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Full Length Research Paper

Chemical composition of chicken meat produced in extensive indoor and free range rearing systems

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The present study involves the analysis of the chemical composition of white meat (breast muscles) and dark meat (leg muscles) of broilers in extensive indoor and free range systems. The length of fattening period was 56 days. At 56 days of age, 6 male and 6 female broilers were randomly selected from each rearing system and slaughtered. Cooled carcasses were dissected into primal cuts. Breast and leg muscle (thigh and drumstick) samples were used for chemical analyses. The obtained results suggested that free range rearing system was more favourable than extensive indoor system, as it resulted in a significantly higher protein content and a lower fat content of white and dark chicken meat. Female broilers produced a higher fat content and a somewhat lower protein content as compared to males.

Key words: Chemical composition, chicken meat, rearing system, sex.

INTRODUCTION

The quality of meat in general and hence poultry meat is an extremely complex notion that can be assessed from different points of view. From the standpoint of consumer interests and the slaughter industry, broilers should have not only high slaughter yields and desirable carcass conformation scores but also good aesthetic, sensory and nutritional characteristics. In that respect, the chemical composition of muscle tissue of major primal cuts is an important element of broiler meat quality (Ristic, 1999; Grashorn and Clostermann, 2002; Holcman et al., 2003; Suchy et al., 2002).

The above quality traits are dependent on a number of factors. Genotype, sex and age stand out among biological factors (Lewis et al., 1997; Bokkers and Koene, 2003; Hellmeister et al., 2003). Among numerous non-genetic factors that may substantially affect certain meat quality traits, particular importance has been attached to broiler rearing system in the past years (Ristić, 2003; Holcman et al., 2003; Bogosavljević-Bošković et al.,2006; Fanatico et al., 2005; Dou et al., 2009). Broiler rearing system is gaining importance along with the fact that the modern broiler meat market dominated solely by price competitiveness is undergoing radical transformation into a market equally dominated by both price and quality competitiveness. Free range rearing systems reduce stress while increasing comfort and bird welfare, thus enhancing the flavour (taste and aroma) of products, as compared to conventionally raised birds.

A positive effect of rearing system on certain meat quality traits (breast and thigh yields, improved sensory quality) was reported by Castellini et al. (2002), Fanatico et al. (2005) and Dou et al. (2009). The authors have also observed a reduced content of fat (abdominal fat in particular) in free range broilers as attributable to more intensive locomotor activity. Castellini et al. (2002) reported higher levels of omega-3 and omega-6 fatty acids, and increased levels of total polyunsaturated fatty acids in free range birds, which enhance meat quality and have consumer health benefits of reducing the risk of different types of cardiovascular disease (Betti et al., 2009).

Aiming at improved meat quality traits, certain broiler

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Table 1. Ingredients and chemical composition of broiler starter (BS) and broiler finisher (BF) diets.

Ingredient	Formulation (calculated values)	Broiler starter diet (BS) (1-28 days)	Broiler finisher diet (BF) days)
1. Grained feeds	Proteins min.	22.0%	20.0%
2. Oil industry products	Fats	5.00%	5.00%
3. Animal-derived feeds	Moisture max.	13.5%	13.5%
4. Other plant-derived products	Cellulose max.	4.00%	5.00%
5. Mineral feeds	Ash max.	8.00%	8.00%
6. Amino acids	Ca	0.90 - 1.10%	0.80 - 1.00%
	P	0.65 - 0.75%	0.60 - 0.80%
	Useable P min.	0.400%	0.350%
	Na	0.15 - 0.20%	0.15 - 0.20
	Lysine min.	1.15%	0.900%
	Methionine + cystine min.	0.850%	0.700%
	Metabolic energies (ME) min.	13.00 MJ/kg	13.0 MJ/kg
Premix VZ Vit B-1 (vitamins, minerals and antioxidant)		1%	-
Premix VZ Vit B-2 (vitamins, minerals and antioxidant)		-	1%

rearers slow down the growth of broilers until they reached a more mature age, and feed diets composed of at least 75% cereals and no animal-derived components, restricts the use of supplements and avoids using any growth stimulators (Laszczyk-Legendre, 1999). Similar methods are employed in rearing French Label Rouge hybrids (Culioli et al., 1990). Carcass and meat traits of broilers reared according to French “label fermier” production standards have been compared with those of “conventional” broilers reared under intensive confined systems. Sensory studies involving the use of all thigh and breast muscles have revealed that “label” meat, although less soft, is more attractive, exhibiting greater firmness and stronger aroma (Culioli et al., 1990). “Label” broilers have a 10% higher level of muscle development, with fattening performance being about 15% lower, as determined from skin lipid content. A similar reduction in intramuscular lipid content is also observed under the “label” production system.

Meat quality traits and broiler production in accordance with the requirements of the animal protection movement were the most important reasons to pass regulations (No. 1538/91 and No. 1804/999) on non-industrial rearing systems and ecological poultry meat production in European Union countries (Ristic, 1999, 2003).

Although performance traits and meat quality of non-industrial and ecological broilers have received increased attention in the scientific community following the adoption of the above regulations, little literature data are available on the chemical composition of breast and leg muscles in broilers from different rearing systems. With this, the objective of this study was to evaluate the effect of rearing system and broiler sex on the chemical composition of broiler meat (white meat, breast muscle and dark meat, leg muscle).

MATERIALS AND METHODS

Chickens, housing and diet

As slow-growing broiler strains, both imported and domestic crossbred ones, are not reared in Serbia, the test material used in this study included a total of 200 one-day-old fast-growing Hybro G broiler strains. The fattening period lasted for 56 days. The rearing technology employed complied with “Extensive indoor” (Barn reared) and «Free range» standards (Commission Regulation EEC, No. 1538/91). During the first 4 weeks, the broilers were reared in the poultry house in a deep litter system (extensive indoor). On day 28, they were assigned to two groups: Group I, including broilers reared in extensive indoor system in the poultry house at a stocking density of 12 birds/m^2, and Group II, comprising free range broilers that were provided a grass range of 1 m^2/bird, along with the identical usable area in the poultry house.

Extensive indoor (Group I) and free range (Group II) rearing systems showed differences not only in stocking density but also in a number of other factors related to rearing conditions. Group I broilers were reared in a deep litter consisting of wood shavings. The litter was not refreshed during the fattening period so as not to disturb the test broilers, that is, to avoid the potential stress effect. Electric lighting system was used. Optimal microclimate conditions were provided by ventilation system (through roof openings and using ventilation fans). As for Group II broilers, a grass-covered range was provided. Apart from the natural environment (grass, fresh air and sunlight, and higher roaming potential), the free range system employed in this study also involved foraging and feeding on natural food from the range.

The test broilers were fed two complete feeds: broiler starter (BS) until day 28 and broiler finisher (BF) from day 28 to day 49 of fattening (both feeds are manufactured by the Veterinary Institute, Zemun, Republic of Serbia) (Table 1). During the last week of fattening (day 49 through day 56), broilers were fed a diet containing ground cereal grains (70% ration) and broiler finisher, BF (30%) (Table 2). The broilers were fed *ad libitum*.

Data collection

Upon fattening (on day 56), the test chickens were weighed. Six

Table 2. Ingredients and chemical composition of diet fed from day 49 to day 56 of fattening trial.

Ingredient	Formulation (calculated values)	Diet (49 to 56 days)
70% ground cereal grains (maize 70%, wheat 10%, wheat meal 10%, wheat bram 10%) + 30% broiler finisher diet (BF)	Proteins min.	13.50%
	Fats	4.09%
	Moisture max.	13.0%
	Cellulose max.	4.20%
	Ash max.	4.64%
	Ca	0.30%
	P	0.52%
	Useable P min.	0.24%
	Na	0.09%
	Lysine min.	0.52%
	Methionine+cystine min.	0.50%
	Metabolic energies (ME) min.	13.17 MJ/kg

male and six female broilers were randomly selected from each group of broilers: Group I (extensive indoor) and Group II (free range) broilers. The chickens selected were manually slaughtered. Upon slaughter and primary carcass processing, the processed carcasses were cooled in a cooling chamber for 24 hours at 0 to 4°C.

Following the chilling procedure, the carcasses were weighed to obtain the dressing percentage of the test broilers. Thereafter, the dressed cold carcass of each broiler was dissected into primal cuts (breast, drumstick, thigh, wing, pelvis and back) following the method prescribed by the Regulation on Poultry Meat Quality (Raseta and Dakic, 1984). The thighs and drumsticks were removed from the carcass by cutting above the thigh, towards the acetabulum and behind the pubic bone (the pelvic/thigh incision). Then, the drumsticks were separated from the thighs by cutting perpendicular to the joint between the drumstick and thigh bones. The wings were removed by the so-called "shoulder" incision through the joint (articulation) surfaces of the scapula and the coracoid. The breast was separated by a cut perpendicular to the ventral joints of ribs, the "rib" incision. The back-pelvis separation was performed by cutting perpendicularly to the vertebral column at the final vertebral level, the "lumbar" incision. Following the carcass dissection, the cuts were weighed and measured for percentage of dressed cold carcass weight. Then, the right drumstick, right thigh and breast were dissected into main tissues (muscle, bone and skin). The separated tissues were weighed, and their respective proportions in the main carcass were recorded. Muscle tissue was sampled for chemical analyses. The samples were stored in a deep freezer at -21°C until analysis performed within one month.

Chemical analysis

The frozen samples were dissected into small pieces and homogenised in a blender at -10°C. Chemical analyses (dry matter, crude protein, ash and fat) were performed according to the Association of Official Analytical Chemists standards (AOAC, 1990). Moisture content was determined by drying a certain amount of meat (≈ 6 g) to constant weight at 105°C. Crude protein was determined by the Kjeldahl method (using the factor 6.25). About 6 g of samples were ashed in a kiln at 550°C to determine the ash content. The Weibull-Stoldt method was used to determine the fat content. Each analysis was repeated twice.

The accuracy and replicability of the above methods were checked using BCR 380 whole milk powder as certified reference material. The results obtained (44.0 ± 0.05 g N/kg and 268.0 ± 0.2g F/kg) were in agreement with the validated/certified values (45.0 ± 0.4g N/kg, 269.0 ± 3.0g F/kg, on a dry matter basis).

Statistical analyses

The data obtained in this study were subjected to conventional statistical methods. The significance of differences was tested by the following mathematical model of analysis of variance:

$$Y_{ijk} = \mu + (RS)_i + (RSxS)_{ij} + e_{ijk}$$

The outlined model matched the 2 x 2 factorial design (2 rearing systems - RS and 2 sexes -S).
The test parameters underwent analysis of variance (ANOVA) using Microsoft STATISTICA Ver.5.0., Stat Soft Inc. (1995.). The significant differences determined by analysis of variance and results of F-exp values were evaluated using LSD-test.

RESULTS AND DISCUSSION

Previous studies (Bogosavljević et al., 2005) suggested that live weight of broiler before slaughter, dressed cold carcass weight, percent yield of major primal cuts, percentage of abdominal fat and percent yield of major breast, thigh and drumstick tissues in extensive indoor and free range reared broilers are less dependent on rearing system than on broiler sex.

Table 3 shows dressed cold carcass weights, percent yield of major primal cuts and abdominal fat in dressed carcasses of male and female broilers. The data given in Table 3 suggest that carcass weight was higher in male broilers than in females. The differences exhibited in terms of the sex effect were statistically highly significant. Horn et al. (1998) reported a higher increase in coefficient of variation of live weight in male chickens in the second part of the rearing period, as compared to females. Using regression analysis, Grashorn and Clostermann (2002) showed that slow-growing hybrids needed 10 to 32 days more to reach the same live weight of 2.000 g as the hybrid Ross on day 42 of age. In this study, the

Table 3. Percent yield of primal cuts (%).

Rearing system (RS)	Sex(S)		Ready to grill (g)	Breast (%)	Drumsticks (%)	Thighs (%)
Extensive indoor (Group I)	Male (n = 6)	$\bar{x}$ ±SE	2523±142.31	29.84±0.44	14.49±0.22	16.38±0.45
		S_d	348.6	1.07	0.55	1.10
		C_V	13.82	3.58	3.79	6.71
	Female (n = 6)	$\bar{x}$ ±SE	2279±35.43	31.12±0.76	13.73±0.23	15.90±0.28
		S_d	86.78	1.86	0.56	0.70
		C_V	3.81	5.97	4.08	4.40
Free range (Group II)	Male (n = 6)	$\bar{x}$ ±SE	2690±61.76	30.44±0.63	14.32±0.44	16.11±0.41
		S_d	151.29	1.54	1.07	1.00
		C_V	5.62	5.06	7.47	6.21
	Female (n = 6)	$\bar{x}$ ±SE	2295±52.20	31.69±0.64	13.40±0.27	16.00±0.22
		S_d	127.87	1.58	0.67	0.54
		C_V	5.57	4.98	5.00	3.37
F_{exp}	F_{RS}		0.99	0.71	0.56	0.05
	F_S		12.12**	3.37	6.37*	0.58
	F_{RSxS}		0.68	0.01	0.06	0.22

$\bar{x}$ - Average, SE – standard error, S_d - standard deviation, Cv -index of variation, ^{ns} –statistically non significant ($P > 0.05$); * – statistically significant ($0.01 \leq P \leq 0.05$); ** – statistically very significantly ($P < 0.01$).

overall feed conversion ratio and carcass and breast meat yields were observed to be lower in slow-growing hybrids than in the Ross hybrid. The meat was darker in colour, and the ratio of abdominal fat to meat in the drumstick was partially higher in slow-growing hybrids than in the Ross hybrid. Differences in terms of sex were recorded for almost all the traits. A large number of studies (Bilgili et al., 1992; Ristic, 1995; Melo et al., 1996; Ozkan et al., 1997) showed that carcass weight was significantly higher in male chickens than in females, due to large differences in body weight. As for the effect of rearing systems, differences in dressed cold carcass weights were low and statistically non-significant. Table 4 shows that breast percentage (31.69%) was highest in female broilers reared in the free-range system and lowest in males in the extensive indoor system. A somewhat higher drumstick percentage was recorded in male broilers in both rearing systems as compared to females. The percent yield of thighs was similar in broilers of both sexes. The analysis of the significance of differences in the percent yield of breast and thighs shows that the differences were not statistically significant ($P > 0.05$). Significant differences ($P < 0.05$) were observed only for the percent yield of drumsticks in male broilers. The percent yield of primal cuts (breast, drumsticks and thighs) in this study was somewhat higher than that obtained by Bogosavljevic-Boskovic et al. (1999) and Milosevic et al. (2003) who used similar methodology in their studies. Certain differences compared to the results reported in the available literature were due to the significant effect of both genetic factors (breed or strain used in the fattening trial) and numerous non-genetic factors (nutrition, length of fattening period, live weight of chicks prior to slaughter, dressed carcass weights, dissection method, etc.) in this study. The abdominal fat content in female chickens from both rearing systems was higher than in males, with the differences, however, being non-significant. These results were in agreement with those of Sütő et al. (1998), who reported similar abdominal fat deposition in both sexes of the commercial broiler hybrid, Arbor Acres Regular until 5 weeks of age. The same authors suggested that abdominal fat deposition was significantly affected by age and sex, but only after 5 weeks of age, when female chickens deposited abdominal fat considerably faster than the males. Until 16 weeks of age, abdominal fat did not exceed 2% in male chickens and was almost 5% in females. At 20 weeks of age, 5.90 (264 g) and 2.40% (130 g) of abdominal fat were deposited by females and males, respectively. The results obtained by Holcman et al. (2003) also confirmed a significant effect of sex on broiler meat quality (females having more fat than the males of the same age).

The percentage of abdominal fat in the broilers tested in this study was somewhat higher than that obtained by Havenstein et al. (1994), who evaluated the effect of genotype and feeding on weight gain and carcass composition in broilers. The results of the chemical composition of breast muscle of broilers in the two rearing systems are given in Table 4. Table 4 shows that the protein content of breast muscle ranged from 22.57 to

Table 4. Chemical composition of breast muscle (%).

Rearing system (RS)	Sex (S)		Breast muscle			
			Protein (%)	Fat (%)	Ash (%)	Dry matter (%)
Extensive indoor (Group I)	Male (n = 6)	$\bar{x}$ ±SE	22.960±0.27	2.260±0.07	1.070±0.03	26.072±0.26
		S_d	0.675	0.182	0.075	0.650
		C_v	2.940	8.050	7.009	2.493
	Female (n = 6)	$\bar{x}$ ±SE	22.570±0.14	2.780±0.13	1.100±0.016	26.047±0.05
		S_d	0.343	0.315	0.039	0.122
		C_v	1.520	11.331	3.536	0.470
Free range (Group II)	Male (n = 6)	$\bar{x}$ ±SE	23.720±0.21	1.960±0.10	1.010±0.03	26.267±0.11
		S_d	0.526	0.257	0.082	0.274
		C_v	2.218	13.112	8.119	1.043
	Female (n = 6)	$\bar{x}$ ±SE	23.440±0.18	1.970±0.11	1.090±0.04	26.067±0.12
		S_d	0.456	0.271	0.105	0.293
		C_v	1.945	13.756	9.633	1.124
F_{exp}	F_{RS}		12.116**	27.215**	0.906^{ns}	0.463^{ns}
	F_S		1.433^{ns}	6.205*	2.238^{ns}	0.507^{ns}
	F_{RSxS}		0.433^{ns}	5.745*	0.462^{ns}	0.307^{ns}

$\bar{x}$ - Average, SE – standard error, S_d - standard deviation, Cv -index of variation, ^{ns} –statistically non significant (P > 0.05); * – statistically significant (0.01 ≤ P ≤ 0.05); ** – statistically very significantly (P < 0.01).

23.72%, being significantly higher (P < 0.01) in free range reared broilers of both sexes. The fat content of breast muscle varied from 1.96 (free range male broilers) to 2.78% (extensive indoor females). Extensive indoor reared females had a higher fat content of breast muscle as compared to both extensive reared males and free range broilers of both sexes, with the differences being statistically very significant (P < 0.01). No significant differences in dry matter and ash content of breast muscle were observed in terms of either the rearing system effect or the sex effect.

Table 5 presents results on the chemical composition of leg (drumstick and thigh) muscles of male and female broilers in two different rearing systems. Table 5 suggests that male broilers in both rearing systems had a higher protein content in leg muscle than females. The difference was statistically significant (P < 0.01). Moreover, the content was significantly higher in free range female broilers than in extensive indoor females. The fat content of thigh and drumstick muscles showed very significant differences (P < 0.01), the content being significantly higher in females than in males. As for the dry matter content of leg muscle, higher values (P < 0.05) were observed in females as compared to males.

The published data show substantial variation in the nutritional value of chicken meat. The present results on the chemical composition, that is, protein, fat, ash and dry matter contents of white meat (breast muscle) and dark meat (leg muscle) complied with the findings obtained by Demby and Cunningham (1980). These authors reported the following range of values for raw chicken meat: 60.4 to 75.4% for water content, 17.0 to 23.3% for protein content, 1.0 to 17,4% for fat content, and 0.7 to 3.6% for ash content, averaging 71.1, 19.8, 7.5 and 1.6%, respectively. However, many variables, such as broiler hybrid or breed, age, sex, nutrition, rearing system, carcass dressing and type of meat, which can affect the nutritional value of meat can also induce small or large differences in the results obtained. Higher significant variability of the fat content can also be due to the use of different sampling methods. Different authors have determined fat content either in muscle alone or in muscle-plus-skin, with subcutaneous fat being also included. Breast muscle-plus-skin was found by Holcman et al. (2003) to contain on average 20.4% proteins, 7.0% fat, 1.0% ash and 28% dry matter. As for leg muscle-plus-skin, the average values as determined by the same authors were as follows: 16.8% proteins, 13.1% fats, 0.9% ash and 30.2% dry matter.

In their study of five different indoor-reared genotypes, Žledner et al. (1995) reported the protein content of leg muscle and breast muscle-plus-skin to range from 15.8 to 17.9% and 21.9 to 23.5%, respectively. The fat content of thigh muscle ranged from 10.6 to 15.6% and that of breast muscle from 3.9 to 8.45%. The ash content of leg and breast muscles was within the range of 0.70 to 0.87% and 1.02 to 1.2%, respectively. The water content of leg muscle varied from 67.8 to 71.3% and that of breast muscle from 68.9 to 72.3%.

Grashorn and Brose (1997) underlined that different

Table 5. Chemical composition of leg muscle (thigh and drumstick) (%).

Rearing system (RS)	Sex (S)		Leg muscle			
			Protein (%)	Fat (%)	Ash (%)	Dry matter (%)
Extensive indoor (Group I)	Male (n = 6)	$\bar{x}$ ±SE	19.210±0.10	6.520±0.13	1.025±0.05	26.352±0.19
		S_d	0.253	0.326	0.134	0.472
		C_v	1.317	5.000	13.054	1.791
	Female (n = 6)	$\bar{x}$ ±SE	18.267±0.20	8.920±0.18	1.033±0.04	27.683±0.19
		S_d	0.492	0.438	0.108	0.456
		C_v	2.694	4.910	10.455	1.647
Free range (Group II)	Male (n = 6)	$\bar{x}$ ±SE	19.500±0.15	6.290±0.13	1.127±0.04	26.497±0.20
		S_d	0.375	0.326	0.091	0.484
		C_v	1.923	5.183	8.075	1.827
	Female (n = 6)	$\bar{x}$ ±SE	19.020±0.22	7.840±0.22	1.042±0.05	27.353±0.40
		S_d	0.545	0.538	0.113	0.988
		C_v	2.865	6.862	10.845	3.612
F_{exp}	F_{RS}		8.778**	14.839**	1.431^{ns}	0.125^{ns}
	F_S		16.337**	134.915**	0.695^{ns}	17.512**
	F_{RSxS}		1.731ns	6.247*	1.030^{ns}	0.825^{ns}

$\bar{x}$ - Average, SE – standard error, S_d - standard deviation, Cv -index of variation, ^{ns} –statistically non significant (P > 0.05); * – statistically significant (0.01 ≤ P ≤ 0.05); ** – statistically very significally (P < 0.01).

production systems result in different meat quality. However, they reported higher differences only for extensive indoor chickens fattened according to the ecologically sound controlled production standards, as opposed to label chickens (less intensive rearing according to the label concept) whose meat quality was similar to that obtained by chickens from conventional commercial fattening system. Muriel and Pascual (1995) found no significant differences in the protein and ash contents of muscles in indoor-reared male chicks (n = 14) slaughtered on day 85 and free range males (n = 12) slaughtered on day 81. Indoor-reared chickens had a somewhat lower meat protein content higher ash content as compared to free range chickens. Holcman et al. (2003) reported that the chemical composition of breast and leg muscle-plus-skin in chickens aged 56 days is not affected by the fattening system that complies with the regulations of the European Union on “extensive indoor“ and “free range“ production systems. Conversely, in his study of meat quality of five different broiler genotypes reared under ecological conditions, Ristić (2003) observed the effect of production system on the chemical composition of breast and drumstick meat.

Furthermore, a number of researchers have stressed the effect of sex on the protein and fat content of broiler meat. A higher fat content in female broilers was reportted by Sanz et al. (1999) and Haro (2005). According to Tumova and Teimouri (2010), the difference observed was associated with metabolic differences, higher competitiveness among males, different fat deposition capacity, different nutritional requirements and a higher hormonal effect in female broilers.

The results of the present study also suggest the effect of rearing system and broiler sex on the protein and fat content of breast and leg muscles. The above results can be attributed to the fact that extensive indoor rearing system and free range system involving access to the outdoors under natural environment conditions (fresh air and sunlight) also resulted in differences in terms of the structural manifestations of tissues and organs, as well as in terms of the biochemical processes involved in the metabolism.

Conclusion

The results of the present study on the chemical composition of white meat (breast muscle) and dark meat (leg muscle) of female and male broilers in two different rearing systems (extensive indoor and free range) suggest the following:

1. The protein content of breast muscle was significantly higher (P < 0.01) in both male and female broilers from free range system than in extensive indoor females.
2. The highest fat content in breast muscle was found in extensive indoor females. The difference observed between the rearing systems and broiler sex was also statistically very significant (P<0.01).

3. The dry matter and ash contents of breast muscle were not significantly affected by the test factors.
4. The protein content of leg muscle was significantly higher in male broilers than in females.
5. The protein content of leg muscle was significantly higher in free range females than in extensive indoor females.
6. Female broilers, as compared to males, had a significantly higher fat content of leg muscle ($P < 0.01$), as well as a higher content of dry matter ($P < 0.05$).

Overall, free range rearing system was more favourable and it resulted in higher protein content and a lower fat content of white and dark chicken meat. Additionally, as compared to male broilers, females had a higher fat content and somewhat lower protein content in the said meat.

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