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A comparative study on the expression of myogenic genes, and their effects on performance and meat quality in broiler chicken strains

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Abstract

The aims of current investigation were to study the growth performance, carcass traits, meat quality and expression profile of *Myostatin* (*MSTN*), *Insulin-like growth factor-1* (*IGF-I*), *Myogenin* (*MyoG*) and *Myogenic regulatory factor 4* (*MRF4*) genes in three commercial broiler strains including Ross (Ross 308), Cobb (Cobb 500), and Arian in 2023. A total number of 240 one-day-old chicks were reared under an equalized standard management condition for 6 weeks. Performance, organ weights, meat quality and the expression level of the myogenic genes in the pectoral muscle were investigated. The lowest body weight (BW), feed intake, weight gain and highest feed conversion ratio (FCR) was observed for Arian at the end of the study. The meat quality was similar between strains. The *IGF-I* expression level was significantly higher on 42 days of age in Cobb compared to Ross and Arian. The *MRF4* expression level was significantly higher on 28 days of age in Cobb compared to Ross. The *MyoG* expression level was significantly lower in Arian compared to Cobb on 42 days of age. Furthermore, the *MSTN* expression level was significantly lower in Cobb compared to Ross and Arian on 42 days of age. The remarkable differences in gene expression levels at the end of the rearing period was supported by higher growth performance and BW of Cobb compared to Ross and Arian strains. In conclusion, the findings of current study could conveniently help assess the performance of these broiler strains under similar rearing condition.

Introduction

Over the last decades, the production and consumption of poultry meat has witnesses significant growth worldwide. The world production of poultry meat is expected to increase by 20.30 million tons between 2017 and 2029.[1] Several factors such as population growth, improvement in per capita income, reduced cost of poultry products and health implications have been contributing to this expansion. Furthermore, poultry products are considered a healthy protein source with no religious restrictions.[2] Poultry has the best feed conversion ratio (FCR) among terrestrial animals with low adverse effect on environment.[3,4] As the demand for poultry meat grows the quality of poultry meat becomes more important.

Muscle growth, also known as myogenesis, is a complicated developmental process. Myogenic regulatory factors (MRF) and myocyte enhancer factor 2 (MEF2) proteins are important transcription factors that are positively involved in the regulation of skeletal muscle development.[5] The MRFs include four tissue specific transcription factors: Myogenic differentiation 1 (MyoD1), Myogenic factor 5, Myogenin (MyoG), and MRF 4. On the other hand, myostatin (MSTN), a member of the transforming growth factor β superfamily secreted from skeletal muscle, acts as a potent negative regulator of muscle differentiation and growth.[6] The *MSTN* modifies the muscle fiber-type composition by regulating *MyoD* and *MEF2* expression.[7] Inhibition of *MSTN* causes myofiber hypertrophy[8] while *MSTN* over-expression decreases the skeletal muscle mass and fiber size.[9]

Additionally, a number of hormones are known to impact on animal growth. The major hormones required to support normal growth in chickens are growth hormone, 3,5,3′-triiodothyronine, thyroxine, and insulin-like growth factor-1 (IGF-I).[10] The IGF-I have been shown to stimulate the growth of the skeletal muscle by enhancing the rate of protein synthesis, therefore, the concentration of IGF-I is often positively correlated with the body weight (BW) in broiler chickens.[11]

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With the increasing demand for animal protein, more studies on the growth and differentiation of skeletal muscle are needed to improve growth rates. Muscle growth rate differs among the various breeds of chicken, therefore, studying the expression of Myogenesis-related genes in different breeds could be a breakthrough in regulating muscle development.[12]

Different commercial broiler hybrids are reared in Iran including Arbor Acres, Arian, Cobb (Cobb 500), Hubbard, Lohmann and Ross (Ross 308).[13] Arian is a native broiler strain of Iran and in contrast to other strains such as Ross and Cobb, few studies have investigated the performance of Arian strain. Continues assessment of local chicken strain is critical to ensure effective production. The aim of this research was to study growth performance, carcass traits, meat quality and changes in the expression of *MRF4*, *MyoG*, *MSTN,* and *IGF-I* genes in different postnatal days in Arian strain and to compare it to Cobb, and Ross.

Materials and Methods

Chickens and treatments. A total number of 240, day-old unsexed chicks representing the three broiler strains, Ross 308, Cobb 500, and Arian were obtained from a commercial hatchery. Hatching eggs, originating from breeder flocks around 45 weeks of age, were vaccinated at the hatchery (infectious bronchitis, Newcastle, and Gumboro disease). The chicks were transferred to the poultry experimental house at Faculty of Veterinary Medicine, Urmia University, Urmia, Iran, where the study was conducted. The birds of each strain were randomly divided into 4 pens (20 birds *per* pen) and they were kept according to the recommended standard conditions, temperature 20.00 - 34.00 ˚C and photoperiod 16 - 24 hr). Floor-pens were located in a house with thermostatically controlled and cross-ventilation. All birds were fed on a four-stage well-balanced commercial corn-soybean meal diet consisting of pre-starter (1 to 7 d) with 2,950 kcal ME kg^{-1}, 22.20% crude protein, starter (8 to 21 d) with 3,000 kcal ME kg^{-1}, 20.80% crude protein, grower (22 to 33 d) with 3,100 kcal ME kg^{-1}, 19.50% crude protein, whereas, the finisher (34 to 42 d) had 3,150 kcal ME kg^{-1}, 18.00% crude protein. Other levels were as recommended by Brazilian Table.[14] Feed and water were present *ad libitum* for the whole duration of the experiment (42 days). All procedures conducted with the chickens were approved by the Animal Research Ethics Board at the Urmia University (Ethical code: IR-UU-AEC-3/64).

Performance, meat quality and carcass composition. The BW, feed intake (FI), weight gain (WG) and FCR of birds were assessed on weekly basis over the period of the study (6 weeks). The FI was calculated as the difference between feed given and feed not consumed. The FCR was calculated as grams feed consumed divided by live BW. At 14, 28, and 42 days of age, 8 chicks *per* strain (four *per* sex) were euthanized.[15] Weight and percentages of internal organs (gizzard, heart, proventriculus, and liver) among the different strains were measured and recorded. At the end of the study chickens were killed by cervical dislocation.[16] After the standard slaughter procedures and dripping, carcasses were weighed without feet and head, and the cuts were performed to evaluate the weight and yield of legs, breast, back, wings, skin and subcutaneous, and abdominal fat.[16,17] Meat quality measurements were performed on the major pectoral muscle of the broiler breast.[18] Approximately 3.00 g of each left breast muscle (pectoralis major) was collected from eight chicks (four males and four females) from each strain group, for gene expression analyses on 1, 14, 28, and 42 days of age. The samples were immediately frozen in liquid nitrogen and stored at – 80.00 ˚C until further analysis.

Meat pH value. Meat pH levels were determined using a digital pH meter (HI 991001; HANNA Instruments, Texas, USA). The electrode was directly introduced into the breast meat. The surface pH of the fillets was measured using two portable surface pH meters. Two measurements were performed for each meat sample by placing the electrode onto the meat surface (top and bottom) and an average pH value was calculated.

Drip loss. The measurement of drip loss was conducted to characterize the water-binding capacity of the meat samples. Drip loss measurements of the breast fillets were conducted after 24 hr of storage. After being packed in plastic bags, meat samples were hung on hooks through their thickest part for 24 hr in a 4.00 ˚C incubator. Samples were weighed before and after hanging. Drip loss was calculated as the loss in weight, corrected for size, and expressed as a percent.

$$DL\ (\%) = (M1\text{-}M2)/M1 \times 100$$

where, *DL* is the drip loss, *M1* is mass before hanging, and *M2* is mass after hanging.

Cooking loss. The measurement of cooking loss was conducted to characterize the water-binding capacity of the meat samples. Measurements of the cooking loss were performed 24 hr after slaughter. A sample of around 3.00 × 5.00 cm was taken with a scalpel from the caudal end of the fillets. The samples were weighed and packed separately in autoclave bags. The samples were cooked at 80.00 ˚C in a water bath until the core temperature of the fillets reached 72.00 ˚C. The core temperature was measured with a food core thermometer (HANNA HI 991001, HANNA Instruments, Texas, USA). A second weighing was conducted after cooking and the cooking loss was calculated as the loss in weight, corrected for size, and expressed as a percent.

$$CL\ (\%) = (M1\text{-}M2)/M1 \times 100$$

where, *CL* is the cooking loss, *M1* is mass before Cooking, and *M2* is mass after Cooking.

Gene expression analysis. Pectoral muscle mRNA expression levels of *MRF4*, *MyoG*, *IGF-I,* and *MSTN* were evaluated by using Quantitative Polymerase chain reaction (qPCR) was conducted using an ABI StepOne Detection System (Applied Biosystems, Waltham, USA). Sequences of broiler chicken *MyoG* (D90157), *MRF4* (D10599), *IGF-I* (NM_001004384), *MSTN* (NM_001001461), and glyceraldehyde 3-phosphate dehydrogenase (*GAPDH*; NM_204305) genes were obtained from the gene bank. All primers were designed using Amplifx Software (version 1.7.0; University of Marseille, Marseille, France), as listed in Table 1. Pectoral muscle samples (3.00 g) were collected from eight chicks from each treatment group per day, on days 1, 14, 28, and 42. Total RNA was extracted from homogenized muscle tissue samples using the column RNA isolation kit (DENAzist Asia, Mashhad, Iran) according to the manufacturer's instructions to extract RNA from the tissue samples. The extracted RNA was then used for cDNA synthesis using DENAzist (thermostable reverse transcriptase with random hexamer) commercial kit according to the manufacturer's instructions.[19] The extracted RNA and synthesized cDNA were checked for concentration and quality (absorbance at 260:280 nm) by NanoDrop 2000c spectrophotometer (Thermo Scientific, Waltham, USA) and were stored in freezers at – 80.00 ˚C for the subsequent examinations.[20] For q-PCR 10.00 µL of SYBR Green (DENAzist Asia) master mix, 1.00 µL forward primer (10.00 pmol), 1.00 µL reverse primer (10.00 pmol), 3.00 µL cDNA (50.00 ng), and 5.00 µL of nuclease-free water were mixed using vortexing. The thermal cycling conditions were set as 95.00 ˚C for 5 min for primary denaturation, and 40 cycles of 95.00 ˚C for 30 sec denaturation, followed by 40 sec at 60.00 ˚C for annealing and 40 sec at 72.00 ˚C for extension with final extension at 72.00 ˚C for 5 min. The quality of PCR products was confirmed by melting curve analysis. Cycle threshold (Ct) values of each sample were recorded and average Ct values of each sample generated in duplicate qPCR reactions. The formula $2^{-\Delta\Delta Ct}$ was used to obtain relative gene expression at different ages of birds using comparative CT method.[21] The results were reported as fold change as compared to the calibrator after normalization of the transcript amount with GAPDH gene (housekeeping gene).

Statistical analysis. The analysis was performed on BW, WG, FI, FCR, weight and percentage of individual carcass components, weight, and percentage of other selected internal organs. Data were presented as mean ± standard error of means. The normality of the data was assessed using Shapiro-wilk test. All parameters were compared among the groups, using one-way ANOVA, followed by Tukey's *post-hoc* test or Kruskal-Wallis test followed by Dunn's multiple comparisons test. All statistical analyses were performed using the Stata Software (version 14; Stata Corp., Lakeway, USA). A $p < 0.05$ was considered statistically significant.

Results

Performance. The weekly BW, FI, FCR, and WG at different ages for Arian, Ross and Cobb broiler strains over the study period are shown in Table 2. Results of broiler performance showed that the Cobb has the highest BW in all ages. The BW was considerably higher at Cobb ($p < 0.05$) compared to Ross on day 14 and 28. Likewise, the body weigh was considerably higher in Cobb ($p < 0.05$) compared to Arian at all ages (Table 2). The FI was lower in Arian compared to other strains and the difference was significant at the end of week 3, 4, 5, and 6 ($p < 0.05$). The highest total FI during the rearing period was observed for Cobb (4621 g *per* bird) which was significantly higher ($p < 0.05$) compared to Ross (4,443 g *per* bird) and Arian (4,298 g *per* bird). No significant difference in total FI was observed between Ross and Arian ($p > 0.05$).

The final FCR at the end of the study was 1.96, 1.67, and 2.2 for Ross, Cobb and Arian respectively. The final FCR was considerably higher ($p < 0.05$) in Arian compared to Cobb and Ross. There was no difference ($p > 0.05$) in weekly WG between strains at the end of week 1, 2 and 5. However, the difference was significant ($p < 0.05$) at the end of week 3, 4 and 6. The lowest WG was observed for Arian at the end of 6th week.

Table 3 shows the mean and relative weight of carcass and internal organs over the period of the study. There was no significant difference in carcass, heart, liver, and gizzard weight between strains at the end of the study ($p > 0.05$).

Table 1. Primer sequences used for real-time polymerase chain reaction.

Genes	Primer sequence (5'-3')	Product size (bp)	Accession No.
MyoG	F: GGAGGCTGAAGAAGGTGAACGA R: CTCTGCAGGCGCTCGATGTACT	127	D90157
MSTN	F: CGCTACCCGCTGACAGTGGAT R: CAGGTGAGTGTGCGGGTATTTCT	132	NM_001001461
IGF-I	F: GAGCTGGTTGATGCTCTTCAGTT R: CCAGCCTCCTCAGGTCACAACT	184	NM_001004384
MRF4	F: CAGGCTGGATCAGCAGGACAA R: GCCGCAGGTGCTCAGGAAGT	106	D10599
GAPDH	F: GCCACACAGAAGACGGTGGAT R: GTGGACGCTGGGATGATGTTCT	86	NM_204305

There was a significant difference in proventriculus weight between strains ($p < 0.05$). The mean weight of proventriculus in Cobb was considerably higher than Ross and Arian strains on day 28 and 42 ($p < 0.05$).

Table 2. Broiler performance in Arian, Cobb 500, and Ross 308 chickens during the study.

Parameters	Arian	Cobb 500	Ross 308
BW (week 1)	153.67[a]	170.71[b]	163.55[b]
BW (week 2)	392.68[a]	422.42[b]	396.21[a]
BW (week 3)	791.66[a]	904.85[b]	869.5[b]
BW (week 4)	1,223.79[a]	1,501.16[b]	1,397.96[c]
BW (week 5)	1,778.33[a]	2,038.20[b]	1,961.7[b]
BW (week 6)	2,324.36[a]	2,718.75[b]	2,658.00[b]
FI (week 1)	130.07	148.30	129.42
FI (week 2)	370.43	342.86	342.86
FI (week 3)	656.00[a]	759.03[b]	750.00[b]
FI (week 4)	785.70[a]	1,047.42[b]	882.60[c]
FI (week 5)	1,106.22[a]	976.80[b]	974.04[b]
FI (week 6)	1,250.45[a]	1,346.67[b]	1,364.09[b]
FI (Total)	4,298.87[a]	4,621.08[b]	4,443.02[a]
FCR (week1)	1.14	1.22	1.10
FCR (week2)	1.55[a]	1.36[b]	1.47[b]
FCR (week3)	1.64	1.58	1.58
FCR (week4)	1.81[a]	1.74[b]	1.67[b]
FCR (week5)	1.99[a]	1.81[b]	1.72[c]
FCR (week6)	2.29[a]	1.97[b]	1.96[b]
FCR (Final)	1.84[a]	1.70[b]	1.67[b]
WG (week1)	113.29	121.50	117.44
WG (week2)	238.59	251.71	232.66
WG (week3)	398.77[a]	479.83[b]	473.29[b]
WG (week4)	432.14[a]	598.91[b]	528.47[c]
WG (week5)	554.53	536.83	564.80
WG (week6)	546.03[a]	680.75[b]	695.19[b]
WG (Total)	2,283.38[a]	2,669.53[b]	2,611.52[b]

FI: Feed intake (g *per* bird per week), WG: weight gain (g *per* bird *per* week), FCR: feed conversion ratio (g feed *per* g gain), and BW: body weight (g).
[ab] Rows with different superscripts differ significantly at $p < 0.05$.

No significant difference was observed in the heart, liver, and gizzard relative weight over the study period among strains ($p > 0.05$). There was a significant difference in proventriculus relative weight among strains ($p < 0.05$). The relative weight of proventriculus in Cobb was considerably higher than Ross on day 28 ($p < 0.05$).

In Table 4, the mean and relative weight of carcass cuts at the end of the study is shown in different strains. The results showed that there is no difference in the weight of different carcass cuts among different strains ($p > 0.05$). The relative weight of breast in the Arian was considerably lower compared to Ross strain ($p = 0.04$) but no significant difference was found in Ross or Arian with Cobb ($p > 0.05$).

Back and neck relative weight was considerably higher in Arian compared to Ross strain ($p = 0.04$) but there was no significant difference in Ross or Arian with Cobb ($p > 0.05$). Likewise, skin and feather relative weight was considerably lower in Ross compared to Arian strain ($p = 0.04$). No significant difference was observed in the relative weight of the other carcass cuts among strains ($p > 0.05$).

The meat quality parameters are presented in Table 4. No significant difference in the meat quality characteristics of breast meat was observed among Arian, Cobb, and Ross strains at the end of the study.

Gene expression. The expression of four genes (*MyoG*, *IGF-I*, *MSTN*, and *MRF4*) were quantified in three strains (Arian, Ross, and Cobb) in four intervals (days 1, 14, 28, and 42) using quantitative real-time PCR. The results for all investigated genes are shown in Figure 1. The *MyoG* levels in the breast tissue was significantly higher in Cobb on 42 days of age compared to the Arian strain ($p < 0.05$), however, there was no significant difference in Ross with Cobb or Arian ($p > 0.05$).

The *IGF-I* levels in the breast tissue were significantly lower in Ross compared to Cobb and Arian on 28 days of age ($p < 0.001$). Likewise, the levels of *IGF-I* were significantly higher in Cobb compared to Ross and Arian on 42 days of age ($p < 0.01$).

Table 3. Relative (%) weight of internal organs (g) in the Arian, Cobb 500, and Ross 308 broiler chickens in different time points. The values within the parentheses are the percentage of weight.

Parameters	Age (day)	Arian	Cobb 500	Ross 308
Carcass	42	1,681.37 (0.65)	1,707.25 (0.65)	1,815.75 (0.68)
Heart	14	3.15 (0.77)	3.51 (0.86)	3.21 (0.80)
	28	7.95 (0.64)	8.03 (0.56)	8.12 (0.56)
	42	13.73 (0.54)	13.51 (0.52)	12.17 (0.45)
Liver	14	14.30 (3.55)	15.66 (3.82)	13.93 (3.46)
	28	33.17 (2.71)	35.97 (2.53)	37.06 (2.58)
	42	55.18 (2.17)	56.83 (2.20)	56.96 (2.15)
Gizzard	14	11.35 (2.84)	13.65 (3.47)	11.31 (2.81)
	28	22.30 (1.81)	24.40 (1.71)	24.81 (1.71)
	42	35.22 (1.41)	35.9 (1.39)	35.23 (1.32)
Proventriculus	14	3.03 (0.75)	3.72 (0.91)	3.01 (0.76)
	28	6.32 (0.51)[ab]	9.27 (0.66)[b]	6.47 (0.45)[a]
	42	9.98 (0.40)[a]	13.66 (0.53)[b]	11.76 (0.44)[a]

Relative weight was calculated as organ weight *per* body weight.
[ab] Rows with different superscripts differ significantly at $p < 0.05$.

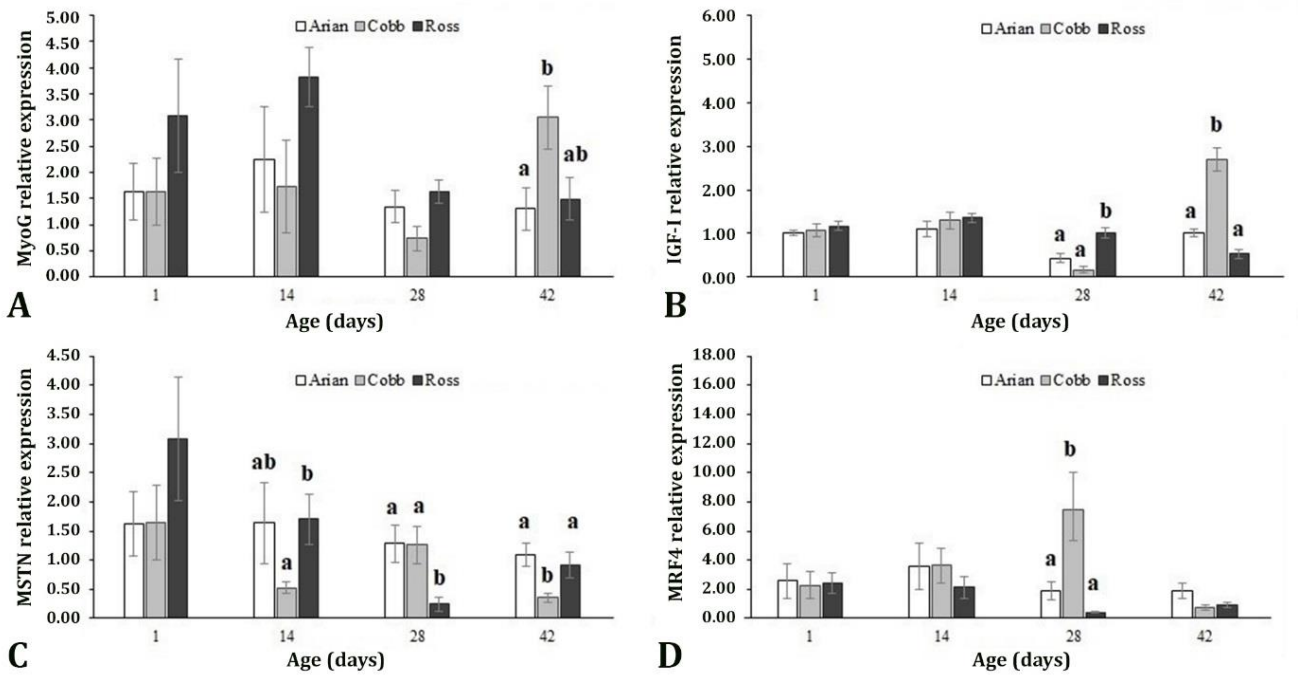

Fig. 1. The expression level of **A)** Myogenin (MyoG), **B)** Insulin-like growth factor-1 (IGF-I), **C)** Myostatin (MSTN) and **D)** Myogenic regulatory factor 4 (MRF4) genes in Arian, Cobb 500, and Ross 308 at different time points. Data are shown as the means ± SEM. Different letters denote significant difference between strains at $p < 0.05$.

The *MSTN* levels in the breast tissue were significantly higher in Ross compared to Cobb on 14 days of age ($p < 0.01$). In contrast, *MSTN* levels in the breast tissue were significantly lower in Ross compared to Cobb and Arian on 28 days of age ($p < 0.01$). Furthermore, *MSTN* levels in the breast tissue were significantly lower in Cobb compared to Ross and Arian on 42 days of age ($p < 0.05$).

There were no statistically significant differences in *MRF* gene expression level between different strains on day 1, day 14 and day 42 ($p > 0.05$). The *MRF4* levels in the breast tissue were significantly higher in Cobb compared to Ross and Arian on 28 days of age ($p < 0.01$).

Table 4. Relative weight of carcass cuts and meat quality characteristics of breast (pectoralis major) in Arian, Cobb 500, and Ross 308 broiler chickens. The values within the parentheses are the percentage of weight.

Parameters	Arian	Cobb 500	Ross 308
Breast	600.75 (0.23)[a]	643.87 (0.24)[ab]	740.25 (0.27)[b]
Leg	467.50 (0.18)	457.87 (0.17)	486.60 (0.18)
Wings	161.00 (0.06)	158.62 (0.06)	156.87 (0.05)
Back and neck	395.75 (0.16)[a]	394.62 (0.15)[ab]	369.12 (0.14)[b]
Feet	96.50 (0.03)	94.50 (0.03)	89.62 (0.03)
Abdominal fat	27.00 (0.01)	26.87 (0.01)	32.87 (0.01)
Skin and feather	309.12	314.87	279.75
pH	6.21	6.29	6.30
Drip loss	2.17	2.17	2.17
Cooking loss	23.34	20.13	24.92

[ab] Rows with different superscripts differ significantly at $p < 0.05$. Relative weight was calculated as cut weight per carcass weight.

Discussion

Commercial broiler strains have the best feed efficiency ratio and the lowest environmental footprint in terms of energy on per kilogram of meat and egg production, therefore, they are considered as an important contributor to food security and protein supply for humans.[4] The present study revealed a great difference in growth performance between strains. In particular, the growth performance was significantly higher in the Cobb compared to Ross and Arian strain. The mean BW of the evaluated broiler chicken ranged from 2,324.30 g in Arian to 2,718.70 in Cobb on 42 days of age indicating significant difference. The Ross broilers evaluated at the end of the study period week were considerably heavier than chickens of the same age reported by Kokoszyński *et al.*[21] Significant differences between commercial and domestic strains have been reported in previous studies. The results of Al-Marzooqi *et al*. study revealed the higher growth performance of Cobb 500 compared to local Omani strain which was in agreement with our study.[22] Furthermore, Benyi *et al*. reported that Ross strain had higher average daily FI and average daily WG compared to Cobb strain.[23] On the other hand, Ojedapo *et al*. reported that Anak strain had higher FI and body WG compared with the Ross strain.[24]

It is believed that broiler chickens with higher WG will consume more feed than others due to their higher nutritional requirements to express their genetic potential.[25]

Our finding showed significant differences in the FI of studied strains with higher FI observed for Cobb and Ross. Previous findings showed that that WG and FCR were affected by strain and Ross broilers achieved higher WG compared to other strains which was in agreement with our findings.[26] In contrast to our findings, Farran *et al*. found no significant difference in live weight and feed to gain ratio among Ross, Arbor acres and Lohman broilers from day 0 to 21.[27] The difference in nutrient utilization between breeds is attributed to differences in the structure of the digestive tract and absorptive capacity, changes in digestive enzyme output and passage rate of digesta.[28]

We also investigated the carcass, internal organ weight, and yield (%) in different strains. The effects of genotype on internal weights have been investigated in previous studies. For example, Benyi *et al*. found that genotype effect on the percentage gizzard weight when comparing Ross and Cobb Avian 48 broiler strains.[23] Except for proventriculus weight at the end of 4th and 6th weeks, we found no difference in the carcass, liver, heart, gizzard weight, and yield between evaluated strains. This was in agreement with findings of Siaga *et al*. who found no significant differences in carcass, breast, back, thigh, wing, drumstick, heart, gizzard, liver and abdominal fat among different strains.[29] In a previous study, Schmidt *et al*. reported that liver relative weights remained constant among the strains which was in agreement with our findings.[30] Likewise, Udeh *et al*. found no difference in the yield of carcass and cuts among Ross, Arbor Acres, and Marshall breeds.[31] Our findings showed that proventriculus weight was significantly higher in Cobb compared to Arian strain. This was consistent with the findings of Kokoszyński *et al*. who stated that the Hubbard F15 chickens had a significantly heavier poventriculus compared to Ross birds.[21] In our study, Arian strain had the smallest proportion of proventriculus to BW. Mussini reported that proventriculus relative weights for all strains were similar until 28 days.[32] In our study, proventriculus relative weights was similar during the rearing period.

We also investigated the carcass cuts weight and yield in different strains. The carcass cuts weight was similar in evaluated strains. Furthermore, our study showed the higher relative weight of breast and lower relative weight of back, neck, skin, and feather in Ross compared to Arian strain with no significant difference between Ross or Arian with Cobb. Previous studies have shown the effect of genotype on carcass cuts and yield. Ikusika *et al*., reported that the Aboaca strain had the highest weight for breast, drumstick, thigh, back, and wing compared to Ross or Anak strains.[33] In other study, Marshall strain of broiler showed superior weight in breast, wing, drumstick, back, and thigh than when compared to Arbour Acres and Hubbard broiler strains.[24] Our findings were in agreement with findings of previous study by Jawasreh *et al*. who reported significant difference in breast percentage among different broiler strains.[34] Higher relative breast weight in fast-growing broiler strains in comparison with slow-growing breeds were also observed previously.[35,36] The difference in breast relative weight between strains is attributed to the differences in breast muscle dimensions and muscle fiber number and size.[37] Furthermore, other factors such as genetic, feed, slaughtering conditions, live weight, sex, and age are associated with carcass and breast yield differences.[38]

Our study found no significant differences in meat quality characteristics among the evaluated strains. The diet type used during this experiment did not have significant effect on meat quality characteristics. The pH values found in the current study were comparable to and within the acceptable range reported in the literature.[22,34] Our results were in agreement with those results obtained by López *et al*. who observed that there were not significant differences in meat pH, cooking loss percentage, lightness, and redness between two commercial broiler strains.[39] Water holding capacity values in the present study are similar to the findings of Abdullah and Matarneh.[40] They observed that water-holding capacity percentage was not significantly affected by differences in carcass weight. This result could be explained by the lack of difference in muscle pH values among carcass weights.

Genetic differences among the broiler chicken strains have been widely investigated and a number of genes have been identified in controlling the growth rate of chickens.[11,41,42] Except for *MSTN*, the expression of evaluated genes was similar in all strains until the end of second week. On 28 days of age, some differences were observed in gene expression profile.

The differences in gene expression are attributed to different factors such as long-term genetic selection, type of production,[43] physiological, and environmental conditions,[44] different genetic origins, skeletal muscle contents,[45] and polymorphisms.[46] Xiao *et al*. reported greater breast muscle weight in fast-growing meat chickens compared to the slow-growing genotype attributed to the higher insulin-like growth factor concentrations in the serum and breast muscle.[11] This was in agreement with our findings as we observed higher *IGF-I* expression on 28 days of age in Ross compared to Arian strain. The relative breast weight was higher in Ross compared to Arian strain which was consistent with gene expression findings. Lalani *et al*. found that *IGF-I* had a positive regulatory effect on muscle differentiation and growth.[47] The higher expression of *IGF-I* and lower expression of *MSTN* at the end of the study supported the growth performance findings which were considerably higher in Cobb compared to other strains.

Results from previous studies have shown a negative association between *MSTN* levels and increases in the size

and number of skeletal muscle fibers or muscle mass.[48] The results of final BW s of the three strains in the current study supported these findings. It is thought that high expression levels of *MSTN* expression prevent excessive muscle growth.[49]

In conclusion, the present study showed significant growth performance variation among several commercial broiler strains reared in Iran. The results of the current study would be useful to evaluate the performance of these strains of broiler under similar rearing condition. The meat quality was similar and no strain showed superiority when compared to Each other. Additionally, a small variation in carcass cuts was found among the strains. The Cobb strain showed higher levels of *IGF-I* and *MRF4* expression which contribute to muscle growth and higher growth performance of the strain. The *IGF-I* gene is considered to be promising marker for the selection of broiler types with a higher growth rate.

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Conflict of interest

The authors declare no conflict of interest.

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