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Phenotypic evaluation of feed efficiency, growth and carcass traits in native turkeys

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ABSTRACT

Improving feed efficiency decreases feed intake, total cost, and the environmental emission of poultry production. This study aimed to investigate different feed efficiency, growth and carcass traits between high and low feed efficiency birds in Iranian native turkeys. Growth and carcass characteristics of native turkeys were recorded. Four different feed efficiency traits, including feed conversion ratio (FCR), residual feed intake (RFI), residual body weight gain (RG), and residual intake and body weight gain (RIG) were calculated. The phenotypic correlations were calculated among feed efficiency measurements and different growth traits. High and low feed efficiency birds based on FCR were compared for growth and carcass traits. The phenotypic correlation between FCR and RFI was 0.5 and FCR was strongly correlated with RG and RIG. Breast muscle weight of high feed efficiency birds based of FCR was significantly higher than low feed efficiency birds. The results showed that phenotypic selection based on each of the feed efficiency traits will automatically progress the others, however, using FCR can be more straightforward in local farms and results in producing more beneficial turkeys with better growth and carcass features.

Keywords: feed efficiency, native turkeys, feed conversion ratio, residual feed intake, native poultry

INTRODUCTION

Feed cost is an important component of poultry production which accounts for 70 percent of the total production costs (Case et al., 2012; Willems et al., 2013). Therefore, low feed efficiency is one of the most important issues in poultry breeding programs. Improving feed efficiency may decrease feed intake, production cost, waste products, and environmental emissions (Aggrey et al., 2010; Willems, 2014). As a result of genetic progress, larger birds need more feed. By improving feed efficiency, birds that eat the same amount of feed as other birds, have higher body weight or weight gain (Case et al., 2012).

Several measures of feed efficiency have been developed and each one has its advantages and disadvantages (Aggrey et al., 2010; Willems et al., 2013). The most routinely used measure is the feed conversion ratio (FCR), which has been studied previously in different livestock, including chickens, cattle, turkeys, sheep and pigs (Aggrey et al., 2010; Berry and Crowley, 2013; Cammack et al. 2005; Case et al., 2012; Do et al., 2013; Leenstra and Pit, 1988; Willems et al., 2013). It is a nonlinear trait that is calculated as the ratio of feed intake to weight gain. It is not distributed normally (Yi et al., 2018). Selecting based on FCR can cause unexpected outcomes as a result of the direct selection. By increasing the selection intensity, direct selection leads to focus of selection on the numerator information, regardless of the distribution properties of the components (Gunsett, 1984; Willems, 2014). It was showed that a linear selection index can be more efficient than selecting based on a ratio trait (Campo and Rodriguez, 1990; Case et al., 2012; Gunsett, 1984). Another measure to predict feed efficiency is the residual feed intake (RFI), which was used in animals such as cattle, chicken and turkeys (Berry and Crowley, 2013; Willems et al., 2014). It is calculated as the difference between actual and predicted feed consumption. More efficient poultry shows a negative value for RFI, which means that its feed intake is less than predicted (Prakash et al., 2020). It is independent of body weight and growth. Despite the advantages of RFI, it should be considered that animals with slow growth, eat less food and may show a more favorable RFI (Berry & Crowley, 2012; Willems et al., 2013).

Residual body weight gain (RG) is another measure that describes the distinction between actual and anticipated body weight gain, which is not accounted for by body weight maintenance and feed intake. So improving RG is related to faster growth and is not associated with any differences in feed intake. A positive value for RG is desirable (Metzler-Zebeli et al., 2018; Willems et al., 2014; Willems et al., 2013). Another feed efficiency measure in animals is residual intake and body weight gain (RIG), which merges RFI and RG and has the advantages of both components of feed efficiency. It can be used independently from body weight to select efficient animals (Berry and Crowley, 2012; Metzler-Zebeli et al., 2018; Willems et al., 2013).

The native population of each species has a vast potential for improvement and they are resistant to different environmental conditions and have high phenotypic variation (Ebrahimzadeh-Allahabad et al., 2015). Iran is a large country with a wide range of weather. There is a considerable phenotypic variety of native poultry in Iran (Kharrati-Koopaee et al., 2019). Iranian native turkeys are not much different from their European ancestors. Since importing to Iran, they did not undergo specific breeding programs to improve growth and feed efficiency. However, over the years, this bird has adapted to Iran's environmental conditions and its genotype has evolved (Yang et al., 2020). While Iranian local turkeys have high meat quality, strong adaptation in addition to high resistance to heat and different diseases, low feed efficiency is still a major concern. Investigation of different feed efficiency traits can open new methods for improving these traits in Iranian local turkeys. Therefore, the aim of this study was to investigate different feed efficiency, growth and carcass traits to estimate their phenotypic parameters, and to analyse the potential differences in growth and feed intake between high and low feed efficiency birds of each measurements in Iranian native turkeys.

MATERIALS AND METHODS

Experimental population

Iranian native male turkeys of the Tatar Turkey Research Centre were used. All steps of experiment were performed according to the animal care and treatment instructions of the University of Guilan, Rasht, Iran, with latitude of 37.1936° N, and longitude of 49.6410° E. The number of 500 birds were raised until the age of 20 weeks under a standard production protocol, which included a standard diet and housing in groups with common drinkers and feeders. At the age of 20 weeks, 75 turkeys were selected randomly and moved to the farm of University of Guilan. They were weighed and identified with a number ring on the right wing. Then they were randomly placed into individual cages 1 m wide, 1 m long and 1 m high. Birds remained in these cages until the end of the trial. From week 20 to 24, turkeys were fed a standard diet (Table 1). The feed was accessible ad libitum, with access to individual drinkers and feeders inside the cage. A lighting program of 16 h of light and 8 h of darkness was used.

Table 1. Diet fed to turkeys from week 20 to 24

Ingredient	Value (%)
Corn	66.7
Soybean meal	20.42
Wheat bran	7
Soy oil	2.41
Calcium carbonate	0.83
Dicalcium phosphate	0.79
Salt	0.25
Sodium bicarbonate	0.15
Sodium bentonite	0.7
Vitamin supplement	0.3
Mineral supplement	0.3
DL-Methionine	0.07
L-Lysine	0.05
Multi-enzyme	0.03

Body weight was evaluated weekly from the beginning (20 weeks old) until the end of the experiment (24 weeks old). Feed consumption was recorded by measuring the weight of the feed added to each feeder daily and weighing the residual feed weekly until the end of the experiment.

Calculation of Feed Efficiency Traits

Data of 5 birds that were sick or in unsuitable cages with higher stress (for example near the door), were excluded from the analysis. In total, 70 birds were involved in further analysis. Average daily gain (ADG) was computed as:

$$\mathrm{ADG} = \frac{\mathrm{BW24\ (g)} - \mathrm{BW20\ (g)}}{\text{days on trial}} \quad (1)$$

where BW20 and BW24 are body weights at 20 and 24 weeks old, respectively. Feed conversion ratio (FCR) was computed as:

$$\mathrm{FCR} = \frac{FI(g)}{\mathrm{WG\ (g)}} \quad (2)$$

where FI is total feed intake during the trial and WG is body weight gain during this time. Metabolic mid-weight (MMW) was computed as:

$$\mathrm{MMW} = \left(\frac{\mathrm{BW20\ (g)} + \mathrm{BW24\ (g)}}{2}\right)^{0.75} \quad (3)$$

The RFI was estimated based on linear regression with the following equation:

$$\mathrm{RFI} = \mathrm{FI} - (b_0 + b_1\ \mathrm{MMW} + b_2\ \mathrm{WG}) \quad (4)$$

where b_0 is the intercept, and b_1 and b_2 are partial regression coefficients. Residual body weight gain (RG) was computed as:

$$\mathrm{RG} = \mathrm{WG} - (b_0 + b_3\ \mathrm{MMW} + b_4\ \mathrm{FI}) \quad (5)$$

where b_0 is the intercept and b_3 and b_4 are partial regression coefficients of MMW and FI, respectively. The RFI and RG were calculated using the R Project for Statistical Computing online software (https://www.r-project.org/).

The residual intake and body weight gain (RIG) was computed as:

$$\mathrm{RIG\ (g)} = \mathrm{RG\ (g)} - \mathrm{RFI\ (g)} \quad (6)$$

Statistical analysis

Pedigrees of birds were unavailable and a small population was used in this study, therefore genetic parameters were not estimated. Descriptive statistics were estimated using R software (https://www.R project.org/). Phenotypic correlations of feed efficiency measures with different traits were calculated. A probability (P) value of < 0.05 was considered statistically significant.

The 70 birds were ranked by feed efficiency measurements (FCR, RFI, RG and RIG) to comprehensively realize the outcomes of phenotypic selection based on feed efficiency measures. The lowest 10% and the highest 10% FCR-ranked, RFI-ranked, RG-ranked and RIG-ranked birds were selected as low and high groups for subsequent analyses. The t-test was used for evaluating each feed efficiency trait between the high and low groups. Birds with high FCR were considered as low feed efficiency (LFE) group and birds with low FCR were considered as high feed efficiency (HFE) group.

Carcass composition

At 24 weeks old, 14 birds, which were 7 birds (10%) with highest FCR and 7 birds (10%) with lowest FCR, were euthanized by cervical dislocation. After slaughter, birds were de-feathered and body weights of carcasses were recorded. Also liver, breast muscle, kidney, abdominal fat, heart, pancreas, bursa, spleen and proventriculus were separated and weighed.

RESULTS AND DISCUSSION

Descriptive statistics

The phenotypic mean, standard deviation (SD), and minimum and maximum values of feed efficiency traits are presented in Table 2.

The means for RFI, RG, and RIG were approximately equal to zero, because they show residuals of a linear model. FCR has a mean of 5.73 gram feed/ gram WG and it has a wide range from 4.02 to 9.08 gram feed/ gram WG. According to the results, the FCR has a wide range which shows this population has a high variation because it is a native breed and breeding programs were not used seriously for meat production targets in this population. It showed that there is a high potential for improving the feed efficiency of Iranian local turkeys. It is similar to the results of a study on the FCR of native chickens which was much greater than that of fast-growing broilers (Yang et al., 2020).

Comparison of the lowest and the highest-ranked birds

The lowest 10% (n=7) and the highest 10% (n=7) of ranked birds based on different feed efficiency measurements (FCR, RFI, RG, and RIG) were separated as two groups (low and high groups) and were compared to each other, as shown in Tables 3. In FCR-ranked birds, the low group is the most efficient group, which has a high feed efficiency. It can be seen that there is a significant difference ($P<0.05$) between low and high FCR-ranked groups in BW24 trait and the low group (high feed efficiency) showed higher body weight at the end of the trial (6887 vs. 6020 g). The interesting results of comparing low and high groups of FCR-ranked birds showed a significant difference between these two groups in WG trait ($P<0.001$), whereas there is no significant difference in FI trait (2210 vs. 1179g). It means that by eating the same amount of food, low group (high feed efficiency) achieves higher weight gain during the trial period. As it was predictable, ADG also has a significant difference between these two groups ($P<0.001$). There was no difference ($P>0.05$) between the two groups for MMW. Additionally, significant differences can be seen in RFI, RG, and RIG measures between high and low groups of FCR-ranked birds.

Table 2. Descriptive statistics of different feed efficiency traits of Iranian local turkeys over the four-week period

Trait	Mean	SD	MIN	MAX
BW20 (g)	4638.66	403.95	3920.00	6264.00
BW24 (g)	6274.19	571.02	5170.00	8020.00
WG (g)	1635.53	356.50	902.00	2930.00
FI (g)	9060.23	1089.38	7159.00	12523.00
ADG (g)	58.41	12.73	32.21	104.64
FCR (g/g)	5.73	1.11	4.02	9.08
MMW	634.46	39.94	566.83	771.39
RFI (g)	0	804.99	-1435.33	2621.24
RG (g)	0	288.51	-715.44	631.07
RIG	0	948.68	-3110.34	1670.29

BW20: body weights in week 20, BW24: body weights in week 24, WG: weight gain, FI: Feed intake, ADG: Average daily gain, FCR: feed conversion ratio, MMW: Metabolic mid-weight, RFI: Residual feed intake, RG: Residual body weight gain, RIG: residual intake and body weight gain

The results of analyzing the RFI-ranked birds separated into two groups are presented in Table 3. The significant difference can be seen in FI trait between two groups (*P*<0.001) which means low RFI-ranked birds eat food less than another group to achieve the same weight gain. All of the other three feed efficiency measurements (FCR, RG, and RIG) were significantly different in these two groups. The results of the RG-ranked birds showed that the high RG group, which is the most efficient group, has significantly lower body weight at the first of the trial (BW20) compared to the low RG group (4578 vs. 5299) (*P*<0.05) (Table 3). Also, the high RG-ranked group was significantly higher in WG and ADG traits compared to another group (*P*<0.001).

It shows that high RG group with significantly lower body weight at the first of the trial had higher WG and finally achieve the same body weight at the end of the trial whereas the amount of eaten food was as same as each other.

As shown in Table 3, WG in the high RIG group, which is the most efficient group, was significantly higher in the high RIG-ranked group (*P*<0.05). Although a significant difference can be seen in FI trait between two high and low RIG groups (8220 vs. 10685). ADG trait has a significant difference (*P*<0.05) but MMW showed no significant difference between the RIG groups (*P*>0.05). All of the other three feed efficiency measurements (FCR, RFI, and RG) were significantly different between these two groups (*P*<0.001). The high RIG group consumed much less food, but achieved greater weight gain compared to the low RIG group.

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Phenotypic correlations

The phenotypic correlations between FCR and weight gain traits (WG and ADG) were large and negative (-0.78) but there was no correlation between FCR and feed intake (Figure 1).

This result is consistent with the outcome of a study on slower-growing broilers which showed that phenotypic selection based on lower FCR can significantly enhance WG, but it had no distinct impact on FI (Wen et al., 2018). It is also in agreement with a study on native chickens, which showed that FCR is negatively correlated with average weight gain, and has a very weak correlation (0.09) with average daily feed intake (Yang et al., 2020).

The phenotypic correlation between FCR and RFI was 0.5 which was in agreement with a study on turkeys (Case et al., 2012) and was higher than another study (Willems et al., 2014). FCR was negatively and highly correlated with RG and RIG.

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Table 3. Comparison of Lowest 10% and Highest 10% birds ranked based on four measurement (FCR, RFI, RG, and RIG)

	FCR-ranked			FCR-ranked			RG ranked			RIG ranked		
Traits	Low	High	*P*-value	Low	High	*P*-value	Low	High	*P*-value	Low	High	*P*-value
BW20 (g)	4677±448[1]	4840±542	*0.5*	4633±266[1]	4478 ±516	*0.49*	5299±526[1]*	4578±498*	0.02	4900±777[1]	4564±371	*0.3*
BW24 (g)	6887±811*	6020±624*	*0.04*	6277±621	6029±472	*0.41*	6595±734	6820±863	0.6	6370±794	6389±502	*0.95*
WG (g)	2210±429***	1179±202***	*< 0.001*	1644±377	1551±199	*0.57*	1296±234***	2242±398***	< 0.001	1470±176*	1825±293*	*0.017*
FI (g)	9584±1804	9467±1410	*0.89*	7934±806***	10464±552***	*< 0.001*	10020±1395	9772±1670	0.76	10685±640***	8220±627***	*< 0.001*
ADG (g)	78.9 ±15.3***	42.1±7.22***	*< 0.001*	58.7±13.5	55.4±7.12	*0.57*	46.3±8.36***	80.1±14.2***	< 0.001	52.5±6.28*	65.2±10.4*	*0.017*
FCR (g/g)	4.34±0.203***	8.07±0.597***	*< 0.001*	4.94±0.620**	6.87±1.20**	*0.002*	7.80±0.689***	4.37±0.233***	< 0.001	7.35±0.916***	4.56±0.405***	*< 0.001*
MMW (g)	662±53.3	632±50.2	*0.29*	634±38.1	617±42.5	*0.42*	677±53.2	655±58.3	0.48	649±66.9	636±36.1	*0.65*
RFI (g)	-399±897*	899±1157*	*0.03*	-1134±174***	1706±608***	*< 0.001*	793±883	-154±794	0.056	1611±714***	-1054±260***	*< 0.001*
RG (g)	443±137***	-504±135***	*< 0.001*	155±197*	-227±295*	*0.014*	-560±103***	467±105***	< 0.001	-411±251***	294±202***	*< 0.001*
RIG	842±828**	-1403±1167**	*0.0013*	1289±282***	-1933±800***	*< 0.001*	-1353±952**	621±775**	0.0011	-2023±703***	1349±193***	*< 0.001*

[1] Means ± standard errors (SD),**P*<0.05, ***P*<0.01, BW20: body weights in week 20, BW24: body weights in week 24, WG: weight gain, FI: Feed intake, ADG: Average daily gain, FCR: feed conversion ratio, MMW: Metabolic mid-weight, RFI: Residual feed intake, RG: Residual body weight gain, RIG: residual intake and body weight gain.

Figure 1. Phenotypic correlations of different feed efficiency traits for the Iranian native tom turkeys (the lower triangle shows the correlation values, and the upper triangle shows the intensity and size of the correlations that is indicated by blue (positive correlation) or blue (negative correlation) circles)

It means that phenotypic selections based on FCR and RG are partially as the same as each other (the correlation of -0.94) and close to phenotypic selections based on RIG (the correlation of -0.71).

According to the phenotypic correlation results, RFI had a high correlation with FI (0.74), whereas the correlation between RFI and WG was 0. These zero correlations were because of the incorporation of MMW and WG in the regression model which was used to evaluate RFI. These outcomes were in agreement with a study on turkeys (Willems et al., 2013). Also, these results were consistent with a study on the slower-growing broiler which found a high and positive correlation between RFI and FI in their research, whereas the phenotypic correlation between RFI and BW was approximately 0 (Wen et al., 2018). These results also were consistent with a study on yellow broilers (Xu et al., 2016). In a study on native chickens, the RFI was positively correlated with FI, while it was not significantly correlated with growth performance, which included WG, MMW, and ADG (Yang et al., 2020). In some studies on other animals like bulls, the same results were observed (Crowley et al., 2010; Montanholi et al., 2009).

However, in a study on turkeys, the low RFI group had significantly less feed intake than the medium and high groups, but had significantly less weight gain (Willems et al., 2013).

In addition, RG had a high positive correlation with weight gain traits (WG and ADG) (0.81), whereas correlations between RG and FI and between RG and MMW were zero. Also, these zero correlations were because of the incorporation of MMW and FI in the regression model which was used to evaluate RG. It is consistent with a study on turkeys (Willems et al., 2013).

RIG had a high negative correlation with FI (-0.63), whereas the correlation between RIG and weight gain traits (WG and ADG) was 0.25. These results are consistent with a study in turkeys in which the most efficient (high) group had significantly lower feed intake and higher weight gain than the medium and low groups. This shows the advantage of merging RFI and RG into a single trait. The high birds according to RIG had both most desirable weight gain and feed intake (Willems et al., 2013). Because the RIG trait has been achieved from a combination of RFI and RG, the phenotypic correlations between RIG and RFI and between RIG and RG were high (-0.96 and 0.61, respectively).

Comparing the high and low feed efficiency birds with the total population

The four most important traits for calculating feed efficiency (BW20, BW24, WG, and FI) were compared between FE, LFE, and the total population (Figure 2). The body weight of both HFE and LFE birds was higher than the body weight of the population at the beginning of the trial (BW20).

At the end of the trial, the body weight of HFE birds was much higher than both of LFE and the population birds. BW24 of LFE was lower than the mean of the total population (Figure 2. b). Also, the WG of the HFE group was much higher than that of the LFE group and the total bird population. In addition, the WG of the LFE group was lower than the average of the whole population (Figure 2 c). HFE and LFE groups had higher levels of feed intake than the total population (Figure 2 d).

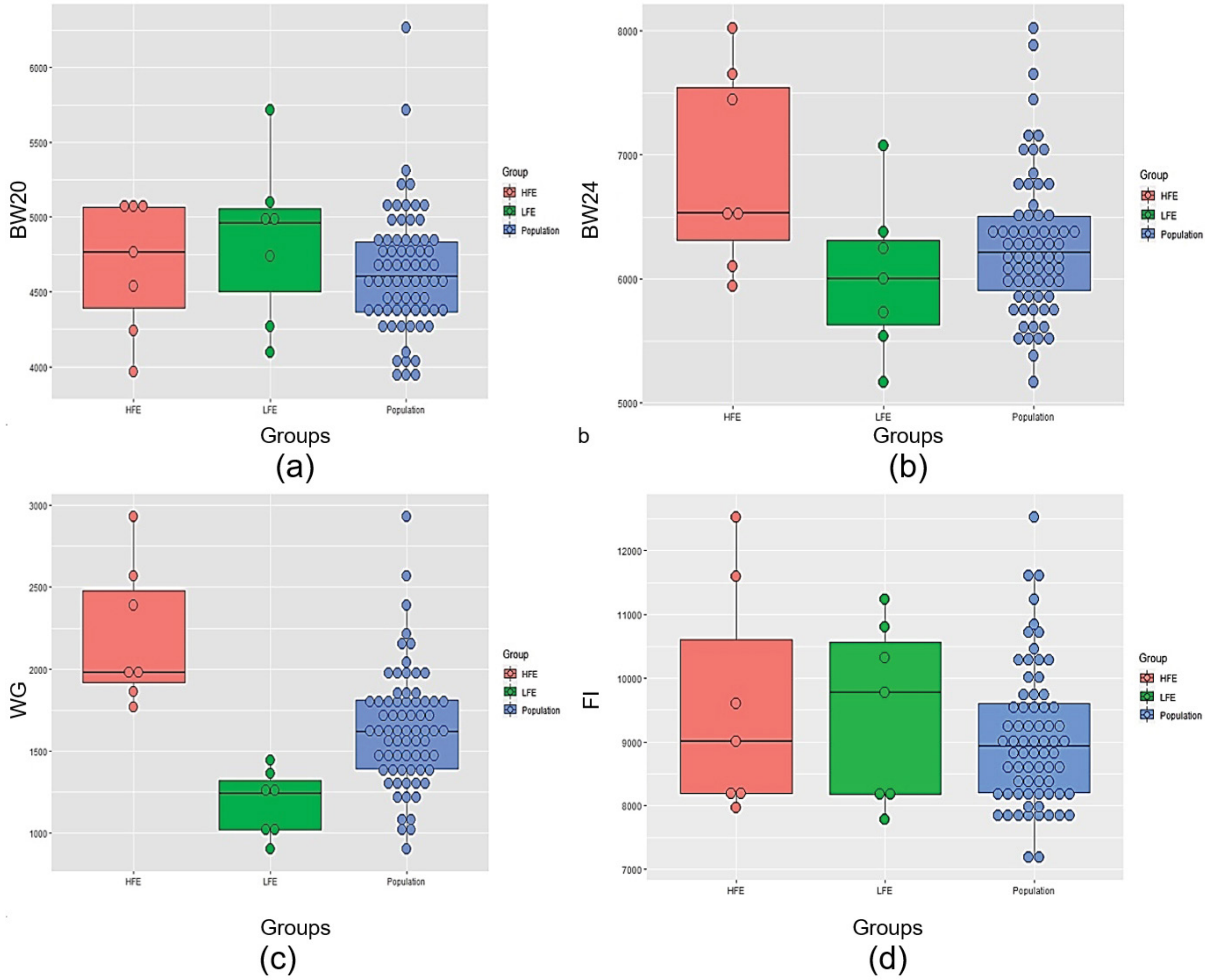

Figure 2. Comparisons of BW20 (a), BW24 (b), WG (c) and FI (d) values among HFE, LFE and population birds (red, green, and blue boxes showed HFE group, LFE group, and total populaton, respectively)

Table 4. Comparison of carcass characteristic HFE and LFE birds

Traits	HFE	LFE	*P*-value
Liver (g)	109±27.5	96.8±13.91	*0.3*
Breast muscle (g)	1287±179*	1081±136*	*0.03*
Kidney (g)	25±3.01	24.5±2.77	*0.7*
Abdominal fat (g)	94.1±37.2	51.3±44.7	*0.07*
Heart (g)	26.8±4.05	26.4±3.09	*0.8*
Pancreas (g)	10.1±1.93	10.7±1.79	*0.5*
Bursa (g)	2.61±1.25	2.82±0.585	*0.68*
Spleen (g)	4.87±2.36	7.28±5.02	*0.27*
Proventriculus (g)	10.5±1.51	11.2±1.14	*0.35*
Carcass (g)	3995±581	3667±273	*0.2*

[1] Means ± standard errors (SD),*$P < 0.05$, **$P < 0.01$

Carcass composition

Carcass characteristics of HFE and LFE groups were compared as shown in Table 4.

Only breast muscle weight was significantly different between the two groups of FCR-ranked birds and HFE birds had higher value. None of the other characteristics showed significant difference. These results showed that improving feed efficiency based on FCR is accompanied with enhanced yield of breast muscle.

CONCLUSION

It is confirmed that there is a high potential for improving the feed efficiency of Iranian local turkeys because of a high variation of feed efficiency trait in this population.

All of four feed efficiency measurements (FCR, RFI, RG and RIG) have their benefits if implemented into a turkey breeding program. Each trait has its advantages and disadvantages.

Breast muscle weight was significantly higher in HFE birds compared to LFE turkeys. Therefore, selecting HFE birds results in higher production of breast muscle tissue.

There are high correlations between the feed efficiency measurements, therefore, choosing based on one of the feed efficiency traits will automatically progress the others. On the other hand, FCR is the most common measurement for evaluating feed efficiency, especially in the native population. Therefore, FCR could be more straightforward in local farms.

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