https://doi.org/10.61308/QZDG7115

Application of wheat dried distiller's grains with soluble (wDDGS) as a feed ingredient for broilers alone or in combination with a probiotic

Pavlina Hristakieva*, Magdalena Oblakova, Nadya Mincheva, Ivelina Ivanova, Nikolay Ivanov, Krasimir Velikov and Ivan Slavov

Agricultural Academy, Agricultural Institute - Stara Zagora, 6000 Stara Zagora, Bulgaria

*Corresponding author: poly_31@abv.bg

Citation: Hristakieva, P., Oblakova, M., Mincheva, N., Ivanova, I., Ivanov, N., Velikov, K. & Slavov, I. (2026). Application of wheat dried distiller's grains with soluble (wDDGS) as a feed ingredient for broilers alone or in combination with a probiotic. *Bulgarian Journal of Animal Husbandry, 63*(1), 31-38

Abstract: The aim of the present experiment was to study the effect of including 15% of wDDGS without and with probiotic-B-Act in the combined feeds for broiler chickens on the performance, carcass characteristics and physicochemical parameters of the meat under floor rearing conditions. To achieve this aim, 3 groups of 60 one-day-old male broiler chickens Ross – 308 were formed (one control and two test), with each group had three subgroups of 20 chickens. The chickens in the control group received balanced, according to the requirements for the hybrid, combined feeds, without wDDGS. The first experimental group received a ration with the participation of 15% wDDGS from one day of age until the end of the experiment (35 days of age). The second experimental group was fed a ration with 15% wDDGS, and a probiotic at a dose of 500 g/ton of feed from one day of age until the end of the experiment. In this study, we found a positive effect on weight from the first to 10 days of growth and a negative effect of the inclusion of 15% wDDGS without probiotic, and 15% wDDGS with probiotic on daily weight gain, feed intake, and feed conversion ratio of broiler chickens during the period from 11 to 35 days of growth. We did not find proven differences between the main characteristics of the carcass in the studied groups of chickens. It was found that the inclusion of 15% wDDGS with a probiotic improves some physicochemical parameters of meat.

Keywords: broilers; wheat DDGS; probiotic; growth performance; carcass; meat quality

INTRODUCTION

Fossil fuel reserves worldwide are constantly decreasing and their use leads to an increase in the concentration of CO2 in the atmosphere. Environmentalists advise minimizing the use of fossil fuels due to their adverse impact on nature (Abas et al., 2015). At the same time, interest in alternative fuels – biofuels – is growing. The use of grain (mainly corn in North America and wheat in Europe) to produce ethanol as a biofuel is increasing (Dien et al., 2002; Rano, 2016). This is a prerequisite for the construction of grain ethanol plants in recent years, both globally and in our country. All this leads to a higher supply of by-products, such as dry distiller's grain with solubles (DDGS), which is the main by-product of ethanol production, which is considered a valuable source of protein for feeding non-ruminant animals (Burton et al., 2013). Accordance with this, numerous studies have been conducted in recent decades on the possibilities of using corn DDGS in poultry feeding (Wang et al., 2007; Choi et al., 2008; Abdel-Raheem et al., 2011; Rashid et al., 2015; Abudabos et al., 2017; Damasceno et al., 2020; Hristakieva et al., 2024). In terms of research on the inclusion of wDDGS in poultry diets, there is also progress (Thacker and Widyaratne, 2007; Swiatkiewicz et al., 2013; Masey O'Neill et al., 2014; Whiting et al., 2017; Whiting et al., 2019; Sharyari et al., 2020; Sepehri et al., 2021). Compared to corn DDGS,

the use of wheat DDGS for poultry as a potential energy source could reduce competition between wheat demand for poultry and bioethanol production (Gozannet et al., 2010; Adebiyi and Olukosi, 2015). Given the potential use of wheat DDGS as a feed ingredient in broiler diets, it is essential to determine the impact of including such an ingredient in the feed on productivity and meat quality. There is undeniable evidence from numerous studies on the beneficial effects of including probiotics in broiler diets on growth and meat quality (Cengiz et al., 2015; Sarangi et al., 2016; Popova, 2017; Ramlucken et al., 2020).

In view of the above, the aim of the present experiment was to study the effect of including 15% of wheat DDGS without probiotic and together with the use of probiotic-B-Act in compound feeds for broiler chickens on their productivity, carcass characteristics and physicochemical parameters of the meat under floor rearing conditions.

MATERIAL AND METHODS

To achieve the goal, 3 groups of 60 one-day-old sexed male Ross-308 broiler chickens (one control and two test) were formed, and each group had three subgroups with 20 chickens each. Chickens in the control group received a balanced compound feed, according to the requirements of the hybrid, without the participation of wDDGS. One experimental group received a ration containing 15% wDDGS from one day of age until the end of the experiment (35 days of age). The other experimental group was fed a ration with the participation of wDDGS in an amount of 15% and a probiotic (B-Act® Strain B. licheniformis (DSM 28710- Huvepharma, Sofia, Bulgaria), in a dose of 500 g probiotic/ton of feed (equivalent to 1.6 × 109 CFU/kg feed) from one day of age until the end of the experiment (35 days old).

Wheat DDGS was from the Essentica plant for the production of ethyl alcohol, grain distillate and DDGS. The physicochemical composition of the experimental batch of wheat DDGS is listed in Table 1.

Table 1. Physicochemical composition of the used batch of wDDGS

Item	Unit (%)	Value
Moisture	% (on a wet basis)	7.35
Crude protein	% (on a wet basis)	33.16
Crude fiber	% (on a wet basis)	4.87
Crude fat	% (on a wet basis)	6.31
Ash	% (on a wet basis)	7.04

Source: Authors' own elaboration

Table 2 shows the data on the composition and nutritional value of the combined feeds used for the respective age periods (up to 35 days of age). They are balanced according to the recommendations for the hybrid. The birds were given drinking water and feed ad libitum. The main growth parameters were controlled: weight (BW) at one day of age, at 10 days, 28 days and 35 days, feed consumption (daily) and recording of dead birds (daily). Based on them, the following main growth performance items were calculated: growth rate, gain (DWG), feed conversion ratio (FCR) and mortality. A slaughter analysis was also performed on 6 chickens from each tested group based on average live weight at the end of the experiment, calculating the carcass yield (Grill/Slaughter weight*100) and relative values of the carcass parts (breast, thighs, wings, back), as well as internal abdominal fat, viscera. Samples of white and red meat (breast and leg) were taken to perform analyses of the sampled meat, of the physical properties - color (L*, a*, b*), water holding capacity % (WHC) and loss during cooking %.

Statistical analysis

Data were processed and analysed with the SPSS software (ver. 19.0, IBM Corp, NY). The variance homogeneity and the normality of distribution of the variables were initially tested. When the null hypothesis was rejected, the Kruskall-Wallis test was applied. Variables with equal variance and normal distribution were tested with one-way analysis of variance (ANO-

Table 2. Ingredients and nutrition composition of feed

Ingredients (%)	Feed / Groups					
	Starter (1-10 day)			Grower(11-35day)		
	Control group	Group with 15% w DDGS	Group with 15% wDDGS + B-Act	Control group	Group with 15% w DDGS	Group with 15% wDDGS + B-Act
Sunflower meal	5.00	-	-	5.00	5.00	5.00
Soybean meal	35.20	29.20	29.20	29.20	19.20	19.20
Methionine	0.18	0.17	0.17	0.15	0.12	0.12
Dicalcium phosphate	1.90	1.90	1.90	1.66	1.60	1.60
Limestone	0.60	0.70	0.70	0.60	0.70	0.70
Salt	0.20	0.20	0.20	0.20	0.20	0.20
Vitamin premix	0.20	0.20	0.20	0.20	0.20	0.20
Wheat	52.34	48.13	48.08	57.65	52.48	52.43
Vegetable oil	4.00	4.00	4.00	5.00	5.00	5.00
B-Act	-	-	0.050	-	-	0.050
Lysine-98%	0.28	0.40	0.40	0.24	0.40	0.40
Wheat DDGS	-	15.00	15.00	-	15.00	15.00
Mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Nutrition composition						
Metabolizable energy (kcal/kg)	2913.54	2874.93	2873.38	3017.35	2931.58	2930.03
Crude protein, %	22.39	22.49	22.43	20.34	20.34	20.33
Crude fiber, %	5.13	4.52	4.52	4.83	4.69	4.69
Lysine, %	1.44	1.41	1.41	1.25	1.23	1.23
Methionine, %	0.51	0.52	0.52	0.45	0.46	0.46
Calcium, %	0.990	1.007	1.023	0.900	0.897	0.913
Abs. phosphorus, %	0.490	0.507	0.507	0.450	0.454	0.454

Source: Authors' own elaboration

VA). In case of statistically significant F-value ($P<0.05$), additional post hoc LSD test for multiple comparisons was run.

RESULTS AND DISCUSSION

Growth performance

The effects of the experimental diets on growth performance of broiler chickens are reported in Table 3. The inclusion of 15% wDDGS without or with probiotic supplementation in the starter and grower periods had an effect on BW, DWG and FCR of broiler chickens. In the starter phase (1-10 days), the inclusion of 15% wDDGS with or without probiotic supplementation had a positive effect on BW, DWG and FCR of broiler chickens. In the starter growth at 10 days, broilers from the group with the inclusion of wDDGS with probiotic showed a significantly higher body weight of 218.72 g and daily weight gain (1-10day)- 17.47 g compared to the control and the group with the inclusion of wDDGS without probiotic at $p=0.000$. In the next phase -Grower, a gradual negative impact of the inclusion of 15% wDDGS without probiotic and

15% w DDGS with probiotic on performance of broiler chicks was observed. At 35 days, we reported the lowest body weight in the group with 15% wDDGS without probiotic 1610.90g, with a slightly higher weight is the group with 15% wDDGS with probiotic – 1650.77 g and with the highest body weight are the chickens from the control group 1783.27g at p<0.05. In this study, we found a negative impact of the inclusion of 15% wDDGS without probiotic and 15% w DDGS with probiotic on daily weight gain, feed intake, feed conversion ratio of broiler chickens during the period from 11 to 35 days of their growth. These results are in agreement with those found by Sharyari et al., 2020. These researchers conducted two parallel experiments with a control diet and diets with 3, 4, 6, and 7% wDDGS levels in the starter, grower, and finisher phases, with 6, 8, 12, and 14% wDDGS content in the starter, grower, and finisher phases, respectively. The researchers found that broiler body weight at 50 days, growth, feed intake, and carcass yield significantly decreased with increasing percentage of wDDGS in the diet (P<0.05). This is also confirmed by Sepehri et al., 2021, who conducted two experiments with Ross 308 broiler chicks using wDDGS in their diets. The results of the first experiment showed that body weight gain was increased in broilers fed 3% wDDGS from 11-21 days of age (P<0.05). The least body weight gain and feed intake were observed in broilers fed 12% DDGS compared to broilers fed 0, 3, and 6% DDGS from 1-21 days of age.

Table 3. Effect of including 15% wDDGS without probiotic and 15% wDDGS with probiotic on performance of broiler chicks

Item	Group			SEM	P- value
	Control	15% w DDGS	15% wDDGS + B-Act		
BW, g					
1 day	44.07	43.70	43.93	0.35	0.760
10 day	190.70 b	192.54 b	218.72 a	2.34	0.000
28 day	1106.07	1013.8	1047.17	23.59	0.081
35 day	1783.27 a	1610.90 b	1650.77 b	37.35	0.039
DWG, g					
1-10 day	14.66 b	14.87 b	17.47 a	0.22	0.000
11-28 day	51.30 a	45.63 b	46.03 b	1.18	0.026
29-35 day	96.74	85.30	86.23	2.98	0.063
1-35 day	49.69 a	44.78 b	45.91 b	1.06	0.039
FI, g					
1-10 day	25.17 b	24.08 b	28.17 a	0.45	0.002
11-28 day	73.40	72.42	75.46	3.55	0.830
29-35 day	141.90	127.94	136.67	5.01	0.218
1-35 day	73.28	73.72	74.19	3.80	0.986
FCR, g/g					
1-10 day	1.72	1.62	1.61	0.04	0.160
11-28 day	1.43 b	1.59 ab	1.64 a	0.05	0.044
29-35 day	1.47	1.50	1.59	0.08	0.567
1-35 day	1.47	1.64	1.62	0.07	0.245
Survivability, %	100	100	100	-	-

[a-b]- Different letters in the row mark significant differences at P<0.05; BW: Body weight; DWG: Daily weight gain; FI: Feed intake; FCR: Feed conversion ratio

Source: Authors' own elaboration

Carcass characteristics

The effect of including 15% wDDGS and 15% wDDGS with probiotic in the compound feeds for broiler chickens from 1 day to 35 days of age raised on the floor on the carcass characteristics are presented in Table 4. In the present study, we have not found any proven differences between the main carcass characteristics in the studied groups of chickens. The carcass yield and the relative values of the individual parts of the carcass did not differ between the groups with the inclusion in the diet of 15% wDDGS without probiotic and 15% wDDGS with probiotic. We have found significant differences in the relative weight of the heart and abdominal fat in the studied groups of chickens. The chickens with the highest percentage weight of heart and abdominal fat were those receiving 15% wDDGS with probiotics at p<0.05. Sharyari et al. (2020) reported that the inclusion of 6, 8, 12 and 14% wDDGS in starter, grower, and finisher, respectively, significantly reduced carcass percentage and significantly increased percentage weight of heart, gizzard, jejunum and ileum of broilers (P<0.05). Rano (2016) and Wang et al. (2007) reported adverse effects of 40% wDDGS on breast yield, with no significant effect on wings, and an increase in total gut and weight. The authors attributed this to the high fiber content of the diet.

Physicochemical parameters of the meat

The results of the physicochemical parameters of breast and thigt meat in this study are shown in Table 5.

In our study, the values of L *, b * and a* for thigh and breast meat characterizing the color did not show any proven differences between the three studied groups. The values of a* (redness) ranged from 2.40 for breast meat from chickens with wDDGS with probiotic to 4.52 for thigh meat from chickens with wDDGS. Authors who reported higher values for this indicator associated increased redness in breast muscle fibers with the presence of WB- wood breast (Baldi et al., 2019; Hammemi et al., 2024). In this study, we found reliable differences between the values of WHC % of breast meat between the studied chicken groups. The highest values of -21.70 WHC% were found in the group of chickens receiving wDDGS and probiotic and the lowest value of WHC – 15.50% in the group with wDDGS, as the difference was proven at P<0.05. A similar trend was expressed in the values of this parameter and in the thigh meat. The lowest values of this

Table 4. Effect of including 15% w DDGS without probiotic and 15% w DDGS with probiotic on carcass characteristics of broiler chicks (Carcass weight %)

Item	Group			SEM	P- value
	Control	15% wDDGS	15% wDDGS + B-Act		
Carcass, %	69.61	68.90	67.55	0.60	0.080
Thighs, %	31.69	31.89	32.31	0.59	0.748
Wings, %	12.11	12.03	12.16	0.26	0.930
Breast with bone, %	34.47	34.94	33.09	0.77	0.244
Back, %	20.49	21.65	21.93	0.60	0.230
Gizzard, %	1.52	1.71	1.78	0.11	0.271
Liver, %	1.93	2.00	2.04	0.09	0.696
Heart, %	0.41 b	0.45 b	0.50 a	0.02	0.003
Spleen, %	0.13	0.10	0.10	0.02	0.383
Abdominal fat, %	0.54 b	0.64 b	0.93 a	0.08	0.016
Viscera, %	6.85	6.11	5.94	0.27	0.072

[a-b]- Different letters in the row mark significant differences at P<0.05

Source: Authors' own elaboration

Table 5. Physico-chemical parameters of the meat

Item	Group			SEM	P- value
	Control	15% wDDGS	15% wDDGS + B-Act		
Thigh					
L *	55.99	54.55	53.95	1.13	0.492
a *	3.91	4.71	4.37	0.66	0.697
b *	3.52	4.52	3.41	1.16	0.779
WHC, %	14.83	10.49	13.40	1.31	0.076
Cooking loss,%	16.78	13.35	14.53	0.85	0.072
Breast					
L *	48.86	51.54	52.75	2.65	0.590
a *	3.10	2.34	2.40	0.34	0.256
b *	4.42	4.35	4.51	0.89	0.990
WHC, %	19.77 ab	15.50 a	21.70 b	1.49	0.021
Cooking loss ,%	15.30	14.77	14.31	0.88	0.741

[a-b]- Different letters in the row mark significant differences at P<0.05
L =lightness, a* =redness, b* =yellowness*
Source: Authors' own elaboration

parameter were again in the group of chickens receiving only wDDGS without probiotic – 10.49% and 13.40% in the group with wDDGS with probiotic and the highest value of -14.83% WHC in the control group, as these differences were unproven. Previous studies have reported that probiotic supplements, Bacillus subtilis in broiler feeds, improve meat characteristics, such as color, pH, loss on roasting and WHC% (Zhang et al., 2015; Mohammed et al., 2021; Mohammed et al., 2024). Probiotic use has been reported to improve WHC and meat tenderness (Liu et al., 2017). According to Cramer et al. (2018), probiotic treatment may also reduce harmful meat abnormalities in animals that have experienced oxidative stress. In terms of cooking loss, %, we found no evidence of differences between the study groups for breast meat and leg meat.

CONCLUSIONS

The inclusion of 15% wDDGS resulted in some reduction in broiler performance after 10 days of age. By this age, we reported advantages in live weight in the groups receiving 15% wDDGS with probiotic and 15% wDDGS without probiotic. Feeding wDDGS-based diets with up to 15% inclusion in broiler production up to 35 days of age did not result in negative effects on the carcass characteristics of the broilers. In this study, the inclusion of 15% wDDGS with probiotic improved WHC in breast meat. As with other physicochemical parameters of meat, we did not find any proven differences between the studied groups in breast meat and leg meat. Overall, the results of this study indicate that wDDGS can be successfully included in broiler diets. The potential negative effects of including wDDGS can be compensate by precise formulating the diet with the amount of DDGS included in the compound feed and taking into account the age and physiological condition of the birds. Therefore, when the cost of alternative feed ingredients dictates, wDDGS can be included in diets at levels up to 15% without detrimental effects on broiler performance.

REFERENCES

Abas, N., Kalair, A. & Khan, N. (2015). Review of fossil fuels and future energy technologies. *Futures*, *69*, 31 - 49. https://doi.org/10.1016/j.futures.2015.03.003.

Abdel-Raheem, S. M., Leitgeb, R. & Iben, C. (2011). Effects of Dietary Inclusion Level of Distillers' Dried Grains with Solubles (DDGS) from Wheat and Corn on Amino Acid Digestibilities in Broilers. *International Journal of Poultry Science*, *10*(12), 952 - 958.

Rashid, A. S., Faraj, A., Majeed, H. H., Salih, M., Umed Hama Aziz, K. & Abdulkarim Muhammad, A. (2015). Effect of using corn distillers dried grains with soluble (ddgs) on broiler chicks performance. *Assiut Veterinary Medical Journal*, *61*(147), 155 - 163. doi: 10.21608/avmj.2015.170249.

Abudabos, A. M., Al-Atiyat, R. M., Stanley, D., Aljassim, R. & Albatshan, H. A. (2017). The effect of corn distiller's dried grains with solubles (DDGS) fortified with enzyme on growth performance of broiler. *Environmental Science and Pollution Research*, *24*(26), 21412 - 21421. DOI 10.1007/s11356-017-9808-5.

Adebiyi, A. O. & Olukosi, O. A. (2015). Metabolizable energy content of wheat distillers' dried grains with solubles supplemented with or without a mixture of carbohydrases and protease for broilers and turkeys. *Poultry Science*, *94*(6), 1270 - 1276. https://doi.org/10.3382/ps/pev089.

Baldi, G., Soglia, F., Laghi, L., Tappi, S., Rocculi, P., Tavaniello, S., Prioriello, D., Mucci, R., Maiorano, G. & Petracci, M. (2019). Comparison of quality traits among breast meat affected by current muscle abnormalities. *Food Research International*, *115*, 369 - 376.

Burton, E. J., Scholey, D. V. & Williams, P. E. V. (2013). Use of cereal crops for food and fuel - characterization of a novel bioethanol coproduct for use in meat poultry diets. *Food Energy Security*, *2*, 197 - 206.

Cengiz, Ö., Köksal, B. H., Tatlı, O., Sevim, Ö., Ahsan, U., Üner, A. G., Ulutas, P. A., Beyaz, D., Büyükyörük, S. & Yakan, A. (2015). Effect of dietary probiotic and high stocking density on the performance, carcass yield, gut microflora, and stress indicators of broilers. *Poultry Science*, *94*, 2395 - 2403.

Choi, H. S., Lee, H. L., Shin, M. H., Cheorun, Jo., Lee, S. K. & Lee, B. D. (2008). Nutritive and economic values of corn distiller's dried grains with solubles in broiler diets. *Asian-Australasian Journal of Animal Science*, *21*(3), 414 - 419.

Cozannet, P., Lessire, M., Gady, C., Métayer, J. P., Primot, Y., Skiba, F. & Noblet, J. (2010). Energy value of wheat dried distillers grains with solubles in roosters, broilers, layers, and turkeys. *Poultry Science*, *89*(10), 2230 - 2241.

Cramer, T., Kim, H., Chao, Y., Wang, W., Cheng, H. & Kim, Y. (2018). Effects of probiotic (Bacillus subtilis) supplementation on meat quality characteristics of breast muscle from broilers exposed to chronic heat stress. *Poultry Science*, *97*, 3358 - 3368.

Damasceno, J. L., Rocha, C. S., Eyng, C., Broch, J., Souza, C., Wachholz, L., Cirilo, E. H., Avila, A. S., Pires Filho, I. C. & Nunes, R. V. (2020). Effect of feeding dried distillers' grains with solubles to broiler chickens from day 0 to 21. *Livestock Science*, *241*, 104232. https://doi.org/10.1016/j.livsci.2020.104232.

Dien, B. S., Bothast, R. J., Nichols, N. N. & Cotta, M. A. (2002). The US corn ethanol industry: An overview of current technology and future prospects. *International Sugar Journal*, *104*(1241).

Hammemi, C., Askri, A., Létourneau-Montminy, M. P. & Alnahhas, **N.** (2024). Current state of breast meat quality in standard-yielding broiler strains, *Journal of Applied Poultry Research*, *33*(1), 100383. https://doi.org/10.1016/j.japr.2023.100383.

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*(3), 12 - 20.

Liu, L., Ni, X., Zeng, D., Wang, H., Jing, B., Yin, Z. & Pan, K. (2017). Effect of a dietary probiotic, Lactobacillus johnsonii BS15, on growth performance, quality traits, antioxidant ability, and nutritional and flavour substances of chicken meat. *Animal Production Science*, *57*, 920 - 926.

Masey O'Neill, H. V., White, G. A., Li, D., Bedford, M. R., Htoo, J. K. & Wiseman, J. (2014). Influence of the in vivo method and basal dietary ingredients employed in the determination of the amino acid digestibility of wheat distillers dried grains with solubles in broilers. *Poultry Science*, *93*(5), 1178 - 1185. https://doi.org/10.3382/ps.2013-03578.

Mohammed, A. A., Mahmoud, M. A., Zaki, R. S. & Cheng, H. W. (2024). Effect of a probiotic supplement (*Bacillus subtilis*) on struggling behavior, immune response, and meat quality of shackled broiler chickens exposed to preslaughter stress. *Poultry Science*, *103*(10), 1 - 9. https://doi.org/10.1016/j.psj.2024.104051.

Mohammed, A. A., Zaki, R. S., Negm, E. A., Mahmoud, M. A. & Cheng, H. W. (2021). Effect of dietary supplementation of a probiotic (Bacillus subtilis) on bone mass and meat quality of broiler chickens. *Poultry Science*, *100*, 1 - 11.

Popova, T. (2017). Effect of probiotics in poultry for improving meat quality. *Current Opinion in Food Science*, *14*, 72 - 77.

Ramlucken, U., Ramchuran, S. O., Moonsamy, G., Lalloo, R., Thantsha, M. S. & van Rensburg, C. J. (2020). A novel Bacillus based multi strain probiotic improves growth performance and intestinal properties of Clostridium perfringens challenged broilers. *Poultry Science*, *99*, 331 - 341.

Rano, N. B. (2016). Nutritional Evaluation of Wheat Distillers Dried Grains with Solubles for Broiler Chickens.

Thesis submitted for the degree of Doctor of Philosophy, School of Agriculture, Food & Rural Development, August, 2016, 248, Newcastle University.

Sarangi, N. R, Babu, L., Kumar, A., Pradhan, C., Pati, P. & Mishra, J. (2016). Effect of dietary supplementation of prebiotic, probiotic, and synbiotic on growth performance and carcass characteristics of broiler chickens. *Veterinary World*, *9*, 313.

Sepehri, M. H., Noori Z., Azarli, A. & Hesabi, N. A. (2021). Determination of wheat distillers dried grains analysis and effect of DDGS on performance and histological characteristics of jejunum in broiler chickens in starter and finisher. *Animal Science Researches of Iran*, *13*(2), 235 - 248.

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.

Swiatkiewicz, S., Arczewska-Wlosek, A., Krawczyk, J., Puchala, M. & Józefiak, D. (2013). Effects of selected feed additives on the performance of laying hens given a diet rich in maize dried distiller's grains with solubles (DDGS). *British Poultry Science*, *54*, 478 - 485.

Thacker, P. A. & Widyaratne, **G. P.** (2007). Nutritional value of diets containing graded levels of wheat distillers grains with solubles fed to broiler chicks. *Journal of the Science of Food and Agriculture*, *87*, 1386 - 1390.

Wang, Z., Cerrate, S., Coto, C., Yan, F. & Waldroup, P. W. (2007). Use of constant or increasing levels of distillers dried grains with soluble (DDGS) in broilers diets. *International Journal of Poultry Science*, *6*, 501 - 507.

Whiting, I. M., Pirgozliev, V., Rose, S. P., Wilson, J., Amerah, A. M., Ivanova, S. G., Staykova, G. P., Oluwatosin, O. O. & Oso, **A. O.** (2017). Nutrient availability of different batches of wheat distillers dried grains with solubles with and without exogenous enzymes for broiler chickens. *Poultry Science*, *96*(3), 574 - 580. https://doi.org/10.3382/ps/pew262.

Whiting, I. M., Rose, S. P., Mackenzie, A. M., Amerah, A. M. & Pirgozliev, V. R. (2019). Effect of wheat distillers dried grains with solubles and exogenous xylanase on laying hen performance and egg quality, *Poultry Science*, *98*(9), 3756 - 3762. https://doi.org/10.3382/ps/pez063.

Zhang, A. W., Lee, B. D., Lee, S. K., Lee, K. W., An, G. H., Song, K. B. & Lee, C. H. (2015). Effects of yeast (Saccharomyces cerevisiae) cell components on growth performance, meat quality, and ileal mucosa development of broiler chicks. *Poultry Science*, *84*, 1015 - 1021.

Received: **September 29, 2025**; *Approved*: **October 25, 2025;** *Published:* **February, 2026**