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Comparison of growth performance, pasture usage, carcass yield and breast meat characteristics of two different slow-growing broiler genotypes kept in the free-range

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Consumers' interest in animal welfare-friendly systems with outdoor access is growing and therefore the necessity has arisen for genotypes suitable for free-range systems. This study aimed to investigate the suitability of two slow-growing broiler genotypes by comparing growth performance, pasture usage, carcass yield and breast meat traits. Two slow growing genotypes Hubbard ISA Red JA-57 (n= 240) and Sasso XL44 × SA51A (n= 240), were raised in free-range system for 63 days, and their suitability was assessed. Body weight, feed consumption and feed conversion rate were weekly determined. To assess the pasture usage (interior, buffer and outer zones), the observations were performed twice a day. The total of 60 birds (n: 30 broilers/genotype) were randomly sampled for slaughter process at 63rd day of age, and subsequently breast muscle samples were processed for the physical quality and chemical composition parameters of the meat.

At 63 days of age, the final body weight was found to be 2918.0 g and 3253.6 g in Hubbard and Sasso birds respectively (P<0.001). Also, a higher body weight gain was observed for Sasso birds than Hubbard birds as well (3210.2 vs. 2874.8 g, P<0.001). The broilers preferred to pasture at the interior zone rather than buffer and outer zones (P<0.001), and usually ~~at~~ in the morning (27.54%) than in the evening (20.93%, P=0.010). The average slaughter weight, carcass weight

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and carcass yield were higher in Sasso genotype (3296.7, 2540.4 g, 77.1%, respectively] at 63 days of age compared to Hubbard genotype (2878.3, 2192.3g and 76.2%, respectively, P<0.001). The weight and relative weight of breast were also higher in Sasso (746.2 g and 29.4% respectively) than the Hubbard genotype (617.6 g and 28.2% respectively, P>0.001). These findings could help free-range broiler producers to choose a more suitable genotype according to the final body weight, feed efficiency, pasture usage, carcass yield, and breast meat characteristics.

KEY WORDS: slow-growing broiler / free range / genotype, pasturing / breast yield

In commercial broiler production, fast growing broiler strains have been selected predominantly for performance traits such as final body weight, feed efficiency and breast meat yield [Tallentire *et al.* 2016]. This has been done with little attention to behavioral and welfare traits as birds have been housed solely indoors in closed broiler houses where behavioral pattern is limited, and welfare impaired [Dawkins and Layton 2012]. Recently however, consumers have started to demand more animal-friendly husbandry during rearing for food production [Hartcher and Lum 2020], which has resulted in growing interest alternative systems such as organic or free-range farming. In these systems, the birds are provided with outdoor access offering possibilities to perform natural behaviors, and, thus, improving their welfare [Wallenbeck *et al.* 2017].

However, for consumers welfare is not the only deterministic factor for buying chicken meat [Stadig *et al.* 2016]. There are other important product quality attributes, for example, hygienic measures, healthiness, taste, odor and price [Vanhonacker and Verbeke 2009]. They are often expected to be superior in organic systems compared to the production ones. [Hughner *et al.* 2007]. Two factors could contribute to the enhanced quality of alternative system meat: the importance of using a slower-growing genotype and giving birds access to a pasture area [Stadig *et al.* 2016].

The choice of a suitable hybrid for free-range, long-rearing production is crucial, as it has been found that fast-growing hybrids, such as Ross 308, have increased health problems and therefore inferior performance during a longer rearing period, compared to birds of slow-growing strains [Wilhelmsson *et al.* 2019]. Fast-growing hybrids usually have a rearing period of 28-42 days, whereas the number of days to reach the slaughter weight of 2-2.5 kg has been estimated to be 50-105 days for the commercially available slow-growing broiler breeds, such as Rowan Ranger [Aviagen 2018] and CobbSasso [2007], and many other slow-growing strains [Fanatico *et al.* 2015, Cruz *et al.* 2018, Mueller *et al.* 2018].

The choice of genotype also influences meat quality parameters including tenderness [Ponte *et al.* 2008]. In a free-range system, an opportunity to access a pasture area provides birds with more exercise, muscle use [Castellini *et al.* 2002], and chance to graze on fresh and diverse plant and animal food sources like insects, arthropods, etc.. Consequently, the quality, composition, taste, its tenderness, flavor, water-holding capacity, and nutrient content of meat could be influenced in the alternative systems [Castellini e*t al.* 2002, Wang *et al.* 2009, Jiang *et al.* 2011, Mikulski *et al.* 2011, Chen *et al.* 2013]. These attributes contribute to excellent sensory quality of broiler meant obtained in alternative systems, for which consumers are willing to pay more. [Castellini *et al.* 2002].

In the free-range system the birds have free access to a pasture area covered by natural or artificial vegetation [Chen *et al.* 2013]. Forage is important as a dietary nutritional source for protein and vitamins [Fanatico 1998, Walker and Gordon 2003], and has also additional feeding materials as macroinvertebrates living in the soil surface, for example ground beetles [*Carabidae*], rove beetles [*Staphlinidae*], spiders [*Araneae*], and earthworms [*Lumbricidae*] [Clark and Gage 1996]. Consumption of these living creatures by the birds has beneficial effects on meat quality, due to their content of tocopherols, carotenoids, and α-linolenic acid [Dal Bosco *et al.* 2012]. Furthermore, this enrichment of environmental condition improves welfare status of birds' [Bergman *et al.* 2019].

Free-range and organic production are increasingly gaining emphasis in Turkey due to their mission to produce healthier meat, improve the welfare of the birds and environmental protection aspects. In Turkey, the number of organic poultry producers increased by 21,8% annually from 2020 to 2021 according to the data published by Republic of Turkey Ministry of Agriculture and Forestry [2022].

In the broiler industry, meat quality is an important issue for both producers and consumers [Chen *et al.* 2013]. Recently, consumers have tended to buy broiler meat produced in free-range and organic systems, because they perceive the meat quality and flavor to be better [McFadden and Huffman 2017; Haque et al., 2020; Mohammadi et al., 2023]. However, the meat quality is a complex issue that is affected by genetic strain [Castellini *et al.* 2008], physical activity [Tong *et al.* 2014], and pasture intake [Ponte et al. 2008], and therefore it may be complex to analyze.

The color profile as lightness [L*], redness [a*], and yellowness [b*] is used to evaluate breast meat color, and consequently meat quality according to the CIE [1978]. It is known that a lower value of L* ensures redder meat color and accepted as one of the indicators for good quality of meat [Singh *et al.* 2021]. When compared to fast-growth broilers raised in the system, the yellowness of meat produced in free-range system with slow-growing genotypes could show increase [Castellini *et al.* 2002, Fanatico *et al.* 2005]. This could be related to consumption of fresh material on pasture, for example grass or clover, with high content of carotenoids [Fanatico *et al.* 2005]. Faria *et al.* [2009] indicated that the consumption of greater number of plants rich in carotenoids cause an increment for b* value which provides yellower color of meat in slow-growing broilers.

The present study was carried out as a part of the FreeBirds project that aimed to develop more effective husbandry practices for organic poultry production to make the chickens spend more time outdoor, in accordance with the organic production concepts [Sozcu *et al.* 2021 a, b]. The aim of the present study was to estimate the adaptability of two commercial populations for free-range system, especially regarding pasturing specification. Therefore, the present findings could be helpful to develop some management tools and pasturing strategies to improve the production performance of slow growing broilers in free-range systems and provide some practical recommendations for organic broiler production. We investigated the suitability of two slow-growing broiler genotypes [Hubbard ISA Red JA-57 and Sasso XL44 × SA51A] for a free-range system by comparing growth performance (63 days of age), pasture usage, carcass yield and breast meat traits.

Material and methods

Animals and housing

In the study, a total of 480 one-day-old chicks of two slow growing genetic line (Hubbard ISA Red JA-57 and Sasso XL44 × SA51A) were kept in a free-range system. The chicks were weighed at the beginning of the experiment using scales at ± 0.1 g precision. Then the chicks were randomly allocated into six experimental pens (n=3 pens/genotype, 80 birds/pen, an equal number of female and male birds) with a floor area of 3 × 7 m^2. The stocking density was 0.26 m^2/bird inside ~~of~~ the experimental pen.

All birds were housed in a free-range system with an outdoor pasture area that was regulated according to the minimum standards in EU Directive 1999/74/EC [1999]. The indoor floor was covered with wood shavings as litter material. The lighting program was applied according to management guidelines (Hubbard Efficiency Plus - Broiler - Guide and Nutrient Specifications, 2019; SASSO Broiler Production Objective, 2019). Circular plastic feeders, plastic bell drinkers and perches (18 cm perch length/bird) were provided in the indoor area. To provide free access to pasture during a day, indoor and outdoor areas were separated by a wall with a small hole. The pasture area (350 m^2/pen) was enclosed by wire fences to keep out predators and contained a shelter. The stocking density was 4.4 birds per m^2 in the pasture area.

During the experiment the birds were fed three different standard diets; starter feed between 1-14 days, grower feed between 15-56 days and finisher feed between 57-63 days. All diets had low fat and high cereals content and free from growth promoters and animal protein. The nutrient level in the diets was analyzed according to the methods given in AOAC [2006] - Table 1. Feed and water were offered ad libitum throughout the experiment. The pasture area was cultivated with 60% perennial ryegrass (Lolium perenne), 30% alfalfa (Medicago sativa), and 10% white clover (Trifolium repens). In the foraging area the birds had an opportunity to supplement their diets with natural vegetation and small living creatures (insects, arthropods, etc.). During the growing period, the climate conditions were monitored daily, and the average temperature and relative air humidity are shown in Figure 1.

Table 1. Ingredients and calculated dietary composition of the broiler feeds

Items	Starter feed (1-14 d)	Grower feed (15-56 d)	Finisher feed (57-63 d)
Ingredients (% of feed)			
wheat	5.35	6.15	9.25
corn	52.84	56.15	59.85
soybean meal (48%)	26.29	22.25	14.26
whole soybean	6.42	6.75	7.74
sunflower (45%)	5.15	5.20	5.50
dicalcium phosphate	1.80	1.50	1.35
limestone	1.60	1.45	1.50
NaCl	0.25	0.25	0.25
premix[1]	0.30	0.30	0.30
Calculated chemical analysis			
ME (kcal/kg)	2832	2908	2955
available phosphorus	0.66	0.53	0.55
chemical analysis (%)			
dry matter	89.9	89.7	89.8
crude ash	7.48	6.35	6.65
crude protein (%)	21.5	20.6	17.5
calcium	1.12	0.88	0.92

[1]Vitamin mineral premix provided per kilogram of diet: vitamin A 4,000,000 IU; vitamin D3 800,000 IU; vitamin E 8,000 mg; vitamin K3 1,200 mg; vitamin B1 800 mg; vitamin B2 2,400 mg; vitamin B6 2,000 mg; vitamin B12 6 mg; vitamin C 20,000 mg; niacin 8,000 mg; biotin 40 mg; folic acid 400 mg; choline chloride 80,000 mg; manganese 32,000 mg; iron 24,000 mg; zinc 24,000 mg; copper 2,000 mg; iodine 400 mg; cobalt 80 mg; selenium 60 mg.

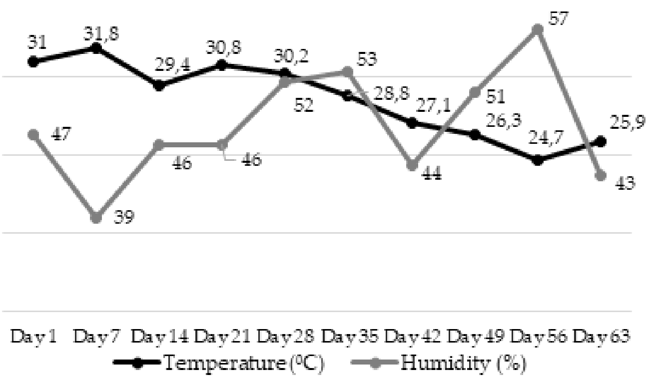

Fig. 1. Mean value of temperature and relative air humidity during the experimental period (between August-October 2020).

Data collection

Body weight and feed consumption were recorded weekly on a pen basis until the end of the experiment (63rd day of age). Feed conversion ratio was calculated using the weekly weight gains and feed consumption values. The mortality in each pen was recorded daily to determine the mortality rates in the groups.

To assess the birds' pasture usage the live observations were performed twice a day for 6 days at 9 weeks of age. The pasture area was divided into 3 sections with same dimensions ~~as~~ i.e. the interior zone (front of the pen), buffer middle of the pen), and outer zone of pasture (back of the pen). The behavior of the birds in the pasture areas were scan sampled for a 10-min period (during morning and evening pasturing periods) in a fixed order to complete the 1-hour observation duration in each experimental pen for each genotype. The direct observations were made during the periods 9.00-10.00 h (morning time) and 17.00-18.00 h (evening time), by the same observer standing outside the pens with an unobstructed view of the entire pen under observation. Each pen was scanned at 10-min intervals, thus giving 6 records per pen. The numbers of birds in each 10-m section of the pasture area were counted as the number of birds pasturing in the interior zone, buffer zone, outer zone, as well as the total birds on the pasture area. Then, the percentage of the pasture using birds was calculated for each genotype as the total number of the birds in the outdoor area divided by the total number of hens in the pen (indoor and outdoor).

A total of 60 birds (10 birds per pen, i.e. 30 birds each genotype) were picked randomly for slaughter at 63rd day of age. Feed withdrawal was applied 12 hours before slaughter. Birds were individually weighed before they were slaughtered in the small-scale slaughterhouse located at the university farm. After slaughter, the carcasses were scalded at 53°C for 120 s prior to plucking [Fanatico *et al.* 2005], and then subjected to manual evisceration. The abdominal fat pad was removed and the organs (heart, liver, gizzard, spleen) were individually weighed. Then the carcasses were divided into primal pieces (breast, thigh, drumstick, wing, neck and back) according to the method described by the Regulation on Poultry Meat Quality [Raseta *et al.* 1984]. The breast meat (pectoralis major) was sampled and chilled at 4°C for 24 h for analyses of chemical and physical meat characteristics. The thighs and drumsticks were removed from the carcass by cutting above the thigh, towards the acetabulum and behind the pubic bone. 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 of the scapula and the coracoid bones. The breast was separated by a cut perpendicular to the ventral joints of ribs, the 'rib' incision. The other part of the carcass was composed of the neck and back parts of the carcass. Then the carcass pieces and organs were weighed and compared for percentage of cold carcass weight.

The right part of the breast muscle samples (n = 30 meat samples/genotype) was used to determine the physical quality parameters of the meat. The pH values were determined at 24-hour postmortem by using a digital pH meter (Mettler Toledo, SevenCompactTM pH/Ion S220, Greifensee, Switzerland) with a glass injection probe introduced 1 cm deep into the muscle of Pectoralis major. To measure the meat color, skin surface was carefully removed and then the color of breast meat was measured by using a spectrophotometer (Konica Minolta Sensing, Inc., Osaka, Japan) with the CIE 1976 Lab system. The meat color was expressed as L* (lightness), a* (redness), and b* (yellowness).

The left part of the breast muscle samples was analyzed to determine the chemical composition. The chemical analysis was performed according to the procedures described by Official Analytical Chemists methods [AOAC International 2006] to determine dry matter (method number 934.01), ash (method number 942.05), crude protein (method number 954.01), and lipid (method number 920.39) content of breast meat.

Statistical analysis

The effects of broiler genotype on broiler growth performance, slaughter yield, carcass composition, organ weights, physical and chemical meat quality parameters for each genotype (Hubbard ISA Red JA-57 and Sasso XL44 × SA51A) were analyzed with the t-test procedure in the statistical analysis software SAS (version 9.4, 2012, Cary, NC, USA). A completely randomized, repeated measure design on a weekly basis was used for performance parameters, and the mean values for each parameter were calculated for weekly basis during experimental periods of 63 days. For the pasture usage, the main effects (effects of genotypes and pasturing time) and the combined effect (genotype × pasturing time) were determined according to the statistical model to a completely randomized design:

$$Y_{ij} = \mu + t_i + \beta_j + (t\beta)_{ij} + \varepsilon_{ij}$$

where:

Y_{ij} – refers to observed value for treatment;

i – in repetition j;

μ – average of the experiment;

t_i – effect of genotype;

β_j – effect of pasturing time;

$(t\beta)_{ij}$ – effect of the interaction between genotype and pasturing time;

ε_{ij} – random error associated to each observation.

Significant differences between means were compared using the Tukey test. Analyses of percentage data were conducted after arcsine square root transformation of the data. The total mortality data were analyzed using chi-square tests to determine differences between the genotypes. Differences were considered statistically significant at $P \leq 0.05$.

Results and discussion

Average values of body weight and body weight gain for two slow growing broiler genotypes in the free-range system are presented in Table 2. Except days 1 and 7 of growing period, the Sasso birds had a higher body weight when compared to the Hubbard between day 14 and 63 (P<0.005). At 63 days of age, the final body weight was found to be 2918.0 g and 3253.6 g in Hubbard and Sasso birds, respectively (P<0.001). On the other han~~ds~~, body weight gain showed significant differences between 35-42 days (382.1 and 443.8 g, P=0.021), 42-49 days (416.8 and 449.2 g, P 0.047) and 56-63 days (445.6 and 594.6 g, P=0.001) among Hubbard and Sasso genotypes, respectively. Throughout the growing period, a higher body weight gain was observed for Sasso birds than the Hubbard birds (3210.2 vs. 2874.8 g, P<0.001).

Table 2. Average body weight and body weight gain of Hubbard and Sasso broilers in free-range system

Items	Genotypes		SEM	*P*-values
	Hubbard	Sasso		
Body weight (g)				
day 1	43.2	43.4	0.8	0.761
day 7	118.8	123.4	2.4	0.078
day 14	306.6	315.0	3.2	0.033
day 21	562.4	588.9	9.8	0.030
day 28	827.9	872.9	15.0	0.022
day 35	1178.8	1252.7	26.3	0.026
day 42	1560.8	1696.5	9.9	<0.001
day 49	1977.7	2145.7	14.1	<0.001
day 56	2472.4	2659.0	27.4	0.001
day 63	2918.0	3253.6	27.3	<0.001
Body weight gain (g)				
days 1-7	75.6	80.0	2.0	0.058
days 7-14	187.8	191.6	2.5	0.130
days 14-21	255.8	273.9	9.9	0.088
days 21-28	265.5	284.0	21.9	0.362
days 28-35	350.9	379.8	19.9	0.149
days 35-42	382.0	443.8	20.6	0.021
days 42-49	416.9	449.2	14.0	0.047
days 49-56	494.7	513.3	35.1	0.551
days 56-63	445.6	594.6	20.8	0.001
days 1-63	2874.8	3210.2	27.4	<0.001

n – 3 replicates per experimental group (80 broilers/pen).

Mean values of feed consumption, cumulative feed consumption and feed conversion ratio for two slow growing broiler genotypes in the free-range system are presented in Table 3. The mean value of feed consumption was found to be higher in Hubbard birds at 1st, 3rd, and 5th weeks, whereas it was found higher in Sasso birds at 4th, 6th, 8th, and 9th weeks (P<0.05). A higher cumulative feed consumption was observed in Hubbard birds at 3rd and 5th weeks (845.1 and 2113.8 g respectively, P<0.05), whereas a higher average for Sasso birds at 9th weeks with a value of 7405.3

Table 3. Average of feed consumption, cumulative feed consumption and feed conversion ratio of Hubbard and Sasso broilers in free-range system

Items	Genotypes		SEM	*P*-values
	Hubbard	Sasso		
Feed consumption (g/bird/week)				
week 1	130.0	118.9	1.9	0.002
week 2	232.3	231.6	6.4	0.894
week 3	482.7	454.3	6.1	0.005
week 4	518.5	575.3	7.4	0.001
week 5	750.2	663.5	8.4	<0.001
week 6	997.8	1081.3	20.8	0.008
week 7	1230.5	1277.9	56.9	0.365
week 8	1332.8	1485.8	46.1	0.015
week 9	1383.7	1516.8	23.5	0.002
Cumulative feed consumption (g/bird)				
week 2	362.3	350.5	7.6	0.128
week 3	845.0	804.8	10.5	0.009
week 4	1363.5	1380.1	14.8	0.248
week 5	2113.7	2043.6	19.4	0.011
week 6	3111.5	3124.9	27.0	0.581
week 7	4342.0	4402.8	70.2	0.349
week 8	5674.8	5888.6	113.7	0.083
week 9	7058.5	7405.4	132.9	0.033
FCR (kg/kg)				
week 1	1.09	0.96	0.02	0.003
week 2	1.18	1.11	0.03	0.068
week 3	1.50	1.37	0.03	0.007
week 4	1.65	1.58	0.04	0.136
week 5	1.79	1.63	0.05	0.017
week 6	1.99	1.84	0.02	<0.001
week 7	2.20	2.05	0.03	0.003
week 8	2.30	2.21	0.06	0.155
week 9	2.42	2.28	0.05	0.026

n – 3 replicates per experimental group (80 broilers/pen).

g (P=0.033). During growing period, FCR was generally found to be more efficient for Sasso genotype. It was found to be lower as 0.96 at 1st week, 1.37 at 3rd week, 1.63 at 5th week, 1.84 at 6th week, 2.05 at 7th week and 2.28 at 9th week (P<0.05) in Sasso genotype.

The mortality was found to be 5.8 and 2.9% in Hubbard and Sasso, respectively (Chi-Square value=2.440, P=0.118).

Pasture usage comparison for two slow growing broiler genotypes in the free-range system is presented in Table 4. Hubbard broilers were found to be pasturing more than Sasso broilers (41.59 vs. 6.88%, P<0.001). It was found that the broilers of both strains preferred to pasture especially at interior zone rather than buffer zone and outer zone. On the other hand, the birds usually preferred morning time for being in the free-range with a higher percentage of 27.54%, than the evening (20.93%, P=0.010). Furthermore, a significant a significant genotype × pasturing time interaction was

Table 4. Pasture usage for two slow growing broiler genotypes in free-range system

Factors	Interior zone	Buffer zone	Outer zone	Total
Genotype				
Hubbard	39.1[a]	1.7[a]	1.5	41.59[a]
Sasso	5.8[b]	0.0[b]	1.1	6.88[b]
SEM	2.1	0.25	0.1	2.28
Pasturing time				
morning	26.1[a]	0.7	0.8	27.54[a]
evening	18.8[b]	0.4	1.8	20.93[b]
SEM	2.1	0.3	0.95	2.28
Genotype × pasturing time				
Hubbard × morning	44.0[a]	1.2	0.97	46.25[a]
Hubbard × evening	34.3[b]	0.9	1.94	36.94[b]
Sasso × morning	8.3[c]	0.0	0.56	8.83[c]
Sasso × evening	3.3[c]	0.0	1.58	4.92[c]
SEM	4.3	0.35	1.35	3.22
P-value				
genotypes	<0.001	<0.001	0.689	<0.001
pasturing time	0.003	0.180	0.309	0.010
genotype × pasturing time	0.006	0.220	0.977	0.044

n – 3 replicates per experimental group (80 broilers/pen).
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observed for the percentage of the interior zone of the pasture used by the birds. (P=0.006).

Slaughter yield, carcass composition and organ weights for two slow growing broiler genotypes at 63 days of age in the free-range system are presented in Table 5. The average slaughter weight, carcass weight and carcass yield were found to be higher in Sasso genotype (3296.7, 2540.4 g, 77.1%, respectively) at 63 days of age compared to the Hubbard genotype (2878.3, 2192.3g and 76.2% respectively, P<0.001).

The weight of wings among the two genotypes was significantly different, but no significant differences were observed for the relative weight of wing. The weight and relative weight of breast were higher in Sasso genotype (746.2 and 29.4%, respectively) than the Hubbard genotype (617.6 g and 28.2%, respectively, P>0.001). A higher relative weight of neck and back was observed in Hubbard genotype compared to the Sasso genotype (24.0 vs. 21.8%, P<0.001). The weight of thigh and drumstick were higher in Sasso (470.7 g and 417.0 g) than the Hubbard birds (400.4 and 352.7 g, P<0.001), whereas no significant differences were observed for the relative weight of thigh and drumstick (P>0.05). On the other hand, the abdominal fat pad was found to be heavier in Sasso birds (60.6 g and 2.38%) than the Hubbard birds (47.6 g and 2.17%, P<0.05).

All analyzed organs were found to be heavier in Sasso birds compared to birds of Hubbard genotype, as the weight of heart, liver, gizzard, and spleen were found to be respectively with values as 14.65, 63.1, 80.4, and 3.83 g in Sasso birds at 63 days of age (P<0.001). However, no significant differences were found regarding the relative weight of heart, liver, gizzard, and spleen, respectively.

Table 5. Slaughter yield, carcass composition and organ weights for two slow growing broiler genotypes in free-range system

Items	Genotypes		SEM	*P*-values
	Hubbard	Sasso		
Slaughter yield parameters				
slaughter weight (g)	2878.3	3296.7	115.3	<0.001
carcass weight (g)	2192.3	2540.4	96.5	<0.001
carcass yield (%)	76.2	77.1	0.94	0.029
Carcass composition (g and % of carcass weight)				
wing (g)	248.3	289.2	16.2	<0.001
wing (%)	11.3	11.4	0.42	0.361
breast (g)	617.6	748.2	32.4	<0.001
breast (%)	28.2	29.5	0.68	<0.001
neck and back (g)	526.1	554.7	37.9	0.078
neck and back (%)	24.0	21.8	1.27	<0.001
thigh (g)	400.4	470.7	26.1	<0.001
thigh (%)	18.3	18.5	0.7	0.353
drumstick (g)	352.3	417.0	20.6	<0.001
drumstick (%)	16.1	16.4	0.5	0.096
abdominal fat (g)	47.6	60.6	5.3	<0.001
abdominal fat, %	2.2	2.4	0.2	0.023
Organ weights (g and % of carcass weight)				
heart (g)	12.5	14.7	0.57	<0.001
heart (%)	0.57	0.58	0.01	0.064
liver (g)	51.8	63.1	4.68	<0.001
liver (%)	2.36	2.48	0.19	0.143
gizzard (g)	67.8	80.4	3.86	<0.001
gizzard (%)	3.09	3.16	0.13	0.160
spleen (g)	3.18	3.83	0.25	<0.001
spleen (%)	0.15	0.15	0.01	0.107

n – 30 broilers per genotype.

Table 6. Physical and chemical meat quality parameters for two slow growing broiler genotypes in free-range system

Items	Genotypes		SEM	*P*-values
	Hubbard	Sasso		
pH	5.8	5.7	0.1	0.221
Lightness (*L**)	56.2	52.9	2.5	0.022
Redness (*a**)	1.1	1.2	0.2	0.518
Yellowness (*b**)	5.8	5.0	0.8	0.038
Moisture (%)	27.3	26.2	1.3	0.207
Ash (%)	3.0	2.8	0.4	0.358
Fat (%)	2.8	4.0	0.6	0.043
Protein (%)	24.8	22.7	1.3	0.028

n – 30 meat samples/genotype.

Physical and chemical quality parameters of breast meat for both broiler genotypes in the free-range system are presented in Table 6. The pH value of breast meat was found to be similar for both Hubbard and Sasso (5.78 and 5.66 respectively, P=0.221). The L* (lightness) was significantly higher in breast meat of Hubbard genotypes with a value of 56.18 (P=0.022). The a* (redness) was found to be similar for breast meat of Hubbard and Sasso genotypes, whereas b* (yellowness) was higher in Hubbard genotype compared to the Sasso (5.78 vs. 5.02, P=0.038). On the other hand, the moisture and ash content of breast meat did not differ significantly, whereas breast meat fat and protein content were significantly higher in Hubbard broilers compared to that of the Sasso broilers (Tab. 6).

This study showed that Sasso broilers had a better growing performance with a higher final body weight and body weight gain, and a more efficient FCR value than Hubbard birds. Furthermore, it was found that slow growing broilers with pasture access reach the targeted slaughter weight at 63 days of age. The observed significant differences in performance could be attributed to the differences between genotypes.

The suitability of genotypes could show variation against extensive environmental conditions such as, foraging behavior, adaptation to ranging etc., and consequently affect animal welfare, carcass, and meat quality traits [Sossidou *et al.* 2011]. The birds from one strain or crossbred can have a better performance in one environment and will perform worse in another environment [EFSA 2010]. Also, it is known that when the birds have been genetically developed adaptation to an extensive production system with outdoor access, the performance, health and welfare status, meat quality improve [Fanatico *et al.* 2005, Fanatico et *al.* 2007, Dal Bosco *et al.* 2014].

Many factors affect growth performance of birds in free-range systems. They are ambient temperature, photoperiod, housing facilities, accessing to pasture, available nutrition sources and feed and water quality, foraging behavior etc., and the variation is usually larger compared to production in closed buildings [Wang *et al.* 2009, Singh *et al.* 2021]. Therefore, it is significantly important to determine the performance of slow growing broiler genotypes according to local environmental and climatic conditions of a producer's country. It could also be beneficial to determine the suitability of genotypes in different rearing conditions as it is important for slow growing genotypes to be locally adapted.

Birds accessing ~~to~~ pasture in alternative systems have a decreased feed efficiency compared to the broilers kept in production systems [Gordon *et al.* 2002, Fanatico *et al.* 2008]. This could be related to unstable temperature, increment of physical exercise on pasture area, resulting in increasing their energy demands and feed requirement for body weight gain [Singh *et al.* 2021]. The observed differences for FCR among the genotypes could be attributed to mobility of birds and foraging at pasture. As the Hubbard genotype was more active on pasture area, it resulted in deterioration in FCR compared to the Sasso genotype. On the other hand, for another commercial slow growing genotype, namely CobbSasso, the FCR value is notified to be 2.14 at 56 days of age by producer company [CobbSasso 2007].

Access to pasture enables birds to perform natural behaviors outdoor and decrease the stocking density inside of the house [Lay *et al.* 2011]. However, the range usage shows differences for individual birds and bird genotype. Furthermore, there are other factors affecting the range use by the birds, for example, age, genetic, flock size, fear level, climatic conditions, daily time, artificial cover on the range area etc. [Kjaer 2000, Singh and Cowieson 2013, Stadig *et al.* 2016]. In a previous study performed by Reiter *et al.* [2006], it was reported that 35% of the flock was used the range, but no variation between the birds and days was found. A circadian rhythm for range use was found and the number of birds on range was found the greatest at noon hours. Conversely, the present findings showed that the slow-growing broilers tended to pasture in the morning hours compared to the evening. On the other hand, in another recent study, range area was used with on average 42.8% of Sasso T451 hybrids raised in free-range system, and it showed an increment with age [Stadig *et al.* 2016].

In the current study, the breast weight, and the abdominal fat pad weight was observed greater in carcass obtained from Sasso. This could be related to genetical differences and the level of physical activity. As mentioned below, due to more activeness of Hubbard birds on the pasture, abdominal fat may explain the lower abdominal fat pad weight compared to the Sasso birds. This is in agreement with previous studies reporting that the genotype was a major factor affecting carcass weight of broilers and carcass yield tended to be lower in slow-growing genotypes relative to the final body weight at slaughter age compared to the fast-growing genotypes [Fanatico *et al.* 2008, Mikulski *et al.* 2011, Cruz *et al.* 2018, Mueller *et al.* 2018, Devatkal *et al.* 2019, Mueller *et al.* 2020, Singh *et al.* 2021]. Castellini *et al.* [2002] and Takahashi *et al.* [2006] clearly demonstrated that slaughter weight shows differences among genetic strains and remains in a linear relationship with carcass weight.

In the current study, a higher value of b* for Hubbard breast meat could be explained by increased activity on pasture which meant more foraging behavior and consumption of plants, when compared to the Sasso genotype. Stadig *et al.* [2016] indicated that the color characteristics of breast meat of Sasso T451 hybrids was found 54.0 for L*, 6.1 for a*, and 14.9 for b*, which meant yellower and darker breast meat in the free-range system.

Previous studies clearly indicated that birds with outdoor access had a lower fat content of meat [Castellini *et al.* 2002, Chen *et al.* 2013]. The current study showed that the genotype could be accepted as an affecting factor for fat and protein content of the meat, due to more exercise and different plant consumption on the range. Accordingly, Hubbard broilers were found to be more active with 41.59% using ~~on~~ the pasture. These findings are supported by Castellini *et al.* [2002], Chen *et al.* [2013], and Dal Bosco *et al.* [2016]. On the other hand, a higher protein content in breast meat in Hubbard broilers could be related to their lower fat content which would increase the protein content of muscles. This change was also observed by da Silva *et al.* [2007].

Conclusions

The hypothesis of the current study was that growth performance, pasture usage, carcass yield and breast meat characteristics would be affected by broiler genotype in free-range system. Significant differences observed for final body weight, feed efficiency and some of meat quality characteristics could be related to pasturing of birds accordingly These findings could be helpful to maximize the pasture use by birds through different strategies. For example, Hubbard broilers were found to be more active in the pasture compared to the Sasso birds. Therefore, the determination of pasturing tendency of different genotypes would be beneficial for pasture enrichment with special shelter or some of trees. Furthermore, the findings could contribute to safer and more natural production standards, increase customer satisfaction, and consequently contribute to more sustainable poultry production and environment protection.

REFERENCES

1. AOAC INTERNATIONAL., 2006 - "Official Methods of Analysis of AOAC International." 18th ed., Gaithersburg, MD.
2. AVIAGEN., 2018 - Rowan ranger broiler performance objectives. Available online: http://en.aviagen.Com/assets/ Tech_Center /Rowan_Range//RowanRanger–Broiler–PO-18–EN.pdf [accessed on 10 October 2022].
3. BERGMANN S., SCHWARZER A., WILUTZKY K., LOUTON H., BACHMEIER J., SCHMIDT P., ERHARD M., RAUCH E., 2017 - Behavior as welfare indicator for the rearing of broilers in an enriched husbandry environment - A field study. ***Journal of Veterinary Behavior: Clinical Applications and Research*** 19, 90-101.
4. CASTELLINI C., BERRI C., L.E. BIHAN-DUVAL E., MARTINO G., 2008 - "Qualitative attributes, and consumer perception of organic and free-range poultry meat." ***World's Poultry Science Journal*** 64, 500-512.
5. CASTELLINI C., MUGNAI C., DAL BOSCO A., 2002 - Effect of organic production system on broiler carcass and meat quality. ***Meat Science*** 60, 219-225.
6. CHEN X., JIANG W., TAN H.Z., XU G.F., ZHANG X.B., WEI S., WANG X.Q., 2013 - Effects of outdoor access on growth performance, carcass composition, and meat characteristics of broiler chickens. ***Poultry Science*** 92, 435-443.
7. CIE (Commission Internationale de l'Eclairage), 1978 - Recommendations on uniform color spaces-color difference equations, psychometric color terms. Supplement No. 2 to CIE Publication No. 15 [E-1.3.1] 1971/[TC-1$3], Paris, France.
8. CLARK MS., GAGE SH., 1996 - Effects of free-range chickens and geese on insect pests and weeds in an agroecosystem. ***American Journal of Alternative Agriculture*** 11, 39-47.
9. COBB-VANTRESS., 2007 - CobbSasso breeder management Supplement available online. https://www.cobb-vantress.com/ assets/ Cobb-Files/ product guides/6c1436d72b/ CobbSasso _Breeder_Management_Supplement_v1_EN.pdf (accessed on 10 October 2022).
10. CRUZ FL., SARAIVA LKV., SILVA GE., NOGUEIRA TM., SILVA AP., FARIA PB., 2018 - Growth and carcass characteristics of different crosses of broiler chickens reared under an alternative system. ***Semina: Ciencias Agrarias*** 39, 317-328.
11. DA SILVA D.C.F., DE ARRUDA A.M.V., GONÇALVES A.A., 2017 - Quality characteristics of broiler chicken meat from free-range and industrial poultry system for the consumers. ***Journal of Food Science and Technology*** 54, 1818-1826.
12. DAL BOSCO A., MUGNAI C., MATTIOLI S., ROSATI A., RUGGERI S., DANUCCI D., CASTELLINI C., 2016 - Transfer of bioactive compounds from pasture to meat in organic free-range chickens. ***Poultry Science*** 95, 2464-2471.

13. DAL BOSCO A., MUGNAI C., ROSATI A., PAOLETTI A., CAPORALI S., CASTELLINI C., 2014 - Effect of range enrichment on performance, behavior and forage intake of free-range chickens. ***Journal of Applied Poultry Research*** 23, 137-145.
14. DAL BOSCO A., MUGNAI C., RUGGERI S., MATTIOLI S., CASTELLINI C., 2021 - Fatty acid composition of meat and estimated indices of lipid metabolism in different poultry genotypes reared under free-range system. ***Poultry Science*** 91, 2039-2045.
15. DAWKINS M.S., LAYTON R., 2012 - Breeding for better welfare: Genetic goals for broiler chickens and their parents. ***Animal Welfare*** 21, 147-155.
16. DEVATKAL S., NAVEENA B., KOTAIAH T., 2019 - Quality, composition, and consumer evaluation of meat from slow-growing broilers relative to commercial broilers. ***Poultry Science*** 98, 6177-6186.
17. EFSA., 2010 - Scientific opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers. ***EFSA Journal*** 8, 1667.
18. EU (EUROPEAN UNION) Directive 1804/1999., 1999 - Organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production. ***Official Journal of the European Communities*** 19, 24-28.
19. FANATICO A., 1998 - Sustainable chicken production: Livestock Production Guide. Appropriate Technology Transfer for Rural Areas (ATTRA). Fayetteville, AK.
20. FANATICO A.C., CAVITT L.C., PILLAI P.B., EMMERT J.L., OWENS C.M., 2005 - Evaluation of slower-growing broiler genotypes grown with and without outdoor access: meat quality. ***Poultry Science*** 84, 1785-1790.
21. FANATICO A.C., PILLAI P.B., CAVITT L.C., OWENS C.M., EMMERT J.L., 2005 - Evaluation of slow-growing broiler genotypes grown with and without outdoor access: Growth performance and carcass yield. ***Poultry Science*** 84, 1321-1327.
22. FANATICO A.C., PILLAI P.B., EMMERT J.L., OWENS C.M., 2007 - Meat quality of slow- and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or without outdoor access. ***Poultry Science*** 86, 2245-2255.
23. FANATICO A.C., PILLAI P.B., HESTER P.Y., FALCONE C., MENCH J.A., OWENS C.M., EMMERT J.L., 2008 - Performance, livability, and carcass yield of slow- and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access. ***Poultry Science*** 87, 1012-1020.
24. FARIA P.B., BRESSAN M.C., SOUZA X.R., RODRIGUES E.C., CARDOSO G.P., GAMA L.T., 2009 - Physical-chemical characteristics of meat in chickens of the Paraíso Pedrês and Label Rouge lines. ***Revista Brasileira de Zootecnia*** 38, 2455-2464.
25. GORDON S.H., CHARLES D.R., 2002 - Niche and Organic Chicken Products. Nottingham University Press, Nottingham, UK.
26. HAQUE M.H., SARKER S., ISLAM M.S., ISLAM M.A., KARIM M.R., KAYESH M.E.H., SHIDDIKY M.J., ANWER M.S., 2020 - Sustainable antibiotic-free broiler meat production: Current trends, challenges, and possibilities in a developing country perspective. ***Biology*** 9, 411.
27. HARTCHER K., LUM H., 2020 - Genetic selection of broilers and welfare consequences: a review. ***World's Poultry Science Journal*** 14, 154-167.
28. HUGHNER R.S., MCDONAGH P., PROTHERO A., SHULTZ C.J., STAN TON J., 2007 - Who are organic food consumers? A compilation and review of why people purchase organic food. ***Journal of Consumer Behavior*** 6, 94-110.
29. JIANG S., JIANG Z., LIN Y., ZHOU G., CHEN F., ZHENG C., 2011 - Effects of different rearing and feeding methods on meat quality and antioxidative properties in Chinese Yellow male broilers. ***British Poultry Science*** 52, 352-358.
30. KJAER JB., 2000 - Diurnal rhythm of feather pecking behaviour and condition of integument in four strains of loose housed laying hens. ***Applied Animal Behavior Science*** 65, 331-347.

31. LAY DC J.R., FULTON R.M., HESTER P.Y., KARCHER D.M., KJAER J.B., MENCH J.A., MULLENS B.A., NEWBERRY R.C., NICOL C.J., SULLIVAN N.P.O., PORTER R.E., 2011 - Emerging Issues: Social sustainability of egg production symposium: Hen welfare in different housing systems. ***Poultry Science*** 90, 278-294.
32. MCFADDEN J.R., HUFFMAN W.E., 2017 - Willingness-to-pay for natural, organic, and conventional foods: the effects of information and meaningful labels. ***Food Policy*** 68, 214-232.
33. MIKULSKI D., CELEJ J., JANKOWSKI J., MAJEWSKA T., MIKULSKA M., 2011 - Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. ***Asian-Australasian Journal of Animal Sciences*** 24, 1407-1416.
34. MUELLER S., TADDEI L., ALBIKER D., KREUZER M., SIEGRIST M., MESSIKOMMER R., GANGNAT I., 2020 - Growth, carcass, and meat quality of 2 dual-purpose chickens and a layer hybrid grown for 67 or 84 D compared with slow-growing broilers. ***Journal of Applied Poultry Research*** 29, 185-196.
35. MUELLER S., KREUZER M., SIEGRIST M., MANNALE K., MESSIKOMMER R.E., GANGNAT I.D.M., 2018 - Carcass and meat quality of dual-purpose chickens (Lohmann Dual, Belgian Malines, Schweizerhuhn) in comparison to broiler and layer chicken types. ***Poultry Science*** 97, 3325-3336.
36. MOHAMMADI H., SAGHAIAN S., BOCCIA F., 2023 - Antibiotic-free poultry meat consumption and its determinants. ***Foods*** 12, 1776.
37. PONTE P.I., ROSADO C.M., CRESPON J.P., CRESPO D.G., MOURAO J.L., CHAVEIRO-SOARES M.A., BRAS J.L., MENDES I., GAMA L.T., PRATES J.A., FERREIRA L.M., FONTES C.M., 2008 - Pasture intake improves the performance and meat sensory attributes of free-range broilers. ***Poultry Science*** 87, 71-79.
38. RASETA J., DAKIĆ M., HIGIJENA MESA (HIGIJENA MESA ŽIVINE I JAJA)., 1984 - Veterinarski fakultet Beograd.
39. REITER K., OESTREICHER U., PESCHKE W., DAMME K., 2006 - Individual use of free-range by laying hens. In 'EPC 2006-12th European Poultry Conference. Verona, Italy, 10-14 September 2006. pp. 346.
40. SINGH M., COWIESON J., 2013 - Range use and pasture consumption in free-range poultry production. ***Australian Journal of Experimental Agriculture*** 53, 1202-1208.
41. SINGH M., LIM A.J., MUIR W.I., GROVES P.J., 2021 - Comparison of performance and carcass composition of a novel slow-growing crossbred broiler with fast-growing broiler for chicken meat in Australia. ***Poultry Science*** 100, 100966.
42. SOSSIDOU E.N., DAL BOSCO A., ELSON H.A., FONTES C., 2011 - Pasture-based systems for poultry production: Implications and perspectives. ***World's Poultry Science Journal*** 67, 47-58.
43. SOZCU A., IPEK A., OĞUZ Z., GUNNARSSON S., RIBER A.B., 2021 a - Comparison of performance, egg quality, and yolk fatty acid profile in two Turkish genotypes (Atak-S and Atabey) in a free-range system. ***Animals*** 11[5], 1458.
44. SOZCU A., IPEK A., OĞUZ Z., GUNNARSSON S., RIBER A.B., 2021 b - Comparison of behavioral time budget and welfare indicators in two local laying hen genotypes (Atak-S and Atabey) in a free-range system. ***Animals*** 12(1), 46.
45. STADIG L.M., RODENBURG B., REUBENS B., AERTS J., DUQUENNE B., TUYTTENS F.A.M., 2016 - Effects of free-range access on production parameters and meat quality, composition, and taste in slow-growing broiler chickens. ***Poultry Science*** 95, 2971-2978.
46. TAKAHASHI S.E., MENDES A.A., SALDANHA E.S.P.B., PIZZOLANTE C.C., PELICIA K., GARCIA R.G., PAZ I.C.L.A., QUINTEIRO R.R., 2006 - Efeito do Sistema de criac¸a˜o sobre o desempenho e rendimento de carcac¸a de frangos de corte tipo colonial (Effect of the breeding system on performance and carcass yield of colonial-type broilers). ***Arquivo Brasileiro de Medicina Veterinaria e Zootecnia*** doi:10.1590/S0102-09352006000400026.

47. TALLENTIRE C.W., LEINONEN I., KYRIAZAKIS I., 2016 - Breeding for efficiency in the broiler chicken. ***A review Agronomy for Sustainable Development*** 36, 1-16.
48. TONG H.B., WANG Q., LU J., ZOU J.M., CHANG L.L., FU S.Y., 2014 - Effect of free-range days on a local chicken breed: Growth performance, carcass yield, meat quality, and lymphoid organ index. ***Poultry Science*** 93, 1883-1889.
49. VANHONACKER F., VERBEKE W., 2009 - Buying higher welfare poultry products? Profiling Flemish consumers who do and do not" ***Poultry Science*** 88, 2702-2711.
50. WALKER A., GORDON S., 2003 - Intake of nutrients from pasture by poultry. ***Proceedings of the Nutrition Society*** 62, 253-256.
51. WALLENBECK A., WILHELMSSON S., JÖNSSON L., GUNNARSSON S., YNGVESSON J., 2017 - Behaviour in one fast-growing and one slower-growing broiler [Gallus gallus domesticus] hybrid fed a high- or low-protein diet during a 10-week rearing period. ***Acta Agriculturae Scandinavica. - Section A: Animal Science*** 168-176.
52. WANG K.H., SHI S.R., DOU T.C., SUN H.J., 2009 - Effect of a free-range raising system on growth performance, carcass yield, and meat quality of slow-growing chicken. ***Poultry Science*** **88**, 2219-2223.
53. WILHELMSSON S., YNGVESSON J., JÖNSSON L., GUNNARSSON S., WALLENBECK A., 2019 - Welfare Quality® assessment of a fast-growing and a slower-growing broiler hybrid, reared until 10 weeks and fed a low-protein, high-protein, or mussel-meal diet. ***Livestock Science*** 219, 71-79.