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Comparison of carcass characteristics, meat quality, and fatty acid composition in slow- and fast-growing broilers at different slaughter weights

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Abstract: This study aimed to compare the slaughter, meat quality characteristics, and fatty acid composition of fast-growing (FAG) and slow-growing (SWG) broilers at different slaughter weights. In the experiments, a total of 90 carcasses were used: 45 SWG (Hubbard-Isa Red JA) and 45 FAG broilers (Ross 308) with 15 carcasses from each slaughter weight group (1500 ± 50 g, 2000 ± 50 g, 2500 ± 50 g). Hot carcass yield and cold carcass yield detected in the FAG broilers were higher than in SGW broilers ($p < 0.001$). As the weight of slaughter increased, hot carcass and cold carcass yield increased ($p < 0.001$). The breast percentage was significantly lower in the SWG broilers compared to the FAG broilers ($p < 0.001$). In contrast, thigh, wing, and abdominal fat percentages were higher in the SWG broilers ($p < 0.001$). The breast percentage increased as the slaughter weight increased ($p < 0.001$). SWG broilers had significantly lower pH, except for the pH 24 of the thigh meat ($p < 0.01$). The L*, a*, and b* values of the SWG broilers were lower than the FAG broilers ($p < 0.01$). In terms of a* values determined initially and at the 24th h in the breast and thigh meat, the 1500 g slaughter weight group had by far the highest value ($p < 0.01$). SWG broilers had significantly lower values in terms of cooking loss, water-holding capacity, and drip loss ($p < 0.001$). C18:2ω6 was detected at higher amounts in the FAG broilers ($p < 0.05$). The FAG broilers had higher PUFA, desired fatty acids, PUFA/SFA, and thrombogenic index values ($p < 0.05$). The results show that FAG broilers can meet the strong worldwide demand for meat quantity and quality. Slaughter weight changes only affected the quantity of the meat.

Key words: Broiler, carcass, genotype, fatty acid composition, meat quality, slaughter weight

1. Introduction

Broiler meat is one of the most important sources of animal protein and is popular in terms of production and consumption. It is an important food that should be included in the diets of individuals suffering from obesity and cardiovascular problems, which have increased rapidly in recent years [1].

As a result of the rapid increase in the world's population, achieving maximum productivity per animal to obtain more products has become an important goal [2]. In this respect, along with studies on genetics and breeding, important developments in feeding programs, hatching techniques, and environmental conditions mean that broiler hybrids can reach a 2998 g body weight at 42 days of fattening[1].

Despite these advances, FAG broiler rearing is criticized in terms of animal welfare. Increased metabolic problems (ascites, heart failure, hypoxia, and sudden death syndrome) and low physical activity are some problems affecting FAG broilers. For this reason, SWG broilers are reared as an alternative to FAG broilers and can reach a 2.20–2.50 kg slaughter weight in 80–120 days [3].

In recent years, as their educational and cultural levels have increased, consumers have increasingly questioned the quality and reliability of animal products and the welfare conditions of animals. Meat quality is complicated and affected by genotype and environmental nutrition factors. Selection studies on creating and developing FAG broilers have also impacted broiler meat quality and flavor. Other studies conducted in recent years have revealed that slaughter weight also affects meat quality [4,5]. Achieving the optimum slaughter weight at earlier stages is a crucial parameter for the profitability of meat-based products, and FAG broilers are advantageous in this respect [6–8]. This study investigated the slaughter and carcass characteristics, meat quality, and fatty acid composition of FAG and SWG broilers at different slaughter weights.

1 Aviagen (2022). Ross 308 Broiler Performance Objectives [online]
Website: http://tr.aviagen.com/brands/ross/products/ross-308 [accessed 06.04.2023].

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2. Materials and methods

All experimental stages in the research were accepted by the Ankara University Ethics Committee (No: 2020-2-7; 22.01.2020).

2.1. Experimental design and animals

Hubbard-Isa Red JA hybrids were used as SWG broilers, and Ross-308 hybrids as FAG broilers. The ingredients and nutrient content of the animal diets according to the fattening period are given in Table 1.

The animals were slaughtered at 3 different weights: 1500 ± 50 g, 2000 ± 50 g, and 2500 ± 50 g. A total of 90 male carcasses were used: 45 in the SWG group and 45 in the FAG group, of which 15 carcasses represented each slaughter weight group. The animals in the desired slaughter weight groups were determined by weighing them before being slaughtered. Subsequently, the animal carcasses were weighed, and the hot carcass weight was determined. Hot carcass yield was determined by dividing this value by the preslaughter body weight. Internal organs were weighed, divided by slaughter weight, and shown as percentages. The pH value of the thigh and breast meat was measured within the first minutes after slaughter (pH_I) and 24 h after (pH_{24}) by a pH meter (Mettler Toledo, USA). Color parameters (lightness (L*), redness (a*) and yellowness (b*)) of the thigh and breast meat were measured within the first minutes after slaughter (L_I*, a_I*, and b_I*) and 24 h after slaughter (L_{24}*, a_{24}*, b_{24}*) using a colorimeter-branded Konica Minolta, CR-400. Each measurement was carried out in 3 replicates, and the average pH and color values of the meat samples were calculated. After 24 h, the carcass weight was noted again, and the cold carcass yield was determined. The cold carcass yield was found by dividing the carcass weight by the preslaughter body weight. The carcasses were separated into thighs, breast, wings, and neck. The parts were weighed and recorded as percentages of the cold carcass weight. After this process, other meat quality analysis samples were taken from the breast part (musculus pectoralis superficialis). Each was placed in plastic bags and preserved at –18 °C. In addition to pH and color analyses, water holding capacity (WHC), cooking loss (CL), drip loss (DL), and fatty acid composition analyses were performed on the meat samples.

The meat samples were stored at –18°C, kept at +4 °C for 24 h, cut and weighed at 5 g (W_S), and divided into 5 separate pieces were placed between filter papers whose weight was previously determined (W_1); next, a 2250-g weight was applied to them for 5 min. After 5 min, the meat samples were removed, and the filter papers were weighed again (W_2). WHC was reported as a percentage by proportioning the difference between W_1 and W_2 to the W_S using Beriain et al. [9] and the method indicated by Grau and Hamm [10].

To determine CL, the meat samples were cut and weighed at 50 g (W_1) and cooked at 80 °C for 45 min, allowing the internal temperature of the samples to reach 70 °C. Afterward, the samples were weighed again (W_2), and the CL was calculated as a percentage by dividing the difference between W_1 and W_2 of the samples by W_1 [11].

The meat samples for DL were weighed, and W_1 was determined. Subsequently, the samples were placed into plastic bags, dried, and W_2 was determined after 1 h. The difference between the two weights was divided by W_1, and DL was determined as a percentage, according to Honikel [11].

The meat samples used to determine the fatty acids were extracted in accordance with Blight and Dyer's [12] procedure and placed in GC-MS vials, which were exposed to fatty acid methyl esters. In addition, HP Agilent 6890/5972-branded gas chromatography-mass spectrophotometer device analysis was carried out. An HP-88 brand (100-m length, 0.25 mm i.d. × 0.20 μm) capillary column was used. The injector temperature was 250 ˚C, the detector temperature was 270 ˚C, the injection split ratio was 1:50, and the total injection volume was 1 μL.

2.2. Statistical analysis

Statistics analyses were made using IBM's SPSS software version 25 (SPSS Inc., Chicago, IL, USA). Two-way analysis of variance was used to define the effects of genotype and slaughter weight on the carcass and meat quality characteristics. Comparisons among means were carried out with the Tukey test.

3. Results

The slaughter and carcass characteristics of the SWG and FAG broilers at different slaughter weights are presented in Table 2. Hot and cold carcass yields significantly differed in FAG and SWG broilers and in slaughter weight ($p < 0.001$). As the slaughter weight increased, hot and cold carcass yields increased ($p < 0.001$). Hot and cold carcass yield values detected in the SWG broilers were significantly lower than in the FAG broilers ($p < 0.001$). The breast percentage was higher in the FAG broilers than in the SWG broilers ($p < 0.001$). When the thigh percentage was investigated, it was higher in the SWG broilers ($p < 0.001$) compared to the breast percentage. The breast percentage increased as the slaughter weight increased ($p < 0.001$). The wing percentage was higher in the SWG broilers than in the FAG broilers ($p < 0.001$). While the heart and liver ratio was unaffected by genotype, it decreased between 1500 g and 2500 g in the slaughter weight groups ($p < 0.05$; $p < 0.001$). The ratio of the spleen and gizzard was significantly higher in the SWG broilers ($p < 0.001$). While the spleen percentage had the lowest rate in the 1500-g slaughter weight group ($p < 0.05$), the gizzard ratio had the highest level at the same slaughter weight (p <

Table 1. Ingredients and chemical composition of the diets of FAG and SWG broilers according to time periods.

Ingredients (kg/ton)	FAG		SWG		FAG and SWG
	0–21 days	22–42 days	0–21 days	22–42 days	43–70 days
Corn	539.00	544.00	546.74	569.71	548.74
Corn gluten	22.00	-	28.00	-	-
DDGS	-	-	40.00	40.00	50.00
Rice bran	-	-	30.00	40.00	50.00
Wheat feed flour	-	50.00	-	-	-
Chickpea	-	20.00	25.00	30.00	50.00
Full fat soya	107.00	83.50	-	34.00	97.00
Soyabean meal	293.00	228.00	227.00	196.00	91.00
Sunflower seed meal	-	40.00	40.00	50.00	75.00
Canola seed meal	-	-	20.00	-	-
Monocalcium phosphate	8.75	6.83	7.10	6.40	4.50
Limestone	15.80	13.83	16.70	15.80	12.60
Sodium sulphate	1.47	1.47	0.58	0.57	0.88
Salt	2.66	2.60	2.79	2.82	2.18
Soya oil	-	-	5.00	5.00	7.50
Methionine	3.17	2.73	2.47	2.54	2.72
Lysine	3.72	4.02	5.59	4.22	5.20
Threonine	1.23	0.92	0.83	0.84	1.18
Choline	0.50	0.50	0.60	0.50	0.40
Vitamin mineral premix*	1.00	1.00	1.00	1.00	1.00
Xylanase complex enzyme**	0.05	0.05	0.05	0.05	0.05
Phytase enzyme***	0.05	0.05	0.05	0.05	0.05
Chemical composition					
Dry matter %	87.8	89.7	88.1	88.2	88.2
Crude protein %	23.9	21.6	21.0	19.2	18.1
Ether extract %	5.2	4.3	4.1	4.2	6.2
Crude fiber %	2.7	3.2	3.1	3.1	3.4
Crude ash %	5.5	4.9	5.5	5.1	5.0
Calcium %	1.08	1.00	1.02	0.97	0.82
Total phosphorus %	0.78	0.73	0.74	0.70	0.68
Metabolizable energy**** (kcal/kg)	3056	3183	2940	2990	3080

FAG: Fast-growing broiler; SWG: Slow-growing broiler; *: Vitamin mineral premix (1 kg): 12,000,000 IU vitamin A, 5,000,000 IU vitamin D3, 65-g vitamin E, 3-g vitamin K3, 3-g vitamin B1, 7-g vitamin B2, 15-g calcium D pantothenate, 4-g vitamin B6, 20-g vitamin B12, 60-g niacin, 2-g folic acid, 250-mg biotin, 25-g Fe, 16-g Cu, 120-g Mn, 110-g Zn, 1.25-g I, 300-mg Se. ** Hostazym X: endo-1,4-β xylanase (min: 30,000 EPU/g), cellulase, hemicellulase, α-amylase, protease. ***OptiPhos 250 OTU: 6-phytase. **** Calculate according to Carpenter and Clegg (1956). Carpenter K., Clegg K. The metabolizable energy of poultry feeding stuffs in relation to their chemical composition. Journal of the Science of Food and Agriculture 1956; 7: 45–51.

Table 2. Slaughter and carcass characteristics of FAG and SWG broilers at different slaughter weights.

	Treatment	Hot carcass yield %	Cold carcass yield %	Breast %	Thigh %	Wing %	Heart %	Liver %	Spleen %	Gizzard %	Pancreas %	Bursa of Fabricius %	Abdominal fat %
Genotype	FAG	67.97	67.55	38.81	29.16	10.36	0.52	2.28	0.09	1.33	0.28	0.20	0.59
	SWG	66.79	66.35	29.08	31.41	13.78	0.51	2.17	0.19	1.57	0.22	0.24	1.62
	P	***	***	***	***	***	-	-	***	***	***	***	***
Slaughter weight	1500 g	66.03^{a}	65.55^{a}	32.58^{a}	30.02	12.37^{a}	0.55^{a}	2.52^{a}	0.12^{a}	1.67^{a}	0.29^{a}	0.24^{a}	0.86^{a}
	2000 g	67.05^{b}	66.56^{b}	34.54^{b}	30.35	12.03^{ab}	0.51^{ab}	2.13^{b}	0.15^{b}	1.38^{b}	0.25^{b}	0.21^{b}	1.22^{b}
	2500 g	69.06^{c}	68.73^{c}	34.70^{b}	30.48	11.81^{a}	0.49^{b}	2.03^{b}	0.15^{b}	1.30^{b}	0.22^{b}	0.21^{b}	1.24^{b}
	P	***	***	***	-	**	*	***	*	***	***	*	***
	FAG-1500 g	66.54	66.11	38.64^{a}	28.76	10.49	0.54	2.44^{ab}	0.09^{a}	1.45^{ab}	0.31	0.06	0.47
	FAG-2000 g	67.57	67.08	38.80^{a}	29.31	10.40	0.52	2.24^{bc}	0.09^{a}	1.29^{ab}	0.29	0.05	0.65
	FAG-2500 g	69.79	69.47	38.98^{a}	29.41	10.20	0.51	2.17^{bc}	0.09^{a}	1.26^{a}	0.25	0.03	0.66
	SWG-1500 g	65.52	65.00	26.53^{b}	31.28	14.25	0.55	2.60^{a}	0.16^{b}	1.89^{c}	0.26	0.04	1.26
	SWG-2000 g	66.54	66.04	30.29^{c}	31.40	13.65	0.50	2.02^{c}	0.21^{c}	1.48^{b}	0.21	0.04	1.79
	SWG-2500 g	68.32	68.00	30.42^{c}	31.55	13.43	0.48	1.90^{c}	0.21^{c}	1.35^{ab}	0.20	0.04	1.81
	SEM	0.16	0.17	0.55	0.15	0.19	0.00	0.04	0.00	0.02	0.00	0.00	0.07
	Genotype * Slaughter weight	-	-	***	-	-	-	*	*	**	-	-	-

FAG: Fast-growing broiler; SWG: Slow-growing broiler.
SEM: Standard error of mean.
-: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

0.001). While the ratio of the pancreas was significantly higher in the FAG broilers, the bursa of Fabricius and abdominal fat were observed to be higher in the SWG broilers ($p < 0.001$). The percentages of the pancreas and bursa of Fabricius showed the highest values at the 1500-g slaughter weight. The abdominal fat percentage increased as the slaughter weight increased ($p < 0.05$). Genotype and slaughter weight interactions were determined as breast, liver, spleen, and gizzard percentages.

The SWG broilers showed significantly lower data except in the 24th-h pH data taken from the thigh, as shown in Table 3 ($p < 0.01$). Different slaughter weights did not cause a change in the pH value measured. When the color data obtained from the breast and thigh initially and at 24 h were examined, it was observed that the L*, a*, and b* rates of the SWG broilers had significantly lower values than the FAG broilers ($p < 0.01$). In terms of a* values determined initially and at 24 h in the breast and thigh meat, the 1500-g slaughter weight group showed the highest values, and there was no significant difference between the two other slaughter weight groups ($p < 0.01$). Genotype and slaughter weight interaction was determined in terms of drip loss and breast a* values measured initially and at 24 h.

The SWG broilers had significantly lower values in terms of DL, WHC, and CL ($p < 0.001$). While there was no significant difference between the different slaughter weights of WHC and CL, the lowest DL value was in the 2500-g slaughter weight group ($p < 0.01$).

When fatty acid composition was evaluated, the C16, C18.1, C18.2ω6, and C16.1 fatty acids had the highest proportional values (Tables 4 and 5). C10 and C16 exhibited a higher rate in meat obtained from the SWG genotype; C18:2ω6 was detected at higher amounts in the FAG broilers ($p < 0.05$). C14.1 had the highest value at the 1500-g slaughter weight, and C18.2ω6 reached its highest

Table 3. Meat quality characteristics of FAG and SWG broilers at different slaughter weights.

	Treatment	pH_I of breast meat	pH_{24} of breast meat	pH_I of thigh meat	pH_{24} of thigh meat	L^*_I of breast meat	a^*_I of breast meat	b^*_I of breast meat	L^*_{24} of breast meat	a^*_{24} of breast meat	b^*_{24} of breast meat	L^*_I of thigh meat	a^*_I of thigh meat	b^*_I of thigh meat	L^*_{24} of thigh meat	a^*_{24} of thigh meat	b^*_{24} of thigh meat	Drip loss %	Water holding capacity %	Cooking loss %
Genotype	FAG	6.24	5.88	6.32	6.06	45.39	2.48	8.89	47.21	3.48	9.98	44.75	4.99	8.50	46.00	6.55	9.72	4.14	20.99	28.06
	SWG	6.15	5.77	6.25	6.05	40.95	1.78	8.03	42.63	2.89	9.14	40.98	3.65	6.84	42.08	5.04	8.08	2.13	17.01	24.05
	P	**	***	***	-	***	***	**	***	***	**	***	***	***	***	***	***	***	***	***
Slaughter weight	1500 g	6.19	5.82	6.28	6.06	43.60	2.41^{a}	8.85	8.85	3.64^{a}	9.83	43.21	4.85^{a}	8.10	44.36	6.31^{a}	9.35^{a}	3.23^{ab}	18.39	26.02
	2000 g	6.20	5.82	6.29	6.05	43.28	2.09^{ab}	8.36	44.95	3.01^{b}	9.49	42.93	4.20^{b}	7.50	44.13	5.72^{b}	8.80^{ab}	3.75^{a}	18.93	26.22
	2500 g	6.20	5.83	6.29	6.06	42.64	1.89^{b}	8.17	44.53	2.90^{b}	9.36	42.45	3.90^{b}	7.38	43.63	5.36^{b}	8.54^{b}	2.42^{b}	19.69	25.93
	P	-	-	-	-	-	**	-	-	***	-	-	***	-	-	**	*	**	-	-
	FAG-1500 g	6.24	5.87	6.31	6.06	45.54	2.56^{a}	9.44	47.33	3.62^{a}	10.25	45.21	5.33	8.93	46.45	7.08	10.30	4.08^{ab}	20.51	27.56
	FAG-2000 g	6.23	5.87	6.33	6.06	45.43	2.61^{a}	8.63	47.26	3.42^{a}	9.92	44.75	5.05	8.36	46.08	6.58	9.65	5.42^{a}	21.54	29.28
	FAG-2500 g	6.24	5.89	6.33	6.07	45.22	2.27^{a}	8.59	47.03	3.41^{a}	9.78	44.29	4.58	8.21	45.46	5.99	9.21	2.91^{bc}	20.93	27.34
	SWG-1500 g	6.14	5.76	6.25	6.05	41.66	2.25^{a}	8.26	43.21	3.66^{a}	9.41	41.21	4.37	7.27	42.26	5.54	8.40	2.38^{c}	16.26	24.48
	SWG-2000 g	6.16	5.76	6.25	6.05	41.13	1.58^{b}	8.09	42.65	2.60^{b}	9.05	41.12	3.35	6.69	42.19	4.86	7.96	2.08^{c}	16.31	23.15
	SWG-2500 g	6.15	5.77	6.25	6.05	40.06	1.50^{b}	7.75	42.02	2.39^{b}	8.95	40.61	3.23	6.54	41.80	4.74	7.88	1.94^{c}	18.46	24.51
	SEM	0.01	0.01	0.00	0.00	0.30	0.07	0.13	0.30	0.07	0.12	0.26	0.12	0.16	0.28	0.13	0.15	0.20	0.44	0.44
	Genotype * Slaughter weight	-	-	-	-	-	*	-	-	**	-	-	-	-	-	-	-	*	-	-

FAG: Fast-growing broiler; SWG: Slow-growing broiler.
SEM: Standard error of mean.
-: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$.

Table 4. Fatty acid composition of FAG and SWG broilers at different slaughter weights.

	Treatment	C10	C12	C13	C14	C14.1	C15	C15.1	C16	C16.1	C17	C17.1	C18	C18.1	C18.2 ω6	C18.3 ω3	C18.3 ω6
Genotype	FAG	0.030	0.052	0.187	0.594	0.111	0.463	0.850	25.916	3.573	0.183	0.304	7.177	28.465	26.253	1.637	0.200
	SWG	0.038	0.051	0.204	0.581	0.119	0.477	0.981	26.550	3.879	0.240	0.321	6.942	28.977	25.183	1.524	0.211
	P	*	-	-	-	-	-	-	*	-	-	-	-	-	*	-	-
Slaughter weight	1500 g	0.034	0.061	0.189	0.581	0.149^{a}	0.472	0.916	26.118	3.985	0.253	0.331	6.995	29.052	25.017^{a}	0.037	0.235
	2000 g	0.037	0.046	0.208	0.574	0.104^{ab}	0.398	0.997	26.309	3.694	0.206	0.315	7.071	28.648	25.71^{ab}	1.541	0.188
	2500 g	0.031	0.048	0.188	0.608	0.092^{b}	0.540	0.833	26.273	3.499	0.175	0.291	7.112	28.463	26.421^{b}	1.641	0.193
	P	-	-	-	-	*	-	-	-	-	-	-	-	-	*	-	-
	FAG-1500 g	0.026^{a}	0.064	0.127	0.567	0.138	0.401^{ab}	0.743^{ab}	25.093^{a}	3.546^{acb}	0.217	0.345	7.349	28.165	26.894 ^{a}	1.795^{a}	0.218
	FAG-2000 g	0.030^{ab}	0.041	0.165	0.555	0.104	0.303^{a}	0.744^{ab}	25.986^{ab}	4.151^{bc}	0.154	0.255	7.236	28.843	26.002 ^{a}	1.513^{ab}	0.187
	FAG-2500 g	0.034^{ab}	0.050	0.268	0.661	0.090	0.685^{b}	1.062^{ab}	26.670^{b}	3.023^{a}	0.177	0.311	6.945	28.387	25.861^{a}	1.604^{ab}	0.195
	SWG-1500 g	0.042^{ab}	0.058	0.250	0.595	0.159	0.544^{ab}	1.089^{ab}	27.144^{b}	4.424^{c}	0.289	0.318	6.642	29.939	23.140^{b}	1.323^{b}	0.252
	SWG-2000 g	0.043^{b}	0.051	0.252	0.592	0.105	0.493^{ab}	1.250^{a}	26.631^{b}	3.237^{ab}	0.259	0.375	6.905	28.453	25.430^{ab}	1.569^{ab}	0.189
	SWG-2500 g	0.028^{ab}	0.045	0.109	0.555	0.094	0.395^{ab}	0.604^{b}	25.876^{ab}	3.975^{abc}	0.173	0.272	7.279	28.539	26.980^{a}	1.679^{a}	0.191
	SEM	0.001	0.003	0.023	0.015	0.009	0.033	0.057	0.148	0.114	0.016	0.015	0.108	0.219	0.259	0.033	0.012
	Genotype * Slaughter weight	*	-	-	-	-	**	**	***	***	-	-	-	-	***	***	-

FAG: Fast-growing broiler; SWG: Slow-growing broiler.
SEM: Standard error of mean.
-: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

value at the 2500-g slaughter weight. Genotype and slaughter weight interactions were determined for C10, C15, C15.1, C16, C16.1, C18.2ω6, C18.3ω3, C20, C20.1, C20.2, C22, and C22.6ω3 fatty acids.

The FAG broilers had higher values in terms of polyunsaturated fatty acids (PUFA), desired fatty acids (DFA), PUFA/SFA, and thrombogenic index (TI) ($p < 0.05$) (Table 6). Genotype and slaughter weight interactions occurred in terms of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), total unsaturated fatty acids (TUFA), DFA, nutritive value (NV), PUFA/SFA, TUFA/SFA, Σω6/Σω3, atherogenic index (AI), and TI parameters.

4. Discussion

This study investigated the effects of 2 different genotypes (FAG and SWG) and 3 different slaughter weights (1500 ± 50 g, 2000 ± 50 g, and 2500 ± 50 g) on slaughter, carcass, and meat quality characteristics and fatty acid composition. It also examined whether genotype slaughter weight interaction affected these characteristics. FAG genotypes were created by selection and genetic studies to attain an optimal slaughter weight in a shorter time and gain higher live weights [13,14]. When the hot and cold carcass yields determined in the study were evaluated, the body weight increase occurred in accordance with the normal fattening process [2]. The carcass yield and breast percentages increased as the slaughter weight increased. Studies have reported that the myofibril area in the muscle increased with a rise in the slaughter weight, which was associated with breast percentage and texture [15]. The carcass yield values of the FAG broilers determined in this study were higher than in the SWG broilers, which is one of the expected results of selection studies [16]. Narinç et

Table 5. Fatty acid composition of FAG and SWG broilers at different slaughter weights.

	Treatment	C20	C20.1	C20.2	C20.3 ω3	C20.3. ω6	C20.4 ω6	C20.5 ω3	C21	C22	C22.1 ω9	C22.2	C22.6 ω3	C23	C24	C24.1
Genotype	FAG	0.048	0.011	0.289	0.091	0.339	2.276	0.237	0.060	0.080	0.024	0.071	0.149	0.035	0.156	0.126
	SWG	0.047	0.011	0.253	0.040	0.332	2.149	0.232	0.080	0.077	0.042	0.043	0.128	0.029	0.127	0.116
	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slaughter weight	1500 g	0.043	0.011	0.305	0.143	0.354	2.272	0.235	0.033	0.080	0.052	0.052	0.151	0.034	0.138	0.133
	2000 g	0.050	0.011	0.258	0.027	0.332	2.318	0.251	0.056	0.094	0.022	0.066	0.136	0.028	0.154	0.130
	2500 g	0.049	0.011	0.250	0.320	0.320	2.047	0.217	0.120	0.062	0.023	0.054	0.129	0.034	0.133	0.100
	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	FAG-1500 g	0.043[ab]	0.011[ab]	0.374[a]	0.220	0.388	2.363	0.262	0.007	0.052[a]	0.028	0.050	0.178[a]	0.027	0.157	0.137
	FAG-2000 g	0.058[b]	0.012[ab]	0.229[b]	0.027	0.287	2.125	0.223	0.097	0.125[b]	0.019	0.094	0.119[b]	0.034	0.146	0.122
	FAG-2500 g	0.042[a]	0.009[a]	0.264[ab]	0.027	0.342	2.341	0.226	0.075	0.063[ab]	0.015	0.070	0.151[ab]	0.044	0.165	0.118
	SWG-1500 g	0.044[ab]	0.011[ab]	0.236[b]	0.066	0.321	2.182	0.208	0.059	0.108[ab]	0.077	0.055	0.124[b]	0.041	0.118	0.128
	SWG-2000 g	0.041[a]	0.010[ab]	0.287[ab]	0.028	0.377	2.511	0.279	0.016	0.063[ab]	0.025	0.037	0.153[b]	0.022	0.162	0.138
	SWG-2500 g	0.047[ab]	0.013[b]	0.236[b]	0.028	0.297	1.753	0.209	0.165	0.061[ab]	0.022	0.038	0.107[ab]	0.023	0.101	0.083
	SEM	0.002	0.000	0.012	0.012	0.013	0.08	0.014	0.015	0.008	0.009	0.008	0.007	0.004	0.012	0.006
	Genotype * **Slaughter weight**	*	*	**	-	-	-	-	-	*	-	-	*	-	-	-

FAG: Fast-growing broiler; SWG: Slow-growing broiler.
SEM: Standard error of mean.
-: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$.

Table 6. Calculated fatty acid rates of FAG and SWG broilers at different slaughter weight.

	Treatment	SFA	MUFA	PUFA	TUFA	DFA	NV	PUFA/ SFA	MUFA/ SFA	TUFA/ SFA	Σω6 / Σω3	AI	TI
Genotype	FAG	34.79	33.46	31.54	65.01	72.19	1.37	0.91	0.96	1.87	14.29	0.43	21.99
	SWG	35.24	34.45	30.10	64.55	71.49	1.35	0.85	0.98	1.83	14.87	0.45	20.84
	P	-	-	**	-	*	-	**	-	-	-	-	**
Slaughter weight	1500 g	34.84	34.63	30.32	64.96	71.95	1.38	0.87	0.99	1.87	14.10	0.44	21.32
	2000 g	35.02	33.92	30.83	64.76	71.83	1.36	0.88	0.971	1.85	14.93	0.44	21.26
	2500 g	35.18	33.31	31.30	64.62	71.73	1.35	0.89	0.94	1.84	14.71	0.44	21.66
	P	-	-	-	-	-	-	-	-	-	-	-	-
	FAG-1500 g	34.00^{a}	33.11^{b}	32.74^{b}	65.86^{b}	73.21^{a}	1.41^{b}	0.96^{b}	0.97	1.94^{b}	12.66^{a}	0.41^{a}	23.38^{a}
	FAG-2000 g	34.77^{ab}	34.25^{b}	30.81^{b}	65.06^{ab}	72.30^{cb}	1.39^{ab}	0.88^{b}	0.98	1.87^{ab}	15.73^{b}	0.43^{ab}	21.05^{cb}
	FAG-2500 g	35.61^{b}	33.02^{b}	31.08^{b}	64.11^{ab}	71.05^{ab}	1.32^{a}	0.87^{ab}	0.93	1.80^{a}	14.49^{ab}	0.46^{c}	21.54^{ab}
	SWG-1500 g	35.68^{b}	36.14^{a}	27.91^{a}	64.06^{a}	70.70^{c}	1.35^{ab}	0.78^{a}	1.01	1.80^{a}	15.54^{b}	0.46^{c}	19.26^{c}
	SWG-2000 g	35.28^{ab}	33.59^{b}	30.86^{b}	64.46^{ab}	71.36^{ab}	1.32^{a}	0.87^{ab}	0.95	1.82^{a}	14.14^{ab}	0.45^{bc}	21.47^{ab}
	SWG-2500 g	34.76^{ab}	33.60^{b}	31.52^{b}	65.12^{ab}	72.40^{cb}	1.38^{ab}	0.91^{b}	0.96	1.88^{ab}	14.93^{ab}	0.43^{ab}	21.79^{ab}
	SEM	0.178	0.276	0.297	0.185	0.168	0.010	0.011	0.010	0.015	0.282	0.003	0.233
	Genotype * Slaughter weight	*	*	***	**	***	*	***	-	*	**	***	***

-: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.
FAG: Fast-growing broiler; SWG: Slow-growing broiler.
SEM: Standard error of mean.
SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; TUFA: Total unsaturated fatty acids.
DFA: Desired fatty acids (C18:0 + TUFA).
NV: Nutritive value (C18:0 + C18:1)/C16:0.
AI: Atherogenic index (C12:0 + 4 × C14:0 + C16:0)/(MUFA + Σω3+ Σω6).
TI: Thrombogenic index (C14:0 + C16:0 + C18:0)/(0.5 × MUFA) + (0.5 × Σω6) + (3 × Σω3) + (Σω3 / Σω6).

al. [17] reported that the cold carcass yield increased as the slaughter weight rose, and higher carcass yield values were obtained in FAG broilers compared to SWG broilers. Similarly, other studies indicated that SWG broilers reached the desired slaughter weight later, and carcass yield was lower than in FAG broilers [18,19].

Breast meat in broiler carcasses is prized because of its high proportional value and low-fat content. The breast percentage is an important selection criterion in creating FAG broilers [20,21]. In this regard, parallel with findings in numerous studies, the current study found that the breast percentage was higher in the FAG broilers [13,22–25]. The thigh, wing, and abdominal fat percentages of the SWG broilers resulted in higher percentages. Similar results were obtained in many studies conducted in accordance with the findings of the current study [16,22,24–26]. The SWG broilers were active and used their wings more frequently. In addition, the selection of the FAG broilers in terms of breast weight caused a decrease in the percentages of other body parts, and this led to a wing percentage increase for the SWG broilers [15,16,27,28], suggesting that the breast muscle developed faster than the thigh muscle. Contrary to this study's findings, Mikulski et al. [23] found that the thigh ratio was higher in FAG broilers than in SWG broilers.

As the slaughter weight increased, a decrease was observed in the percentages of internal organs and bursa of Fabricius but not in the spleen percentage. Since the weight of the organs did not change as much as the body weight increased, their ratio was expected to decrease.

The pH value is an important meat quality characteristic in transforming muscle into meat. There is a significant decrease between the values measured initially and 24 h after slaughtering because of glycolytic enzyme activation and the amount of glycogen content in the muscle after slaughtering [18]. In the present study, the SWG broilers showed lower pH values than the FAG broilers, which can be explained by the lower glycogen content of the SWG broilers or the slower pH decrease when the FAG broilers were slaughtered [18]. In previous related studies, the pH decrease was higher in SWG broilers [17,24–26,29–32]. Unlike our findings, Devatkal et al. [33] found that the pH was 24 times higher in SWG broilers. Jaturasitha et al. [34] found no significant difference between FAG and SWG broilers.

When color data were examined, the SWG broilers had lower values. The color of meat changes under the influence of many intrinsic factors, including genotype, sex, age, feeding method, outdoor access, muscle myoglobin, hemoglobin content, and operations performed on the carcass [6]. Similar to our results, the b* values determined by Weimer et al. [13], the L* and b* values established by Singh et al. [25], the L* value reported by Quentin et al. [26], and the L*, a*, and b* values collected by Sirri et al. [35] were lower in SWG broilers. The content of muscle myoglobin pigment is one of the most important factors affecting the color and amount of pigment content that increases as the animal's age advances [18,23,36]. The a* parameter obtained from SWG broilers showed higher values in numerous previous studies [25,26,37] because the animals were at a more advanced slaughter age. Despite the findings of these studies, in the current study, the a* value determined from the SWG broilers was lower than that of the FAG broilers. Similarly, Fanatico et al. [18], Fanatico et al. [27], and Nielsen et al. [38] determined that the a* value was lower in SWG broilers.

Nikolic et al. [8] pointed out that different slaughter weights influenced the carcass yields and parts but did not affect the meat's pH and color. Several studies determined that slaughter weight affects some meat quality parameters. Bianchi et al. [39] found that a lower carcass weight results in higher a*, lower pH, and cooking loss values. Yalçın et al. [5] reported that a higher carcass weight leads to lower pH but that a lower carcass weight results in higher L*, lower thawing loss, and higher cooking loss values in the breast muscle. In this study, the slaughter weight affected several of the meat quality parameters. The a* value measured from the breast and thigh was the highest for the 1500-g slaughter weight; the b* value measured from the thigh muscle at the 24th h and DL were the lowest at the 2500-g slaughter weight.

Regarding DL, WHC, and CL, the SWG broilers had lower values than the FAG broilers. A low WHC means that a large amount of water can be lost during the processing of the meat; therefore, a financial loss will occur along with a loss in final product weight [40]. Fanatico et al. [27] reported that since breast meat thickness and size were higher in FAG broilers, the rate of water loss was lower than in SWG broilers. Sante et al. [41] indicated that myosin's water binding and WHC were higher at higher pH values. However, Berri et al. [30] found a negative correlation between the pH 24 measured from the breast muscle and DL. The low pH 24 value of the SWG broilers in which the DL was determined as the highest in this study supports this finding. Similar to our findings, Fanatico et al. [18], Mikulski et al. [23], Canoğulları Doğan et al. [24], Singh et al. [25], Fanatico et al. [27], Devatkal et al. [33], and Sirri et al. [35] reported that SWG genotypes had lower WHC. Different from this study's results, Chodova et al. [42] reported that the genotype difference did not affect WHC and CL. According to Sarıca et al. [43], FAG genotypes have lower WHC. The fat ratio in muscle content is an important parameter affecting cooking loss, and CL is more common in muscles with higher fat content [15].

In addition to its affordability, broiler meat is one of the most consumed meats due to its high-quality proteins and fatty acid composition. Determining the fatty acid composition of meat is essential because each fatty acid detected has a different melting point, affecting how the meat tastes and is consumed [44]. The fatty acid composition in the broiler meat assessed in this study was influenced by some intrinsic (age, sex, genotype) and extrinsic (diet, feeding type, outdoor access, temperature) factors [45]. In addition, the different composition of maternal fatty acids given to the animals 3 weeks after hatching reflected the fatty acid composition of their meat [46]. In this study, significant differences were found in terms of fatty acid composition for different genotypes and slaughter weights. Sung et al. [47] reported that when the fatty acid composition of broiler meat was evaluated, palmitic acid (C16:0) was one of the main fatty acids forming the content. In the current study, C16:0 had the highest value among the fatty acids assessed.

Fatty acid composition in foods used in human nutrition is important in terms of chronic and cardiovascular diseases. SFA, PUFA, PUFA/SFA, and $\Sigma\omega6/\Sigma\omega3$ ratios are important parameters that allow us to have an idea about a particular meat's nutritional value. PUFA is the amount of unsaturated fatty acids determining whether a specific food is healthy. In terms of healthy nutrition, increasing the PUFA ratio in the diet is crucial, especially ω3 PUFA [48].

In the present study, this rate was significantly higher in the FAG broilers. Barton et al. [49] indicated that animals with high muscle content have higher PUFA values due to the high rates of membrane phospholipids.

It is recommended that the ideal Σω6/Σω3 ratio in foods should be higher than 0.4 and lower than 4.0 [44,50]. In the current study, the Σω6/Σω3 ratio was between 12.66 and 15.73 for the different genotypes and slaughter weights. Broiler meat is rich in ω6, and the 18:2ω6 fatty acid had the highest rate. 18:2ω6 and 18:3ω3 fatty acids are essential acids that are not synthesized in the body and that must be acquired through diet [51]. Therefore, the PUFA/SFA ratio should be more than 0.45 in the diet content [52]. In this study, the Σω6/Σω3 ratio was between 0.78 and 0.96 for the different genotypes and slaughter groups. The AI and TI ratios should be low in food. Ulbrich and Southgate [53] indicated that the AI ratio should not be higher than 0.5; however, Popova et al. [54] reported that an AI ratio of less than 1 benefits human health. In the current study, the AI ratio was within a normal range of 0.41 to 0.46.

5. Conclusion

The FAG broilers showed higher percentages of carcass yield, breast, pH, color, drip loss, water holding capacity, cooking loss, 18.2ω6 fatty acid, PUFA, DFA, PUFA/SFA, and TI. The SWG broilers exhibited higher ratios of thigh, wing, abdominal fat, and C.10 and C.16 fatty acids. As the slaughter weight increased, the carcass yield, breast, thigh, and abdominal fat percentages increased, and the a* value determined from the breast and thigh meat decreased. Fatty acids were in the desired ranges for human health. Broiler meat is one of the most produced and consumed in the world. Because of growing consumer concerns about broiler welfare, SWG broilers have increasingly been used in production in recent years. To attain higher production, using FAG broilers is advantageous, but, concurrently, improving animal welfare conditions should also be considered.

Conflict of interest

The authors declare that they have no conflicts of interest.

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