Research Article

Growth Traits and Carcass Characteristics of Kalosi Chicken Selected Based on Residual Feed Intake (RFI) Phenotype

Andi Tenri Bau Astuti Mahmud[1], Lellah Rahim[2], Muhammad Ihsan Andi Dagong[2*], Sri Rachma Aprilita Bugiwati[2], Wempie Pakiding[2]

[1]Doctoral Program, Faculty of Animal Science, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10 Tamalanrea Makassar, South Sulawesi, Indonesia; [2]Department of Animal Production, Faculty of Animal Science, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10 Tamalanrea Makassar, South Sulawesi, Indonesia.

Abstract | The residual feed intake (RFI) in chickens, which is usually calculated during the growth period, is a measure of feed efficiency that does not depend on the level of production. The study aimed to evaluate the growth performance, carcass quality, physical meat characteristics, and sarcomere properties of Kalosi chicken, which were grouped according to high and low Residual Feed Intake (RFI) phenotype. This study used 64Kalosi chickens kept intensively in individual cages. Chicks were reared from 24 to 70 days old. Data on feed consumption and body weight gain were collected every week. The residual feed intake value was calculated based on the average daily feed intake (ADFI), average daily gain (ADG) and mid-body weight metabolism regression results. At the end of the study (on the 70th day), the chicken was then slaughtered to obtain meat samples that would then be analyzed for the carcass quality, including the percentage of carcass and non carcass, sarcomere, and physical characteristics, including the pH value, water holding capacity, meat color, cooking loss and tenderness. The sarcomere, pH value, color, cooking loss, water holding capacity, and tenderness were all the same, and there was no significant difference in the RFI with feed intake or body weight gain in Kalosi chicken based on high and low RFI phenotypes. High RFI has good carcass quality, which lies in the weight of carcass parts, larger meat and high meat percentage with low bone percentage. Based on these results, it can be concluded that the selection based on the residual feed intake phenotype did not produce any difference in the sarcomere and physical quality characteristics of the meat in Kalosi chickens, so RFI traits could be used as one of the selection parameters for Kalosi chickens.

Keywords | Kalosi Chicken, RFI, Feed Efficiency, Carcass Quality, Physical Meat Quality, Growth Traits.

Received | September 12, 2022; **Accepted** | October 18, 2022; **Published** | December 12, 2022
***Correspondence** | Muhammad Ihsan Andi Dagong, Department of Animal Production, Faculty of Animal Science, Hasanuddin University, Jl. Perintis Kemerdekaan Km. 10 Tamalanrea Makassar, South Sulawesi, Indonesia; **Email:** ihsandagong@gmail.com
Citation | Mahmud ATBA, Rahim L, Dagong MIA, Bugiwati SRA, Pakiding W (2023). Growth traits and carcass characteristics of kalosi chicken selected based on residual feed intake (rfi) phenotype. Adv. Anim. Vet. Sci. 11(1): 1-10.
DOI | http://dx.doi.org/10.17582/journal.aavs/2023/11.1.1.10
ISSN (Online) | 2307-8316

INTRODUCTION

One of the obstacles in developing native chickens is the growth rate and efficiency in using the feed, which is still low compared to commercial broilers. One effort to overcome this is by selecting fast-growing native chickens and efficient feed use.

Feed efficiency can be improved in a number of ways, including genetic and breeding methods. The selection of feed efficiency traits like feed conversion ratio (FCR) and residual feed intake (RFI) has significantly increased commercial broiler feed utilization over the past few decades (Yuan et al., 2015). The feed consumption ratio (FI) to increased body weight is the most succinct way to describe

FCR. Based on multiple linear regression equations of production requirement and body weight (BW) over a given rearing period, RFI is defined as the difference between actual and predicted feed consumption. RFI in chickens acts as a strategy to improve feed efficiency in poultry (Bottje & Carstens, 2009). Thus the relationship between feed intake and growth represented by several properties such as feed conversion ratio (FCR) and residual feed intake (RFI) as the difference between feed intake and estimated feed intake based on energy requirements for production and maintenance. RFI was initially applied by (Carolina, 1984) to beef cattle and was first used on chickens by (Zhang et al., 2017).

FCR and RFI are quite heritable in poultry (Begli et al., 2016; Zuidhof et al., 2014). FCR and RFI are widely used to measure feed efficiency in poultry production. Both FCR and RFI have moderate heritability since genetic selection for one of the two traits capable to increase feed efficiency in chickens (Aggrey et al., 2010). Several studies have shown that the heritability for FCR and RFI has a moderate heritability of 0.29 and 0.50, respectively (Liu et al., 2019). Arkansas broilers revealed that the assessed heritability of FCR and RFI was 0.41 and 0.42 at 5 to about a month and a half old enough, separately (Aggrey et al., 2010). Heritability estimates for FCR and RFI were reported to be 0.91 and 0.21 at 37 to 40 weeks of age and 0.13 and 0.29 at 57 to 60 weeks of age, respectively, after research on the genetic features of the two egg-laying phases of chickens (Yuan et al., 2015). In commercially slow-growing meat breeds, the heritability estimates for the feed efficiency traits FCR and RFI were estimated to be 0.33 and 0.45 respectively (N'Dri et al., 2006). RFI heritability estimates are typically better than FCR heredity estimates, despite estimates of feed efficiency features differing between chicken populations and research. Thus, choosing one of these two characteristics can increase feed use effectiveness. It is common practice to quantify feed efficiency in production animals using the feed conversion ratio (FCR) and residual feed intake (RFI) (Aggrey et al., 2010). FCR describes the ratio of feed intake to body weight gain. Meanwhile, the RFI is defined as the difference between actual and expected feed intake with body weight and weight gain or knowing the difference between actual and predicted feed consumption after determining the value of variability in basic needs and growth (Koch et al., 1963; Luiting, 1990). However, since FCR is highly correlated with FI and ADG, it is difficult to distinguish traits to predict the actual response (Luiting, 1990).

FCR cannot be normally distributed, thus, there is a high correlation between the two components of the trait. FI is usually more difficult to measure than growth so feed efficiency measures have been developed. Feed efficiency is usually expressed as the amount of FI per body weight gain (BWG) which is referred to as the feed conversion ratio (FCR). FCR is estimated to be the ratio between the ratio variance and the phenotypic correlation between the two ratios; however, from the genetics it is slightly correlated and difficult to increase without a direct influence of growth. In contrast, RFI is independent of production traits but moderately correlated with FCR and FI (Koch et al., 1963) Thus, RFI has been considered one of the desirable criteria for genetic improvement of energy efficiency in chicken breeding and was found in several studies (Siegel, 2014).

RFI is needed for maintenance, growth, productivity where a low RFI value is more efficient. According to (Alende et al., 2016), RFI is an index between feed consumption and average body weight gain in a certain period. This feed conversion ratio is related to growth. This is in accordance with the opinion of (Aggrey et al., 2010) that RFI can be used as a livestock breeding program to increase meat production, which is generally focused on growth and feed conversion phenotypes and those with moderate heritability values such as meat production (carcass traits and meat quality).

Although increasing the RFI has a more negligible effect on livestock performance, the physicochemical properties, taste precursors, and biochemical compounds in meat, such as tenderness and flavor, may be affected by genetic improvement for RFI. (Liu et al., 2019) and (Lee et al., 2015) contended that HRFI and The digestive tract, protein synthesis, lipid metabolism, and molecular transport and absorption pathways of LRFI differ from one another. (Abasht et al., 2019) showed that HRFI and LRFI upregulated different metabolic pathways such as sugar nucleotide biosynthesis, glycogen, metabolism and lipid transport. Several studies confirmed the relationship between RFI and meat quality parameters in slow growing chickens (Wen et al., 2018) in slow-growing chicken breast and thigh meat, RFI was found to have no significant correlation with subcutaneous fat thickness or intramuscular fat.

Based on several studies, this study aims to identify differences in the growth traits, sarcomere, carcass quality, and physical characteristics of native chicken meat selected based on the residual feed intake (RFI) phenotype.

MATERIALS AND METHODS

Experimental animals

This study was conducted in March-November 2021 at the Poultry Livestock Laboratory for maintenance. Physical sample testing of meat and its sarcomeres were conducted at the Livestock Products Technology Laboratory and the In Vitro Embryo Production Laboratory, Faculty of Animal Husbandry, Hasanuddin University, Indonesia. The design of this study was divided into 2 groups, namely the HRFI group and the LRFI group. Then a t-test was performed to determine whether there was a difference between each measuring parameter.

The type of native chicken used in this study was Kalosi chicken, obtained from breeding in the poultry production laboratory. A total of 200 DOC chicks were kept in brooding cages until they were 24 days old, then sexed to get 64 male chicks kept in individual cages until they were 70 days old. This study uses roosters because the purpose is for meat growth while female chickens are for breeders. The growth of the rooster is faster than the hen because the hen will be divided into two, namely for basic needs and for egg production. 64 samples met because based on the selection results from the Kalosi chicken population during the brooding phase and were taken based on roosters that met criteria such as agile, healthy body condition and a dominant black color phenotype for further investigation and the observation system was carried out per individual (tail), thus, it was included sufficient.

The chicks are then given an identification number, vaccinated against ND/AI, and weighed. Individual data such as body weight and feed consumption were measured every week from the third week (day 24^{th}) to the tenth week (day 70^{th}) for the RFI measurement as described by (Poompramun et al., 2021). The chickens were then grouped based on the RFI value into two groups, namely high RFI (HRFI) and low RFI (LRFI), as many as 15 chickens with the highest-ranking value from the two groups were then slaughtered at the end of the study. HRFI and LRFI are grouped according to their efficiency level where HRFI shows a positive value which means it is not efficient while LRFI shows a negative value which means it is more efficient.

Residual Feed Intake (RFI)

Between 24 and 70 days of age, total and average daily feed intake (ADFI) were measured since the age of 24 it is a phase that has been separated from the brooding phase so that at that age it can be maintained individually, meanwhile, the age of 70 days is the optimal growth phase. Individual body weight at the beginning and end of the study was measured to calculate the average daily growth (ADG) and metabolic body weight ($MBW^{0.75}$), and feed conversion ratio (FCR). $MBW^{0.75}$ was obtained as the middle BW and was increased to 0.75. RFI is formulated using the model (Aggrey et al., 2010) [RFI = ADFI - (a0 + a1 x $MBW^{0.75}$ + a2 x ADG)].

Carcass quality sample collection and preparation

Carcass characterization and measurement of carcass quality at the end of rearing were taken based on the results of RFI data. A total of 15 Kalosi chickens from HRFI and LRFI were slaughtered and tested for carcass and non-carcass quality. Parameters observed on carcass quality included slaughter weight, carcass weight and percentage of thigh weight, wing weight, back weight, and breast weight, while non carcass weights were non carcass weight and percentage of head weight, neck weight, claw weight, innards weight, and feather weight and boneless on the breast, upper thighs, and lower thighs.

After the chickens were cut and weighed first, then the fur, head, legs, and offal were removed and weighed as non-carcass data. The carcass was weighed and separated between the parts of the carcass. How to measure the parts of the carcass and non carcass is done by weighing each carcass and non carcass piece then from these results a calculation is carried out to determine the percentage of carcass and non carcass and their parts.

Physical meat sample collection and preparation

Figure 1: Meat of Kalosi chicken

A total of 15 chickens from each group (HRFI and LRFI) were slaughtered at the end of the study to obtain a sample of meat quality. The meat obtained from the left *pectoralis major* muscle was then packed in plastic bags and stored at 4°C for 24 h before measuring of pH value with a pH meter. To determine the accurate meat color, a colorimeter (Minolta Konika, Japan) was used to identify the lightness (L*), redness (a*), and yellowness (b*) by using the CIE-LAB system (Van Laack et al., 2000).

Water holding capacity (WHC) was evaluated according to the method described by (Hamm, 1960). For cooking loss, meat samples were weighed, vacuum-packed in plastic bags, and cooked in a water bath at 85°C for 45 min, after reaching the internal temperature in the temperature range of 75°C to 80°C. The sample is then cooled and dried with a paper tissue and reweighed. The difference in sample weight before and after cooking is used to calculate the percentage of cooking loss (Pospiech & Montowska, 2011). The cooked sample used for the cooking loss test was then continued for shear force measurement to measure the tenderness value of the meat.

Sarcomere meat sample collection and preparation

The meat within a size of 1 x 1 x 1.5 cm was used to measure sarcomere length and fiber diameter. Each sample was added with 5% glutaraldehyde (Buffer A) for 4 hours in the refrigerator. Buffer A was replaced with buffer B and incubated for 20 hours at 40˚C or stored in the refrigerator. Then, the meat was mixed with buffer B within the blender or distilled water with 0.9% NaCl until smooth. The fiber was taken using a pipette and placed into a glass object along with the liquid. Then, it was covered with a cover glass.

Samples were observed under a microscope with a magnification of 40-100 times. For measurements, photos of objects were taken using Axio vision 4.8 software. The sarcomere length was first the image and entered into the application, then the image was scanned with a magnification of 40-100 times.

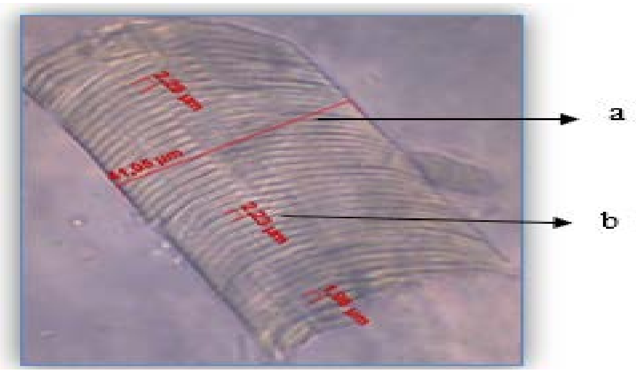

Figure 2: Measurement of sarcomere length and muscle fiber diameter. a. Diameter of muscle fibers, b. Sarcomere length.

Statistical Analysis

All the meat quality data were analyzed using an independent t-test using SPSS software version 22.

RESULTS

Growth Traits

Improving feed efficiency plays important in poultry breeding strategies. The residual feed intake (RFI) in chickens is measured during the growth period and does not depend on the level of production.

RFI was significantly related to feeding conversion ratio and average daily feed consumption. Our results were not significantly related to initial body weight (BW), final weight gain, and average daily body weight. It is estimated that the consumption of LRFI is lower than HRFI while ADG is not significantly different because the feed consumed in LRFI is absorbed more than that of HRFI.

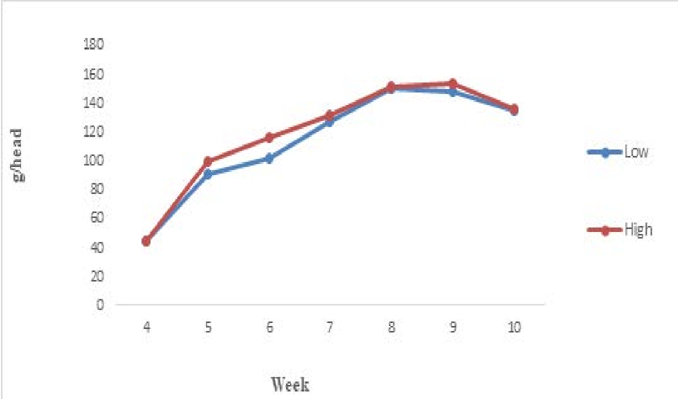

Figure 3: The average daily growth (ADG) of Kalosi chickens based on the RFI phenotype during the rearing period.

The growth data of Kalosi chicken is presented in Figure 3. Our findings showed the growth of LRFI and HRFI increased every week, however, our results did not significantly different. RFI was related to FI, while RFI was not significant with growth performance. RFI was related to FI, while RFI was not significant with growth performance. While growth, including BW, MBW, and ADG, has no significant correlation with ADFI, RFI has a significant positive correlation with ADFI. The findings were consistent with this result, which is research on broiler chickens (Metzler-Zebeli et al., 2017), livestock (Nkrumah et al., 2004) and sheep (Zhang et al., 2017) which suggested that RFI was phenotypically independent of growth performance.

Residual Feed Intake (RFI)

The average feed consumption, Body Weight (BW_{24}, BW_{70}, BW_{Met}), Average Daily Growth (ADG), Feed Conversion Ratio (FCR), Average Daily Feed Intake (ADFI), and Residual Feed Intake (RFI) of Kalosi chickens are presented in Table 1.

The results delineate that the values of Body Weight (BW_{24}, BW_{70}, BW_{Met}), ADG were not significantly different (P>0.05), although the values of BW_{70}, $BW_{Met,}$ and ADG tended to be greater in HRFI than LRFI. Meanwhile, the value of FCR, and ADFI was significantly different

Table 1: Body weight (BW_{24}, BW_{70}, BW_{Met}), ADG, FCR, ADFI and RFI (Residual Feed Intake) phenotype of Kalosi chicken

Parameters	HRFI (n=15)	LRFI (n=15)	P-Value
Body Weight 24 (BW_{24}) (g)	185.60±20.17	191.27±25.11	0.50
Body Weight 70 (BW_{70}) (g)	1058.60±138.64	1033.93±279.70	0.76
Body Weight Metabolism (BWMet) (g)	124.41±11.11	122.61±20.79	0.77
Average Daily Growth (ADG) (g)	18.57±2.80	17.93±5.84	0.70
Feed Conversion Ratio (FCR)	2.92±0.32	2.41±0.43	0.00**
Average Daily Feed Intake (ADFI) (g)	53.62±4.36	40.98±3.11	0.00**
Residual Feed Intake (RFI)	6.19±2.52	-6.42±2.04	0.00**

Notes: HRFI; High residual feed intake, LRFI; Low residual feed intake.
Different superscripts in the same row showed a significant difference (P<0.001). ** P < 0.001

(P<0.01) based on HRFI and LRFI groups. The value of FCR in HRFI is preponderant than the LRFI group. This indicates that the ability of chickens to convert meat is better at LRFI, which is denoted by a lower value, but body weight which is not significantly different in the two RFI groups.

The Table 1 shows a significant difference in the average daily feed intake of the two groups of Kalosi chickens selected based on their RFI values (high and low RFI). This is presumably because the metabolic weight of the LRFI is lower than the HRFI, thus, the consumption is different as well (Wen et al., 2018) showed that low FCR can improve feed efficiency and ADG without affecting native chickens' feed consumption. The low RFI group tended to have a lower average daily feed consumption than the high RFI group, but there was no difference between the HRFI and LRFI groups regarding body weight differences.

Carcass Characteristics

Differences in carcass characteristics between the two RFI groups are shown in Table 2. Slaughter weight, percentage of carcass weight, and non-carcass weight in the HRFI group were better than in the LRFI group, although there was no significant difference. It had no different ; however, the value was higher. This is presumably because the weight of metabolism in LRFI is lower than HRFI so that consumption is also different. The percentage of carcass weight and non-carcass weight was relatively larger, in HRFI because the slaughter weight was also high and in line with the final weight and feed consumption of Kalosi chickens. The results of this study are in accordance with (Yang et al., 2020) that there is no difference in carcass quality in the HRFI and LRFI groups, these other fixed tend to be larger in HRFI.

In general, the percentage of the carcass in LRFI tends to be higher than HRFI but there is no significant difference in the carcass parts. The percentage of the carcass on the breast, back, and wings was higher in LRFI than in HRFI. While the carcass in the upper thigh and lower thigh is larger in HRFI than LRFI. This is presumably because the LRFI carcass formation is more than HRFI so it is categorized as more efficient. In addition, in the breast part, from the separation between bone and meat, the LRFI section shows a higher percentage of bone than HRFI, which causes the bone height to be seen

The percentage of meat in the carcass was not significantly different (P>0.05) was greater in HRFI than LRFI, likewise with the ratio between meat and bones. Meanwhile, the percentage of bone did not differ significantly but tended to be greater in LRFI than HRFI.

The percentage of the breast is greater than the other carcass pieces, in which LRFI is 25.62% and HRFI is 25.57%. Judging from the composition of the percentage of meat and bone in HRFI it is better than LRFI because of the high percentage of meat and low percentage of bone which indicates that the carcass portion of HRFI is dominated by meat.

The percentage of upper thighs and lower thighs in the percentage of meat is greater in HRFI than LRFI, while the bone is greater in LRFI than HRFI. This indicates that the carcass percentage of the upper and lower thighs is of better quality because it is seen from the larger percentage of meat in HRFI and bone in LRFI. In this case, more meat than bone means that the bone size is smaller in HRFI than LRFI. (Massolo et al., 2019) stated that the amount of breast weight as a measure of meat quality because most muscles are the largest carcass component.

The percentage of non carcass in HRFI tends to be higher than LRFI but there is no significant difference in non carcass parts. The percentage of non-carcass on the head and neck was higher in LRFI than HRFI, while on the claws,

Table 2: Percentage and parts of carcass and non-carcass of Kalosi chicken based on RFI phenotype

Parameters	HRFI ± SD (n=15)	LRFI ± SD (n=15)	P-value
Slaughter Weight (g)	1035.13±139.47	919.16±104.10	0.02*
Carcass (%)	64.39±1.76	64.08±2.39	0.69
Non Carcass (%)	48.85±1.95	47.65±2.28	0.13
Commercial cut			
Breast (%)	25.57±1.72	25.62±2.28	0.95
Back (%)	23.52±2.05	23.98±2.15	0.55
Wings (%)	14.99±0.66	15.40±0.76	0.14
Upper Thigh (%)	17.93±1.05	17.19±1.39	0.11
Lower Thigh (%)	17.98±0.78	17.81±1.11	0.63
Meat	48.85±1.95	47.65±2.28	0.13
Breast (%)	81.18±2.43	80.44±4.54	0.58
Upper Thigh (%)	76.81±4.92	74.32±7.61	0.30
Lower Thigh (%)	79.69±4.37	78.31±3.29	0.34
Bone	12.65±1.59	12.78±1.31	0.79
Breast (%)	18.82±2.43	19.56±4.54	0.58
Upper Thigh (%)	23.19±4.92	25.68±7.61	0.30
Lower Thigh (%)	20.31±4.37	21.68±3.29	0.34
Meat to Bone Ratio	4.45±0.83	4.20+1.08	0.46
Non Carcass			
Head (%)	11.83±1.19	12.43±1.95	0.32
Neck (%)	17.18±2.10	17.46±2.26	0.73
Claw (%)	15.74±0.90	15.61±1.98	0.82
Innards (%)	27.58±1.19	27.04±2.35	0.58
Feather(%)	27.66±4.29	27.45±6.56	0.92

Notes: HRFI; High residual feed intake, LRFI; Low residual feed intake * $P < 0.05$

offal and feathers tended to be higher in HRFI than LRFI. This is presumably from the size of the long intestine which can be seen from the greater weight of the viscera.

Physical Meat and Sarcomere Characteristics

Data on the average physical quality of Kalosi chicken meat which includes pH, color, water holding capacity, tenderness, and cooking loss, are presented in Table 3. There is no difference in the pH value, color, water holding capacity, tenderness, and cooking loss between the HRFI and LRFI chicken groups. Similar results were also reported by (Poompramun et al., 2021) who also found that there was no significant difference in the physical quality of meat in the two groups of high RFI (HRFI) and low RFI (LRFI) Korat chickens.

These results indicate that the physical quality characteristics of Kalosi chicken meat based on the best RFI phenotype were obtained in the low RFI group which was characterized by low RFI and FCR values followed by pH, color, and DPD values that were close to normal meat quality.

Table 3: Physical meat characteristics of Kalosi chicken based on RFI phenotype

Parameters	HRFI (n=15)	LRFI (n=15)	P-Value
pH	6.43±0.18	6.47±018	0.64
Color			
a*	4.68±2.79	6.02±3.04	0.22
b*	10.62±4.21	11.66±2.63	0.42
L*	32.66±14.38	33.96±14.13	0.80
Tenderness			
Raw meat	0.55±0.13	0.56±0,11	0.82
Cooked meat	0.84±0.13	0.87±0.11	0.41
WHC	37.91±14.69	41.58±17.16	0.54
Cooking loss	14.60±11.88	15.27±7.31	0.85

Notes: HRFI; High residual feed intake, LRFI; Low residual feed intake; pH; Power of hydrogen, (L*) lightness, (a*) redness, (b*) yellowness, WHC; Water holding capacity. ** $P < 0.001$, * $P < 0.05$

Each type of muscle both from mammals and from birds or fish has the same physical structure (Osawa et al., 2001). Each muscle is wrapped and separated from each other by the connective tissue epimysium. In general, the rheological properties of meat depend on the muscular fibers and connective tissue. Therefore, the major cause of the meat toughness is due to the shortening of the muscles during the rigormortis phase as a result of the cattle moving. The shorten muscles during rigormortis produce flesh with a short sarcomere length and contain more actymyosin or complex interfilamentous bonds. The average value of sarcomere length and fiber diameter as presented in Table 4.

Table 4: Sarcomere length and fiber diameter (μm) of Kalosi chicken based on RFI phenotype

Parameters	HRFI (n=15)	LRFI (n=15)	P-Value
Sarcomere length (μm)	1.940.19	2.04018	0.13
Fiber diameter (μm)	41.675.75	40.176.32	0.50

Notes : HRFI ; High residual feed intake, LRFI ; Low residual feed intake ** $P < 0.001$, * $P < 0.05$

The sarcomere length and the diameter of meat fiber in Kalosi chicken were 1.94 m and 41.67 m based on HRFI, while were 2.04 m and 40.17 m based on LRFI. The sarcomere length and fiber diameter did not show significant differences in the RFI group. However, based on the value of sarcomere length and fiber diameter, LRFI showed a better value than HRFI due to changes in muscle fiber diameter. The shorter of muscle before the rigor mortis process, the shorter length of the sarcomere, causes the meat becomes tough.

DISCUSSIONS

These outcomes are consistent with the findings of the research carried out by (Liu et al., 2019), which stated that LRFI chickens consumed significantly less feed than HRFI chickens but did not differ in body weight parameters. These results indicate that selection on RFI properties can impact decreasing feed intake but does not cause changes in body weight gain.

Based on Table 1, a significant difference are shown in the average daily feed intake based on their RFI values, however, there is no difference on body weight between the HRFI and LRFI. In general, RFI selection can improve feed efficiency (Wen et al., 2018). Success in meat-producing poultry farming is not only measured by feed efficiency, but also by the proportion of muscle and low fat (Zerehdaran et al., 2004). Several studies reveal that low RFI is very effective in reducing fat in broiler chicken (Richards et al., 2003; Yang et al., 2010).

In addition, native chickens' FCR is significantly better than that of fast-growing broilers (Brameld & Parr, 2016) (Lee & Aggrey, 2016). (Yang et al., 2020), research introduced that there was an extraordinary potential to improve the feed effectiveness of Wannan Yellow chickens. Additionally, there was no significant correlation between FCR and ADFI, and there was a significant negative correlation between FCR and ADG (Yang et al., 2020). However, RFI has no significant correlation with growth performance, such as weight, MBW0,75, or ADG, while ADFI has a significant positive correlation with RFI.Previous findings back up this finding from broiler chickens (Metzler-Zebeli et al., 2018), cattle (Nkrumah et al., 2004), and sheep (Zhang et al., 2017).

Meanwhile, the differences between HRFI and LRFI in carcass characteristics are presented in Table 2. It shows the percentage of meat for upper thighs and lower thighs in HRFI is better than LRFI, however, LRFI is better in the percentage of bone. (Asril et al., 2016) stated that carcass weight will affect the percentage of carcass and its parts. The breast and thighs are more dominant during growth than the wings. (Nita et al., 2015) stated that based on the size and structure of wing feathers, it can be predicted that food substances in the form of protein and energy will be used in large quantities for the formation of bones, meat, and feathers. Furthermore, Table 3 tells us the results are close to normal meat quality. The value of average pH is in normal category. This finding is consistent with studies in slower growing broilers (Wen et al., 2018) and cattle (Fidelis et al., 2017).

On the other hand, Table 3 describes that the pH of meat at HRFI is lower than at LRFI. It is different from the previous results, showing that the LRFI is lower than the HRFI although there is no significance (Yang et al., 2020). Additionally, the pH variation is determined by the amount of glycogen in the muscle of the meat. The high glycogen in the muscle can lower the pH of the meat (Berri et al., 2005).

Additionally, according to (Beauclercq et al., 2017), pH has a significant impact on the quality of poultry meat and is closely linked to muscle processing capacity and sensory quality. As a result, there may be more muscle glycogen in high RFI chickens than in low RFI chickens, resulting in a lower muscle pH. High pH meat results in black, tough, and dry meat (Alnahhas et al., 2014), whereas meat with a low pH results in meat becoming pale, brittle, and exudative (Woelfel & Sams, 2001). Muscle undergoes structural changes as a result of the meat's quality(Alnahhas et al., 2014). In this study, the average pH value was in the normal group. Our results showed that feed efficiency may not have an impact on the physical quality of the meat.

Meanwhile, Table 4 illustrates the sarcomere length and fiber diameter (μm) of Kalosi meat by the RFI group which there are no significant differences. According to (Libro, 2010), the average length of the sarcomere is 2.5 m for relaxed muscles, while contracting muscles can be shorter than 1.5 m. The changes in muscle fiber diameter occur indirectly. Additionally, changes in muscle fiber diameter are influenced by the length of the sarcomere. The increase in the average value of sarcomere length was followed by a decrease in the average fiber diameter value. The diameter of muscle fibers will lengthen along with the muscle contracts, and shorten in a relaxed (Simoes et al., 2005). These muscles consist of cylindrical muscle cells called muscle fibers. The muscle fibers contain myofibrils. These myofibrils are contractile of muscle cells (Osawa et al., 2001).

CONCLUSIONS

The results of this research indicate that efforts to increase feed efficiency by reducing the RFI value of Kalosi native chickens can reduce daily feed intake but do not affect body weight gain. There is no difference in the sarcomere and physical characteristics of Kalosi chicken meat (pH, color, water holding capacity, tenderness, and cooking loss) based on high RFI and low RFI phenotypes so the selection of native chicken based on the RFI phenotype can be one of the selection parameters in producing free-range chickens that are efficient in feed use. In addition, the selection of Kalosi chicken with a low RFI value had an impact on the meat tenderness based on the sarcomere value. HRFI has good carcass quality, which lies in the weight of the carcass, and meat is larger and the percentage of meat is high while the percentage of bone is low. In addition, HRFI has a low innards weight.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the field technicians who have assisted in carrying out research activities and the poultry production laboratory of the Hasanuddin University Faculty of Animal Science, which has provided individual cage facilities to support this research. In addition, the authors would like to show their gratitude to doctoral dissertation research and National Research Priority flagship program research for state universities for the 2021 fiscal year Number: 007/E4.1/AK.04.PRN/2021 dated September 14, 2021 who have funded this study.

CONFLICT OF INTEREST

The authors do not have any conflict of interest.

NOVELTY STATEMENT

As one of the stages of feed efficiency and genetic development of Indonesian native chickens, this study is the first to provide findings relating to performance characteristics and meat quality based on Residual Feed Intake of Kalosi chickens.

AUTHORS CONTRIBUTIONS

ATBAM: Collecting data, selecting chicken, and data analysis.
LR: Assembled research design and reviewed the manuscript.
MIAD: Assembled research design, data analysis, and manuscript writing.
SRAB: Reviewed and advised for fine-tuning manuscript.
WP: Coordinated in all research activities and data collection.

REFERENCES

Abasht B., Zhou N., Lee W. R., Zhuo, Z., & Peripolli, E. (2019). The metabolic characteristics of susceptibility to wooden breast disease in chickens with high feed efficiency. Poult. Sci., 98(8): 3246–3256. https://doi.org/10.3382/ps/pez183.

Aggrey S. E., Karnuah A. B., Sebastian B., Anthony N. B. (2010). Genetic properties of feed efficiency parameters in meat-type chickens. Genet. Select. Evol., 42(1): 1–5. https://doi.org/10.1186/1297-9686-42-25.

Alende M., Lancaster P. A., Spangler M. L., Pordomingo A. J., Andrae J. G. (2016). Residual feed intake in cattle : Physiological basis . A review residual feed intake in cattle : physiological basis . A Review El consumo residual en bovinos : base fisiológica . Revisión bibliográfica. Revi. Argentina de Prod. Anim., 36(2): 49–56.

Alnahhas N., Berri C., Baeza E., Chabault M., Le Bihan-Duval E., Boulay M., Jego Y., Baumard Y. (2014). Selecting broiler chickens for ultimate pH of breast muscle: Analysis of divergent selection experiment and phenotypic consequences on meat quality, growth, and body composition traits. J. Anim. Sci., 92(9): 3816–3824. https://doi.org/10.2527/jas.2014-7597.

Asril M., Samadi S., Usman Y. (2016). Effect of substitution of amtabis fermented with Aspergillus Niger on weight and percentage of croiler carcasses. Scientific J. Unsyiah Agric. Student. 1 (1): 835 – 842. https://doi.org/10.17969/jimfp.v1i1.1240.

Beauclercq S., Hennequet-Antier C., Praud C., Godet E., Collin A., Tesseraud S., Métayer-Coustard S., Bourin M., Moroldo M., Martins F., Lagarrigue S., Bihan-Duval E. Le, Berri C. (2017). Muscle transcriptome analysis reveals molecular pathways and biomarkers involved in extreme ultimate pH and meat defect occurrence in chicken. Scient. Rep., 7(1): 1–13. https://doi.org/10.1038/s41598-017-06511-6.

Begli H. E., Torshizi R. V., Masoudi A. A., Ehsani A., Jensen J. (2016). Longitudinal analysis of body weight, feed intake and residual feed intake in F2 chickens. Livest. Sci., 184: 28–34. https://doi.org/10.1016/j.livsci.2015.11.018.

Berri C., Debut M., Sante-Lhoutellier V., Arnould C., Boutten B., Sellier N., Baeza E., Jehl N., Jego Y., Duclos M. J., Le Bihan-Duval E. (2005). Variations in chicken breast meat quality: Implications of struggle and muscle glycogen content at death. Brit. Poult. Sci., 46(5): 572–579. https://doi.org/10.1080/00071660500303099.

Bottje W. G., Carstens G. E. (2009). Association of mitochondrial function and feed efficiency in poultry and livestock species. J. Anim. Sci., 87(14 Suppl). https://doi.org/10.2527/jas.2008-1379.

Brameld J. M., Parr T. (2016). Improving efficiency in meat production. Proceed. Nutrit. Soci., 75(3): 242–246. https://doi.org/10.1017/S0029665116000161.

Carolina N. (1984). Linear index selection to improve traits defined as ratio. J. Anim. Sci. 59(5): 1185-1193. https://doi.org/10.2527/jas1984.5951185x

Fidelis H. A., Bonilha S. F. M., Tedeschi L. O., Branco R. H., Cyrillo J. N. S. G., Mercadante M. E. Z. (2017). Residual feed intake, carcass traits and meat quality in Nellore cattle. *Meat Sci.*, *128*: 34–39. https://doi.org/10.1016/j.meatsci.2017.02.004.

Hamm (1960). Biochemistry of meat hydration. Advances in food research cleveland 10,435-443. Salami., 31–38. https://doi.org/10.1016/b978-0-12-809598-0.00002-0.

Koch R. M., Swiger L. A., Chambers D, Gregory K. E. (1963). Efficiency of feed use in beef cattle. J. Anim. Sci. 22:486-494.

Lee J., Aggrey S. E. (2016). Transcriptomic differences of genes in the avian target of rapamycin (avTOR) pathway in a divergent line of meat-type chickens selected for feed efficiency. Genet. Molecul. Res., 15(2): 1–11. https://doi.org/10.4238/gmr.15027120.

Lee J., Karnuah A. B., Rekaya R., Anthony N. B., Aggrey S. E. (2015). Transcriptomic analysis to elucidate the molecular mechanisms that underlie feed efficiency in meat-type chickens. Molecul. Genet. Genomi., 290(5): 1673–1682. https://doi.org/10.1007/s00438-015-1025-7.

Libro. (2010). Handbook of meat processing. In *Handbook of meat processing* . https://doi.org/10.1002/9780813820897.ch30.

Liu R., Liu J., Zhao G., Li W., Zheng M., Wang J., Li Q., Cui H., Wen J. (2019). Relevance of the intestinal health-related pathways to broiler residual feed intake revealed by duodenal transcriptome profiling. Poult. Sci., 98(3): 1102–1110. https://doi.org/10.3382/ps/pey506.

Luiting P. (1990). Genetic variation of energy partitioning in laying hens: Causes of variation in residual feed consumption. World's Poult. Sci. J., 46(2): 133–152. https://doi.org/10.1079/WPS19900017.

Metzler-Zebeli B. U., Magowan E., Hollmann M., Ball M. E. E., Molnar A., Lawlor P. G., Hawken R. J., O'Connell N. E., Zebeli Q. (2017). Assessing serum metabolite profiles as predictors for feed efficiency in broiler chickens reared at geographically distant locations. Brit. Poult. Sci., 58(6): 729–738. https://doi.org/10.1080/00071668.2017.1362688.

Metzler-Zebeli B. U., Magowan E., Hollmann M., Ball M. E. E., Molnár A., Witter K., Ertl R., Hawken R. J., Lawlor P. G., O'Connell N. E., Aschenbach J., Zebeli Q. (2018). Differences in intestinal size, structure, and function contributing to feed efficiency in broiler chickens reared at geographically distant locations. Poult. Sci., 97(2): 578–591. https://doi.org/10.3382/ps/pex332.

N'dri A. L., Mignon-Grasteau S., Sellier N., Tixier-Boichard M., Beaumont C. (2006). Genetic relationships between feed conversion ratio, growth curve and body composition in slow-growing chickens. Brit. Poult. Sci., 47(3): 273–280. https://doi.org/10.1080/00071660600753664.

Nita N. S., E. Dihansih A. (2015). Effect Of Different Levels Of Protein Feed Against The Weight Of Carcass Components And Non Carcass Component Of Male Layer. J. Archipel. Farm, 1(2): 89–96.

Nkrumah J. D., Basarab J. A., Price M. A., Okine E. K., Ammoura A., Guercio S., Hansen C., Li C., Benkel B., Murdoch B., Moore S. S. (2004). Different measures of energetic efficiency and their phenotypic relationships with growth, feed intake, and ultrasound and carcass merit in hybrid cattle. J. Anim. Sci., 82(8): 2451–2459. https://doi.org/10.2527/2004.8282451x.

Osawa K., Miyazaki K., Shimura S., Okuda J., Matsumoto M., Ooshima, T. (2001). Identification of cariostatic substances in the cacao bean husk: Their anti-glucosyltransferase and antibacterial activities. J. Dental Res., 80(11): 2000–2004. https://doi.org/10.1177/00220345010800111001.

Poompramun C., Molee W., Thumanu K., Molee A. (2021). The significant influence of residual feed intake on flavor precursors and biomolecules in slow-growing Korat chicken meat. Anim. Biosci., 34(10): 1684–1694. https://doi.org/10.5713/AB.20.0736.

Pospiech E., Montowska M. (2011). Technologies to improve water-holding capacity of meat. Cont. Meat Qualit, April 2016, 61–80.

Richards M. P., Poch S. M., Coon C. N., Rosebrough R. W., Ashwell C. M., McMurtry J. P. (2003). Feed restriction significantly alters lipogenic gene expression in broiler breeder chickens. J. Nutrit., 133(3): 707–715. https://doi.org/10.1093/jn/133.3.707.

Massolo R., Mujnisa A., Agustina L. (2019). Percentage of carcass and abdominal fat of broilers given prebiotic dahlia tuber inulin (Dahlia variabillis). Anim. Feed Nutrit. Bulet. 12(2):50-58.

Siegel P. B. (2014). Evolution of the modern broiler and feed efficiency. Annu. Rev. Anim. Biosci., 2: 375–385. https://doi.org/10.1146/annurev-animal-022513-114132.

Simoes J. A., Mendes M. I., Lemos J. P. C. (2005). Selection of muscles as indicators of tenderness after seven days of ageing. Meat Sci., 69(4): 617–620. https://doi.org/10.1016/j.meatsci.2004.10.012.

Van Laack R. L. J. M., Liu C. H., Smith M. O., Loveday H. D. (2000). Characteristics of pale, soft, exudative broiler breast meat. Poult. Sci., 79(7): 1057–1061. https://doi.org/10.1093/ps/79.7.1057.

Wen C., Yan W., Zheng J., Ji C., Zhang D., Sun C., Yang N. (2018). Feed efficiency measures and their relationships with production and meat quality traits in slower growing broilers. Poult. Sci., 97(7): 2356–2364. https://doi.org/10.3382/ps/pey062.

Woelfel R. L., Sams A. R. (2001). Marination performance of pale broiler breast meat. Poult. Sci., 80(10): 1519–1522. https://doi.org/10.1093/ps/80.10.1519.

Yang L., Wang X., He T., Xiong F., Chen X., Chen X., Jin S., Geng Z. (2020). Association of residual feed intake with growth performance, carcass traits, meat quality, and blood variables in native chickens. J. Anim. Sci., 98(7): 1–11. https://doi.org/10.1093/jas/skaa121.

Yang X., Zhuang J., Rao K., Li X., Zhao R. (2010). Effect of early feed restriction on hepatic lipid metabolism and expression of lipogenic genes in broiler chickens. Res. Vet. Sci., 89(3): 438–444. https://doi.org/10.1016/j.rvsc.2010.04.003.

Yuan J., Dou T., Ma M., Yi G., Chen S., Qu L., Shen M., Qu L., Wang K., Yang N. (2015). Genetic parameters of feed efficiency traits in laying period of chickens. Poult. Sci.,

94(7): 1470–1475. https://doi.org/10.3382/ps/pev122.
Zerehdaran S., Vereijken A. L. J., Van Arendonk J. A. M., Van Der Waaij E. H. (2004). Estimation of genetic parameters for fat deposition and carcass traits in broilers. Poult. Sci., 83(4): 521–525. https://doi.org/10.1093/ps/83.4.521.
Zhang X., Wang W., Mo F., La Y., Li C., Li F. (2017). Association of residual feed intake with growth and slaughtering performance, blood metabolism, and body composition in growing lambs. Scient. Rep., 7(1): 1–11. https://doi.org/10.1038/s41598-017-13042-7.
Zuidhof BL, S., VL C., DR K., FE R. (2014). Growth , efficiency, and yield of commercial broilers from 1957, 1978, and 2005. Poult. Sci., 93: 2970–2982.