Uttar Pradesh Journal of Zoology

Volume 45, Issue 14, Page 26-33, 2024; Article no.UPJOZ.3664
ISSN: 0256-971X (P)

Impact of Low-Quality Rice on Broiler Chicken Performance and Gene Expression

Ameera M. Said [a*], Ali R. Abed [a] and Latif I. Kadhim [a]

[a] Department of Public Health, Collage of Veterinary Medicine, University of Kerbala, Iraq.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i144176

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/3664

Original Research Article

Received: 15/04/2024
Accepted: 19/06/2024
Published: 21/06/2024

ABSTRACT

Rice is a promising grain that is reasonably priced and may be effectively added to chicken rations. It is more readily available than corn and has comparable protein and metabolizable energy levels. The current study aimed to see the effect of partially replacing corn with low quality rice and see its effect on broiler chickens. by measuring their live weights, feed intake, weight gain, and feed conversion ratio. A total of one hundred sixty (160) one-day-old unsexed chicks of the Rose 308 breed were purchased from a local hatchery. The birds were fed on basal diet for two weeks (14 days). On the fifteenth of the experiment, the birds were randomly divided into 4 groups each group contain forty (40) birds and each group was subdivided into two -replicates, each replicate contain 20 birds, in a sector design. The control group (T0) was fed on the basal diet, while the birds in group T1, T2, and T3 were fed rations with 10 percent, 20 percent, and 30 percent rice, respectively, replacing corn in the diet. The study showed that there is a significant increase in live body weight and weight gain in the control group and the 10 percent rice group when compared to the rest of the groups and there is a significant increase in the amount of food intake and the

**Corresponding author: Email: mameera079@gmail.com;*

Cite as: *Said, Ameera M., Ali R. Abed, and Latif I. Kadhim. 2024. "Impact of Low-Quality Rice on Broiler Chicken Performance and Gene Expression". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (14):26-33. https://doi.org/10.56557/upjoz/2024/v45i144176.*

amount of food conversion ratio in the 20 % and 30 % rice groups when compared to the control group and the 10 % groups. Standards of broiler chickens also increase in the IGF-1 in the 20 % and 30 % rice group with convergence in sensory test results. The study concluded that increasing the rice percentage to more than 10 percent leads to a negative impact on the production.

Keywords: Broiler; low quality rice; productive performance; IGF-1.

1. INTRODUCTION

The primary source of protein in broiler feed is typically derived from plant-based ingredients, such as soybean meal, corn gluten meal and canola meal. These ingredients are rich in essential amino acids, which are the building blocks of protein. Amino acids such as lysine, methionine and threonine are particularly important in broiler diets as they are limiting amino acids, meaning their availability can affect overall protein synthesis [1].

The food or diet given to broiler chickens has a significant impact on their gut health. The gut plays a crucial role in digestion, nutrient absorption and immune function, and maintaining a healthy gut is essential for the overall well-being and performance of broiler chickens (Taylor-Bowden et al*.,* 2021).

Soybean meal and yellow corn are standard feed ingredients because of their high nutritional levels. It seems that the developing world's use of poultry products such as meat and eggs is rising. As a result, the cost of producing chicken would rise due to an increase in worldwide demand for the primary feedstuffs for poultry [2].

Rice stands out as a versatile and energy-dense option, offering potential benefits to broiler chickens when incorporated into their diets. The use of rice in chicken diets has grown in popularity. Being an excellent source of protein, energy, vitamins, and minerals, it has a lot of promise as a nutritional element [3].

Chicken insulin-like growth factor I (IGF-1) has been identified as a biological candidate gene responsible for body composition, growth, fat deposition & metabolic activities in chickens (Hosnedlova et al., [4] and it is a critical regulator of satellite cell proliferation & skeletal muscle hypertrophy [5]. The IGF-1 is produced in the liver in response to the action of the growth hormone in the pituitary [6]. The liver is the primary organ where they produce IGF-1, but some organs such as the pituitary, brain, ovary, spleen, & muscle, are also known to synthesize IGF-1 [7]. Insulin-like growth factor-1 (IGF-1) is a member of the polypeptide hormone family, preproinsulin, which consisted of proinsulin, IGF-I, IGF-II and C peptide with several metabolic functions, IGF-1 has a great importance during postnatal growth and is mainly produced by the liver under the influence of growth hormone and nutritional conditions & acting in an endocrinological manner on its target tissues [8].

2. MATERIAL AND METHODS

A total of one hundred sixty (160) one-day-old unsexed chicks of the Rose 308 breed were purchased from a local hatchery. The birds were fed on basal diet for two-weeks (14 days), On the fifteenth, of the experiment the bird was randomly divided into 4 groups each group contain a forty (40) birds, and each group was subdivided into two groups, each group contain 20 birds, in a sector design. The control group (T0) was fed on the basal diet, while the birds in groups T1, T2, and T3 were fed rations with 10 percent, 20 percent, and 30 percent rice, respectively, replacing corn in the diet. The weight of chicken and consumed feed were collected at the end of every week. The broiler chicken diet composition is shown in Table (1).

2.1 Gene Expression for IGF1

Total RNA was extracted from liver tissues of broiler chickens using Trizol reagent following the manufacturer instructions (RNeasy Mini Ki, Catalogue no.74104). The recovered RNA was reverse-transcribed into cDNA following the manufacture protocol (Thermo Fisher, Catalog number: EP0441). cDNA was amplified by real-time PCR using SYBR Green PCR Master Mix (Quantitect SYBR green PCR kit, Catalog no, 204141). The qPCR was done with a reaction volume of 25μL consisting of 3 μl total RNA, 0.25 μl reverse transcriptase, 12.5 μl 2x Quantitect SYBR green PCR master mix, 0.5 μl of each primer, and 8.25 μl RNase free-water. A thermal cycler was used to obtain the final reaction mixture and programmed. Afterwards, a melting curve analysis was done to verify the specificity of the PCR product. The β-actin gene was

Table 1. Composition of the broiler chicken diet (Kg per ton)

Ingredients	T0 (1-14 days)	T1 (15-35 days)	T2 (15-35 days)	T3 (15-35 days)
Yellow corn	53.2	43.2	36.2	26.2
Soya	31	31	31	31
Rice	0	10	20	30
Premix	2.5	2.5	2.5	2.5
Soya hulls	2.5	2.5	2.5	2.5
wheat	7.5	7.5	7.5	7.5
Lime	1.2	1.2	1.2	1.2
Oil	1.1	1.1	1.1	1.1
Antifungal	1	1	1	1
Enzyme	100	10	10	10

Premix composition per kg: vitamin D, 2,400 IU; vitamin E, 60.0 mg; vitamin K, 3.0 mg; vitamin B1, 3.0 mg; vitamin B2, 8.0 mg; vitamin B6, 4.0 mg; vitamin B12, 0.02 mg; niacin 50.0 mg; pantothenic acid 15.0 mg; biotin 0.40 mg; folic acid 2.0 mg; Cu 15 mg; Fe 40 mg; Mn 100 mg; Zn 100 mg; I 1.0 mg; Se 1 mg

Table 2. Nucleotides sequences of IGF 1 gene

Gene	Accession N	Sequence	Size (pb)
IGF1	M74176.1	F: 5'-CAGAGCAGATAGAGCCTGCG-3' R: 5'-TCTGCAGATGGCACATTCAT-3	655

selected as a reference gene for expression analysis. Primer sequences are shown in Table 2. ΔCT was determined for IGF-I gene using threshold cycle (CT) values that was normalized to those of the β- actin housekeeping in each sample. Lower ΔCT indicates increased expression [9].

2.2 Statistical Analysis

Graph Pad software Prism version (8.0) was used to conduct the statistical analysis. The standard of significance for the analysis was P - 0.05, and the data points were reported as mean and Standard Error.

3. RESULTS AND DISCUSSION

The current study live body weight shows no significant difference between control group and 10 percent rice group in all the period of the experiment, on the other hand there was a significant ($P \leq 0.05$) increase between 20 % & 30 % rice group, while there were no significant difference between 20 % rice group & 30 % rice group as compare to each other in 3 ^{red} week & 4th week while, 30 % rice group show a significant ($P \leq 0.05$) decrease in live body weight in the 5th week as compared to the other groups as shown in Table (3).

In the study there was no significant difference in feed intake in the week 3 in the control group as compared to the other groups. While in week 4 & 5 the 30 % rice show a significant ($P \leq 0.05$) increase in feed intake as compared to the other group. Also 20 % rice show a significant ($P \leq 0.05$) increase in feed intake in 4th & 5th week as compared with the control & the 10% rice, while control group showed a significant ($P \leq 0.05$) decrease in the 5th week as compared with the other groups. as shown in Table (4).

Weight gain show a significant ($P \leq 0.05$) increase in all the period of the experiment in the control group & 10% rice group as compared with the 20 % & 30 % rice group , while 30 % rice group show a significant ($P \leq 0.05$) decrease as compeer with the other group in the 5th week of the study as shown in the Table (5).

Table 3. Effect of basal diet, 10% rice, 20% rice & 30% rice on broiler live body Wight

Parameters	Control group	10 % rice group	20% Rice group	30% Rice Group
3^{red} week	718.9 ± 13.65 A	713.4 ± 16.18 A	695.4 ± 12.83 B	697.1 ± 26.47 B
4th week	1226.4 ± 16.32 A	1227 ± 26.45 A	1184.1 ± 32.14 B	1176.8 ± 20.45 B
5th week	1930 ± 34.24 A	1916.5 ± 23.47 A	1829 ± 55.24 B	1783.1 ± 43.71 C

Table 4. Effect of basel diet, 10% rice, 20% rice & 30% rice on broiler feed intake

	Control	10%	20%	30%
week3	630 ± 5.4 A	640 ± 5.3 A	634 ± 4.3 A	640 ± 4.88A
week 4	875 ±12.7 C	880 ± 13.2 C	900 ± 11.5 B	925 ± 12.7 A
week 5	1120 ± 20.4 D	1165 ± 23.4 C	1180 ± 17.7 B	1200 ±28.9 A

Table 5. Effect of basel diet, 10% rice, 20% rice & 30% rice on broiler Weight gain

Parameters	Control Group	10 Rice Group	20% Rice Group	30% Rice Group
3ed week	361.1917 ± 21.14 A	355.6917 ± 15.64 A	337.6917 ± 22.81 B	339.3917 ±25.31 B
4th week	507.5 ±15.84 A	513.6 ± 22.14 A	488.7 ± 16.82 B	479.7 ± 28.21 B
5th week	703.6 ± 30.43 A	689.5 ± 30.78 A	644.9 ± 40.16 B	606.3 ± 36.12 C

Table 6. Effect of basal diet, 10%, 20% & 30% rice on Feed conversion ratio

Parameters	Control group	10 rice group	20% Rice group	30% Rice Group
3rd week	1.744226 ± 0.13 B	1.771197 ± 0.11 B	1.865607 ± 0.14 A	1.856262 ± 0.14 A
4th week	1.724138 ± 0.12 C	1.70366 ± 0.12 C	1.790464 ± 0.15 B	1.824057 ± 0.16 A
5th week	1.591814 ±0.11 D	1.624365 ± 0.12C	1.736703 ± 0.13 B	1.84727 ± 0.14 A

Feed conversion ratio showed a significant ($P \le 0.05$) increase in the 20% & 30% rice groups as compare with the control group & the 10% rice group in all the period of the experiment, while the control group showed a significant ($P \le 0.05$) decrease in the control group as compared to other group in the 5th week, as shown in Table (6).

In the gene expression the control group show a significant ($P \le 0.01$) decrease in the IGF-1 gene folding change as compare with the other groups, also 10 % rice group show a significant ($P \le 0.01$) decrease in the folding change as compare with 20 % & 30 % rice group , while there were no significant difference between 20% and 30% rice groups as compare with each other as shown in Figs. (1 and 2).

In the Sensory analysis Tenderness show a significant decrease in the control group and 10 % rice group as compeer with 20% and 30 % rice group, the Juiciness show no significant difference between all the experiment groups, on the other hand the color of the control group show a significant decrease as compeer with the 10 %, 20 % and 30 % rice group, the flavor and the palatability show a significant increase in the control group as compeer with the other group.as shown in Table (7).

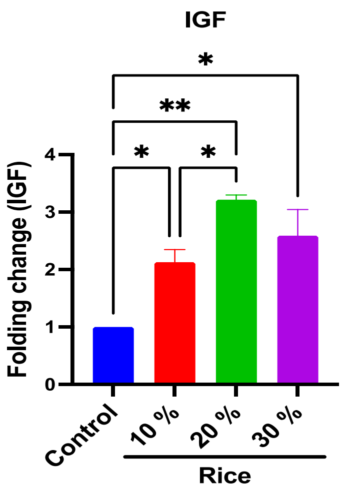

Fig. 1. Fold change comparison between the groups expressed igf-1 gene. This shows significant upregulation of the rice group compared with control groups

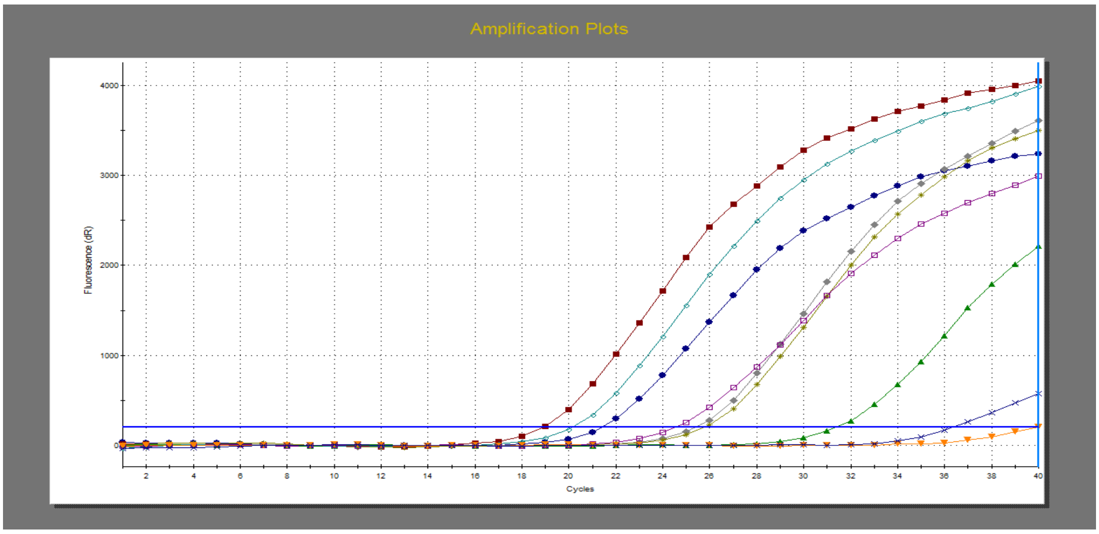

Fig. 2. Amplification curve of the tested samples represents the igf-1 gene. This indicates a successful RNA extraction and cDNA synthesis

Table 7. Sensory analysis of basal diet, 10%, 20% & 30% rice

Parameters Group	**Tenderness**	**Juicy**	**Color**	**Flavor**	**Palatability**
Group 1 (CON)	4.2± 0.B	4.4 ±0.2 A	3.2±0.6 C	4.8 ± 0.4 A	4.8± 0.5 A
Group 2 (10 % rice)	4.2 ± 0.7 B	4.4 ± 0.5 A	4 ±0.5 B	4.3 ±0.7 B	4.0 ± 0.8 B
Group 3 (20 % rice)	4.5 ±0.6 A	4.6 ± 0.6 A	4.6 ±0.3 A.	4.2± 0.5 B	4.2 ± 0.9 B
Group 4 (30 % rice)	4.6 ± 0.4 A	4.2 ±0.4 A	4.8±0.7 A	4.2 ± 0.4 B	4.0 ± 0.7 B

The current study found that there was a significant increase in the average live weight of broiler chickens in the control group & the group that was fed with 10% rice, in contrast to the groups that were fed 20% & 30% rice, and this is what we observed in Table (2) in the third, fourth, and fifth weeks of the experiment, This result may be occur due to the presence of substances in rice such as anti-nutrients & these substances play an important role in the process of absorbing & breaking down substances & enzymes within the intestine, when the amount of rice in the feed increases, the amount of these anti-nutrient will increase, & thus this affects live body [10].

Lectinsthat found in rice serve various functions in plants; some can interfere with nutrient absorption & digestion. Lectins bind to carbohydrates in the gut lining or to specific receptors on the surface of cells, potentially disrupting normal nutrient absorption processes [11].

Tannins are polyphenolic compounds found in some varieties of rice. While they have antioxidant properties, high levels of tannins may also interfere with the absorption of certain minerals and nutrients. Tannins can form complexes with proteins and minerals, limiting their bioavailability and absorption [12,13]

Rice is known to contain enzyme inhibitors that may affect the activity of digestive enzymes in the gastrointestinal tract. These inhibitors, while part of the plant's natural defense mechanism, can influence the efficiency of nutrient digestion and absorption. Enzymes play a pivotal role in breaking down complex nutrients into forms that the body can absorb. When enzyme inhibitors are present in rice, they can hinder the normal digestive process, potentially affecting the absorption of essential nutrients like carbohydrates and proteins [14,15].

It is noted from the current study that there is an increase in the amount of food intake by the broiler that were fed with 20% & 30% of rice compared to the control group and the 10 % rice group. This result may be due to the presence of a large amount of high carbohydrates in both the 20 % and 30 % rice groups that leads to an increase in the amount of insulin in the body leads to an increase in the amount of the ghrelin hormone which lead to hunger and leads to the consumption of larger quantities of food conception For this reason we notice an increase in the food eaten when compared with the control groups and the 10 group during the fourth and fifth weeks of the experiment [16,17].

High-carbohydrate meals, especially those with a high glycemic index, can lead to a rapid increase in blood sugar levels, triggering a subsequent insulin response. The insulin surge may contribute to a quick drop in blood sugar, potentially leading to feelings of hunger [18]. In the short term, insulin can contribute to a decrease in hunger by promoting the storage of glucose in tissues. However, an exaggerated insulin response, often associated with rapidly digestible carbohydrates, may lead to a subsequent drop in blood sugar levels, potentially triggering hunger.

The study also shown that there is a significant increase in the weight gain in the control group and the 10% rice group when compared with the 20% & 30% rice group during the fourth and fifth weeks of the experiment. Perhaps the reason is due to the presence of anti-nutrients, which are present in rice & play an important role in the process of absorbing all of the minerals, proteins & vitamins, which affects the weight of the bird & thus a decrease in the weight of the bird when compared to the control group (Abbas, 2020).

The study also show a decrease in the feed conversion ratio for the control group & the 10% rice group compared to the 20% & 30% rice group. These results appeared due to the increase in the amount of feed intake eaten by the 20% & 30% with a decrease in weight gain by these birds. The control & 10% group, because of its increase in the amount of feed eaten & the decrease in the amount of weight gained by the bird, leads to a higher feed conversion ratio, as the higher this percentage is, the more it is a negative factor, which leads to economic losses.

In the current study there was an increase in the IGF-1 in the experiment groups as compeer with the control group. High-carbohydrate diets can indeed stimulate IGF-1 production in broiler chickens [19]. This effect is partly due to the fact that carbohydrates, especially simple carbohydrates like glucose, can stimulate insulin secretion which can stimulate the production of IGF-1 in various tissues, including the liver. Increased IGF-1 levels can then promote growth in broiler chickens [20]. Carbohydrates can influence IGF-1 production, other factors such as protein intake, specific carbohydrate sources, & overall diet composition also play significant roles in regulating growth, on the other hand if there's an excess of carbohydrates in the diet, leading to chronically elevated insulin levels, it can potentially lead to insulin resistance, where cells become less responsive to insulin's effects. This can affect glucose metabolism and may indirectly influence IGF-1 signaling, in a high-carbohydrate diet, both insulin and IGF-1 levels increase due to the carbohydrate-induced release of insulin and subsequent stimulation of IGF-1 production, while insulin helps regulate glucose metabolism. Begum et al*.,* [21].

High-carbohydrate diets may influence glycogen reserves, which in turn can impact the rate of lactic acid production post-slaughter. Proper post-slaughter pH decline is essential for meat tenderness [22]. If pH decline is too slow or incomplete, it can result in tougher meat. Also Carbohydrates can influence the water-holding capacity of meat. Adequate glycogen reserves in muscles can help retain water, leading to juicier and tenderer meat. High-carbohydrate diets can lead to increased glycogen storage in muscle tissue [23].

The Maillard reaction is a chemical reaction between amino acids and reducing sugars that gives browned foods their characteristic flavor and color. Carbohydrates, particularly reducing sugars like glucose and fructose, are essential for this reaction to occur. Therefore, a high-carbohydrate diet may result in increased levels of reducing sugars in the muscle tissue, which could contribute to more pronounced browning during cooking [24]. During cooking, glycogen can break down into glucose, which then participates in the Maillard reaction, leading to browning of the meat surface. caramelization of sugars can also contribute to browning. High-carbohydrate diets may increase the availability of sugars in meat, which can undergo caramelization when exposed to high heat during cooking [25--32].

4. CONCLUSION

From the current results, the increase amount of the rice in the feed lead to increase feed intake and feed conversion ratio with decrease of live body weight gain and weight gain and increase in the IGF-1 protection with Convergence in sensory test results.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dinani OP, Tyagi PK, Wani MA, Ongmoo H, Sharma K. Review on feeding value of rice gluten meal. Int. J. Curr. Microbiol. Appl. Sci. 2020;9:1256-1262.
2. Alshelmani MI, Abdalla EA, Kaka U, Basit MA. Nontraditional feedstuffs as an alternative in poultry feed. In *Advances in poultry nutrition research*. IntechOpen.
3. Pandey V, Singh SK, Korada M, Singh DK, Khaire AR, Habde S, Majhi PK. Stability analysis in rice (*Oryza sativa* L.) genotypes with high grain zinc. Indian Journal of Agricultural Research. 2020;54(6):689-698.
4. Hosnedlova B, Vernerova K, Kizek R, Bozzi R, Kadlec J, Curn V, Horna H. Associations between IGF1, IGFBP2 and tgfß3 genes polymorphisms and growth performance of broiler chicken lines. Animals. 2020;10(5):800.
5. Ahmad SS, Ahmad K, Lee EJ, Lee YH, Choi I. Implications of insulin-like growth factor-1 in skeletal muscle and various diseases. Cells. 2020;9(8):1773.
6. Takahashi Y. The role of growth hormone and insulin-like growth factor-I in the liver. International Journal of Molecular Sciences. 2017;18(7):1447.
7. Rhyu J, Yu R. Newly discovered endocrine functions of the liver. World Journal of Hepatology. 2021;13(11):1611.
8. Al-Hassani AS, Abdul-Hassan IA, Al-Hassani DH. Some Biochemical traits in broiler chicken as affected by insulinlike growth factor-1 (IGF-1) gene polymorphisms. Journal of Entomology and Zoology Studies. 2018;6(2):864-868.
9. Fouda M, Ateya A, Araby I, Elzeer A. Genetic polymorphisms and expression pattern of IGF-I gene in commercial broiler strains. JAPS: Journal of Animal & Plant Sciences. 2021;31(6).
10. Erdaw MM, Beyene WT. Anti-nutrients reduce poultry productivity: influence of trypsin inhibitors on pancreas. Asian Journal of Poultry Science. 2018;12(1):14-24.
11. Kiarie EG, Steelman S, Martinez M. Does supplementing β-mannanase modulate the feed-induced immune response and gastrointestinal ecology in poultry and pigs? An appraisal. Frontiers in Animal Science. 2022;3:875095.
12. Hassan IAG, Elzubeir EA, El Tinay AH. Growth and apparent absorption of minerals in broiler chicks fed diets with low or high tannin contents. Tropical Animal Health and Production. 2003;35:189-196.
13. Choi J, Tompkins YH, Teng PY, Gogal Jr RM, Kim WK. Effects of tannic acid supplementation on growth performance, oocyst shedding, and gut health of in broilers infected with eimeria maxima. Animals. 2022;12(11):1378.
14. Dinani OP, Tyagi PK, Mir NA, Mandal AB, Tyagi PK, Tiwari SP. Effect of feeding rice distillers dried grains with solubles (rDDGS) and rice gluten meal (RGM) based diet on the gut health of broiler chicken. J. Entomol. Zool. Stud. 2018;6:67-71.
15. Samtiya M, Aluko RE, Dhewa T. Plant food anti-nutritional factors and their reduction strategies: an overview. Food Production, Processing and Nutrition. 2020;2:1-14.
16. Te Pas MF, Borg R, Buddiger NJ, Wood BJ, Rebel JM, van Krimpen MM, Schokker D. Regulating appetite in broilers for improving body and muscle development–A review. Journal of Animal Physiology and Animal Nutrition. 2020;104(6):1819-1834.
17. Chuang WY, Hsieh YC, Chen LW, Lee TT. Evaluation of the relationship between adipose metabolism patterns and secretion of appetite-related endocrines on chicken. Animals. 2020;10(8):1282.
18. Woods SC, Lutz TA, Geary N, Langhans W. Pancreatic signals controlling food intake; insulin, glucagon and amylin. Philosophical Transactions of the Royal Society B: Biological Sciences. 2006;361(1471):1219-1235.
19. Melnik B. Dietary intervention in acne: Attenuation of increased mTORC1 signaling promoted by Western diet. Dermato-Endocrinology. 2012;4(1): 20-32.

20. Chen P, Li S, Zhou Z, Wang X, Shi D, Li Z, Xiao Y. Liver fat metabolism of broilers regulated by Bacillus amyloliquefaciens TL via stimulating IGF-1 secretion and regulating the IGF signaling pathway. Frontiers in Microbiology. 2022 ;13:958112.
21. Begum M, Hossain MM, Kim IH. Effects of the plant extract YGF251 on growth performance, meat quality, relative organ weight, nutrient digestibility and blood profiles in broiler chickens: possible role of insulin-like growth factor 1. *Veterinární medicína*. 2014;*59*(9).
22. Smulders F, Hofbauer P, Geesink GH. The conversion of muscle to meat. Meat Inspection and Control in the Slaughterhouse. 2014;399-421.
23. Sultana K, Jayathilakan K, Sajeevkumar VA. Chemistry of Animal Tissues. In *Advances in Food Chemistry*: Food Components, Processing and Preservation. Singapore: Springer Nature Singapore. 2022;385-437.
24. Chansataporn W, Nopharatana M, Samuhasaneetoo S, Siriwattanayotin S, Tangduangdee C. Effects of temperature on the main intermediates and products of the Maillard Reaction in a Chicken Breast Meat Model System.; 2019.
25. Gibis M. Heterocyclic aromatic amines in cooked meat products: Causes, formation, occurrence, and risk assessment. Comprehensive Reviews in Food Science and Food Safety. 2016;15(2):269-302.
26. Zozo B. Determination and characterisation of the function of black soldier fly larva protein before and after conjugation by Maillard reaction (Doctoral dissertation, Cape Peninsula University of Technology); 2020.
27. Nath P, Pandey N, Samota M, Sharma K, Kale S, Kannaujia P, Chauhan OP. Browning reactions in foods. In *Advances in Food Chemistry:* Food Components, Processing and Preservation. Singapore: Springer Nature Singapore.; 2022;117 -159.
28. Taylor-Bowden T, Bhogoju S, Khwatenge CN, Nahashon SN. The Impact of Essential Amino Acids on the Gut Microbiota of Broiler Chickens. Microorganisms. 2024;12(4): 693.
29. Ghanghas N, MT M, Sharma S, Prabhakar PK. Classification, composition, extraction, functional modification and application of rice (*Oryza sativa*) seed protein: A comprehensive review. Food Reviews International. 2022;38(4):354-383.
30. Jayaprakash G, Bains A, Chawla P, Fogarasi M, Fogarasi S. A narrative review on rice proteins: Current scenario and food industrial application. Polymers. 2022;14(15):3003.
31. Alagawany M, Elnesr SS, Farag MR. The role of exogenous enzymes in promoting growth and improving nutrient digestibility in poultry. Iranian Journal of Veterinary Research. 2018;19 (3): 157.
32. Abazari A, Navidshad B, Aghjehgheshlagh FM, Nikbin S. The effect of rice husk as an insoluble dietary fiber source on intestinal morphology and Lactobacilli and Escherichia coli Populations in Broilers; 2016.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/3664