The main fatty acids found were oleic (C18:1), palmitic (C16:0), and linoleic (C18:2). Capons had greater ($P \leq 0.05$) C18:1 content but lower ($P \leq 0.01$) butyric acid (C4:0), caprylic acid (C8:0), stearic acid (C18:0), and ($P \leq 0.05$) arachidonic acid (C20.4) content than roosters. The objective of sensory analysis was making the comparison of the *Amarela* and *Pedrês* meat with a free-range chicken and a broiler. Panelists classified the capon meat (*Amarela* and *Pedrês*) as juicier and less tough and fibrous than rooster meat. Broilers were in general juicier, tenderer, and less fibrous than the other chickens in this study. The results of sensory evaluation complement those obtained in physicochemical analysis, suggesting that caponization promotes an overall improvement in meat quality.

Key words: capon, rooster, caponization, physicochemical quality, sensory evaluation

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INTRODUCTION

Currently, consumers demand more variety and high-quality characteristics of different poultry meat products. One of these products is the capon (male rooster with surgically removed testes before reaching sexual maturity). Removal of the testicles produces a change in the animal's metabolism affecting the growth, behavior, tissue composition, chemical composition, and organoleptic quality of meat (Miguel et al., 2008; Sirri et al., 2009). The principal metabolic effect of caponization is the increase of fat content—abdominal, subcutaneous, and intramuscular (Chen et al., 2000; Tor et al., 2002, 2005; Symeon et al., 2010, 2012). This effect has improved meat quality (Miguel et al., 2008; Webb and O'Neill, 2008; Symeon et al., 2010), enhancing the flavor, texture, and meat juiciness, and making it more appreciated by consumers than rooster meat of the same age (Chen et al., 2005; Tor et al., 2005). Several authors report significant changes in the fatty acid profile of rooster meat after caponization (Tor et al., 2005; Sirri et al., 2009). A decrease in saturated fatty acids (**SFA**) and increase in unsaturated fatty acids (**UFA**) content in capon meat would be beneficial for the human diet. The objective of this study was the comparison of the physicochemical composition of capons and roosters (two autochthonous Portuguese chicken breeds, *Amarela* and *Pedrês*), treated under the same conditions until slaughter. The phenotypic information about these breeds is inconsistent, except for external characteristics such as type of feathering, color of paws, crest shape, etc., as described in genealogical books. The *Amarela* breed roosters present a

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feathering of rust to yellow-straw tone. The tail is characterized by its jet-black color with glaring metallic greenish blue, and the wings present a jet-black color. The breed *Pedrês Portuguesa* presents plumage with tinted dark gray and white (DGAV, 2013). The study also included a sensory evaluation by a trained taste panel to compare the sensory characteristics of capon and rooster meat with a free-range chicken and broiler.

MATERIALS AND METHODS

Animals were directly acquired to abattoirs as carcasses and we did not experiment with live animals. The research project was approved by the Agro Program of the INIAP from the Portuguese Agricultural Ministry. All procedures were conducted according to the guidelines of Council Directive 86/609/EEC (European Community, 1986) on the protection of animals used for experimental and other scientific purposes.

Animals and Sampling

Forty chickens of autochthonous *Amarela* breed (20 roosters and 20 capons [castrated rooster] and 40 of autochthonous *Pedrês Portuguesa* breed (20 roosters and 20 capons) were used. Birds were housed under free-range conditions in one pen of 20 m^2 with a density of 4 animals per m^2. The basal diets were commercial concentrate (Table 1) with ad libitum feed and water. The birds were castrated at 9 wk of age and were slaughtered at 140 d of age in a local commercial broiler slaughterhouse.

In sensory analysis, 5 free-range chickens (raised in a free-range system and fed with 70% cereals; minimum age of slaughter 81 d and average carcass weight 2.2 kg) and 5 broilers (fast-growing chickens with age of slaughter between 32 and 40 d, fed with commercial feed; average carcass weight 1.6 kg) were purchased in a supermarket with the above-mentioned designations. Carcasses were taken to the Carcass and Meat Technology and Quality Laboratory of the Agriculture School (Bragança, Portugal) 24 h after slaughter and were divided into halves. The right halves were reserved for physicochemical analysis and the left for sensory analysis. Then all samples were vacuum-packed and frozen at −21°C until analyzed.

Physical and Chemical Analysis

On the d before physical and chemical analyses, samples were thawed at 4°C. Physicochemical determinations were performed on the breast (pectoralis major muscle), leg (thigh and drumstick), and wing. Meat was dissected separating the skin, meat, and bones. All analyses were made in triplicate.

Instrumental Analysis. The measurement of pH 24 h after slaughter in the pectoralis major muscle was performed according to the Portuguese standard NP 3441 (2008) (ISO 2917:1999), using a portable potentiometer (HANNA pH meter HI 99163, Woonsocket, RI, USA), equipped with a spear electrode (FC 232D, Woonsocket, RI, USA) penetrator, and calibrated with standard buffers with the following pH 4.01–7.02. Water activity ($\mathbf{a_w}$) was determined using a_w probe (HygroPalmAw1, rotronic 8303, Bassersdorf, Switzerland) according to AOAC (1990). Meat color was estimated on the pectoralis major muscle and leg and wing muscles using the lightness ($\mathbf{L^*}$), redness ($\mathbf{a^*}$), and yellowness ($\mathbf{b^*}$) system with a colorimeter Minolta CR-10 (Minolta, Osaka, Japan). This system of color was described with the coordinates $L^*a^*b^*$ (CIE, 1986). Color measurements were made on freshly cut surfaces in s after carcass dissection. Determination of hue ($\mathbf{H^*}$) and chroma ($\mathbf{C^*}$) attributes was made according to the following equations:

$$H^* = \arctan\left(b^*/a^*\right).$$
$$C^* = \sqrt{\left((a^*)^2 + (b^*)^2\right)}.$$

Chemical Analysis. Moisture content determination was carried out following the Portuguese standard NP 1614 (2002) based on ISO 1442:1197;

Table 1. Chemical composition of the experimental diets.

Item	Diets by age	
	0 to 4 wks	5 to 18 wk
Analytical components (%)		
CP	19.0	15.0
Crude fiber	3.50	3.20
Phosphorus	0.53	0.70
Methionine	0.37	0.20
Sodium	0.20	0.10
Calcium	1.20	1.50
Crude fat	5.00	3.20
Crude ash	6.60	7.00
Lysine	0.99	0.70
Additives		
Amino acids (mg/Kg)		
Hydroxy analogue of methionine[1]	0.08	
L-lysine		48.0
Vitamins (IU/kg)		
Vitamin A	12500	15000
Vitamin D_3 (cholecalciferol)	3000	3000
Vitamin E (dl-α-tocopheryl acetate)	30.0	40.0
Biotin (mg/Kg)		0.20
Trace elements (mg/kg)		
Cupper[2]	8.00	11.0
Manganese[3]	100.0	75.0
Zinc[4]	80.0	75.0
Iron	515.0[a]	81.0[b]
Iodine[5]	0.99	2.00
Cobalt[6]	0.06	0.50
Selenium[7]	0.30	0.20

[1]acids content 85%; acid monomer 65%.
[2]Cupric sulfate pentahydrate.
[3]Manganese oxide.
[4]Zinc oxide.
[5]Calcium iodate anhydrous.
[6]Basic cobalt carbonate (II) monohydrate.
[7]Sodium selenite.
[a]Iron (III) oxide – 425 mg/kg and iron (II) sulphate monohydrate – 90 mg/kg.
[b]Iron (II) carbonat.

samples were dried in a drying oven (Raypa DO-150, Barcelona, Spain) for 24 h at 103°C ± 2°C. Ash content was assessed according to the Portuguese standard NP 1615 (2002) corresponding to ISO 936:1998; samples were incinerated at 550°C ± 25°C during 5 to 6 h in a muffle furnace (Vulcan BOX Furnace Model 3–550, Yucaipa, CA). The determination of protein content was performed according to the Portuguese standard NP 1612 (2002) based on ISO 937:1978 using Digest System K-437 and Sampler System Kjeldahl K370 (Flawil, Switzerland). Protein content was determined, multiplying the amount of azote per factor 6.25. Haem pigments were obtained using the reflectance of the exposed surface by spectroscopy by a Spectronic Unicam 20 Genesys (SPECTRONIC 20 GENESYS, Thermofisher Scientific, Austin, Texas, USA). The method is based on the muscle pigment content by Hornsey (1956). Hydroxyproline was determined following the Portuguese standard NP 1987 (2002) based on ISO 3496:1994; samples were hydrolyzed in an oven (Raypa DO-150, Barcelona, Spain) at 105°C for 16 h. The absorbance was measured at 558 nm using the equipment Spectronic Unicam 20 Genesys (Unicam, USA) and total collagen content was calculated by multiplying the amount of hydroxyproline by 8. Fat determination was performed using the BÜCHI Fat Determination System (AOAC International) described by Teixeira and Rodrigues (2013). It consists of the Extraction Unit B-815 (Flawil, Switzerland) for simultaneous extraction/saponification of the fatty acids, and the Fat Determination B-820 (Flawil, Switzerland), which determines fat content based on the isolated fatty acids (total SFA, total monounsaturated fatty acids [**MUFA**] and total polyunsaturated fatty acids [**PUFA**]) by means of gas chromatography.

Sensory Analysis

Sensory analysis of breast, thigh, and drumstick samples of *Amarela* and *Pedrês* breed roosters and capons, respectively, and of free-range chickens and broilers, was made by a trained taste panel of 9 members. Panel members were selected and trained according to Portuguese guidelines (NP-ISO-8586-1:2001 based on ISO 8586-1:1993). On the d before the sensory session, samples were thawed at 4°C. Samples were separated into breast, thigh, and drumstick, then dissected and deboned. Samples were wrapped individually in aluminum foil and coded randomly with 3-digit numbers, then placed in the oven until it reached an internal temperature of around 75°C (NP-ISO-8586-1 2001 - ISO 8586-1:1993). Immediately after cooking, samples were divided into $2 \times 2 \times 1$ cm^3 pieces, wrapped in aluminum foil, identified, placed in a preheated oven at 60 to 70°C, and evaluated within 10 min. The panel members were seated in individual booths in a temperature and light controlled room. In all sessions, the room temperature was 20 to 22°C, with 60 to 70% humidity and booths had red light.

After a training period of 6 sessions evaluating, describing, and discussing chicken meat quality characteristics, panelists were asked to assess each sample for the sensory attribute: odor intensity (odor associated with raw meat, animal species, or cooked chicken meat), off-odor (an odor that is not natural or up to standard owing to deterioration or contamination) intensity, color (color perceived between whitish and yellowish), toughness (the force needed to chew), juiciness (water perceived during mastication), fibrousness (fibers perceived during mastication), taste intensity (taste of raw meat, associated with the animal species, or cooked chicken meat), off-taste intensity, flavor intensity (flavor associated with raw meat, animal species, or cooked chicken meat), and off-flavor intensity. An unstructured scale of 10 cm, anchored at the extremes (0 - sensation absence, and 10 - extremely intense sensation) was used. Panelists were asked to indicate a point on the scale corresponding to the perceived intensity for each attribute. The sensory evaluation consisted of 10 sessions. In each session panelists evaluated 9 samples corresponding to 9 of the 18 different treatments combining breed (*Amarela*, *Pedrês*), caponization (capon and rooster), free-range chicken and broiler, and anatomical part (breast, thigh, and drumstick). Samples were always presented in the same conditions for all panelists, randomly in each session.

Statistical Analysis

Physical and chemical Analysis. The data were analyzed according to a 2 × 2 factorial design using the GLM procedure of SPSS statistical package version 20. Data were analyzed by ANOVA with sex and breed as fixed effects. Average values of carcass were obtained from the sum of different anatomical parts (breast, leg, and wing). The least square means were calculated and the Tukey test was used to determine significant differences. All statistical differences were considered significant at a level of $P \leq 0.05$.

Sensory Analysis. The model used was a completely randomized factorial design with 6 groups of chickens (*Amarela* capon, *Amarela* rooster, *Pedrês* capon, *Pedrês* rooster, free-range chicken, and broiler) considering the carcass as a whole (average of sum of the breast, thigh, and drumstick), as fixed factors, and no random effects. A sensory profile for the different chicken meat was developed by a Generalized Procrustes analysis (**GPA**). GPA is a powerful multivariate technique extensively used in sensory evaluation. The analysis minimizes differences among assessors, identifies agreement among them, and summarizes the sets of 3-dimensional data (objects, characteristics, and assessors). The data matrices of 6 (groups of chickens) by 10 (sensory attributes) for the 9 assessors were matched to

Table 2. Effect of sex and breed on carcass weight, physicochemical composition of chicken meat.

Item[1]	Sex (S)		Breed (B)		SEM	Significance		
	Capons (n = 20)	Roosters (n = 20)	*Amarela* (n = 20)	*Pedrês* (n = 20)		S	B	S*B
Carcass weight (kg)	3.204	3.170	2.992	3.366	0.01	NS	NS	NS
Physical composition								
pH_{24}	5.81	5.83	5.84	5.81	0.01	NS	NS	NS
Water activity	0.949	0.951	0.949	0.941	0.00	NS	NS	NS
Color parameters								
lightness (L^*)	49.9	50.23	49.0	51.1	0.22	NS	***	NS
redness (a^*)	12.9	9.23	15.4	7.24	0.31	***	***	**
yellowness (b^*)	11.1	11.8	10.4	12.4	0.13	NS	***	***
Hue (H^*)	45.9	55.8	37.5	62.8	0.84	***	***	***
Chroma (C^*)	18.3	15.7	19.4	15.0	0.24	***	***	NS
Chemical composition (%)								
Moisture	73.5	73.8	74.3	73.1	0.07	*	***	*
Ash	1.88	1.72	2.26	1.38	0.03	NS	***	***
CP	22.2	22.1	22.1	22.2	0.10	NS	NS	NS
Pigments	1.11	0.94	0.88	1.16	0.04	*	*	NS
Hydroxyproline	0.15	0.13	0.14	0.14	0.01	NS	NS	NS
Collagen	1.21	1.00	1.10	1.12	0.06	NS	NS	NS
IMF	4.19	3.87	3.70	4.35	0.10	*	*	*

[1]pH_{24} = muscle pH 24 h postmortem; IMF = intramuscular fat; NS = not significant; * = $P \leq 0.05$; ** = $P \leq 0.01$; *** = $P \leq 0.001$.

find a consensus. These data sets were analyzed using XLSTAT software (Addinsoft, 2013a).

RESULTS AND DISCUSSION

Carcass Composition

There were no differences in carcass weight sex or breed effect (Table 2). Tor et al. (2002), Miguel et al. (2008), and Symeon et al. (2010, 2012) did not observe differences for carcass weight between cocks and capons.

Physical and Chemical Composition

The effect of sex and breed on physicochemical composition of chicken meat can be observed in Table 2. Results show that pH_{24} and a_w value were not affected by sex or breed. Also Lin and Hsu (2002), Miguel et al. (2008), Symeon et al. (2010, 2012), and Volk et al. (2011) reported that caponization had no effects on pH value. The breed results confirm the research of Díaz et al. (2010) and Souza et al. (2011), who found no differences among breeds (indigenous Mos and Sasso T-44 and X-44; Super Pesadão, Paraíso Pedrês and Cobb, respectively). The pH_{24} values found were within the expected limits of 5.75 and 5.96 at the end of the postmortem process according to Castellini et al. (2002) and Qiao et al. (2002).

The *Pedrês* breed presented higher ($P \leq 0.001$) L^*, b^*, and H^*, but smaller ($P \leq 0.001$) a^* and C^* values than *Amarela*. Capons had significantly greater ($P \leq 0.001$) a^* and C^* but smaller ($P \leq 0.001$) H^* than roosters. According to the L^* values reported in the literature on the quality classification of chicken meat (Fletcher, 2002; Qiao et al., 2002), the values obtained are of one normal meat. In relation to color parameters, the capon meat differed from the rooster meat only because of a^* value. Caponization increased a^* value in comparison with rooster meat, contradictory to Miguel et al. (2008) who observed lower a^* value in capons than cocks, but found no differences for L^* and b^* values. However, Lin and Hsu (2003), Sirri et al. (2009), and Symeon et al. (2010, 2012) found that caponization decreases a^* value, increasing the L^* and b^* values, contradicting results observed in this study, which can be explained by a lower level of pigments observed in capons (Sirri et al., 2009). Volk et al. (2011) noted that caponization increases L^* value in capon meat and decreases a^* but found no differences for the b^* value. From this analysis it appears that castration can affect the characteristics of muscles and these can be due to a larger fraction of red fibers, as well as increased pigments in muscle, which gives a darker red color. According to Hsu and Lin (2003) and Miguel et al. (2008), a decreased a^* in capons must be attributed to the higher percentage of intramuscular fat (**IMF**) in capon meat, causing fat deposition and a proportional reduction of blood vessels and, therefore, the meat a^*, also resulting in brighter meat (greater L^* values).

It has been reported that breed is a factor that affects poultry meat color (Fletcher, 2002). In our experiment, *Pedrês* showed higher ($P \leq 0.001$) L^* and b^* but smaller ($P \leq 0.001$) a^* than *Amarela* meat. Wattanachant et al. (2004) have reported an increase in L^*, a^*, and b^* values in indigenous breed chickens as compared with broilers of a similar weight. Also Castellini et al. (2002) observed greater L^* and b^* in organic broilers relative to broilers but no difference for a^* value. Regarding H^* and C^* values (Table 2), it is verified that capon meat presented smaller H^* value (45.90 vs 18.33) and higher C^* (55.79 vs 15.72), boasting, therefore, a more vivid color in relation to rooster meat; the same is observed for the *Amarela* in relation to the *Pedrês* breed (37.45 vs 62.83; 19.36 vs 14.97 for H^* and C^*, respectively). These results suggest that cock meat can present greater

Table 3. Effect of sex and breed on fatty acid profile of chicken meat intramuscular fat.

	Sex (S)		Breed (B)			Significance		
Item[1]	Capons (n = 20)	Roosters (n = 20)	*Amarela* (n = 20)	*Pedrês* (n = 20)	SEM	S	B	S*B
C4:0	1.04	1.35	1.44	0.96	0.04	**	***	*
C8:0	3.41	4.27	3.86	3.79	0.11	**	NS	NS
C12:0	0.62	0.62	0.59	0.64	0.03	NS	NS	NS
C14:0	4.80	4.27	4.72	4.39	0.22	NS	NS	NS
C16:0	18.2	17.9	18.2	17.9	0.14	NS	NS	NS
C16:1	5.11	4.69	4.55	5.24	0.13	NS	*	NS
C18:0	4.40	5.03	4.20	5.16	0.07	**	***	***
C18:1	28.1	26.2	26.6	27.7	0.33	*	NS	NS
C18:2	12.5	12.1	12.0	12.6	0.18	NS	NS	NS
C20:4	0.48	0.89	0.45	0.89	0.06	*	*	*
SFA	32.5	33.4	33.0	32.8	0.22	NS	NS	NS
MUFA	33.2	30.9	31.2	32.9	0.43	*	NS	NS
PUFA	12.9	13.0	12.4	13.5	0.19	NS	NS	NS
PUFA/SFA	1.04	0.94	0.96	1.03	0.02	*	NS	NS
UFA/SFA	0.40	0.40	0.38	0.42	0.01	NS	*	NS

[1]C4:0 = butyric acid; C8:0 = caprylic acid; C12:0 = lauric acid; C14:0 = myristic acid; C16:0 = palmitic acid; C16:1 = palmitoleic acid; C18:0 = stearic acid; C18:1 = oleic acid; C18:2 = linoleic acid; C20:4 = arachidonic acid; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; UFA = unsaturated fatty acids; NS = not significant; * = $P \leq 0.05$; ** = $P \leq 0.01$; *** = $P \leq 0.001$.

oxidation of pigments (greater H*) and smaller quantity of pigments (lower C*) compared to capon; the same is observed for *Pedrês* in relation to the *Amarela* breed.

Table 2 shows the meat chemical composition. Capon meat showed lower ($P \leq 0.05$) moisture content than rooster as described in the research by Sirri et al. (2009) and Lin et al. (2011). However, Miguel et al. (2008) and Volk et al. (2011) reported that castration had no effect on moisture content. Miguel et al. (2008) found that there were no differences between sexes in relation to ash content, whereas Sirri et al. (2009) registered that caponization increased its content, which was also found in the present work. Caponization had no effect in protein content in agreement with Miguel et al. (2008), Sirri et al. (2009), and Volk et al. (2011), with average values of 22%. Lin et al. (2011) observed that moisture and ash content was lower in capon meat, but found no differences for protein content. Sirri et al. (2009) found that caponization decreased pigment content, which was not found in this study.

Castrated chickens showed greater IMF content in contrast with the majority of the literature reported by several authors (Tor et al., 2002, 2005; Miguel et al., 2008; Sirri et al., 2009; Symeon et al., 2010, 2012; Lin et al., 2011; and Sinanoglou et al., 2011 in breast meat), confirming the increase of intramuscular fat content in capon meat. Nevertheless, Volk et al. (2011) have found no differences in IMF content between cocks and capons.

Amarela showed greater ($P \leq 0.001$) moisture and ash content, and smaller ($P \leq 0.05$) haem pigments and IMF content than *Pedrês,* but no differences were found between breeds for protein, hydroxyproline, and collagen content. Castellini et al. (2002) and Wattanachant et al. (2004) reported differences for moisture, ash, and IMF content (broiler vs. organic broiler and Thai indigenous vs. broiler, respectively).

However, Castellini et al. (2002) observed no difference for protein content, and verified higher value for pigments in organic broilers. Wattanachant et al. (2004) observed greater protein and collagen content in Thai indigenous than broilers. Souza et al. (2011) observed differences between strains (Super Pesadão and Paraíso Pedrês vs. Cobb) for moisture content, but no noted differences for ash, protein, and ether extract content. Significant interactions between sex and breed indicated bigger differences for a*, b*, H*, and ash between roosters and capons in the *Amarela* breed than in *Pedrês*.

Fatty Acid Composition

The effect of sex and breed on the fatty acid profile of chicken meat IMF is shown in Table 3. Roosters had higher ($P \leq 0.01$) butyric acid content (**C4:0**), caprylic acid (C8:0), and stearic acid (**C18:0**) and greater ($P \leq 0.05$) arachidonic acid (**C20:4**) than capons, but no significant differences were found for total SFA, PUFA, and UFA/SFA content. Roosters had smaller ($P \leq 0.05$) oleic acid (**C18:1**) and MUFA content than capons, improving ($P \leq 0.05$) the relationship of PUFA/SFA in capon meat in comparison to rooster. The ratio PUFA/SFA was higher ($P \leq 0.05$) in capons than roosters. Sirri et al. (2009), studying the effect of caponization on hybrid animals, did not find differences between MUFA and PUFA content, but observed greater SFA content in capon meat. Also, Sinanoglou et al. (2011) reported a lower value of MUFA, PUFA, and ratio PUFA/SFA in capon meat, but greater SFA content than rooster meat, evidencing the negative effect of caponization on the fatty acids profile. The value obtained in the present study for ratio PUFA/SFA was greater than found by Sinanoglou et al. (2011) studying caponization in medium-growth broilers.

The *Pedrês* breed had smaller ($P \leq 0.001$) C4:0 content, but higher ($P \leq 0.001$) C18:0 content and ($P \leq 0.05$) palmitoleic acid (C16:1) and C20:4 content than *Amarela* (Table 3). This fact explains the greater

Table 4. Procrustes analysis of variance for chicken meat sensory analysis.

Source	df	ss[1]	MS	Prob > F
Residuals after scaling transformation	32	23.9	0.748	
Scaling transformation	8	9.5	1.18	0.170
Residuals after rotation	40	33.4	0.84	
Rotation	360	68.1	0.189	1.000
Residuals after translation	400	101.5	0.254	
Translation	80	470.3	5.88	<0.0001
Corrected total	480	571.7	1.19	

[1]ss = Sum of squares.

($P \leq 0.05$) value for UFA/SFA ratio observed in the *Pedrês* breed in relation to *Amarela*. However, Wattanachant et al. (2004) reported differences in SFA (greater Thai indigenous) and PUFA content (greater broiler) between broiler and Thai indigenous breeds, but no differences for MUFA content. Also, Castellini et al. (2002) observed higher SFA and PUFA content in organic broilers, but lower MUFA content in organic broilers than in inorganic broilers. According to Enser et al. (1998) the British Department of Health considers as the minimum value for a healthy diet a PUFA/SFA ratio of 0.45. The values observed in this study were greater than the recommended.

Ten individual fatty acids were detected on meat independently of sex and breed (Table 3). The main fatty acids detected were C18:1, palmitic acid (**C16:0**), and linoleic acid (**C18:2**), according Sinanoglou et al. (2011) when studying the effect of caponization on medium-growth broilers. However, Miguel et al. (2008) reported that between cocks and capons of the Castellana Negra breed, C18:2 was principal, followed by C16:0 and C18:1. Wattanchant et al. (2004) observed that in broiler meat the predominant fatty acids were C18:1, C16:0, C18:0, and C18:2, whereas for the Thai indigenous breed the fatty acids were C16:0 followed the C18:1, C18:0, and C18:2.

Sensory Analysis

The taste panel used 10 attributes (odor intensity, off-odor intensity, color, toughness, juiciness, fibrousness, taste intensity, off-taste intensity, flavor intensity, and off-flavor intensity) to describe the differences among the different groups of animals (*Amarela* capon, *Amarela* rooster, *Pedrês* capon, *Pedrês* rooster, free-range chicken, and broiler).

Table 4 refers to the Procrustes analysis of variance (**PANOVA**) for chicken meat sensory analysis. The PANOVA table summarizes the efficiency of each GPA transformation in terms of reduction of the total variability, showing that the translation step ($P < 0.0001$) was highly efficient in reducing the variability of settings; all other parameters were not significant ($P > 0.05$).

Residuals by groups of chicken (Figure 1) showed that broilers had the lowest value followed by the *Amarela* capon and free-range chickens, indicating the greatest consensus among evaluators, whereas the *Pedrês* rooster (greatest residue) showed the lowest consensus.

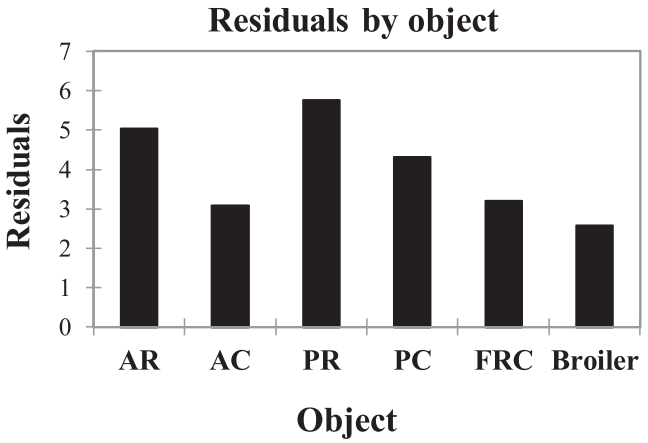

Figure 1. Residual variance for each meat sample (group of chickens) for sensory analysis. *A*R (Amarela rooster); *A*C (*Amarela* capon); *P*R (*Pedrês* rooster); *P*C (*Pedrês* capon); FRC (free-range chicken).

Table 5. Residual variance, scaling factors, and percentage variation explained by the first 2 principal components for each assessor for each chicken meat group sensory analysis.

Assessor	Residual	Scaling factor	F1[1] (%)	F2[2] (%)	F3[3] (%)
1	2.28	1.13	49.3	22.6	5.15
2	2.83	1.08	62.3	10.0	10.9
3	2.37	1.05	48.5	22.4	12.6
4	1.58	1.33	49.0	13.1	23.0
5	2.77	1.06	36.2	21.0	26.7
6	2.94	0.767	73.0	6.21	5.96
7	3.82	0.68	36.9	24.7	21.4
8	1.76	1.72	54.7	23.9	6.37
9	3.61	1.01	70.7	5.65	12.27

[1]F1 = First principal component of Generalized Procrustes analysis (GPA).
[2]F2 = Second principal component of GPA).
[3]F3 = Third principal component of GPA.

The training period allowed the assessors to standardize evaluation methodology. However, no training can eliminate the variation among panelists (Stone and Sidel, 2004). Assessors 7 and 9 presented the greater residue, which means that their evaluations do not match the consensus (Table 5). Some panelists did not use the scale for evaluation of the attributes the same way, whereas some focused on a narrower part of the scale; others used a wider part, as can be observed in the scaling factors shown in Table 5. Assessors 1, 2, 3, 4, 5, 8, and 9 tended to use a wider scale than the other assessors because they presented scaling factors greater than 1, especially assessor 4.

The next results correspond to the Principal Component analysis (**PCA**) step (unstandardized PCA, Addinsoft, 2013b). Whereas the GPA already includes a rotation step for each configuration so that it matches the consensus configuration, the PCA corresponds here to the optimal transformation of the consensus configuration under the usual PCA constraints. The PCA transformation is then applied to each configuration corresponding to each assessor. The eigenvalues show how much of the variability corresponds to each axis

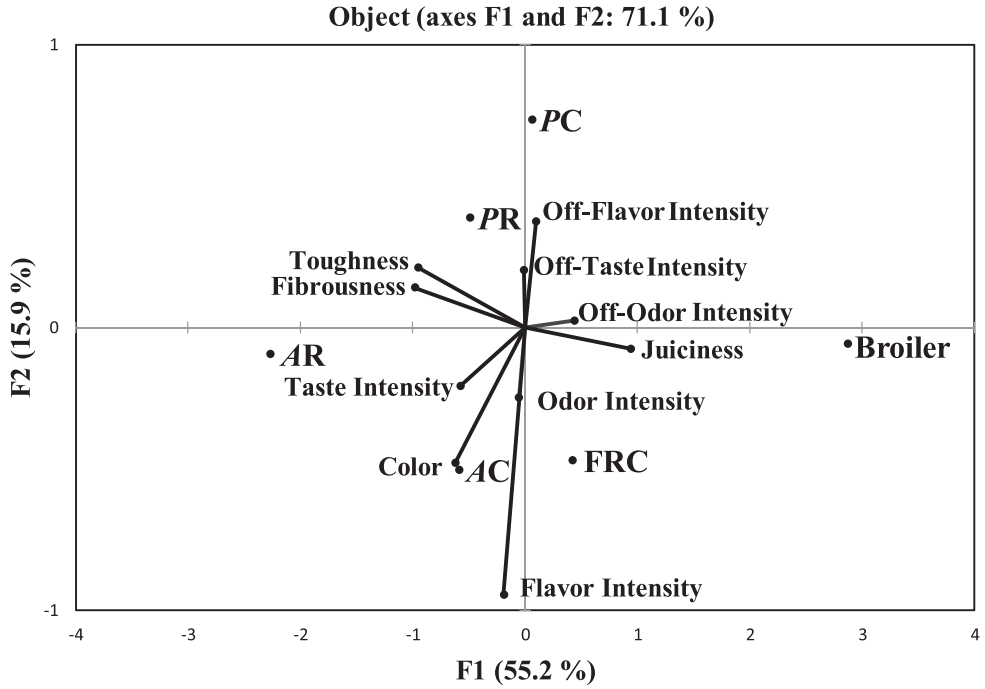

Figure 2. Consensus configuration: joint representation of correlation between sensory traits and first 2 dimensions and groups of chicken meat coordinates for different groups of chicken sensory analysis. F1 = first principal component of Generalized Procrustes Analysis (GPA); F2 = second principal component of GPA; *A*R (*Amarela* rooster); *A*C (*Amarela* capon); *P*R (*Pedrês* rooster); *P*C (*Pedrês* capon); FRC (free-range chicken).

(Table 5). The first dimension explains 55.2% of the variability and the second 15.9%. Only the first 2 axes represent 71.1% of the total variability; a similar value (72.8%) was described by Rodrigues and Teixeira (2013) in Terrincho lamb. However, the value obtained in the present study is greater than the 68.2% registered by Rodrigues et al. (2009) in Terrincho lamb meat, but less than the 93% found by Rodrigues and Teixeira (2009) in fresh Serrano meat of young goats; Paulos et al. (2015), reported 86.2% of the variability in the first 2 axes, in fresh sausage manufactured with goat and sheep meat, and Rodrigues and Teixeira (2014) verified 83.6% in pork meat.

When the variability is divided by assessors (Table 5), it is noted that the results are consensual among all the panelists except 5 and 7, who show less variability for Factor 1. Assessor 7 presents greater variability for Factor 2, whereas assessor 5 shows greatest variability for Factor 3. To minimize differences among evaluators, GPA was used to obtain a consensus (Figure 2). As previously noted, the first 2 main axes of the consensus configuration represent 71.1% of the total variation among samples. The points are all near the first Cartesian axes, explaining the fact that 55.2% of variability is concentrated in the first dimension.

Two commercial products (free-range chickens and broilers) with widespread consumption were used to compare with capons in terms of sensory analysis and to determine the response of panelists comparing capon meat with commercial chicken meats. The different groups of chickens were clearly discriminated and identified by the panelists. Broiler evaluation is clearly different from the other groups. In relation to off-flavor and off-taste intensity, these attributes are related to the *Pedrês* breed. Regarding the juiciness characteristic, it was observed that the broiler obtained the highest value on the intensity scale. Analyzing the *Amarela* rooster, it was verified that it has the least juiciness, compared to the other groups of animals. Rooster meat is characterized by presenting the greatest toughness and fibrousness. It was observed that the *Pedrês* rooster and *Pedrês* capon are closer, as well as the *Amarela* capon and free-range chicken meant. Broiler meat had the highest juiciness and lowest toughness and fibrousness (Figure 2). The *Amarela* capon had the greatest color intensity, once the vectors are directly correlated to the coordinates of the *Amarela* capon. The results of sensory analysis showed that caponization improved sensory characteristics for the *Amarela* breed; however, in the *Pedrês* breed this effect showed little evidence. The sensory characteristics of *Pedrês* rooster and capon meat for the attributes of juiciness, toughness, and fibrousness were similar to free-range chicken meat, particularly the *Pedrês* capon even though capons were 60 d older.

In a sensory analysis performed by Muriel (2004), no differences were observed between roosters and capons for toughness, juiciness, and flavor, contrary to the present study. Miguel et al. (2008), for the native breed Castellana Negra, found that capons were juicier and less fibrous than cocks, which might be due to the greater fat content in the capon. According to Lin and Hsu (2013), capon meat (Taiwan native) features more juiciness and flavor, and more tenderness in capon breast than rooster. Calik et al. 2015 observed that caponization (native Greenleg partridge) improved the

sensory characteristics for leg meat; however, breast meat improved only the flavor attribute. Caponization has improved the lipid profile and sensory characteristics of meat, making it juicier, tenderer, and less fibrous, improving capon meat quality when compared with rooster meat raised under the same production system. The results showed that the panelists discriminated different meat origins and distinguished the quality attributes of the capons in comparison to free-range chickens and broilers.

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