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Influence of Sex on the Physical-chemical Characteristics of Abdominal Chicken Fat

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ABSTRACT

The aim of this study was to determine if sex influenced abdominal fat yield, chemical composition, pH, color, fatty acid profile, and stability (by Differential Scanning Calorimetry – DSC) of Cobb chickens. Abdominal fat yields of 1.86 and 1.49% were obtained for females and males, respectively. Abdominal fat lipid contents of 70.68 and 74.36 g/100g, moisture content of 27.87 and 24.09 g/100g, protein content of 0.91 and 0.95 g/100g, ash content of 0.038 and 0.041 g/100g were obtained in males and females, respectively. Fat pH was not different between sexes, with values of 6.71 for males and 6.63 for females ($p<0.05$). Color L* values of 58.67 and 55.42, a* values of 4.95 and 3.44, and b* values of 7.36 and 8.18 were obtained for males and females, respectively. Female abdominal fat contained higher proportion of oleic acid (53.87%) followed by palmitic acid (30.07%), whereas 34.69% palmitic acid, 31.92% oleic acid, and 25.30% linoleic acid were determined in males. The proportions of the evaluated fatty acids were significantly different ($p>0.05$) between males and females, except for palmitic acid. The DSC analysis showed no significant difference ($p>0.05$) between sexes for melting and crystallization points. It was concluded that sex influences abdominal chicken fat yield, chemical composition, color, and DSC parameters.

INTRODUCTION

Broiler production has exponentially increased as a consequence of intensive genetic selection and better nutrition. Today, broilers present high feed conversion, high carcass yield, and can be finished in a much shorter time compared with a few decades ago (Silva *et al.*, 2012).

Chicken meat consumption and production have steadily increased in Brazil. Brazil is one the three largest producers of poultry meat in the world, alongside the United States and China and it is the largest exporter since 2004, according to the ABPA (Associação Brasileira de Proteína Animal, 2014). The Brazilian broiler industry applies modern technologies, and its excellent live performance indices and wide diversity of value-added products ensure good greater profitability to processing companies (Olivo & Olivo, 2006).

Chicken meat, due to its relatively low production cost, is the cheapest meat protein source. It has high nutritional value (Sunooj *et al.*, 2009), because it is rich in proteins, as well as in iron and B-complex vitamins (Centenaro *et al.*, 2008). It also contains high essential fatty acids (Pereda, 2005), and its consumption allows reducing blood cholesterol levels in non-hypertriglyceridemic individuals (Chiu, 2001).

The processing industry has focused in obtaining increasing carcass yield and byproduct utilization, as well as reducing organic waste, which

contaminates the environment (Chiu *et al.*, 2007). Blood, offal, and fat account for 15 to 25% of the total carcass weight (Beraquet, 1990) and, according to Nollet & Toldrá (2011), chicken byproducts represent about 6% of total carcass yield; however, this volume varies as a function of bird sex, age, body weight, etc.

Abdominal fat chicken accounts for approximately 2% of carcass weight, and in most processing plants is sent together with the bones for the mechanical separation of meat or it is rendered with the other residues (Chiu, 2001) for the production of meat meals and rendered fat. However, this fat could be used for the production of foods, such as meat sausages, margarine and cosmetic creams, because its liquid or semi-liquid state at room temperature, due to its high unsaturated fatty acid content, promotes good texture in those products. In addition, its unsaturated fatty acid composition is desirable in foods, as these acids reduce the risk of coronary heart disease (Chiu *et al.*, 2007).

Abdominal fat is often lost during evisceration, and it is seldom utilized in Brazil. Its physical characteristics, odor, desirable natural flavor, and rich composition in unsaturated fatty acids makes it suitable as a food ingredient and as fat base in food formulations (Chiu, 2001). Therefore, objective of this study was to evaluate the influence of sex on the physical-chemical characteristics and stability of the abdominal fat of Cobb broilers.

MATERIAL AND METHODS

Abdominal fat samples of 13 straight-run Cobb broiler flocks from different farms (10 birds per flock) was collected from the evisceration sector of a large processing plant located in west of the state of Santa Catarina, Brazil. Fat was collected after evisceration and giblet (liver and heart) removal.

Abdominal fat yield determination

Firstly, carcass yield of 200 Cobb® broilers (100 males and 100 females), with 2.7-2.9 kg average body weight at slaughter, was determined. After carcasses were completely deboned, maximum yield of carcass parts was determined. Fat surrounding the gizzard and in the abdominal cavity was collected after evisceration and giblet (liver and heart) removal. Abdominal fat yield was calculated as a function of bird weight and sex. After carcass cut up, parts were weighed to determine their yield (%) as a proportion of carcass weight, according to Moreira *et al.* (1998).

Physical-chemical characterization of the abdominal fat

After abdominal fat was removed from the carcasses, a 400 g pooled sample of the abdominal fat of 10 males or 10 females per flock was collected. Samples were placed in transparent polypropylene containers, sealed, duly identified, and submitted to physical-chemical analyses (pH, color, and ash, protein, moisture, lipid, and fatty-acid contents). All analyses were performed in triplicate.

Fat samples submitted to physical-chemical analyses were ground in a food grinder (Mastermix, Arno, Brazil) until a homogeneous mixture was obtained, packed in polypropylene and identified.

The pH was determined by the potentiometric method using a DM-22 Digimed pH meter. The determination of ash was carried out according to the methodology described in Instruction No. 20 (Brazil, 1999). Protein content was determined according to the AOAC method (1995), based on nitrogen content obtained by acid digestion (Kjeldahl method). Moisture content was gravimetrically determined by direct drying in an oven (Fanem, model 320-SE, São Paulo, Brazil) at 105 °C, according to Normative Instruction N. 20 (Brazil, 1999). Lipid content was determined using the methodology adapted from Adolfo Lutz Institute (IAL, 1985), according Instruction N. 20 (Brazil, 1999), in a Soxhlet apparatus (New Techniques Eq.p / Lab MOD: NT 340, Brazil).

Fat color, measured as L* (lightness), b* (yellowness) and a* (redness) of the CIELAB system, was determined using a portable colorimeter (Minolta Chroma, Cr-400 model, Japan).

Fatty acid profile

The analysis of fatty acid profile was carried out in 200 g abdominal fat samples of 10 females and 10 males per flock. Samples were collected, identified, and frozen in controlled-temperature freezing chamber to at least -23°C. Samples were analyzed in triplicate.

Lipids were first extracted by the method of Bligh & Dyer (1959), which extracts lipids using solvents, and not heat, thereby providing better conservation of the extracted compounds. The obtained lipid fraction was subjected to acid esterification, according to Hartman & Lake (1973), and injected into a gas chromatograph (GC-2010 Plus) (Shimadzu, Kyoto, Japan) for 25 min runs, according to DIN EN 14103 (2003) norm for methyl ester determination. The following chromatographic conditions were applied: He as

carrier gas, split injection mode at 1:50 ratio, 250°C injector and detector temperature, and 1µL injection volume. Column temperature was set at 120°C for 2 min, increased in 10°C/min until reaching 180°C, where it remained for 3 min, and then increased in 5°C/min until 230°C, where it remained for 2 min. The internal standardization method was applied, using methyl heptadecanoate as standard (Sigma Aldrich). Fatty acids were identified by comparing the retention time of their ethyl esters of the fatty acids in the samples with the known fatty acid ethyl esters standards (methyl oleate, methyl stearate, methyl linolenate, methyl palmitate, and methyl linoleate; Sigma Aldrich).

Differential Scanning Calorimetry (DSC)

The DSC curves were obtained in a DSC-Q200 equipment (TA-Instruments, USA) calibrated with high-purity indium (99.99%, mp = 156.6 °C, ΔH = 28.56 J/g). The enthalpy and temperature of 3.0mg of abdominal fat samples were recorded using the following parameters: 50 mL/min air flow, heating 10 °C/min rate, -40 to 80 °C heating range. The analysis was performed in sealed aluminum crucibles. The parameters applied were similar to those reported by Marikkar *et al.*, (2002), including onset temperature (T_0), peak temperature (T_p), conclusion temperature (T_c), and reaction enthalpy or ΔH (J/g).

Statistical analysis

A completely randomized experimental design was applied, with three replicates per treatment. Data were submitted to analysis of variance (ANOVA), and means were compared by Tukey's test at 95% significance level ($p < 0.05$), using Statistica® 8.0 software (STATSOFT INC., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Abdominal fat yield

Table 1 shows the abdominal fat yield (%) obtained from gizzard and abdominal cavity of the carcass of male and female broilers.

Table 1 – Abdominal chicken fat on the carcass, visceral region and abdominal cavity, in relation to gender of the chicken.

Sample	Total abdominal fat in the carcass (%)	Fat present in the viscera (%)	Fat in the abdominal cavity (%)
Male	1.49 [b] ±0.01	23.73 [a] ± 0.99	76.27 [b] ± 0.99
Female	1.86 [a] ±0.01	15.95 [b] ± 2.36	84.05 [a] ± 2.36

*Means followed by different letters within each column indicate significant differences according to Tukey's test ($p<0.05$)

According to Souza-Soares & Siewerdt (2005), carcass fat yield is a measure of chicken meat quality. The breast area has low fat content as these muscles do not need to store energy, differently from the legs, which require energy for movement, from subcutaneous fat deposits, used for thermal insulation of the body, and abdominal fat, which serves as an energy reserve.

The abdominal fat yield of male and female broilers was 1.49% and 1.86%, respectively (Table 1), and were significantly different, demonstrating that females deposit more abdominal fat than males, as previously observed by Kubena *et al.* (1974), who obtained values of 1.50% for males and 2.67% for females. Souza-Smith & Siewerdt (2005) reported that fat deposits are proportionately larger in females than in males, mainly because females present larger adipocytes, as also mentioned by the Cobb-Vantress manual (2001), Chiu (2001), Rostagno (2005), Pereda (2005), Olivo & Olivo (2006), Centenaro *et al.* (2008), and Murakami *et al.* (2010).

According to Pereda (2005), fat accumulates in chickens mainly in the body cavity, subcutaneous tissue, and intra- and inter-muscularly, whereas Souza-Smith & Siewerdt (2005) found that the largest fat deposits were subcutaneous and around the viscera.

During the automated evisceration stage in processing plants, part of the abdominal fat remains attached to the abdominal cavity, whereas the fat surrounding the gizzard is removed. In the present experiment, after evisceration, the abdominal cavity presented higher proportion of fat, with 76.27% and 84.05% in males and females, respectively, while the remaining 23.73% and 15.05% surrounded the gizzard (Table 1). Although the results showed that sex directly influenced the proportions of fat in those regions after evisceration, it should be mentioned that evisceration is automated, and that the equipment is adjusted according to bird size and shape (parts ratio). No literature reports on this assessment were found.

Physical-chemical characterization of the abdominal fat

Table 2 shows the physical-chemical parameter measured in the abdominal fat obtained from male and female Cobb broilers with 2.7 to 2.9 kg slaughter weight. Chicken abdominal fat is used by the processing industry for the production of mortadella, meatballs, and burgers due to its low cost and good sensorial, physical, and chemical characteristics

Table 2 – Physicochemical characteristics of abdominal chicken fat in males and females.

Samples	Moisture (g/100g)	Protein (g/100g)	Ash (g/100g)	Lipids (g/100g)	pH
Male	27.87[a] ± 1.56	0.91[a] ±0.09	0.038[a] ± 0.015	70.68[b] ± 1.74	6.71[a] ± 0.11
Female	24.09[b] ± 1.57	0.95[a] ±0.07	0.041[a] ± 0.009	74.36[a] ± 1.94	6.63[a] ± 0.16

*Means followed by different letters within each column indicate significant differences according to Tukey's test (p<0.05).

(Chiu & Gioielli, 2002; Chiu *et al.*, 2007). A physical characteristic of chicken abdominal fat that may be particularly interesting for the production of sausages is its melting point (Mahgoub *et al.*, 2002; Centeraro *et al.*, 2008), which is determined by its fatty acid profile and their saturation degree, as determined by Chiu (2001), Mahgoub *et al.* (2002), Pereda (2005), Chiu *et al.* (2007), and Centenaro *et al.* (2008).

The proximate analysis results showed that abdominal fat consisted of approximately 70.7 g lipids/100 g of fat in males and 74.3 g lipids/100 g of fat in females, and 27.9 g moisture/100 g of fat in males and 24.1 g moisture/100 g of fat in females, indicating the influence of sex on abdominal fat lipid content, which is higher in females than in males. This effect may be attributed to genetics and growth rates. Abdominal fat protein contents of 0.91% and 0.95% and ash contents of 0.38% and 0.41% were determined in males and females, respectively, and were not significantly different between sexes (p>0.05).

The abdominal fat pH values (Table 2) measured in males and females were 6.71 and 6.63 male and female, respectively, and were not statistically different (p>0.05). These values are higher the typical initial meat pH values, which is justified by the fact that fat does not participate in the establishment of *rigor mortis*, when the muscle is transformed into meat.

Color Evaluation

Table 3 shows the abdominal fat color analysis results of male and female chickens. genders. The color components, L*, a*, and b* were statistically different (p<0.05) between sexes. Males presented higher L* (58.67 *vs*. 55.42) and a* (4.95 *vs*. 3.44) values compared with females, whereas females presented higher b*(8.18 *vs*. 7.26) values than males. No studies evaluating the influence of sex on chicken abdominal fat color were found in the literature. Lopes *et al.*, (2013), who evaluated the abdominal fat color of Ross® chickens fed cashew nut meal, and obtained values of L*, a* and b* of 71.51, 05.27 and 13.84, respectively.

Table 3 – Values of L*, a* and b* of abdominal chicken fat in relation to gender.

Sampels	L*	A*	b*	a*/b*
Male	58.67 [a] ±0.76	4.95 [a] ±0.27	7.36 [b] ±0.37	0.67
Female	55.42 [b] ±1.82	3.44 [b] ±0.36	8.18 [a] ±0.32	0.42

*Means followed by different letters within each column indicate significant differences according to Tukey's test (p<0.05).

According to Oda *et al.* (2003), chicken muscle color is influenced by diet and genetics. Duarte (2007) observed that tissue lightness (L*) is associated with its water levels and with the development of *post-mortem* biochemical reactions during processing, and according to Lopes *et al.* (2013), higher L*values of correspond to lighter meat color, whereas low L* values to darker meat.

Esteve-Garcia *et al.* (1999) observed that intramuscular color fat is influenced by dietary lipids. Le Bihan-Duval *et al.* (1999), evaluating chicken meat color, found a positive correlation between meat lightness and abdominal fat percentage, and suggested that the latter may reduce meat redness. According to Faria *et al.* (2009), age at slaughter, genetics, and sex affect the chemical composition of chicken meat, and found lower b* values and higher a* values in the meat of males compared with females.

Meat hemoglobin content and chemical state influence a* and b* values: high a* values are related with myoglobin oxidation, whereas low b* values indicate low hemoglobin content (Lawrie, 2005). In the present experiment, b* values were higher than a* values, indicating that abdominal fat color was closer to yellow than to red, and this was visually detectable in the samples. According to Olivo (1999), the ratio between a* and b* values can be used to estimate the myoglobin content in a sample. Myoglobin is the main parameter to determine the color of the meat and meat products, which intensity increases with myoglobin content (Olivo & Olivo, 2006). In the present experiment, myoglobin content, determined as a*:b* ratio, was higher in the abdominal fat samples of males compared with females (0.67 and 0.42, respectively). This result is consistent with Olivo & Olivo (2006), who stated that the concentration of heme pigments in

chicken meat can be influenced by sex, and that the meat of male chickens often contains more pigment than that of females.

Fatty acid profile

Table 4 shows the proportions of unsaturated and saturated fatty acids determined in the abdominal fat of male and female chickens. The abdominal fat of females consisted mainly of oleic acid (53.87%), followed by palmitic acid (30.07%), whereas in males, most of the fat consisted of palmitic acid (34.69%), followed by oleic acid (31.92%). The proportion of linoleic acid was about five times higher in males (25.30%) than in females (5.26%). On the other hand, stearic, and linolenic fatty acids were found in small quantities. The proportions of most fatty acids (stearic, oleic, linoleic, and linoleic acids) were significantly different ($p<0.05$) between males and females, except for palmitic acid.

Chiu (2001) determined 60.1% and 62.1% unsaturated fatty acids in the abdominal fat of male and female chickens, respectively, demonstrating that, in general, chicken fat contains a large proportion of unsaturated fatty acids. These results confirm the influence of fatty acid composition on the physical characteristics of chicken fat, which remains in a semi-liquid state at room temperature due to its high proportion of unsaturated fatty acids, as mentioned by Chiu (2001).

Chiu (2001) found that oleic acid is the most common fatty acid present in the chicken fat, representing 43.4% of the total content, but did not mention any sex differences. In the present study, the abdominal fat of females contained 53.87% oleic acid compared with 31.92% in males. On the other hand, that author observed that palmitic acid (24.7%) accounted for the highest proportion of saturated fatty acids, as also determined in the present study, with 34.69% and 30.07% for males and females, respectively.

According to Chiu & Gioielli (2002), abdominal chicken fat has low stearic acid content (6%) compared with pork fat (10.8%) or beef tallow (28.3 %). Higher steric-acid values were found in chicken fat (7.5-8.9%) by Hilditch (1941). The results of the present study, of 5.52% and 7.83% in males and females, respectively are consistent with those findings.

The fatty acid present in the lowest proportion in the abdominal fat of chickens of both was linolenic acid (2.47% and 2.97% for males and females, respectively). This result is in agreement with the reports of chicken fat fractions by Chiu & Gioielli (2002), of 1.2%, and of Viau & Gandemer (1991), of 1.2 to 2%. On the other hand, Hilditch (1941) and Chiu (2001) did not find any linolenic acid in chicken fat.

Marikkar *et al.* (2002) evaluated the profile of fatty acids of chicken fat and found 27.29% of palmitic acid, 4.77% of stearic acid, 44.11% of oleic acid, 13.71% of linoleic acid and 0.71 % of linolenic acid. These values are different from those obtained in the present this study possibly due to differences in the production system; however, no direct comparisons can be made as the origin and sex of chickens in that study are not reported.

Chicken fat can be used for the production other food products, such as margarine, according to Grompone *et al.* (1998), because of its high palmitic acid content. The abdominal fat palmitic acid contents obtained in the present study were 34.69% and 30.07% in males and females, respectively, and are consistent with those observed by Grompone *et al.* (1998).

Differential Scanning Calorimetry (DSC)

The DSC is commonly used to evaluate the stability of oils and fats and to detect possible frauds, particularly when the mixture of vegetable oils and animal fats and the inclusion of animal fats in products are not allowed due to standardization issues or for religious reasons (Dahimi *et al.,* 2014; Marikkar *et al*., 2002; Sunooj *et al.,* 2009).

The results of temperature changes in abdominal fat are presented in Table 5. The DSC was shown

Table 4 – Fatty acids present in the abdominal chicken fat in relation to gender.

Fatty acids	Symbol	Unsaturations	Male	Female
			% of fatty acid in mass	
16:0 – palmitic	-	Saturated	34.69^{a}±4.05	30.07^{a}±0.52
18:0 – estearic	-	Saturated	5.52^{b}±0.39	7.83^{a}±0.06
18:1 – oleic	ω-9	Unsaturated	31.92^{b}±2.05	53.87^{a}±0.40
18:2 – linoleic	ω-6	Unsaturated	25.30^{a}±1.67	5.26^{b}±0.04
18:3 – linolenic	ω-3	Unsaturated	2.47^{b}±0.32	2.97^{a}±0.02

*Means followed by different letters within each column indicate significant differences according to Tukey's test ($p<0.05$).

Table 5 – DSC parameters of abdominal fat chicken in relation to gender.

	DSC of Crystallization				DSC of melting			
Samples	T_o/ºC	T_p/ºC	T_c/ºC	ΔH/J/g	T_o/ºC	T_p/ºC	T_c/ºC	ΔH/J/g
Male	-0.30^b ±0.05	-5.57^a ±0.04	-7.97^a ±0.11	1.32^a ±0.12	-25.33^a ±0.20	-3.65^b ±0.03	0.68^a ±0.02	10.93^a ±0.15
Female	-0.53^a ±0.05	-5.12^a ±0.02	-7.59^a ±0.04	1.09^a ±0.07	-24.37^b ±0.23	-4.10^a ±0.30	0.19^b ±0.02	9.06^a ±0.16

* T_0 "*onset*" initial temperature, T_p temperature of Pick, T_c "*endset*" conclusion temperature (T_c) and enthalpy ΔH.

*** Means followed by different letters within column indicate significant differences according to Tukey's test ($p<0.05$).

to be a suitable technique for the evaluation of the thermal stability of the evaluated abdominal chicken fat samples. Broiler sex did not affect enthalpy results ($p>0.05$). In the study of Dahimi *et al.* (2014), chicken fat (no origin was reported) was subjected to DSC at a temperature program of -70 to 50°C, heating rate of 5°C/min to determine crystallization and melting points. Those authors obtained crystallization at -41.033°CT_0, 22.625 (J/g) ΔH, and of 16.315°C T_c. Melting point was determined at -46.140°C T_0, -69.753 (J/g) ΔH, and 32.650°C T_c. The results of the present study differ from those found by Dahimi *et al.*, (2014), which may be explained by differences in the temperature program applied in DSC and possible due to raw material factors (origin, gender, extraction and pretreatment processes, etc.).

The crystallization behavior profile of fats is directly related to their unsaturated fatty acids high content, which, according Dahimi *et al.* (2014), is about 85% in chicken fat. In the present study, the exothermic reaction peak temperature was -5.57°C and 5.12°C for males and females, respectively (Table 5). Changes in the melting profile are assigned to the content of saturated fatty acids and, according to Dahimi *et al.* (2014), is about 13% in chicken fat. The endothermic melting reaction peak was measured at a temperature of -3.65°C and -4.10°C for males and females, respectively. Although chicken sex significantly influenced the fatty acid profile of abdominal fat, it was not sufficient to cause significant changes in DSC ($p>0.05$).

CONCLUSIONS

Sex influences the physical-chemical parameters of abdominal chicken fat. Female carcasses contain a higher percentage of fat than that of males. Moisture and lipid contents, and fat color were statistically different between males and females, whereas other parameters, such as protein, pH and ash, were not affected by sex.

Based on the nutritional composition results obtained in the present study, it is suggested that abdominal chicken fat can potentially be used as a raw material for production of other food products, and therefore, may be an added-value product of broiler processing.

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