ZANCO Journal of Pure and Applied Sciences

TYPE Original article
DOI http://dx.doi.org/10.21271/ZJPAS.37.4.6

OPEN ACCESS

*Corresponding author
Mohamed Idris Alshelmani
mohammed.alshelmani@uob.edu.ly

RECEIVED :09 /02 /2025
ACCEPTED :20/04/ 2025
PUBLISHED :31/ 08/ 2025

KEYWORDS:
Blood biochemistry,
Broiler, DDGS,
Dressing traits, Growth performance,
Meat quality.

Effect of Inclusion Corn Distillers' Dried Grains with Soluble on Performance, Carcass and Meat Quality on Broiler Chicken

Majdi Abdelfaraj Kairalla[1], *Mohamed Idris Alshelmani[2], Imdakim Mohamed Muftah[3] and Abdalhakim Amer Aburas[4]

[1]Department of Animal Production, Faculty of Agriculture, University of Sebha, Sebha, Libya.

[2]Department of Animal Production, Faculty of Agriculture, University of Benghazi, Benghazi, Libya.

[3]Department of of Food Sciences, Faculty of Agriculture, University of Sebha, Sebha, Libya.

[4]Department of Animal Production, Faculty of Agriculture, University of Alzintan, Alzintan, Libya.

ABSTRACT

Evaluating the impact of adding distillers' dried grains with solubles (DDGS) on broiler performance was the aim of the current experiment. A total of 240 one-day-old broiler chicks (Ross 308) were obtained from a local hatchery and divided into four dietary treatments randomly. There were four replicates of each treatment, fifteen birds per replicate. In broiler diets, DDGS was added at percentages of 0%, 10%, 20%, and 30% DDGS. At day 42, one bird per replication was selected to examine blood biochemistry, carcass traits, and meat quality. The findings showed that the group of birds fed a 20% DDGS considerably (P<0.05) improved the growth performance and feed conversion ratio (FCR) compared to the other groups. In addition, the birds fed DDGS basal diets were considerably (P<0.05) lower in total cholesterol, triglycerides and LDL compared to the control. The inclusion of 30% DDGS led to decreased broiler performance and carcass yield. In conclusion, the DDGS can be fed to the broilers up to 20% without adverse effects on growth performance.

1.Introduction

Poultry products consumption have been globally increased as the global population has grown, especially in the developing region (Kairalla et al. 2022a, Kairalla et al., 2022b, Kairalla et al., 2023). At the same time, the demand for the main poultry feed ingredients elevated. As a result, the availability of feedstuffs for the monogastrics is becoming more competitive (Alshelmani et al., 2021a, Alshelmani et al., 2021b, Alshelmani et al., 2024). The limitation of animal feed ingredients and the increasing cost of traditional animal feedstuffs have encouraged the utilization of agroindustrial by-products as feeds because annual feed demands are more than the available feeds produced (Alshelmani, 2015). The production of biofuel has increased worldwide, leading to the manufacture of distillers dried grains with solubles (DDGS) as an industrial by-product.

The industrial by-product (DDGS) is a by-product feed ingredient derived from corn, rice or wheat primarily used in animal nutrition, particularly in poultry and ruminant diets. DDGS contains a rich profile of proteins, fiber, vitamins, and minerals, allowing it to be a valuable addition to animal diets (Garbossa et al., 2025). It has been indicated that DDGS contains a high source of protein, carbohydrates and fiber. In addition, it is important for poultry production, and it promotes the gut health of the birds. It also contains an appropriate amount of essential amino acids, vitamins, polyunsaturated fatty acids (PUFA) and minerals (Baéza, 2024). Therefore, DDGS can be used as an alternative to soybean meal, leading to minimizing the feed costs in poultry diets (Abd El-Hack et al., 2019, Elbaz et al., 2022 Hristakieva et al., 2023).

Another important point to consider is that the abundant quantities of DDGS encouraged poultry sectors to substitute some of the soybean meal by such py-product (nolle al., 2003). It is recommended to provide DDGS at 6% and 12 – 15% in starter and finisher phases, respectively (Lampkins et al., 2004). The rise in prices of soybeans and corn prices has motivated the poultry sectors to include the DDGS as a promised ingredient for poultry (Sharyari et al., 2020). The inclusion of DDGS can be provided up to 25% without negative effects in the productivity (Świątkiewicz and Koreleski, 2008.)

Broiler performance of growth with the addition of DDGS has been studied thoroughly (Dal Pont et al., 2023, Hristakieva et al., 2024). However, the knowledge and usage of such by-products still rare in the Middle East region, and it could substitute portions of soybean meal in the animal's diet. Therefore, the objective of this study was to evaluate the impacts of corn DDGS on production performance, carcass traits, meat quality, and serum lipid profiles in broilers.

2. MATERIALS AND METHODS

2.1 Ethical Approval

The experiment was approved by Sebha University Ethics Committee. The current study was conducted at the Poultry Production Unit, Department of Animal Production, Faculty of Agriculture, University of Sebha, Libya.

2.2 Proximate Analysis

Commercially tested material DDGS was purchased from the Egyptian local market, which was imported from the USA, and a sample was taken for further chemical evaluation. Samples of DDGS (Table 1) were analyzed according to the methods described by AOAC (1995). Kjeldahl and soxhlet apparatuses were used to determine the crude protein and ether extract, respectively. Dry matter and ash content were determined using oven and muffle furnace, respectively.

Table 1. Proximate analysis of DDGS, (% of DM)

Composition	%
Dry matter	88
Crude protein	27
Ether extract	12
Crude fiber	7
Nitrogen free extract	37.5
Ash	4.5

2.3 Birds and Diets

A total of 240 one-day-old unsexed broiler chicks (Ross 308) were provided from a local hatchery, and raised on two-tiered floor batteries with cages. The birds were assigned randomly into four groups with four replicates of 15 birds in each. The ration formulation was according to the NRC (1994). Four dietary treatments were offered ad libitum to the birds as 0, 10, 20 and 30% DDGS (Table 2).

2.4 Production Performance

The body weight was individually taken every week. The body weight gain (BWG) was recorded, and the feed consumption per replicate was recorded weekly. Furthermore, the weekly feed conversion ratio (FCR) for each replicate was calculated. The growth performance was presented in starter, finisher and overall to give the full picture of broiler productivity.

2.5 Blood Samples

The measurement of meat pH, color and water-holding capacity was implemented on breast muscle as described in processes by (Alshelmani et al., 2017a, Kairalla et al., 2023).

At day 42, one bird per replicate was randomly selected (four birds per treatment), and blood samples were collected (Aziz et al., 2024). A sterile injector was used to draw blood samples from the wing vein, and then transferred into K3EDTA tubes. The samples were centrifuged at 3000 g for 15 minutes, and kept at -20ºC for further analysis. The biochemical parameters were done based on the techniques described by (Kairalla et al., 2022b, Mustafa et al., 2024). An automatic blood analyzer (BC 3,200, Nanshan, and automatic biochemical analyzer (Spectrophotometer V 1.0; Revision for Alpha-1,101,1,102, 1,502; Laxco Inc. Shenzhen 518,057, P.R. China) were used to determine blood hematology and biochemistry, respectively. On day 42, one bird per replicate (four birds per treatment) was randomly chosen for evaluation of dressing percentage and meat quality. Assigned birds were fasted for 12 h before slaughtering and individually weighed as pre-slaughtering weight and slaughtered according to the Islamic religion instructions with a sharp knife (Kairalla et al., 2023).

2.6 Slaughter and Sampling Processing

2.6.1 Internal Organ Weights

Internal organs and abdominal fat were weighed and expressed as relative of final live body weight (LBW).

The measurement of meat pH, color and water-holding capacity was implemented on breast muscle as described in processes by (Alshelmani et al., 2017a, Kairalla et al., 2023).

2.6.2 Determination of Muscle pH

About five g of meat sample was homogenized in 25 ml of distilled water. The pH (Mettler Toledo, AG 8603, Switzerland) was measured after transferring the homogenate into a beaker , and after each reading, the probe was rinsed with distilled water (Kairalla et al., 2023).

2.6.3 Meat Color Measurement

Samples were measured on breast meat samples using a Color Flex Spectrophotometer (WR-10, Shenzhen, China), Alshelmani et al. (2017a) and Kairalla et al. (2023).

2.6.4 Water-Holding Capacity

The drip loss (DL) and cooking loss (CL) procedures were applied as described by (Alshelmani et al., 2017a, Kairalla et al., 2023).

2.7 Statistical Analysis

One-way ANOVA was used for the experiment. A statistical analysis system's general linear model approach was used to analyze the data (SAS, 2003). The linear and quadratic effects of enhancing the DDGS inclusion levels in comparison to the controls were evaluated using orthogonal polynomial contrasts. Effects were considered significant at ($P<0.05$) using Tukey's test.

Table 2. The typical diets composition for the trial (% as fed).

Starter diet (0-21d)					Finisher diet (22-42d)			
	DDGS levels (%)							
Ingredient	**0**	**10**	**20**	**30**	**0**	**10**	**20**	**30**
Corn	58.00	55.84	52.56	49.27	64.54	60.89	57.26	53.99
Soybean meal (44%)	29.80	23.19	16.58	9.97	23.88	17.57	11.26	4.95
DDGS	00.00	10.00	20.00	30.00	0.00	10.00	20.00	30.00
Corn gluten meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Corn oil	2.50	1.65	1.45	1.25	2.5	2.40	2.25	1.70
Limestone	1. 10	1.10	1.10	1.10	1.00	1.00	1.00	1.00
Di-Calcium Phosphate	2.10	2.10	2.10	2.10	1.95	1.95	1.95	1.95
Vitamin and Mineral Premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
NaCl (salt)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-Lysine	0.15	0.17	0.24	0.30	0.20	0.25	0.31	0.42
DL-Methionine	0.20	0.22	0.24	0.28	0.22	0.23	0.26	0.28
Threonine	0.13	0.13	0.13	0.13	0.11	0.11	0.11	0.11
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis (% as fed basis)								
M.E (kcal/ kg)	2995	2995	2995	2995	3120	3120	3120	3120
Crude protein, %	21.00	21.00	21.00	21.00	19.00	19.00	19.00	19.00
Crude fiber, %	2.72	2.74	2.76	2.88	4.20	4.20	4.22	4.50
Lysine, %	1.44	1.42	1.44	1.46	1.24	1.24	1.26	1.28
Methionine, %	0.52	0.52	0.52	0.52	0.45	0.45	0.45	0.45
Calcium, %	1.02	1.03	1.04	1.05	0.91	0.91	0.92	0.93
Abs. phosphorus, %	0.50	0.50	0.50	0.50	0.50	0.55	0.55	0.55
Digestible lysine%	1.38	1.38	1.38	1.38	1.29	1.29	1.29	1.29
Digestible Met+Cys%	0.98	0.98	0.98	0.98	0.92	0.92	0.92	0.92
Digestible threonine%	0.88	0.88	0.88	0.88	0.82	0.82	0.82	0.82

* Each 1 kg Premix contained: Vit A 3350000 IU; Vit D3 760 000 IU; Vit E 6700 IU; Vit K3 335 mg; Vit B1 334 mg; Vit B2 1670 mg; Vit B6 500 mg; Vit B12 3.4 mg; Niacin 10000 mg; Ca.D. Pantothenate 3334 mg; Biotin 16.7 mg; Folic acid 334 mg; Trace minerals: Iron 13350 mg; Copper 3335 mg; Zinc 16700 mg; Manganese 25000 mg; Iodine 500 mg; Cobalt 84 mg; Selenium 100 mg; Additives: Ethoxyquine 600 mg; and Carrier ($CaCO_3$) up to 1 kg.

3. Results and Discussion

3.1 Production Performance

Table 3 points out the impact of inclusion DDGS on growth efficiency throughout the study period. In the starter phase, BWG was increased (linear and quadratic, P= <0.0001) in birds fed a 20% DDGS compared to the other groups, whereas the addition of 20% DDGS in the diets led to considerable improvement (linear, P= 0.0023) in FCR against those groups fed 10% or 30% DDGS basal diets. The BWG was improved (linear and quadratic, P= <0.0001) in birds fed 20% DDGS basal diet compared to the other groups in the finisher and overall periods.

The birds fed with a 30% DDGS basal diet exhibited a significant increase in FI (linear and quadratic, P= <0.0001) during the finisher phase and (linear, P=0.0038; quadratic, P= <0.0077) in the overall period. The inclusion of a 20% DDGS basal diet led to significant improvement in FCR (linear and quadratic, P= <0.0005) in the finisher phase and (linear and quadratic, P= <0.0001) in the overall period.The improvement in growth performance in the DDGS group at moderate levels could be attributed to the presence of non-starch polysaccharides (NSP) in small amounts which can act as prebiotics, leading to gut health promotion of the birds (Kareem et al., 2016). The results are agree with Hristakieva et al. (2023), who found that incorporating moderate ratios of

DDGS in the broiler feed led to enhanced productivity. The results are also in line with Damasceno et al. (2020), who claimed that inclusion of corn DDGS at 16% in broiler diets had no negative impacts on growth performance. Good quality corn DDGS might be offered to broilers at 150 and 200 g/kg diet in starter and finishers, respectively (Ravindran and Singh 2024).The reduction in BWG and FCR in birds fed 30% DDGS could be attributed to the increase of fibers and NSP. Therefore, productivity was adversely affected (Dal Pont et al., 2023). In addition, the negative influence may be due to the Millard reaction during processing which may lead to a reduction the availability of lysine (Dal Pont et al., 2023). In the current study, economic efficiency (data not shown) was 1.96 in group of birds fed 20% DDGS against 1.70, 1.81 and 1.66 in birds fed 0%, 10% and 30%, respectively.One important point to consider is that cellulolytic enzymes or fermented DDGS by cellulolytic bacteria may lead to improved nutrient availability and gut health. Thus, improving productivity performance of the chickens (Alshelmani et al., 2016, Alshelmani et al., 2017b, Zengin et al., 2022, Baéza, 2024).

Table 3. Effect of inclusion DDGS on broiler performance during feeding trial.

Traits	**DDGS (%)**						
	0	**10**	**20**	**30**	**SEM[1]**	**Contrast P- values**	
			0 – 21days			**Linear**	**Quadratic**
Body weight gain (g/bird)	793.25^{b}	797.07^{b}	859.34^{a}	782.34^{b}	4.4194	<0.0001	<0.0001
Feed consumption (g/bird)	940.25	956.00	959.33	966.71	7.6064	0.1471	0.5803
Feed conversion ratio (FCR)	1.18^{ab}	1.20^{a}	1.11^{b}	1.23^{a}	0.01675	0.0023	0.0563
		22 – 42 days					
Body weight gain (g/bird)	1370.33^{b}	1424.92^{a}	1448.18^{a}	1239.03^{c}	13.971	<0.0001	<0.0001
Feed consumption (g/bird)	3027.68^{b}	3008.08^{c}	2994.18^{d}	3036.14^{a}	1.9775	<0.0001	<0.0001
Feed conversion ratio (FCR)	2.21^{b}	2.11^{b}	2.06^{b}	2.45^{a}	0.04841	0.0005	0.0005
		Overall (0 – 42 days)					
Body weight gain (g/bird)	2163.75^{c}	2221.99^{b}	2307.57^{a}	2021.35^{d}	13.083	<0.0001	<0.0001
Feed consumption (g/bird)	3967.93^{b}	3964.08^{b}	3953.51^{b}	4002.85^{a}	7.6748	0.0038	0.0077
Feed conversion ratio (FCR)	1.83^{b}	1.78^{bc}	1.71^{c}	1.98^{a}	0.02096	<0.0001	<0.0001

$^{a-d}$ Means ± SEM. values with various superscript letters in the same row are differ substantially.
[1] Pooled standard error.

3.2 Blood Biochemistry

The change of DDGS inclusion on biochemical parameters is presented in Table 4. It is observed that the group of birds fed DDGS basal diets was significantly lower in total cholesterol (linear, P=<0.0001; quadratic, P= 0.0010), triglycerides (linear, P=<0.0001) and LDL (linear, P=<0.0001; quadratic, P= 0.0061) compared to the control. Nevertheless, HDL has increased significantly (linear, P=<0.0001; quadratic, P= 0.0021) as the ratios of DDGS were increased in broiler feeds.The reduction in total cholesterol, triglycerides and LDL along with increasing HDL in broilers fed DDGS basal diets could be attributed to the existence of PUFA in DDGS (Abdulla et al., 2019, Elbaz et al., 2022). This encouraging output may offer healthy poultry products for human diets (Abdulla et al., 2019). The outcomes are consistent with Elbaz et al. (2022), who showed that there are no significant differences among broilers fed a DDGS basal diets in blood total protein and albumin. Likewise, the results obtained by Wickramasuriya et al. (2019) showed no effects on plasma total protein, AST and ALT (as an indicator to liver health) in laying hens fed DDGS basal diet.

Table 4. Influence of DDGS inclusion on blood biochemistry of broiler chickens.

Parameters	**DDGS (%)**						
	0	**10**	**20**	**30**	**SEM[1]**	**Contrast P- values**	
						Linear	**Quadratic**
Total cholesterol	222.55^{a}	215.46^{b}	211.31^{c}	210.32^{c}	0.7506	<0.0001	0.0010

(mg/dL)							
Triglycerides (mg/dL)	93.35[a]	90.16[b]	86.57[c]	82.85[d]	0.5961	<0.0001	0.6468
LDL-cholesterol (mg/dL)	94.28 [a]	90.21 [b]	90.37[b]	89.88[b]	0.4747	<0.0001	0.0061
HDL-cholesterol (mg/dL)	111.06[c]	117.08[b]	120.34[a]	120.87[a]	0.7486	<0.0001	0.0021
Total protein (g/L)	2.72	2.81	2.90	2.95	0.2014	0.8622	0.9293
Albumin (g/L)	1.21	1.26	1.28	1.29	0.0206	0.0765	0.3043
Globulin	1.51	1.55	1.61	1.66	0.2042	0.9552	0.9850
[2]A/G ratio	0.9436	0.8217	0.7990	0.7805	0.1002	0.6645	0.6007

[a-d]Means ± SEM. values with various superscript letters in the same row are differ substantially.
[1] Pooled standard error.
[2] Albumin/Globulin ratio.

3.3 Dressing Percentage

The influence of DDGS inclusion on dressing percentage is presented in Table 5. The addition of 30% DDGS in the diets led to a considerable decline (linear, P=0.0004; quadratic, P= <0.0001) in carcass yield. While birds that consumed a 20% DDGS basal diet showed a reduction (linear, P=0.0019; quadratic, P= <0.0030) in abdominal fat against the other groups. The findings are consistent with Ravindran and Singh (2024), who mentioned that the addition of 20% corn DDGS in broiler feeds had no adverse impact on carcass or breast yield. The improvement in carcass yield in the group of birds fed 10% or 20% DDGS could be attributed to the enhancement in their growth performance as a result of the nutreints in DDGS.

The negative effect on carcass yield in the group of birds fed a 30% DDGS basal diet could be attributed to the excess of fibers and NSP in their diets. The outputs are in agreement with Sharyari et al. (2020), who concluded that a group of broilers fed a diet provided with 14% wheat DDGS led to a reduction in carcass yield. This result is incompatible with the current experiment which can be referred to the levels of canola meal (containing anti-nutritional factors) which were 9% in the aforementioned above.

Table 5. Effect of DDGS inclusion on carcass traits.

Parameters (%)	DDGS (%)					Contrast P- values	
	0	10	20	30	SEM[1]	Linear	Quadratic
Carcass yield	65.07[ab]	66.42 [a]	66.62[a]	63.37[b]	0.40652	0.0004	<0.0001
Abdominal fat	1.047[a]	0.985[ab]	0.920 [b]	0.992[a]	0.01711	0.0019	0.0030
Gizzard	1.792	1.797	1.795	1.807	0.01481	0.8963	0.7972
liver	1.895	1.892	1.890	1.890	0.00813	0.9660	0.8754
Heart	0.49	0.48	0.49	0.47	0.00881	0.9729	0.8853

[a, b] Means ± SEM. values with various superscript letters in the same row are differ substantially.
[1] Pooled standard error.

3.4 Meat Quality

Table 6 represents the effect of DDGS inclusion on meat quality. No remarkable change between dietary treatment in DL, CL, pH and meat color (P> 0.05). The outputs are in line with those of Hristakieva et al. (2023), who found that meat pH, DL and CL were not affected in broilers fed DDGS basal diets. The findings are also agree with Zengin et al. (2022), who claimed that the incorporation of 10% DDGS or fermented DDGS did not affect the meat quality. The current results observed that meat color was less than L 56, and tended to be darker. This output was in line with Zengin et al. (2022), who claimed that meat color tended to be darker as a result of the addition of DDGS in broiler diets. This result could be due to the pH of the breast meat which was less than 6 in the current study, so that there is a strong correlation between meat color and pH (Hughes et al., 2014). Although there were no considerable differences among dietary treatments in the current results, it was reported that there was a positive correlation between lysine, cysteine and threonine availability with meat color in broilers fed DDGS (Świątkiewicz and Koreleski, 2008). The excessive heat during the process of biofuel may have led to a Maillard reaction between reducing sugars and the epsilon amino group of lysine. Thus, the availability of lysine decreased (Świątkiewicz and Koreleski, 2008

Table 6. Effect of DDGS inclusion on meat quality

Indices	DDGS (%)						
	0	10	20	30	SEM[1]	Contrast P- values	
			Sartorius			Linear	Quadratic
Drip loss (%)	3.52	3.52	3.52	3.52	0.03090	0.9985	0.9671
Cooking loss (%)	8.45	8.45	8.45	8.45	0.13079	1.0000	0.9922
pH	5.75	5.75	5.75	5.75	0.08863	1.0000	0.9885
Meat color							
L*	47.62	47.64	47.66	47.64	0.08547	0.9854	0.7809
a*	6.85	6.85	6.85	6.86	0.03351	0.9970	0.9494
b*	7.62	7.63	7.62	7.62	0.06939	0.9998	0.9755
			Pectoralis				
Drip loss (%)	5.637	5.632	5.630	5.630	0.05118	0.9995	0.9602
Cooking loss (%)	11. .57	11.56	11.55	11.57	0.09637	1.0000	1.0000
pH	5.45	5.42	5.45	5.46	0.02142	0.9980	0.9525
Meat color							
L*	45.85	45.86	45.84	45.86	0.03868	0.9957	0.9912
a*	3.45	3.46	3.45	3.47	0.04449	0.9997	0.9695
b*	9.69	9.68	9.69	9.68	0.05613	0.9988	0.9940

[1] Pooled standard error
L*: Lightness, a*: Redness, b*: Yellowness

4. Conclusion

In conclusion, the incorporation of corn DDGS up to 20% in broiler feed may improve the growth performance and minimize the production cost of animal ration formulation. On the other hand, the DDGS proportion higher than the aforementioned above appears not to be suitable for broiler chickens.

Conflict of interest

No conflicts of interest are disclosed by the authors.

References

Abdulla, N. R., Loh, T. C., Foo, H. L., Alshelmani, M. I. & Akit, H. 2019. Influence of dietary ratios of n-6: n-3 fatty acid on gene expression, fatty acid profile in liver and breast muscle tissues, serum lipid profile, and immunoglobulin in broiler chickens. The Journal of Applied Poultry Research, 28, 454-469.

Alshelmani, M. I., Abdalla, E. A., Kaka, U. & Basit, M. A. 2021a. Nontraditional Feedstuffs as an Alternative in Poultry Feed. Advances in Poultry Nutrition Research IntechOpen.

Alshelmani, M. I., El-Safty, S. A., Kairalla, M. A. & Humam, A. M. 2024. Enzymes in Poultry Feed. Feed Additives–Recent Trends in Animal Nutrition. IntechOpen.

Alshelmani, M. I., Kaka, U., Abdalla, E. A., Humam, A. M. & Zamani, H. U. 2021b. Effect of feeding fermented and non-fermented palm kernel cake on the performance of broiler chickens: a review. World's Poultry Science Journal, 77, 377-388.

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q. & Lau, W. H. 2016. Effect of feeding different levels of palm kernel cake fermented by Paenibacillus polymyxa ATCC 842 on nutrient digestibility, intestinal morphology, and gut microflora in broiler chickens. Animal Feed Science and Technology, 216, 216-224.

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q. & Lau, W. H. 2017a. Effect of feeding different levels of palm kernel cake fermented by Paenibacillus polymyxa ATCC 842 on broiler growth performance, blood biochemistry, carcass characteristics, and meat quality. Animal Production Science, 57, 839-848.

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q. & Lau, W. H. 2017b. Effect of solid state fermentation on nutrient content and ileal amino acids digestibility of palm kernel cake in broiler chickens. Indian Journal of Animal Sciences, 87, 1135-1140.

Alshelmani, M. M. I. 2015. Effect of feeding palm kernel cake fermented by fiber degrading bacteria on performance of broiler chicken. Doctor of Philosophy Thesis, UPM, Malaysia.

AOAC. 1995. Official methods of analysis. Association of Official Analytical Chemists. Washington, DC.

Aziz, H. I., Mirza, R. A., Karim, K. Y., Sabir, P. S. & Khidhr, A. M. 2024. Modulation of Intestinal Histology and Immune Functions Using Different Level of Salvia Indica Supplementations with Stocking Density in Local Quails. Zanco Journal of Pure and Applied Sciences, 36, 55-62.

Baéza, E. 2024. Is it interesting to use distillers dried grains with solubles (DDGS) in ducks' diets? World's Poultry Science Journal, 1-16.

Dal Pont, G. C., Lee, A., Bortoluzzi, C., Junior, N. R., Farnell, Y., Pilla, R., Suchodolski, J., Ceccantini, M., Eyng, C. & Kogut, M. 2023. Distillers dried grains with soluble and enzyme inclusion in the diet effects broilers performance, intestinal health, and microbiota composition. Poultry Science, 102, 102981.

Elbaz, A., Gad, G. G. & Thabet, H. 2022. Effect of feeding corn distillers dried grains with solubles on growth performance, nutrients digestibility, plasma metabolites, immunological status, and intestinal health of broilers. Egyptian Journal of Nutrition and Feeds, 25, 85-94.

Garbossa, P. L. M., Poleti, M. D., Garbossa, C. a. P., Alves, L. K. S., Chaves, R. F., Cantarelli, V. D. S. & Ferraz, J. B. S. 2025. A case study on the cost-benefit perspective on the influence of high-protein Distiller's Dried Grains with Solubles (HP-DDGS) pricing and inclusion levels on economic sustainability in pig production. Livestock Science, 292, 105632.

Hristakieva, P., Mincheva, N., Ivanova, I., Oblakova, M., Ivanov, N. & Slavov, I. 2023. Use of Distiller´ s Dried Grains with Solubles (DDGS) from corn or wheat in broiler diets. Bulgarian Journal of Animal Husbandry/Životnov Dni Nauki, 60, 23-34.

Hristakieva, P., Mincheva, N., Ivanova, I., Oblakova, M., Ivanov, N., Velikov, K., Slavov, I. & Foucault, S. 2024. Possibilities of Inclusion of corn Distillers Dried Grains with Solubles (DDGS) alone or in combination with Probiotic as Broiler Feed Ingredient. Bulgarian Journal of Animal Husbandry/Životnov Dni Nauki, 61, 12-20.

Hughes, J., Oiseth, S., Purslow, P. & Warner, R. 2014. A structural approach to understanding the interactions between colour, water-holding capacity and tenderness. Meat Science, 98, 520-532.

Kairalla, M. A., Aburas, A. A. & Alshelmani, M. I. 2022a. Effect of diet supplemented with graded levels of ginger (Zingiber officinale) powder on growth performance, hematological parameters, and serum lipids of broiler chickens. Archives of Razi Institute, 77, 2077-2083.

Kairalla, M. A., Alshelmani, M. I. & Aburas, A. A. 2022b. Effect of diet supplemented with graded levels of garlic (Allium sativum L.) powder on growth performance, carcass characteristics, blood hematology, and biochemistry of broilers. Open Veterinary Journal, 12, 595-601.

Kairalla, M. A., Alshelmani, M. I. & Imdakim, M. M. 2023. Effect of diet supplemented with different levels of moringa powder on growth performance, carcass characteristics, meat quality, hematological parameters, serum lipids, and economic efficiency of broiler chickens. Archives of Razi Institute, 78, 1421-1430.

Kareem, K. Y., Loh, T. C., Foo, H. L., Akit, H. & Samsudin, A. A. 2016. Effects of dietary postbiotic and inulin on growth performance, IGF1 and GHR mRNA expression, faecal microbiota and volatile fatty acids in broilers. BMC Veterinary Research, 12, 1-10.

Mustafa, M. M., Isa, R. H., Zangana, S. A. & Hassan, W. H. 2024. Role of glycerides of organic acids on broiler recovery challenged with the Newcastle disease virus (NDV) isolated from broiler chicken fields. Zanco Journal of Pure and Applied Sciences, 36, 96-103.

NRC 1994. Nutrient Requirements of Poultry (9th Rev. Ed.). National Academy Press, Washington, DC.

Ravindran, V. & Singh, Y. 2024. Influence of graded levels of maize distillers dried grains with solubles (mDDGS) on the performance, digestive tract development and carcass characteristics of broilers. Journal of Applied Animal Nutrition, 12, 73-82.

SAS. 2003. Statistical analytical system. SAS Institute Inc., Cary, NC, USA.

Sharyari, M., Emadinia, A., Davoodi, A., Salehi, A. & Jalili, G. 2020. Effect of wheat distillers dried grains with soluble on performance, carcass characteristics and immunity of broiler chicks. Journal of Livestock Science, 11, 54-59.

Świątkiewicz, S. & Koreleski, J. 2008. The use of distillers dried grains with solubles (DDGS) in poultry nutrition. World's Poultry Science Journal, 64, 257-266.

Wickramasuriya, S. S., Macelline, S. P., Kim, E., Cho, H. M., Shin, T. K., Yi, Y. J., Jayasena, D. D., Lee, S.-D., Jung, H. J. & Heo, J. M. 2019. Physiological impact on layer chickens fed corn distiller's dried grains with solubles naturally contaminated with deoxynivalenol. Asian-Australasian Journal of Animal Sciences, 33, 313-323.

Zengin, M., Sur, A., İlhan, Z., Azman, M. A., Tavşanlı, H., Esen, S., Bacaksız, O. K. & Demir, E. 2022. Effects of fermented distillers grains with solubles, partially replaced with soybean meal, on performance, blood parameters, meat quality, intestinal flora, and immune response in broiler. Research in Veterinary Science, 150, 58-64.