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Growth Performance, Carcass Traits and Meat Quality of Slower-growing and Fast-growing Chickens Raised with and without Outdoor Access

Dariusz Mikulski*, Joanna Celej, Jan Jankowski, Teresa Majewska and Marzena Mikulska
Department of Poultry Science, Faculty of Animal Bioengineering, University of Warmia and Mazury, Oczapowskiego 5, 10-719 Olsztyn, Poland

ABSTRACT : The objective of this study was to determine the effect of genotype (slower-growing vs. fast-growing) and production system (access to outdoors vs. indoor) on the growth performance, carcass yield and meat quality (chemical composition, physicochemical and sensory properties) of chickens. The experiment was performed on 1,040 day-old hybrid male chickens of two genotypes. Slower-growing chickens (Hubbard JA957, certified) and fast-growing chickens (Hubbard F15) were fed identical diets until 65 days of age. Both genotypes (each represented by 520 birds) were divided into two subgroups and were raised in pens on litter with outdoor access or in indoor confinement without outdoor access (four replications per subgroup, each of 65 birds). Until day 21, the birds stayed in the indoor facility, in deep-litter pens. The birds could forage on pasture 12 h daily, commencing at three weeks of age. Stocking density was 0.13 m^2 floor space per bird in pens on litter, and 0.8 m^2 per bird in grassy yards. Compared with fast-growing, slower-growing chickens were significantly lighter (by 17%), had a lower breast and thigh muscle yield and a higher abdominal fat content, but they were characterized by higher survival rates at 65 days, a higher protein content and a lower fat content of breast meat. Outdoor access had no negative effects on the growth performance, muscle yield, the fatty acid profile and oxidative status of meat lipids. The meat of free-range chickens was darker in color, it had a higher protein content and a better water-holding capacity, but it was less juicy than the meat of birds raised indoors. (**Key Words :** Slower-growing Chickens, Outdoor Access, Growth Performance, Carcass Traits, Meat Quality)

INTRODUCTION

The quality attributes of food products, including poultry meat, have been attracting an increasing interest in recent years. Modern consumers are often aware of the relationship between meat quality and safety and animal welfare (Hermansen, 2003; Grunert et al., 2004), and many of them believe that organic food products have superior sensory properties and report that they "taste better" (Latter-Dubois, 2000).

Slow-growing chicken genotypes require a longer fattening period and are well adapted to outdoor farming conditions (Fanatico et al., 2005, 2006). One of the most successful specialty poultry production systems in Europe is the French Label Rouge program, which requires outdoor access. The program meets consumer expectations of organic poultry production, and is regarded as providing branded low-fat meat products with exceptional flavor characteristics, highly appreciated by connoisseurs (Lewis et al., 1997; Castellini et al., 2002c; Gordon and Charles, 2002). In Poland, certified chickens are available for pasture-based poultry production, and a good example of a free-range rearing program is "*kurczak zagrodowy z Podlasia*" ("organically raised chickens of Podlasie").

Poultry meat quality is affected by the genotype, diet, age at slaughter and motor activity of birds, and their adaptation for outdoor production (Castellini et al., 2008). Following the success of the French Label Rouge program, different genotypes (breeds, lines) of slow-growing chickens have been tested during rearing periods of 63 to 120 days in different alternative production systems. On the other hand, fast-growing chickens are still used for free-range production both in Europe and in the US (Network for Animal Health and Welfare in Organic Agriculture, 2002). Therefore, the variation in poultry meat quality

* Corresponding Author : D. Mikulski. Tel: +48-89-523-37-00, Fax: +48-89-52-333-23, E-mail: dariusz.mikulski@uwm.edu.pl
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between alternative production systems can be large (Castellini et al., 2008).

With this in consideration, the objective of the present study was to compare the growth performance, meat yield and quality (chemical composition, physicochemical and sensory properties) of slower-growing and fast-growing chickens raised with and without outdoor access.

MATERIALS AND METHODS

Experimental materials and procedures

The experiment were conducted from May to July of 2007 at experimental farm of the Department of Poultry Science, University of Warmia and Mazury (53°47′ North, 20°30′ East, 122 m above sea level) in Olsztyn, Poland. All procedures were approved by the Local Ethics Committee at the University (opinion no. 41/N). During the experiment, the average daily mean temperature was 19.2°C (mean of highest temperatures 29.8°C and of the minimum 8.7°C), with 6 d of rain and total precipitation of 29.3 mm. The trial was performed on 1,040 day-old hybrid male chickens of two genotypes, supplied by La Gamme Hubbard (Sedar Co., Międzyrzec Podlaski, Poland), i.e. fast-growing (FG) and slower-growing (SG) certified chickens. SG chickens, produced by crossing slow-growing JA57 females with fast-growing M99 males, are well adapted to the free-range environment. Sex of hatching chicks were determined by experienced sexers according to the vent (cloacal) sexing method. Both genotypes (each represented by 520 birds) were divided into two subgroups and were raised in pens on litter with outdoor access (O) or in indoor confinement (I) without outdoor access. The four treatments were as follows: SG-O, SG-I, FG-O and FG-I (four replications per subgroup, each of 65 birds).

The birds of indoor system (I) were raised in pens, in a poultry research house with a concrete floor and windows and was equipped with upper fans for ventilation. Indoor pens measured 2.90 m×2.95 m (0.13 m^2 per bird) and contained 2 bell waterers and hanging tube feeders. Thermostatically controlled heater and electric brooders, which extended along the length of the house, were used to provide additional heat during brooding. Brooding temperature was initially set to 33±1°C and was gradually reduced over 3 wk to acclimate chicks to outdoor temperatures. Incandescent light (25 lx) placed at bird level was used for illumination. The lighting program was as follows: 24 h light/d until day 3, 14 h light/d from day 3 to 14, 16 h light/d from day 14 to 21. From day 22, the photoperiod was limited to natural daylight, which was approximately 15 h light/d. For the SG-O and FG-O treatments, outdoor access from these pens was provided after 3 wk of age during daylight hours through a single doorway measuring 35 cm×50 cm. The grassy paddock measured 16.8 m×3.0 m (0.80 m^2 per bird in the paddock) and were completely covered with 40% Perennial ryegrass (*Lolium perenne*), 40% Kentucky bluegrass (*Poa pratensis*) and 20% Red fescue (*Festuca rubra*). The outdoor portion of each pen was also equipped with a water pan with reservoir, range-type tube feeder with a rain shield and a tarp to provide partial shading of the pasture. Ground and overhead predators were excluded by electric net fencing and netting over the paddocks, respectively. The birds could forage on paddocks 12 h daily and then were confined to indoor pens. Indoor pens and pens with outdoor access were interspersed in the same building; pens were randomly assigned.

All chickens were raised for 65 days and had free access to fresh drinking water and were fed *ad libitum* identical pelleted diets purchased from Sedar Co. (Międzyrzec Podlaski, Poland). From day 57 to 65, the birds were fed a finisher diet containing wheat grain (1:1). The nutritional value of the pasture was not determined. The diets contained no antibiotic growth promoters or coccidiostats. The composition and nutritional value of mixtures are presented in Table 1.

Broilers and feed were weighed at 21, 42 and 65 day of age for determination live body weight and feed efficiency. Liveability was recorded as a percentage of live birds day, and the feed allowance was adjusted accordingly. At 65 days of age, eight birds representing average weight were selected from each treatment and slaughtered in the department processing plant, 12 h after feed withdrawal. Chickens were not transported and were electrically stunned (110 V; 350 Hz) before killing. After killing, carcasses were immerged into hot water (56°C for 120 s) and then plucked and manually eviscerated (nonedible viscera: intestines, proventriculus, gall bladder, spleen, esophagus and full crop). Head, neck, legs, edible viscera (heart, liver, gizzard), and fat (perivisceral, perineal, and abdominal) were removed to obtain the ready-to-cook carcass. After evisceration, whole carcasses were prechilled at 12°C for 15 min, air chilled and stored for 12 h at 4°C and then hand-deboned on a cone at 24 h postmortem. The carcass, stomach, abdominal fat, breast meat (including *pectoralis major* and *pectoralis minor* muscles) and leg meat (including thigh and drumstick meat) were weighed. Percent of eviscerated carcass was calculated as the ratio between the eviscerated carcass and live body weight after fasting. The percentages of weights of breast meat, leg meat, edible viscera and abdominal fat were calculated in relation to eviscerated carcass weight.

The right *pectoralis major* and thigh muscle samples at 24 h postmortem were used to determine color, pH, water-holding capacity and content of water, protein and fat. The left *pectoralis major* samples had been vacuum-packaged, quickly frozen in -26°C at 24 h postmortem, and then stored

Table 1. Composition (%) and calculated nutrient content of diets fed to chickens from 1 to 65 days of age

Ingredient	Starter	Grower 1	Grower 2	Finisher
	1 to 11 d	12 to 24 d	25 to 35 d	36 to 65 d
Maize	20.30	23.70	25.90	20.30
Wheat	42.90	40.30	40.30	50.30
Soybean meal	30.80	30.00	23.20	21.80
Sunflower meal	-	-	3.00	-
Soybean oil	2.40	2.80	4.40	4.60
Dicalcium phosphate	1.24	0.96	0.96	0.82
Limestone	0.28	0.34	0.10	0.10
$NaHCO_3$	0.14	0.14	0.14	0.10
Salt	0.26	0.28	0.26	0.30
DL-methionine 99	0.66	0.56	0.54	0.60
L-lysine 99	0.52	0.42	0.70	0.58
Vitamin-mineral premix[1]	0.50	0.50	0.50	0.50
Calculated analyses				
ME (kcal/kg)	3,003	3,046	3,150	3,220
Crude protein (%)	21.68	21.18	19.34	18.49
Methionine+cystine (%)	0.98	0.92	0.87	0.87
Lysine (%)	1.26	1.21	1.14	1.05
Ca (%)	1.10	1.00	0.96	0.93
Available P (%)	0.45	0.39	0.39	0.37
Na (%)	0.15	0.15	0.15	0.15

[1] Supplied the following per kg of starter and grower 1 diet (1 to 24 d): 25,000 IU vit A, 7,000 IU vit D_3, 91 mg vit E, 6 mg vit K_3, 3 mg vit B_1, 10 mg vit B_2, 6 mg vit B_6, 100 mg niacin, 24 mg pantothenic acid, 2 mg folic acid, 0.4 mg biotin, 600 mg choline, 200 mg Mn, 180 mg Zn, 100 mg Fe, 30 mg Cu, 2 mg J, 0.7 mg Se. Supplied the following per kg of grower 2 and finisher diet (25 to 65 d): 18,000 IU vit A, 4,000 IU vit D_3, 50 mg vit E, 3 mg vit K_3, 2 mg vit B_1, 8 mg vit B_2, 4.5 mg vit B_6, 65 mg niacin, 18 mg pantothenic acid, 1.5 mg folic acid, 0.2 mg biotin, 350 mg choline, 120 mg Mn, 100 mg Zn, 65 mg Fe, 12 mg Cu, 0.8 mg J, 0.35 mg Se.

at -26°C until lipid oxidation, shearing force and sensory analysis. A similar procedure was used for abdominal fat samples before fatty acid evaluation.

Analysis

Percentage moisture, protein and fat content were determined in meat samples according to the Association of Official Analytical Chemists (AOAC, 1990). All chemical analyses were carried out in triplicate. Ultimate pH (pHu) after 24 h postmortem was measured with a WTW pH-meter, model inoLab level 2, with a Polilyte Lab electrode (Hamilton), after the homogenization of 5 g raw muscle with 5 ml distilled water. The water-holding capacity (WHC) of meat was measured based on forced drip loss and free water content determined by the Grau and Hamm method (Oeckel van et al., 1999). Infiltration area was a result interpreted as inversely proportional the WHC of meat. Meat color was characterized based on the values of the parameters L*, a*, b* in the CIELAB system (Commission Internationale de l'E´ clairage, 1978). The parameters L* (lightness), a* (redness) and b* (yellowness) were measured by the optical reflection method, using a MiniScan XE Plus device (HunterLab). The cross-sectional area of muscles was measured three times at different sites and the final value for each bird is the average of those readings.

The degree of lipid oxidation of breast muscle was estimated as described by Pikul et al. (1989), based on TBARS (Thiobarbituric Acid Reactive Substances) values. Absorbance was measured with a Specord 40 spectrophotometer (Analytik Jena AG). TBARS values were expressed in mg malondialdehyde per kg meat. Warner-Bratzler shear force (WBS) was assessed following heat treatment, using a universal Instron 5,542 testing machine equipped with a 500N load cell. Cylinders (at least 5), 1.27 cm in diameter and 2 cm in height, were cut out from meat samples prepared as described by Honikel (1998), and were stored in aluminum foil at 4°C for 24 h. The maximum shear force required to cut each of the cylinders across the fibers was recorded during measurement. Breasts were punctured across muscle fibers with shear force reported in newtons (N).

Approximately 3 d after slaughtering, a sensory analysis was conducted on breast meat at the University of Warmia and Mazury Department of Commodity Science and Animal Raw Material Processing. After thawing overnight at refrigerated temperature (4°C), breast meat was cooked in 0.62% NaCl to an internal temperature of 75°C (at a weight

ratio of solution to meat of 2:1). Meat was cut into 1.9 cm, bite-size cubes and served without the skin. Six trained panelists were asked to evaluate liking of aroma, tenderness, juiciness and flavor of each meat sample individually, on a 1 to 5 scale (1 = very disagreeable; 2 = disagreeable; 3 = neither agreeable nor disagreeable; 4 = agreeable; 5 = very agreeable). Panel members were not given any information about the meat or the experimental treatments and procedures. Panelists were randomly presented samples from all treatment groups in duplicate. Between each sample, panelists were instructed to cleanse their palates with distilled water. A 15-min break period was allocated to the panelists halfway through the session.

Fatty acid composition was determined in abdominal fat samples. Fatty acid methyl esters were prepared by Peisker's method (Peisker, 1964). A 6,890 N gas chromatograph (Agilent Technologies Inc. Palo Alto, CA) with a flame ionization detector (FID) was applied. Treatment conditions were as follows: temperature: detector 250°C, injector 225°C, column 180°C; carrier gas -helium, flow rate 0.7 cm^3/min, and the length of the capillary column 30 m, internal diameter 0.32 mm. Fatty acids were identified based on retention times.

Statistical analysis

Prior to the statistical analysis, data were checked for normality by the Shapiro-Wilk test. The homogeneity of variance across treatments was assessed by Levene's test. All data were verified statistically by two-way ANOVA using a general linear model procedure of Statistica 8.0 software (StatSoft Inc., 2007). If a significant treatment effect was observed, the post-hoc Newman-Keuls test or the nonparametric Kruskal-Wallis ANOVA rank test were applied to determine differences between treatment groups. Treatment effects were considered to be significant at $p \leq 0.05$. All data were expressed as mean values with pooled standard errors.

RESULTS

Effect of genotype

The final body weight of SG chickens (Table 2) was approximately 17% lower ($p<0.01$) than the final body weight of FG chickens, while feed efficiency remained at a comparable level. At the second stage of rearing, mortality rates were threefold lower in SG chickens than in FG birds (1.8% vs. 5.1%).

Compared with FG chickens, SG birds had a significantly lower ($p<0.05$) yield of breast and thigh muscles (Table 3). The carcasses of SG birds had a higher proportion of less valuable portions, like frame with neck ($p<0.05$) and abdominal fat ($p<0.01$), in comparison with FG chickens.

The effects of genotype on the chemical and physicochemical properties of the breast and thigh muscle in chickens are presented in Table 4 and 5, respectively. Breast meat from SG chickens contained significantly ($p<0.05$) more protein and considerably less intramuscular fat

Table 2. Effect of genotype and production system on the growth performance of chickens

Treatment[2]	Body weight (kg)		Feed conversion ratio (kg/kg)			Mortality (%)	
	42 d	65 d	1 to 42 d	22 to 65 d	1 to 65 d	22 to 65 d	1 to 65 d
SG-O	1.94	3.64	1.73	2.79	2.56	1.24	3.71
SG-I	1.94	3.64	1.70	2.77	2.53	2.25	2.50
FG-O	2.37	4.40	1.68	2.72	2.47	1.83	3.65
FG-I	2.41	4.41	1.69	2.74	2.48	4.52	6.03
Pooled SEM	0.010	0.017	0.014	0.020	0.017	nd	nd
Genotype							
SG	1.94[b]	3.64[b]	1.71	2.78	2.54	1.79	3.04
FG	2.39[a]	4.40[a]	1.68	2.73	2.48	5.08	6.77
p-values	0.0001	0.0001	0.334	0.270	0.078	nd	nd
Production system							
O	2.15	3.99	1.71	2.76	2.52	1.51	3.69
I	2.11	3.90	1.69	2.76	2.51	3.00	3.67
p-values	0.129	0.758	0.707	0.967	0.837	nd	nd
Interaction	0.160	0.833	0.569	0.562	0.587	nd	nd
Genotype×production system							

[a-b] Means within a column lacking a common superscript differ ($p<0.05$).

[2] SG = Slower-growing genotype; O = Outdoor access; I = Indoor confinement; FG = Fast-growing genotype.

nd = No determined.

Table 3. Effect of genotype and production system on meat yield[1]

Treatment[2]	RTC yield[3] (%)	Breast muscles[4,5] (%)	Thigh muscles[4] (%)	Drumstick muscles[4] (%)	Frame yield[4,6] (%)	Abdominal fat[4] (%)
SG-O	76.00	22.60	13.72	9.77	34.12	3.05
SG-I	76.04	23.59	13.80	9.88	32.53	2.41
FG-O	76.66	25.00	15.33	10.30	29.91	1.63
FG-I	76.24	24.53	14.56	10.06	31.77	1.83
Pooled SEM	0.482	0.371	0.221	0.136	0.523	0.159
Genotype						
SG	76.02	23.13[b]	13.76[b]	9.83	33.27[a]	2.71[a]
FG	76.42	24.73[a]	14.89[a]	10.16	30.97[b]	1.74[b]
p-values	0.680	0.026	0.006	0.215	0.014	0.007
Production system						
O	76.30	23.71	14.46	10.01	32.18	2.39
I	76.14	24.06	14.18	9.97	32.15	2.11
p- values	0.855	0.714	0.402	0.820	0.853	0.407
Interaction Genotype×production system	0.823	0.310	0.294	0.536	0.083	0.118

[a-b] Means within a column lacking a common superscript differ ($p<0.05$).
[1] Values are means of 8 male birds.
[2] SG = Slower-growing genotype; O = Outdoor access; I = Indoor confinement; FG = Fast-growing genotype.
[3] Ready-to-cook (RTC) yield represents chilled carcass weight as a percentage of live body weight.
[4] Calculated as a percentage of chilled RTC weight. [5] Pectoralis major and Pectoralis minor (boneless, skinless).
[6] Frame is the carcass including skin and neck, with the breast, wings and legs removed.

Table 4. Effect of genotype and production system on the chemical composition and physicochemical properties of the breast muscle in chickens aged 65 days[1]

Treatment[2]	Chemical composition			pH_u	WHC[3] (cm^2)	Color		
	DM (%)	Fat (%)	Protein (%)			Lightness (L*)	Redness (a*)	Yellowness (b*)
SG-O	26.24	0.73	24.83	5.74	5.28	61.71	4.15	14.03
SG-I	25.49	0.79	24.23	5.69	6.22	62.22	3.43	13.51
FG-O	25.88	0.89	24.65	5.76	5.01	60.00	3.62	12.20
FG-I	25.21	1.50	23.34	5.70	6.82	62.94	4.32	12.71
Pooled SEM	0.131	0.106	0.141	0.015	0.238	0.391	0.296	0.305
Genotype								
SG	25.86	0.76[b]	24.53[a]	5.71	5.75	61.96	3.79	13.77[a]
FG	25.57	1.17[a]	24.04[b]	5.73	5.85	61.37	3.95	12.44[b]
p-values	0.178	0.031	0.011	0.293	0.692	0.491	0.765	0.033
Production system								
O	26.05[a]	0.82	24.73[a]	5.75	5.14[b]	60.80[b]	3.87	13.05
I	25.35[b]	1.14	23.79[b]	5.70	6.52[a]	62.58[a]	3.88	13.11
p-values	0.005	0.091	0.001	0.740	0.003	0.021	0.989	0.996
Interaction Genotype×production system	0.858	0.168	0.082	0.255	0.298	0.094	0.257	0.383

[a-b] Means within a column lacking a common superscript differ ($p<0.05$).
[1] Values are means of 8 male birds. [2] SG = Slower-growing genotype; O = Outdoor access; I = Indoor confinement; FG = Fast-growing genotype.
[3] Water-holding capacity.

Table 5. Effect of genotype and production system on the chemical composition and physicochemical properties of the thigh muscle in chickens aged 65 days[1]

Treatment[2]	Chemical composition			pH_u	WHC (cm^2)	Color		
	DM (%)	Fat (%)	Protein (%)			Lightness (L*)	Redness (a*)	Yellowness (b*)
SG-O	27.02	7.37	19.23	6.14[a]	6.05	51.40	10.29	12.64
SG-I	26.74	7.79	18.89	6.01[b]	6.19	53.04	10.61	13.27
FG-O	26.77	7.09	19.60	6.05[ab]	5.58	51.71	9.80	12.13
FG-I	26.44	7.33	19.14	6.09[ab]	5.61	53.11	11.39	13.88
Pooled SEM	0.210	0.260	0.138	0.016	0.140	0.357	0.299	0.238
Genotype								
SG	26.88	7.58	19.06	6.08	6.12	52.22	10.45	12.95
FG	26.61	7.20	19.39	6.07	5.59	52.45	10.55	12.95
p-values	0.531	0.501	0.260	0.904	0.067	0.790	0.805	0.900
Production system								
O	26.88	7.22	19.43	6.10	5.80	51.55[b]	10.03	12.37[b]
I	26.59	7.56	19.01	6.05	5.90	53.07[a]	11.00	13.57[a]
p-values	0.501	0.545	0.155	0.148	0.772	0.038	0.118	0.010
Interaction Genotype×production system	0.953	0.872	0.836	0.011	0.851	0.867	0.295	0.204

[a-b] Means within a column lacking a common superscript differ ($p<0.05$).
[1] Values are means of 8 male birds. [2] SG = Slower-growing genotype; O = Outdoor access; I = Indoor confinement; FG = Fast-growing genotype.

($p<0.01$). The values of L* (lightness) and a* (redness) in the meat of SG and FG chickens were similar, but breast muscles from SG chickens were marked by significantly higher yellowness (b*; $p<0.05$). Thigh meat from SG chickens, compared with FG chickens, tended ($p = 0.067$) to have a worse water-holding capacity (WHC). Chicken genotypes had no impact on the sensory properties (taste, aroma, juiciness, tenderness) of breast muscles (Table 6) and the fatty acid profile of lipids (Table 7).

Effect of production system

Free-range chickens and chickens raised in confinement

Table 6. Effect of genotype and production system on the sensory attributes, shear force evaluation and lipid oxidation of the breast muscle in chickens aged 65 days[1]

Treatment[2]	Aroma (points)	Flavor (points)	Tenderness (points)	Juiciness (points)	WBS[3] (N)	TBARS (mg/kg)
SG-O	5.00	4.21	4.79	3.50	15.84	0.600
SG-I	4.71	4.36	4.86	4.07	13.78	0.659
FG-O	5.00	4.13	4.88	3.50	13.03	0.628
FG-I	5.00	4.29	4.93	4.07	16.06	0.626
Pooled SEM	0.041	0.069	0.049	0.095	0.614	0.018
Genotype						
SG	4.86	4.29	4.82	3.79	14.81	0.629
FG	5.00	4.20	4.90	3.77	14.44	0.627
p-values	0.057	0.574	0.438	1.000	0.824	0.943
Production system						
O	5.00	4.17	4.83	3.50[b]	14.34	0.615
I	4.86	4.32	4.89	4.07[a]	14.92	0.642
p- values	0.057	0.292	0.545	0.002	0.688	0.455
Interaction Genotype×production system	0.057	0.950	0.931	1.000	0.042	0.427

[a-b] Means within a column lacking a common superscript differ ($p<0.05$).
[1] Values are means of 8 male birds. [2] SG = Slower-growing genotype; O = Outdoor access; I = Indoor confinement; FG = Fast-growing genotype.
[3] WBS = Warner-Bratzler shear force values (N).

were characterized by similar body weight gains, feed conversion (Table 2) and carcass traits (Table 3). Mortality rates were lower in chickens which used outdoor areas than in those raised indoor (1.51 vs. 3.0%).

The effects of housing conditions on the chemical and physicochemical properties of the breast and thigh muscle in chickens are presented in Table 4 and 5. The breast meat of free-range chickens contained significantly ($p<0.01$) more dry matter and protein ($p<0.05$) than the breast meat of chickens raised without outdoor access (Table 4). The color of the breast and thigh muscles of chickens grown with outdoor access was significantly ($p<0.05$) darker, compared with birds raised in confinement. Changes in the color of meat were accompanied by a better WHC of breast muscles and lower juiciness of breast (Table 6) from free-range chickens. Housing conditions had no impact on the fatty acid profile of lipids in abdominal fat (Table 7).

DISCUSSION

The certified chickens used in this experiment may be classified as medium-growing. At 42 days of age, the body weights of SG and FG chickens reached 1.94 kg and 2.39 kg, respectively. The survival rates were higher in SG chickens than in FG birds, which is consistent with the findings of other authors (Castellini et al., 2002a; Pietrzak et al., 2006). The mortality rates of FG chickens were threefold higher, and 90% of the cases detected were due to sudden death syndrome (SDS). Lewis et al. (1997) reported no mortality cases in SG birds, and a mortality rate of 11% in FG birds. Another reason for the foregoing effect might be reduced motor activity of FG chickens in comparison to SG. In previous work, Castellini et al. (2002a,c) observed that FG chickens, in comparison to SG, spent less time walking and preferred to stay indoors rather than outdoors. Free-range offers the freedom for chickens to exercise in the paddock, which might improve the development of the bone, reduce leg weakness problems and could be beneficial for health maintenance. In this study, neither chicken genotype nor production system affected the feed conversion ratio (FCR). Similar results were obtained by Pietrzak et al. (2006) and Santos et al. (2005), while in a study by Bassler and Ciszuk (2002) FCR was higher in SG birds than in FG chickens ($p\leq0.05$).

As expected, SG chickens had a lower total muscle yield, which was also reported by other authors (Berri et al., 2001; Janocha et al., 2004). In an experiment by Nielsen et al. (2003), SG chickens were characterized by a significantly ($p<0.05$) lower breast muscle yield, but higher ($p<0.05$) yield of thigh and drumstick muscles than FG chickens.

The increase in the abdominal fat content of the carcass, noted in SG chickens, was quite surprising, although it was also observed by Pietrzak et al. (2006) in seven-week-old certified chickens. The higher abdominal fat content in SG broilers suggests that the diets fed to experimental chickens probably contained too much energy and protein, in relation to the nutrient requirements of birds. In such a case, the carbon chains of amino acids after deamination may become a source of energy deposited as abdominal fat. In

Table 7. Fatty acid profile of the breast muscle in chickens aged 65 days (percentage content in total fatty acids) [1]

Treatment[2]	Palmitic (C16:0)	Palmitoleic (C16:1)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)	Linolenic (C18:3)	UFAs	SFAs
SG-O	25.09	6.32	5.69	35.18	24.16	1.86	67.52	30.78
SG-I	25.61	5.81	5.85	34.59	24.56	1.83	66.80	31.46
FG-O	25.39	6.38	5.88	34.85	23.90	1.78	66.91	31.26
FG-I	25.40	6.42	5.80	34.88	23.94	1.83	67.08	31.20
Pooled SEM	0.244	0.121	0.086	0.213	0.245	0.020	0.257	0.263
Genotype								
SG	25.33	6.08	5.76	34.91	24.35	1.84	67.19	31.09
FG	25.39	6.40	5.84	34.87	23.92	1.81	67.00	31.23
p-values	0.932	0.167	0.698	0.967	0.399	0.347	0.765	0.837
Production system								
O	25.22	6.34	5.78	35.03	24.04	1.83	67.24	31.00
I	25.50	6.12	5.83	34.74	24.25	1.83	66.94	31.33
p-values	0.608	0.343	0.823	0.540	0.674	0.768	0.611	0.582
Interaction	0.623	0.258	0.531	0.494	0.729	0.332	0.414	0.508
Genotype×production system								

[1] Values are means of 8 male birds.
[2] SG = Slower-growing genotype; O = Outdoor access; I = Indoor confinement; FG = Fast-growing genotype.
UFAs = Unsaturated fatty acids; SFAs = Saturated fatty acids.

contrast to the present results, Lewis et al. (1997), after 48 days fattening, and Castellini et al. (2002c) both slaughtered broilers at the 82nd day of age and reported that FG chicken had higher abdominal fat ratio than SG. On the other hand, Grashorn (2006) observed no significant difference for fat pad yield between FG and SG chicken. Fat deposition is affected many factors like diet, age, genotype, environmental conditions, sex, etc. Wang et al. (2009) found that the abdominal fat yield of chickens in the free-range system was significantly lower than chickens in the indoor treatment. Conventional diets typically meet NRC requirements for commercial broilers; however, these requirements were developed for fast-growing broilers in indoor production. Although some producers use a low energy diet to raise birds more slowly to improve the meat quality (Komprda et al., 2000), there were no carcass and meat quality advantages from using a low nutrient feed (Fanatico et al., 2007b). Havenstein et al. (2003) found that modern diets resulted in better growth rates but also produced considerably higher fat levels than 1957 diets.

There are many aspects to overall meat quality of poultry products, which may be affected by genotype, production system, diet, age, stocking density, temperature, exercise and pasture intake (Gordon and Charles, 2002). The decrease in the intramuscular fat content and the increase in the protein content of breast muscles in SG chickens, noted in our study, correspond with the findings of Castellini et al. (2006), Pietrzak et al. (2006) and Fanatico et al. (2007b). In contrast, Tang et al. (2009) observed a higher intramuscular fat content in SG birds. Castellini et al. (2006) demonstrated that a lower intramuscular fat content was accompanied by lower meat juiciness in SG broilers. In the present experiment, chicken genotype had an insignificant effect on meat lightness (L*). Other authors (Debut et al., 2003; Castellini et al., 2006; Fanatico et al., 2007b) have found that SG birds are redder and darker than FG birds. The L* value indicates the degree of paleness and is associated with poor meat quality; pale, soft, and exudative meat is an increasing problem in the poultry industry. Berri et al. (2001) found that the breast meat of breeds selected for fast-growth was more pale and less red than that of nonselected birds, which was explained by a lower level of heme. Because heme pigments normally increase with age, SG birds normally have a redder meat than FG because the slow-growing are typically older (Gordon and Charles, 2002). On the other hand, research results show that meat color may be affected by fillet thickness (Fletcher, 2002) and difference in muscle fiber type (Lonergan et al., 2003). The meat of the SG birds was more yellow than that of the FG birds ($p<0.05$), which agrees with other findings (Fanatico et al., 2005; Santos et al., 2005). The yellowness of the breast muscle in SG birds may be related to increased foraging of plant material. Although the amount of foraging behavior was not quantified, SG birds were observed to forage more than FG birds. FG chickens did not venture outdoors as often as SG birds and when they did go outdoors, they spent more time resting than foraging. The most pasture used in free-range production is designed to be lawn and offers little nutrients for poultry, as in the present study. The highest quality and most palatable forage that can be offered to poultry is a blend of grasses and legumes, like clover. In such a case, the pasture may contribute to nutrient intake and result in feed cost savings (Fanatico et al., 2005). Legumes in the pasture may increase the omega-3 fatty acids and vitamins in poultry meat and eggs. Pasture may have also the potential to contribute to flavor, and some forages and herbs (such as rosemary) may result in distinctive flavors (Gordon and Charles, 2002). However, Peter et al. (1997) studied the impact of protein level and energy level on carcass and meat quality of slow-growing meat chickens grown to 12 wk and found that breast meat quality (chemical composition, grill loss, shear force) was only slightly influenced by feeding. Similarly, Fanatico et al. (2007b) showed that meat quality differences exist among genotypes with different growth rates and reared in alternative production systems but there were no meat quality advantages from using a low nutrient feed.

In our study, the effect of genotype on the physicochemical properties of meat was insignificant. The WHC of thigh meat tended ($p = 0.067$) to be lower in SG chickens than in FG birds. The above could be due to the fact that the muscles of SG chickens were smaller and thinner than those of FG broilers, which put them at risk of greater water loss (Fanatico et al., 2005). SG birds are also known to be more sensitive to pre-slaughter stress (Lewis et al., 1997; Debut et al., 2003). *Rigor mortis* proceeds probably faster in SG chickens in comparison with FG broilers, thus reducing pHu and WHC (Debut et al., 2003; Lonergan et al., 2003; Fanatico et al., 2005).

In this experiment, chicken genotype had no impact on the fatty acid profile of abdominal fat and the sensory attributes of meat. Similar results were reported by Latter-Dubois (2000), Castellini et al. (2002c) and Pietrzak et al. (2006). It should be stressed that SG chickens with a decreased intramuscular fat content were usually characterized by lower meat juiciness (Castellini et al., 2006; Fanatico et al., 2007a).

Housing conditions (with/without outdoor access) had no significant effect on the body weight of chickens, FCR and carcass traits. Yet the opportunity to use outdoor space probably had a beneficial influence on the health status of birds, as indicated by lower mortality rates in outdoor access broilers (1.5% vs. 3.0%). Also, other authors reported no effect of the production system on carcass muscle yield (Muriel and Pascual, 1995) and abdominal fat

content (Grashorn and Brose, 1997) in chickens. In contrast, Castellini et al. (2002b) found that the chickens raised with outdoor access had a significantly lower abdominal fat content.

Meat color is one of the first characteristics noted by customers, particularly in boneless products, and it is an indicator of meat quality. Texture and water-holding capacity are also important meat quality characteristics that can affect consumer preferences. In this study, outdoor access had a positive effect on the color and protein content of meat. The breast meat of free-range (outdoor access) broilers was less juicy, probably due to a lower content of water ($p = 0.005$) and intramuscular fat ($p = 0.091$), in comparison with birds raised indoor. The initial juiciness of meat is related to water release during chewing, whereas final juiciness is determined by the lipid content of meat (Cross et al., 1978). According to Fletcher (2002), differences in dry matter content and juiciness of meat, may be due to the fact that free-range birds have a greater motor activity than indoor confinement chickens without outdoor access. Similar relationships, confirming a higher dry matter content of meat from chickens raised with outdoor access, were noted by Fanatico et al. (2005). Castellini et al. (2002b) and Husak et al. (2008) reported also that the meat of free-range chickens, compared with broilers raised indoor, was tougher and had higher shear force values (Santos et al., 2005).

CONCLUSIONS

The results of the present study indicate that meat quality differences may exist among breeds with different growth rates and reared with or without outdoor access. Compared with fast-growing birds, slower-growing chickens had a lower breast and thigh muscle yield, but they were characterized by higher survival rates at 65 days, a higher protein content and a lower fat content of breast meat. Outdoor access had no negative effect on the growth performance and muscle yield of chickens. The meat of free-range chickens was darker in color, it had a higher protein content and a better water-holding capacity, but it was less juicy than the meat of birds raised indoors.

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REFERENCES

Association of Official Analytical Chemists 1990. Official methods of analysis of the Association of Official Analytical Chemists. 15th Edn. Ed. Ass. Off. Analyt. Chemists, Washington.

Bassler, A. and P. Ciszuk P. 2002. Pilot studies in organic broiler production - management and cross-breeds. Ekologiskt lantbruk 34.

Berri, C., N. Wacrenier, N. Millet and E. Le Bihan-Duval. 2001. Effect of selection for improved body composition on muscle and meat characteristics of broilers from experimental and commercial lines. Poult. Sci. 80:833-838.

Castellini, C., C. Berri, E. Le Bihan-Duval and G. Martino. 2008. Qualitative attributes and consumer perception of organic and free-range poultry meat. World's Poult. Sci. J. 64:500-513.

Castellini, C., A. Dal Bosco, C. Mugnai and M. Bernardini. 2002a. Performance and behaviour of chickens with different growing rate reared according to the organic system. Ital. J. Anim. Sci. 1:291-300.

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

Castellini, C., C. Mugnai and A. Dal Bosco. 2002b. Effect of organic production system on broiler carcas and meat quality. Meat Sci. 60:219-225.

Castellini, C., C. Mugnai and A. Dal Bosco. 2002c. Meat quality of three chicken genotypes reared according to the organic system. Ital. J. Food Sci. 14:401-412.

Commission Internationale de l'E´ clairage (CIE). 1978. Recommendations on uniform color spaces, color-difference equations, psychometric color terms. Suppl. 2 to CIE Publ. No. 15 (E-1.3.1.) 1971/(TC-1-3). Central Bureau of the Commission Internationale de l'E´ clairage, Paris, France.

Cross, H. R., R. Moen and S. Stanfield. 1978. Guidelines for cookery and sensory evaluation of meat. American Meat Society Association (Ed.) Chicago.

Debut, M., C. Berri, E. Baeza, N. Sellier, C. Arnould, D. Guemene, N. Jehl, B. Boutten, Y. Jego, C. Beamont and E. Le Bihan-Duval. 2003. Variation of chicken technological meat quality in relation to genotype and pre slaughter stress conditions. Poult. Sci. 82:1829-1838.

Fanatico, A. C., L. C. Cavitt, P. B. Pillai, J. L. Emmert and C. M. Owens. 2005. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: meat quality. Poult. Sci. 84:1785-1790.

Fanatico, A. C., P. B. Pillai, L. C. Cavitt, J. L. Emmert, J. F. Meullenet and C. M. Owens. 2006. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: sensory attributes. Poult. Sci. 85:337-343.

Fanatico, A. C., P. B. Pillai, J. L. Emmert, E. E. Gbur, J. F. Meullenet and C. M. Owens. 2007a. Sensory attributes of slow- and fast-growing chicken genotypes raised indoors or with outdoor access. Poult. Sci. 86:2441-2449.

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

Fletcher, D. L. 2002. Poultry meat quality. World's Poult. Sci. J. 58:131-145.

Gordon, S. H. and D. R. Charles. 2002. Niche and organic chicken products. Nottingham University Press, Nottingham.

Grashorn, M. A. 2006. Fattening performance, carcass and meat quality of slow and fast growing broiler strains under intensive and extensive feeding conditions. Page 249 in XII Eur. Poult. Conf., Verona, Italy. (Ed. I. Romboli, D. Flock, and A. Franchini). World's Poult. Sci. Assoc., Italian Branch, Bologna, Italy.

Grashorn, M. A. and G. Brose. 1997. Quality assurance in label programs for chicken meat. Poultry meat quality. Proc. XIII Europ. Symp. Quality Poult. Meat. 21-26 September, 1997, Poznan, Poland: pp. 619-624.

Grunert, K. G., L. Bredahl and K. Brunso. 2004. Consumer perception of meat quality and implications for product development in the meat sector - a review. Meat Sci. 69:259-272.

Havenstein, G. B., P. R. Ferket and M. A. Qureshi. 2003. Carcass composition and yield of 1957 versus 2001 broiler when fed representative 1957 and 2001 broiler diets. Poult. Sci. 82: 1509-1518.

Hermansen, J. E. 2003. Organic livestock production systems and appropriate development in relation to public expectations. Livest. Prod. Sci. 80:3-15.

Honikel, K. O. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49:447-457.

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

Janocha, A., M. Osek and A. Milczarek. 2004. The effect of broiler chicken origin on growth performance and post slaughter parameters. Zesz. Nauk. Przegl. Hod. 73:79-85.

Komprda, T., J. Zelenka, E. Fajmonova, A. Jarosova and I. Kubis. 2000. Meat quality of broilers fattened deliberately slow by cereal mixtures to higher age: 1. Growth and sensory quality. Arch. Geflugelkd. 64:167-174.

Latter-Dubois, E. 2000. Poulets fermiers: Leurs qualite´s nutritionnelle et organoleptiques et la perception du consommateur. M.S. Faculte´ des Sciences de l'Agriculture et de L'Alimentation. Univ. Laval, Quebec, Canada.

Lewis, P. D., G. C. Perry, L. J. Farmer and R. L. S. Patterson. 1997. Responses of two genotypes of chicken to the diets and stocking densities typical of UK and "Label Rouge" systems: I. Performance, behaviour and carcass composition. Meat Sci. 45:501-516.

Lonergan, S. M., N. Deeb, C. A. Fedler and S. J. Lamont. 2003. Breast meat quality and composition in unique chicken populations. Poult. Sci. 82(12):1990-1994.

Muriel, A. and M. R. Pascual. 1995. Carcass and meat characteristics from free-range chickens. Proc. XII Europ. Symp. Quality Poult. Meat. 25-29 September, 1995, Zaragoza, Spain: pp. 219-224.

Network for Animal Health and Welfare in Organic Agriculture. 2002. Final recommendation and comments. http://www.veeru.reading.ac.uk/organic/

Nielsen, B. L., M. G. Thomsen, D. B. Sørensen and J. F. Young. 2003. Feed and strain effects on the use of outdoor areas by broilers. Br. Poult. Sci. 44:161-169.

Oeckel, M. J. van, N. Warnants and Ch. V. Bouquee. 1999. Comparison of different methods for measuring water holding capacity and juiciness of pork versus on-line screening methods. Meat Sci. 5:1313-320.

Peisker, K. 1964. A rapid semi-micro method for preparation of methyl esters from triglycerides using chloroform, methanol, sulphuric acid. J. Am. Oil Chem. Soc. 11:87-90.

Peter, W., S. Danicke, H. Jeroch, M. Wicke and G. von Lengerken. 1997. Influence of intensity of nutrition on selected parameters of carcass and meat quality of French Label type chickens. Arch. Geflugelkd. 61:110-116.

Pietrzak, D., J. Mroczek, E. Leśnik and E. Świerczewska. 2006. Quality of meat and fat from three breeding lines of chickens served feed with or without antibiotic growth stimulator. Med. Wet. 62:917-921.

Pikul, J., D. E. Leszczyński and F. A. Kummerow. 1989. Evaluation of three modified TBA methods for measuring lipid oxidation in chicken meat. J. Agric. Food Chem. 37:1309-1313.

Santos, A. L., N. K. Sakomura, E. R. Freitas, C. M. S. Fortes and E. N. M. Carrilho. 2005. Comparison of free range broiler chicken strains raised in confined or semi-confined systems. Braz. J. Poult. Sci. 7:85-92.

StatSoft Inc. Statistica (data analysis software system). 2007. version 8.0 www.statsoft.com.

Tang, H., Y. Z. Gong, C. X. Wu, J. Jiang, Y. Wang and K. Li. 2009. Variation of meat quality traits among five genotypes of chicken. Poult. Sci. 88:2212-2218.

Wang, K. H., S. R. Shi, T. C. Dou and H. J. Sun. 2009. Effect of a free-range raising system on growth performance, carcass yield, and meat quality of slow-growing chicken. Poult. Sci. 88:2219-2223.