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ANIMAL SCIENCE

Inclusion of maize distillers' dried grains with solubles (DDGS) associated with the use of metabolisability-enhancing additives in the diet of laying quails

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Abstract: This study aimed to incorporate maize distillers' dried grains with solubles (DDGS) into the diet of laying Japanese quail, along with two feed additives, xylanase and a metabolizability enhancer based on clay and algae. A completely randomized design with four treatments, 7 replications, and 6 birds per experimental unit. The treatments were: control, reference diet; DDGS, diet formulated with the inclusion of 150 g/kg DDGS; DDGS + xi, diet formulated with the inclusion of 150 g/kg DDGS and 1 g/kg xylanase enzyme (on top); DDGS + caa, diet formulated with the inclusion of 150 g/kg DDGS and 10 g/kg clay and algae-based metabolizability enhancer (on top). The productive performance of the birds was analyzed in three periods of 21 days each, the quality of the eggs was also measured at the end of each period. No significant differences were observed between the treatments for the variables analyzed. However, for the production cost of feed, the diets containing DDGS showed savings of R$ 10 per 100 kg of feed. Maize DDGS can be included in the diet of laying Japanese quail at 150 g/kg because it has a lower production cost and does not affect egg performance and quality.

Key words: alternative feed, production costs, egg quality, egg production, sustainability.

INTRODUCTION

Ethanol is made from maize. However, as with other processes, the ethanol production chain generates waste. One of these residues is called maize distillers dried grains with solubles (DDGS), which appears in animal nutrition as an alternative in the feeding of ruminants and non-ruminants (Bittencourt 2018).

With a significant protein content and metabolizable energy, it can make a positive contribution to quail production and potentially enter the formulation matrix as a partial substitute for maize and soybean meal. Studies on the use of this co-product are important to determine the limits of its use, as this product is an important source of protein, amino acids, energy, phosphorus, and other nutrients. However, one point to consider when using it is the wide variation in its composition, which should be analyzed prior to use (Schone et al. 2017).

One of the ways to improve the contribution of fibrous feeds in the diet of non-ruminant animals, thus allowing the deliberate inclusion of DDGS in the diet of laying quail, is to add additives to the diet. These include exogenous enzymes, each of which has a specialty and attractiveness to a particular substrate. Xylanase, for example, is an enzyme used to hydrolyze xylan present in plant cell walls, making nutrients available to the

endogenous enzymes of these animals (Brito et al. 2008).

Another additive that can be used to improve the digestibility of fibre-rich diets and contribute to good poultry performance is the cofactor based on montmorillonite clay mineral and algae extract (*Ulva lactuda* and *Solieria chordalis*). This cofactor aims to improve the action of endogenous enzymes by providing a greater contact surface between the enzyme and the substrate, thus acting as a catalyst for digestive enzymes.

In view of the above, this study aimed to evaluate the inclusion of DDGS in the diet of laying quails (*Coturnix coturnix japonica*) in combination with two exogenous additives (xylanase enzyme and enzymatic cofactor of montmorillonite clay mineral and algae extract) in order to evaluate the birds' performance, egg quality and the production cost of the feed.

MATERIALS AND METHODS

The experiment was carried out at the Iguatemi Experimental Farm in the laying coturniculture sector, during the months of May, June, and July of 2021, following the rules proposed by the Animal Experimentation Ethics Committee of the State University of Maringá (UEM) (Protocol No. 8147180521).

Facilities, planning, and experimental diets

One hundred and sixty-eight female quails of the Vicami® strain, aged between 168 and 243 days, were used in a completely randomised design with four treatments with 7 replications, and 6 birds per experimental unit. The treatments were: Control: diet based on maize and soybean meal; DDGS: diet formulated with the inclusion of 150 g/kg DDGS; DDGS + xi: diet formulated with the inclusion of 150 g/kg DDGS and 1 g/kg of xylanase enzyme (on top); DDGS + caa: diet formulated with the inclusion of 150 g/kg DDGS and 10 g/kg of the metabolizability enhancer based on clay and algae.

The birds were housed in a conventional laying house with side walls made of masonry up to 0.50 m in height, completed with wire mesh up to the roof and equipped with movable side curtains. The house contained galvanized wire cages (0.5 × 0.5 × 0.5 m), with nipple drinkers and trough-type feeders available throughout the entire experimental period.

The experimental diets were formulated based on maize and soybean meal (Table I) to meet the nutritional requirements of the layers, considering the chemical composition and energy values of the diets suggested by Rostagno et al. (2017). The diets were isoprotein and isoenergetic for all treatments.

Temperature and humidity were recorded twice daily, at 8 a.m. and 4 p.m. During the experimental period, the average temperature recorded was 24.1 °C, with a minimum of 17.7 °C and a maximum of 29.6 °C, and the average relative humidity was 76.6%. Feed and water were provided ad libitum. The lighting schedule was 17 hours of light (artificial + natural).

The birds and feed were weighed weekly to determine weight gain, feed intake, and feed conversion ratio. Feed intake was calculated as the difference between the feed offered and the leftovers, while weight gain was obtained from the difference between the final and initial body weights of the birds. Feed conversion ratio was determined in two ways: one based on dozens of eggs, indicating the amount of feed required to produce one dozen eggs, and the other based on weight, representing how many kilograms of eggs were produced per kilogram of feed consumed.

Table I. Centesimal and calculated composition of experimental diets for Japanese quail in the laying phase.

Ingredients (g/kg)	Control[4]	DDGS[5]	DDGSxi[6]	DDGScaa[7]
Maize	611.1	538.9	538.9	538.9
Soybean meal	292.1	203.1	203.1	203.1
Corn DDGS	0.00	150.0	150.0	150.0
Bicalcium Phosphate	11.1	12.2	12.2	12.2
Limestone	69.6	69.4	69.4	69.4
NaCl	3.40	3.20	3.20	3.20
Soybean Oil	1.10	10.0	10.0	10.0
L-Lysine HCL	2.70	4.30	4.30	4.30
DL-Methionine	4.20	3.80	3.80	3.80
L-Threonine	0,60	1.00	1.00	1.00
BHT[1]	0.10	0.10	0.10	0.10
Premix[2]	4.00	4.00	4.00	4.00
Calculated composition				
ME[3] (MJ/kg)	11.7	11.7	11.7	11.7
Crude protein (g/kg)	190.0	190.0	190.0	190.0
Calcium (g/kg)	31.6	31.6	31.6	31.6
Phosphorus Total (g/kg)	3.30	3.30	3.30	3.30
Potassium (g/kg)	7.00	7.00	7.00	7.00
Chlorine (g/kg)	2.60	2.60	2.60	2.60
Sodium (g/kg)	1.60	1.60	1.60	1.60
Digestible Lysine (g/kg)	11.1	11.1	11.1	11.1
Digestible Met+cis (g/kg)	9.10	9.10	9.10	9.10
Digestible Threonine (g/kg)	7.90	7.90	7.90	7.90
Digestible Tryptophan (g/kg)	2.30	2.30	2.30	2.30

[1]BHT (Butyl Hydroxy Toluene). [2]Mineral/vitamin supplementation per kg of feed: Zinc, 126 mg; Iron, 98 mg; Manganese, 155 mg; Copper, 30,624 mg; Cobalt, 0.40 mg; Iodine, 1,936 mg; Selenium, 0.51 mg; Vitamin A, 2,664 mg; Vitamin D_3, 1,665 mg; Vitamin E, 16 mg; Vitamin K_3, 4,028 mg; Vitamin B_1, 1,112 mg; Vitamin B_2, 8 mg; Vitamin B_6, 2,100 mg; Vitamin B_{12}, 20 µg; Pantothenic acid, 16 mg; Niacin, 40 mg; Choline, 560 mg. [3]ME: metabolisable energy. [4]Control: reference feed. [5]DDGS: 150g/kg of corn DDGS. [6]DDGSxi: 150g/kg of corn DDGS + xylanase. [7]DDGScaa: 150g/kg of corn DDGS + montmorillonite clay mineral and algae extract.

Egg quality

During the last three days of each 21-day cycle, the internal and external quality of the eggs were analyzed, in addition to determining their average weight. Only saleable eggs were used. The characteristics evaluated were: average egg weight (g), specific weight (g/mL), Haugh unit (HU), yolk and albumen index, shell percentage, yolk percentage, albumen percentage, shell thickness (mm), and yolk color.

The average weight of the eggs was determined by dividing the total weight of the eggs in each replicate by the number of eggs produced. The yolk and albumen were separated for weighing on a precision balance, and the weight of the albumen was obtained by subtracting the weight of the yolk and shell from

the weight of the egg. The weight data made it possible to quantify the percentages of yolk, albumen, and shell concerning the weight of the egg according to the following equation: % of component = (weight of component (g) / weight of egg (g)) x 100.

The following formula was used to calculate the Haugh unit (HU) to correlate egg weight with the height of the thick white: HU = 100log (H + 1.75 - 1.7W0.37), where H is the height of the albumen in millimeters and W is the weight of the egg in grams (Haugh 1937).

To calculate the yolk index (YI), a digital caliper was used to measure the height and width of the yolk and the values were entered into the equation described by Sharp & Powell (1930): YI = (YH/YW), where YH is the height of the yolk (mm), and YW is the width of the yolk (mm).

The method used to measure specific gravity or relative density is described by Thompson & Hamilton (1982), based on the immersion of eggs in containers of saline solution (densities of 1.065, 1.070, 1.075, 1.080, 1.085, 1.090, and 1.095).

Eggshell thickness was measured after drying for 24 hours at room temperature and then in an oven at 60 °C for 72 hours. After this two, different points in the mid-cross section were selected to verify the measurement using a micrometer with 0.01 mm graduation (Lin et al. 2004).

Analysis of the production costs of the diets

To determine the cost of feeding Japanese quail in the laying phase, the values per kilogram of raw materials were used, and the values were updated to the Maringá – Paraná region. The fixed costs did not change during the experiment and were considered constant.

Statistical analysis

Statistical data analysis was performed using the SAS statistical program (SAS II 2009). The data were first analyzed for normality using the Shapiro-Wilk test. After verifying that the residuals of the variables showed a normal distribution, the analysis of variance was performed using the PROC GLM of the computer program, and the means were compared using the Tukey test ($P<0.05$).

RESULTS

Egg quality

Table II shows that there was no difference ($P>0.05$) between the treatments for the quality variables evaluated: Haugh unit, yolk and albumen index, specific weight, egg weight, percentage of albumen, yolk and shell, shell thickness and shell weight per area.

Productive performance

With the inclusion of DDGS and enzymes in the diets of laying quail, there were no differences ($P>0.05$) for the variables of initial and final body weight, feed consumption, laying rate, feed conversion per kilogram of eggs, feed conversion per dozen eggs, and egg mass (Table III).

Analysis of the production costs of the diets

According to Table IV, it is feasible to include 150 g/kg of DDGS in the diets of laying Japanese quails since it does not affect the performance and egg quality variables and is economically more advantageous. This happens since, for every 100 kg of feed produced, the producer/industry would save about R$ 10, considering that feed represents 70% of the cost of animal production, i.e., it is the largest percentage. Saving at this stage can lead to total savings and a higher final profit for the quail farmer.

Table II. Egg quality of Japanese quail as a function of different treatments.

Variables	Control	DDGS	DDGSxi	DDGScaa	SEM	P-value
HU	91.17	91.60	91.75	90.36	0.1205	0.3123
YI	0.502	0.501	0.510	0.510	0.0009	0.4899
SW (g ml[1])	1.065	1.067	1.069	1.069	0.0003	0.2197
EW (g)	10.87	10.80	11.13	11.14	0.0088	0.1843
% Albumen	60.84	61.33	62.01	60.85	0.1069	0.1050
% Yolk	31.20	30.96	30.26	31.21	0.0857	0.1890
% Eggshell	7.77	7.68	7.75	7.91	0.0189	0.6624
ST	0.215	0.207	0.213	0.323	0.0213	0.4047
SWUSA	3.96	3.91	3.95	4.00	0.0088	0.6695

Control: reference feed; DDGS: 150 g/kg of corn DDGS; DDGSxi 150 g/kg of corn DDGS + xylanase; DDGScaa: 150 g/kg of corn DDGS + montmorillonite clay mineral and algae extract; SEM: standard error of mean; HU: Haugh unity; YI: yolk index; SW: specific weight; EW: egg weight; SWUSA: shell weight per unit surface area; ST: shell thickness; NS: not significant.

Table III. Mean performance of Japanese quail at 25 to 34 weeks of age as a function of the different treatments.

Variables	Control	DDGS	DDGSxi	DDGScaa	SEM	P-value
iBW (g)	170.7	169.4	168.0	169.0	0.184	0.770
fBW (g)	183.7	182.1	181.5	180.0	0.248	0.775
DFI (g)	29.0	31.3	29.6	30.0	0.0001	0.238
ELR (%)	88.5	92.2	89.7	90.0	0.273	0.842
FCkg (kg/kg)	3.02	3.14	2.95	2.97	0.015	0.942
FCdz (kg/dz)	0.44	0.45	0.44	0.44	0.001	0.767
EM (g)	9.31	9.80	9.19	9.33	0.044	0.703

Control: reference feed; DDGS: 150 g/kg of corn DDGS; DDGSxi: 150 g/kg of corn DDGS + xylanase; DDGScaa: 150 g/kg of corn DDGS + montmorillonite clay mineral and algae extract; SEM: standard error of mean; iBW: initial body weight; fBW: final body weight; DFI: daily feed intake; ELR: egg-laying rate; FCkg: feed conversion per kilogram of eggs; FCdz: feed conversion per dozen eggs; EM: egg mass.

DISCUSSION

Egg quality

Maize and soybean meal are the main ingredients in quail diets and are already well established as undisputed sources of energy and protein, respectively. However, finding these ingredients at an attractive price is not always possible. The availability of the ingredients is directly affected by the seasonality of the price of these grains, depending on the region, the climatic periods of the year, and phases such as the off-season (Leite et al. 2011).

Feeds with nutritional values similar to maize and soybean meal can be used as an alternative feed source for formulating poultry diets. This makes the use of maize DDGS a viable alternative for inclusion in the diet, partially replacing maize and soybean meal due to its nutritional properties (Leite et al. 2011).

The results of this study, including DDGS and the additives xylanase and algoclay complex, did not differ from the control for the quality of Japanese quail eggs. Corroborating the results of dos Santos et al. (2025), working with DDGS together with an enzyme complex, it was also

Table IV. Feed costs for laying quail as a function of the different treatments.

Ingredients	Control	150 g/kg DDGS	Price/kg
Corn	99.6	87.8	1.63
Soybean meal	85.9	59.7	2.94
Maize DDGS	0.00	18.9	1.26
Bicalcium Phosphate	13.8	15.2	12.5
Limestone	1.25	1.24	0.18
Soybean oil	0.29	2.95	2.95
Premix	1.86	1.86	4.65
NaCl	0.16	0.27	0.49
DL-Methionine 99%	24.0	20.7	56.0
L-Lysine HCL 78%	11.0	17.6	40.0
L-Threonine 99%	1.33	2.14	20.0
BHT	0.76	0.76	75.8
Total price[1] (R$)	240.0	229.2	
Price/kg (R$)	2.39	2.29	
Price/kg ($)	12.8	12.3	

[1]**Estimated price for 100 kg of feed.**

observed that there was no significant difference for the following internal quality parameters: Haugh unit and yolk index.

Since the Haugh Unit is responsible for quantifying the albumen and its presence inside the eggs, this parameter ranges from 20 to 110 and is most often found in the 50 to 100 range. Therefore, the higher the Haugh Unit value also means the greater the amount of protein present in the egg. The fact that there was no difference between treatments in this parameter shows that maize distillers' grains are an alternative for feeding quails in the laying phase and that their use does not reduce the protein present in this product (Panini 2019).

According to USDA (2000), eggs are considered of excellent quality if they have Haugh Unit values above 72. In this study, it can be seen that the Haugh Unit values are considered to be of excellent quality, as all Haugh Units are above 90%, indicating that the use of 15% DDGS, with or without additives, in the diet of Japanese quail did not affect the internal quality of the eggs.

In terms of external quality, analyzed by measuring the parameters of specific density and shell thickness of quail eggs, there was no significant difference, i.e., the shell thickness was not affected by the inclusion of this by-product, thus not affecting the calcium deposition of the layer in the eggshell (Panini 2019).

According to Leite (2018), the inclusion of soluble fibre in the diet of laying hens shows satisfactory results for poultry farmers. The inclusion of a moderate amount improves the parameters of shell strength and thickness, thus reducing the incidence of the production of eggs that are not suitable for consumption, such as broken, cracked, deformed, and/or thin-shelled eggs.

Lumpkins et al. (2005) and Świątkiewicz & Koreleski (2006) found no effect of DDGS on egg external quality in their studies, similar to the results observed in this study. Yidiz et al. (2018)

evaluated the inclusion of up to 300 g/kg DDGS in the diets of laying quails with or without enzyme supplementation. Also, they found no differences in shell thickness compared to the control diet.

However, different results were presented by Abousekken (2014), who, when evaluating the replacement of maize and soybean meal with DDGS along with a protease enzyme. The author reported that mean egg production, egg mass, feed conversion ratio, and change in body weight of Japanese quail were significantly reduced as DDGS replacement in the diet increased.

The average specific gravity of quail eggs fed diets containing DDGS in this study ranged from 1.065 to 1.069 g/cm³. According to Mendonça (2013), the specific gravity values of quail eggs of good quality are around 1.064 to 1.072. Therefore, it can be concluded that the addition of DDGS to the diet of Japanese quail maintained the good external quality of the eggs. Moreover, the calcium deposition rate showed a slight improvement, although not significant, with the specific gravity increasing from 1.065 in the control treatment to 1.069 in the treatment, including 150 g/kg DDGS, which contributed to good shell thickness and did not affect marketability.

Productive performance

In studies using DDGS, with or without enzyme supplementation in the diet of laying quails, no effect on productive performance was observed, confirming the results of the following studies (Świątkiewicz & Koreleski 2006, Cheon et al. 2008, dos Santos et al. 2025).

The xylanase and enzyme complex treatments did not differ in any way from the control treatment. This is explained by the fact that when an exogenous enzyme is added to a diet high in fibre and non-amylaceous polysaccharides (NAPs), it acts by hydrolyzing the NAPs, increasing the utilization of nutrients such as protein and energy, and potentially reducing the viscosity of the digesta (Zijlstra et al. 2010).

However, other studies in the literature provide data that allow us to reflect on how beneficial the inclusion of fibre and DDGS can be. It is also important to consider whether it is even necessary to include exogenous enzymes in the diet to improve the expressiveness of the results of the fibrous diets tested.

Bittencourt (2018), when working with different levels of inclusion of this co-product in the diet of laying quails, reported that the inclusion level of 50 g/kg DDGS was better for the laying rate than the same parameter evaluated in the control diet, as well as in this study, where the inclusion of 150 g/kg, although not statistically significant, increased the laying rate by four percentage points from 88.46 to 92.22.

Similarly, the results reported by Saeed et al. (2017) in laying hens support the idea that moderate inclusion of DDGS can be incorporated without compromising performance, and may even improve specific traits such as egg quality and nutrient deposition. In their study, DDGS levels up to 50% maintained production, while higher levels combined with vitamin E enhanced internal egg components due to improved antioxidant status. When considered together with the numerical increase in laying rate observed at 150 g/kg in our study, these findings suggest that quails, like hens, may benefit from the functional properties of DDGS, particularly its fiber and residual oil fractions. Overall, this reinforces the potential of DDGS as a viable ingredient to enhance productivity beyond basic nutrient contribution.

Analysis of the production costs of the diets

Deniz et al. (2013), in their study analyzing the inclusion of up to 200 g/kg of DDGS, concluded a savings of about R$10 per ton of feed produced. This study was concluded by comparing the

production cost of treating 200 g/kg of maize co-product with a diet without its inclusion, just as the present work shows significant savings when this co-product is included.

For example, Procópio et al. (2022) simulated about ten thousand possible feed cost scenarios for each inclusion level up to 200 g/kg DDGS at equidistant levels of 50 g/kg. They concluded that as the level of DDGS in the diet of laying hens increased, the cost of the diet decreased.

Procópio et al. (2022) also revealed each treatment's financial risk and profit, showing that the treatment without maize co-product inclusion had the lowest financial return, with an average of R$ 91.5. Meanwhile, the treatment with 50 g/kg DDGS inclusion had the highest profit margin, around R$ 131.4, followed by the 200 g/kg and 150 g/kg treatments with R$ 120.9 and R$ 110.3, respectively.

Poultry farming is a productive activity in which poultry farmers have risks, and when analyzing the economic risk of the treatments, it is defined by the probability of cases in which the profit margin is negative. The risk of the treatments, defined by the probability of cases in which the profit margin is negative, i.e., situations in which the total revenue obtained by marketing the eggs is less than the cost of feeding the bird, was used in an economic analysis. This analysis concluded that the treatments without including DDGS presented a higher percentage of economic risk, around 7.89% of the total of ten thousand simulated cases. On the other hand, for the treatments with the inclusion of 50 g/kg, 100 g/kg, and 200 g/kg of DDGS, the economic risk is no more than 1% (Procópio et al. 2022).

In the scenario between 2020 and 2021, where there was a major economic crisis caused by COVID-19, the country's economic activities faced a shortage of inputs, the hiring of specialized labor, difficulties in disposing of goods, and a reduction in egg production. Comparing the production in the third quarter of 2020 with the same period in 2021, it is possible to see a reduction in egg production of 18 million dozen and a decrease in laying farms in 16 of Brazil's 26 states. It is important to analyze the financial risk of this activity and look for ways to reduce the risks of doing it so that the producer can stay in business longer (Soares & Ximenes 2022).

We are susceptible to unannounced crises such as COVID-19, which ultimately affect the Brazilian agribusiness market, that already suffers mainly from instability in the prices of inputs and products in certain locations, caused by logistical difficulties. The instability in the prices of grains used in laying diets is not new and has been reported for two decades, by de Souza Loureiro et al. (2007).

CONCLUSIONS

The inclusion of 150 g/kg DDGS in the diet of Japanese quails in the laying phase did not alter the production performance of the birds or the internal and external quality of the eggs, resulting in a greater economic benefit. Not unlikely the latter, the use of exogenous additives (xylanase and metabolisability enhancers based on clay and algae) did not show any alteration in the same parameters in the diet of laying quails.

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Data availability

The datasets generated during the current study are available from the corresponding author upon request.