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The use of dried distiller's grains with solubles (DDGS) combined with the use of additives in the diet of broiler quails

Utilização dos grãos secos de destilaria de milho com solúveis (DDGS) associado ao uso de aditivos na dieta de codornas de corte

Marcos Adriano Pereira Barbosa*[1], Mariani Ireni Benites[1], Debora Rodrigues de Aquino[1], Pedro Afonso de Souza Ezidio[1], Caroline Espejo Stanquevis[1], Vinicius Ricardo Cambito de Paula[2], Daiane de Oliveira Grieser[3], Simara Marcia Marcato[1]

1 Universidade Estadual de Maringá (UEM), Maringá, Paraná, Brazil
2 Universidade Federal do Mato Grosso (UFMT), Sinop, Mato Grosso, Brazil
3 Universidade Federal do Sul e Sudeste do Pará (Unifesspa), Xinguara, Pará, Brazil
*corresponding author: marcosbarbosa0597@hotmail.com

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Abstract: This study aimed to evaluate the effect of using DDGS as an alternative to traditional feed ingredients in the diet of broiler quails, in association with the of two additives, to assess performance, carcass yield and parts, body chemical composition, relative organ weight, and the production cost of the feeds. A total of 360 unsexed broiler quails (*Coturnix coturnix coturnix*) were used, distributed into four treatments: Control: reference diet based on corn and soybean meal; DDGS: diet with 15% inclusion of DDGS; DDGS + xil: diet with 15% inclusion of DDGS and 0.01% xylanase enzyme (on top); DDGS + caa: diet with 15% inclusion of DDGS and 0.1% of a metabolizability enhancer based on clay and algae, with five replications and eighteen birds per experimental unit. From 1 to 14 days of age, there was an effect only on feed intake (P<0.05), with the control treatment showing higher consumption. During the periods of 15 to 35 days and 1 to 35 days, no differences (P>0.05) were observed for performance variables, body composition, relative organ weight, and there were no differences in carcass yield and parts at 35 days. It is concluded that in diets for European quails, 15% DDGS can be included during the growth phase without affecting performance and with greater economic efficiency. The use of additives was not shown to be effective in the diets of growing broiler quails.

Key-words: alternative feed; *Coturnix coturnix coturnix*, algae extract; xylanase.

Resumo: Este trabalho buscou avaliar o efeito da utilização do DDGS como uma alternativa ao uso dos alimentos tradicionais na alimentação de codornas de corte em associação com dois aditivos, para avaliar o desempenho, rendimento de carcaça e partes, composição química corporal, peso relativo dos órgãos e custo produtivo das rações. Foram utilizadas um total de 360 codornas de corte (*Coturnix coturnix coturnix*), não sexadas, distribuídas em quatro tratamentos: Controle: dieta referência à base de milho e farelo de soja; DDGS: dieta com inclusão de 15% de DDGS; DDGS + xil: dieta com inclusão de 15% de DDGS e 0,01% de enzima xilanase (on top); DDGS + caa: dieta com inclusão de 15% de DDGS e 0,1% do melhorador de metabolizabilidade à base de argila e algas, com cinco repetições e com dezoito aves por unidade experimental. De 1 a 14 dias de idade, houve efeito apenas para consumo de ração (P<0,05), apresentando, assim, o tratamento controle um maior consumo. Nos períodos de 15 a 35 dias e de 1 a 35 dias, não houve diferença (P>0,05) para as variáveis de desempenho, composição corporal e peso relativo dos órgãos, o mesmo ocorre para o rendimento de carcaça e partes aos 35 dias. Conclui-se que, em dietas de codornas europeias, pode-se incluir em 15% o DDGS na fase de crescimento sem interferir no desempenho e com maior aproveitamento econômico. A utilização de aditivos não demonstrou ser efetiva nas dietas de codornas de corte em fase de crescimento.

Palavras-chave: alimento alternativo; *Coturnix coturnix coturnix*; extrato de algas; xilanase.

1. Introducion

Farmers and the food industry are increasingly interested in developing alternative feed ingredients for poultry diets, seeking to reduce costs without compromising animal performance. Corn is the primary energy source, and soybean meal the most common protein source in non-ruminant diets[1]. Nevertheless, the use of alternative foodstuffs has become increasingly popular in quail production, supported by studies showing that agroindustrial byproducts can reduce feed costs without adversely affecting animal performance or product quality.

However, such alternative ingredients must be carefully evaluated[2], as they may contain antinutritional factors that interfere with nutrient digestion and absorption, such as non-starch polysaccharides (NSPs)[3,4]. This class encompasses a wide variety of polysaccharides found in plant cell walls, such as cellulose, hemicellulose, chitin, and pectin. At high concentrations, these compounds can increase intestinal viscosity and reduce nutrient digestibility, ultimately impairing animal performance[5,6].

When analyzing the inclusion of fibrous ingredients in non-ruminant diets, it is important to consider both the quantity and characteristics of fibers, particularly their solubility. In adequate quantities, dietary fibers increase the retention time of digesta in the upper gastrointestinal tract, thereby promoting gizzard development. The gizzard plays a fundamental role in poultry digestion, and its mechanical activity stimulates the production of endogenous enzymes, enhancing the digestibility of nutrients such as starch, protein, and lipids[7].

Dried distillers' grains with solubles (DDGS) have emerged as a promising alternative to corn and soybean meal in non-ruminant diets. DDGS is a co-product of corn ethanol production. In this process, starch is fermented by yeasts and enzymes, yielding ethanol and carbon dioxide[8]. DDGS possesses favorable nutritional characteristics for quail diets, including a crude protein content of approximately 30%[9], in addition to a high metabolizable energy value for birds. Its utilization in quail diets can reduce production costs and minimize environmental impacts. In Brazil, corn-based ethanol production has grown significantly, generating large amounts of waste that may pose an environmental risk if not properly managed. Utilizing DDGS in animal feed is an environmentally sustainable solution, as it diverts waste toward productive use, enhancing economic and ecological sustainability in both poultry and ethanol industries[10].

Given the potential of DDGS as an alternative to corn and soybean meal in quail diets, further research is needed to evaluate its effects on animal performance. In particular, it is important to assess the use of DDGS with and without feed additives, such as exogenous enzymes[11]. Non-ruminants lack the capacity to hydrolyze NSPs and fully access nutrients within fibrous matrices. Therefore, supplementation with exogenous enzymes, such as xylanases, cellulases, and glucanases, can help hydrolyze NSPs in feed, improving energy utilization and reducing the negative impact of indigestible components on digesta viscosity[4, 12].

In light of the foregoing, this study aimed to examine the potential of DDGS as an alternative to corn and soybean meal in broiler quail diets, in combination with two exogenous additives, and assess the effects on bird performance, carcass yield, body chemical composition, relative organ weights, and production costs.

2. Material and methods

The experiment was conducted between May and June 2022 at the Broiler Quail Production Sector of the Iguatemi Experimental Farm, Maringá, Paraná, Brazil. Experimental procedures were approved by the local Animal Ethics Committee (Protocol No. 8147180521).

2.1 Facilities, design, and experimental diets

A total of 360 unsexed broiler quail (*Coturnix coturnix*) were used. Birds were distributed into four treatments, as follows: control, reference diet based on corn and soybean meal; DDGS, diet containing 15% DDGS; DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase (added on top); and DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer. Each treatment comprised 18 birds (experimental unit) and 5 replications.

During the experimental period (1 to 35 days of age), the birds were housed in 2.5 m^2 pens in a conventional shed. Each pen had rice straw bedding and 0.50 m high masonry walls, covered with wire mesh extending to the roof. The shed was equipped with movable curtains. Feed and water were provided ad libitum. Until 14 days of age, protective brooder rings were used to minimize temperature fluctuations and shield the birds from air drafts. Heating was provided continuously by 250 W electric infrared heat lamps mounted under reflective hoods.

Air temperature and relative humidity were recorded twice a day (early morning and late afternoon) throughout the experimental period. Maximum and minimum dry bulb hygrometers were installed at two points in the shed, one at bird level and the other in the general environment. In the starter phase, the minimum, average, and maximum temperatures were 20.87, 27.58, and 36.35 °C, respectively. The minimum, average, and maximum relative humidity values were 45.67%, 64.11%, and 76.33%, respectively. In the grower phase, the minimum, average, and maximum temperatures were 17.35, 24.20, and 30.29 °C, respectively. The minimum, average, and maximum relative humidity values were 46.79%, 68.05%, and 76.83%, respectively.

All experimental diets were formulated to be isoproteic and isoenergetic, based on previously reported chemical composition, energy values(13), and amino acid profiles(14). Additives were incorporated on top. Xylanase was added at a rate of 0.01 g kg^{-1} feed. The enzyme cofactor product, which contains a combination of the clay mineral montmorillonite and algal (*Ulva lactuca* and *Solieria chordalis*) extracts, was included at 0.10 g kg^{-1} feed. These inclusion levels were maintained in the starter and grower phases (Tables 1 and 2).

Table 1. Ingredient composition and calculated nutrient content of experimental diets for broiler quail in the starter phase (1 to 14 days of age).

Ingredient (%)	Control[4]	DDGS[5]	DDGS + Xyl[6]	DDGS + DE[7]
Corn grain	41.79	37.40	37.40	37.40
Soybean meal	50.97	40.01	40.01	40.01
DDGS	0.00	15.00	15.00	15.00
Dicalcium phosphate	1.44	1.44	1.44	1.44
Limestone	0.37	0.37	0.37	0.37
Common salt	0.46	0.45	0.45	0.45
Soybean oil	3.79	4.14	4.14	4.14
L-Lysine HCl	0.20	0.20	0.20	0.20
DL-Methionine	0.44	0.45	0.45	0.45
L-Threonine	0.13	0.13	0.13	0.13
BHT[1]	0.01	0.01	0.01	0.01
Vitamin–mineral premix[2]	0.40	0.40	0.40	0.40
Total	100.00	100.00	100.00	100.00
Calculated composition				
ME[3] (Mcal kg^{-1})	2.997	2.997	2.997	2.997
Crude protein (%)	27.50	27.50	27.50	27.50
Calcium (%)	0.65	0.65	0.65	0.65
Chlorine (%)	0.32	0.32	0.32	0.32
Potassium (%)	1.07	1.07	1.07	1.07
Sodium (%)	0.20	0.20	0.20	0.20
Phosphorus (%)	0.41	0.41	0.41	0.41
Digestible lysine (%)	1.60	1.60	1.60	1.60
Digestible methionine + cysteine (%)	1.15	1.15	1.15	1.15
Digestible threonine (%)	1.04	1.04	1.04	1.04
Digestible tryptophan (%)	0.31	0.31	0.31	0.31

[1] Butylated hydroxytoluene; [2] Provided per kg of product: vitamin A, 2,500,000 IU; vitamin D3, 750,000 IU; vitamin E, 5000 IU; vitamin B1, 625 mg; vitamin B2, 1500 mg; vitamin B6, 1250 mg; vitamin B12, 5000 mcg; vitamin K3, 750 mg; calcium pantothenate, 3000 mg; niacin, 6000 mg; folic acid, 250 mg; biotin, 50.0 mg; choline, 75 g; antioxidant, 4360 mg; zinc, 12.5 g; iron, 12.5 g; manganese, 15.0 g; copper, 3000 mg; cobalt, 50 mg; iodine, 250 mg; and selenium, 62.5 mg; [3]ME, Metabolizable energy [4]Control, reference diet based on corn and soybean meal; [5]DDGS, diet containing 15% DDGS; [6]DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase; and [7]DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer.

Table 2. Ingredient composition and calculated nutrient content of experimental diets for broiler quail in the grower phase (15 to 35 days of age).

Ingredient (%)	Control[4]	DDGS[5]	DDGS + Xyl[6]	DDGS + DE[7]
Corn grain	50.99	43.73	43.73	43.73
Soybean meal	41.56	32.86	32.86	32.86
DDGS	0.00	15.00	15.00	15.00
Dicalcium phosphate	1.68	1.74	1.74	1.74
Limestone	0.12	0.16	0.16	0.16
Common salt	0.47	0.46	0.46	0.46
Soybean oil	3.88	4.56	4.56	4.56
L-Lysine-HCl	0.30	0.44	0.44	0.44
DL-Methionine	0.43	0.38	0.38	0.38
L-Threonine	0.16	0.17	0.17	0.17
BHT[1]	0.01	0.01	0.01	0.01
Vitamin–mineral premix[2]	0.40	0.40	0.40	0.40
Total	100.00	100.0	100.00	100.00
Calculated composition				
ME[3] (Mcal kg^{-1})	3.036	3.036	3.036	3.036
Crude protein (%)	23.50	23.50	23.50	23.50
Calcium (%)	0.61	0.61	0.61	0.61
Chlorine (%)	0.32	0.32	0.32	0.32
Potassium (%)	0.92	0.92	0.92	0.92
Sodium (%)	0.20	0.20	0.20	0.20
Phosphorus (%)	0.41	0.41	0.41	0.41
Digestible lysine (%)	1.45	1.45	1.45	1.45
Digestible methionine + cysteine (%)	1.04	1.04	1.04	1.04
Digestible threonine (%)	0.94	0.94	0.94	0.94
Digestible tryptophan (%)	0.29	0.29	0.29	0.29

[1] Butylated hydroxytoluene; [2]Provided per kg of product: vitamin A, 2,500,000 IU; vitamin D3, 750,000 IU; vitamin E, 5000 IU; vitamin B1, 625 mg; vitamin B2, 1500 mg; vitamin B6, 1250 mg; vitamin B12, 5000 mcg; vitamin K3, 750 mg; calcium pantothenate, 3000 mg; niacin, 6000 mg; folic acid, 250 mg; biotin, 50.0 mg; choline, 75 g; antioxidant, 4360 mg; zinc, 12.5 g; iron, 12.5 g; manganese, 15.0 g; copper, 3000 mg; cobalt, 50 mg; iodine, 250 mg; and selenium, 62.5 mg; [3]ME, Metabolizable energy [4]Control, reference diet based on corn and soybean meal; [5]DDGS, diet containing 15% DDGS; [6]DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase; and [7]DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer..

2.2 Production performance

Feed intake, weight gain, and feed conversion ratio (FCR) were analyzed in the starter (1 to 14 days) and grower (15 to 35 days) phases. Birds were weighed at 1, 14, and 35 days of age. Feed and leftovers were weighed to monitor feed intake and FCR. Dead birds were counted daily to adjust feed intake calculations[(15)].

2.3 Relative organ weights and small intestine length

For determination of relative organ weights, two birds per experimental unit (selected based on mean body weight ± 5%) were slaughtered at 14 and 35 days of age. The birds were sacrificed, bled, and eviscerated via an abdominal incision to excise the heart, gizzard, liver, and small intestine. These organs were weighed on a precision scale (g), and their relative weights (%) were calculated in relation to live body weight (g) using Eq. (1):

(1) Relative organ weight = Organ weight/Live body weight × 100

The length of the small intestine (cm) was measured using a tape measure.

2.4 Body chemical composition, fat and protein deposition rates, and carcass energy retention

Body chemical composition was determined at the end of each experimental phase. At 14 and 35 days of age, four and two birds per replicate, respectively, were selected based on mean body weight ± 5%. The birds were slaughtered and frozen whole (including feathers, viscera, head, and feet). Subsequently, samples were thawed, weighed, ground in an industrial mill, and homogenized. The homogenized samples were dried in a forced-air oven at 55 °C for 72 h. Then, the dried samples were re-ground and sent to the Laboratory of Animal Nutrition (LANA) at the Department of Animal Science, State University of Maringá, Paraná, Brazil, for analysis. Chemical composition was determined by measuring dry matter, mineral matter, crude protein, and ether extract contents(16).

Body chemical composition data at 14 and 35 days of age, along with data from an additional group of 20 birds slaughtered at hatch, were used to calculate protein deposition (PDR) and fat deposition (FDR) rates (g day^{-1}), as shown in Eqs. (2) and (3), respectively.

(2) $PDR=(CP_f - CP_i)/t$

(3) $FDR=(CF_f - CF_i)/t$

where CPf and CPi are the final and initial carcass protein contents (g), respectively; CFf and CFi are the final and initial carcass fat contents (g), respectively; and t is the experimental period (days)(16,17).

From PDR and FDR values, it was possible to calculate carcass energy retention (CER) (Eq. 4).

(4) $CER=(5.66 \times PDR)+(9.37 \times FDR)$

where 5.66 and 9.37 represent the energy values (kcal g^{-1}) of protein and fat, respectively(18).

2.5 Carcass and cut yields

After an 8 h fasting period, the birds were weighed and individually identified with a plastic tag on the left foot. Fasted live body weights were recorded individually. Then, the birds were desensitized, sacrificed by cervical dislocation between the occipital and atlas bones, bled for 2 min in a slaughter cone, and manually plucked. The birds were gutted for the removal of viscera, feet, neck, and head and weighed again. Carcasses were not washed after evisceration to prevent weight alteration due to water absorption. Carcass and cut yields (%) were calculated from weight data (g) using the following equations (Eqs. 5 and 6):

(5) Carcass yield=Carcass weight×100/Live body weight

(6) Cut yield=Cut weight×100/Carcass weight

2.6 Analysis of diet costs

The costs of starter and grower diets for broiler quail were calculated based on the price per kilogram of raw materials. Prices refer to market values in May 2022 in Maringá, Paraná, Brazil. Fixed costs were assumed to remain constant throughout the experimental period.

2.7 Statistical analysis

Statistical analyses were performed using SAS software(19). First, data were tested for normality using the Shapiro–Wilk test. Once the residuals were confirmed to be normally distributed, analysis of variance (ANOVA) was conducted using the PROC GLM procedure of SAS, and means were compared using Tukey's test at $p < 0.05$.

3. Results and discussion

3.1 Production performance

Dietary treatments did not influence the body weight, weight gain, or FCR ($p > 0.05$) of birds aged 1 to 14 days; however, feed intake was significantly influenced by diet ($p < 0.05$). Birds fed the control diet exhibited a higher feed intake, reaching 10 g bird^{-1} day^{-1}, compared with birds fed the DDGS diet. Among birds aged 15–35 days, diets did not exert significant effects on any variable ($p > 0.05$). In considering the entire growth period of broilers, from 1 to 35 days of age, the analysis revealed a lack of significant effects ($p < 0.05$) on body weight, weight gain, feed intake, and FCR (Table 3).

Table 3. Production performance of broiler quail fed different diets during growth.

Variable	Diet				SEM	p-value
	Control	DDGS	DDGS + Xyl	DDGS + DE		
1 to 14 days of age						
Body weight (g)	73.55	75.44	74.80	71.37	0.398	0.6902
Weight gain (g)	65.09	66.98	66.26	62.90	0.358	0.6869
Feed intake (g bird^{-1})	135.52a	122.74b	125.64ab	129.69ab	1.094	0.0401
FCR (g g^{-1})	2.08	1.86	1.89	2.07	0.020	0.1905
15 to 35 days of age						
Body weight (g)	189.28	193.93	191.31	191.45	0.392	0.7334
Weight gain (g)	119.56	118.50	116.50	120.08	0.488	0.8521
Feed intake (g bird^{-1})	291.07	310.26	295.23	315.64	1.917	0.6507
FCR (g g^{-1})	2.53	2.62	2.53	2.64	0.031	0.9328
1 to 35 days of age						
Initial body weight (g)	8.54	8.54	8.54	8.54	0.007	0.8412
Final body weight (g)	189.28	193.93	191.31	191.45	0.392	0.7334
Weight gain (g)	180.74	185.39	182.77	182.91	0.396	0.7252
Feed intake (g bird^{-1})	509.36	516.96	478.36	533.50	3.726	0.4608
FCR (g g^{-1})	2.81	2.78	2.61	2.92	0.013	0.5237

Means in a row followed by different letters differ significantly at $p < 0.05$ by Tukey's test. FCR, feed conversion ratio; Control, reference diet based on corn and soybean meal; DDGS, diet containing 15% DDGS; DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase; and DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer; SEM, standard error of the mean.

DDGS is a viable source of protein and energy, with the potential to replace the commodities traditionally used in quail nutrition. The availability and price of both corn and soybean meal are subject to seasonal variations, prompting the search for alternative ingredients for feed formulation.

In the early stages of life, the digestive tract of birds is not fully developed, which can directly influence feed intake, particularly when diets are high in fiber. In this study, the diets containing DDGS had elevated fiber levels, which likely contributed to the reduced feed intake observed in starter quail (1–14 days of age). Birds in the control group had a higher feed intake (135.52 g bird^{-1}) than birds fed the DDGS diet (<130 g bird^{-1}). A previous study on DDGS inclusion recommended not providing broilers with diets rich in fiber before 14 days of age, as dietary fiber can reduce amino acid metabolizability. This effect is compounded by the limited enzymatic and digestive activity of quail chicks, making them more sensitive to feed quality[21].

Nevertheless, the inclusion of a controlled amount of fiber in quail diets may be an interesting strategy, given that feed intake decreased but the other performance variables (body weight, weight gain, and FCR) were not significantly influenced. Of note, although differences were not significant, the

FCR of experimental groups was 20 g g^{-1} lower than that of the control, representing important savings for poultry farmers.

The results for body weight, weight gain, and FCR during starter and grower phases revealed that the inclusion of DDGS in broiler quail diets, with or without the addition of digestibility enhancers, does not negatively affect production performance. The diets were formulated to be isoproteic and isoenergetic, which required the inclusion of synthetic amino acids to maintain their nutritional adequacy. These findings are in agreement with previous studies reporting no significant differences in performance among broilers fed diets containing 0 and 15% DDGS(22) and up to 20% DDGS[23].

The lack of significant differences in body weight, weight gain, and FCR between diets can be explained by the presence of fiber. The fibrous fraction of feed leads to gel formation in the gastrointestinal tract of quail, preventing the action of hydrolytic enzymes and rendering some nutrients unavailable for absorption, consequently impairing growth parameters[24].

3.2 Relative organ weights and small intestine length

There was no effect ($p > 0.05$) of diets on the relative weights of the gizzard, heart, liver, and intestine or small intestine length in any of the evaluated periods (1–14 and 1–35 days of age) (Table 4).

Table 4. Relative organ weight and small intestine length of broiler quails at 14 and 35 days of age according to dietary treatment.

Variable	Diet				SEM	p-value
	Control	DDGS	DDGS + Xyl	DDGS + DE		
14 days of age						
Gizzard (%)	3.28	3.42	3.07	2.82	0.048	0.3248
Heart (%)	0.75	0.84	0.80	0.81	0.006	0.6580
Liver (%)	2.19	2.28	2.25	2.23	0.041	0.1239
Intestine (%)	3.62	3.46	3.62	3.17	0.038	0.3826
Small intestine (cm)	46.90	46.21	46.80	45.70	0.099	0.9166
35 days of age						
Gizzard (%)	2.52	2.37	2.26	2.23	0.024	0.4630
Heart (%)	0.96	0.98	0.92	0.99	0.008	0.7023
Liver (%)	1.71	1.55	1.42	1.79	0.028	0.1840
Intestine (%)	2.49	2.33	2.12	2.37	0.016	0.3585
Small intestine (cm)	64.85	59.63	59.20	61.32	0.560	0.4191

Means in a row followed by different letters differ significantly at $p < 0.05$ by Tukey's test. Control, reference diet based on corn and soybean meal; DDGS, diet containing 15% DDGS; DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase; and DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer; SEM, standard error of the mean.

Previous studies reported similar findings, whereby DDGS inclusion levels of 6%, 12%, and 18% in broiler diets did not exert significant effects on the relative weights of the heart or gizzard at 35 days[25]. In another study, the relative weights of the heart and gizzard and intestinal parameters (weight and length) were not influenced by the inclusion of DDGS in broiler quail diets[26]. In broiler chickens aged up to 42 days, dietary inclusion of 16% DDGS also did not affect these organ parameters[26].

Intestinal morphometry is a key factor for evaluating the suitability of alternative ingredients to replace corn and soybean meal in quail nutrition. The characteristics of the digestive tract are directly linked to health and intestinal integrity. Intestine weight, for example, is correlated with mucus composition, which plays a protective role by shielding the intestinal lining from physical damage caused by the diet and by preventing self-digestion[24]. Intestinal length is closely related to digestive efficiency and nutrient retention capacity, also being directly associated with digestive capacity. In other words, the larger the intestine of quail, the greater the capacity for nutrient utilization, given that the food bolus will remain in contact with digestive enzymes for a longer period[27].

In this context, the lack of significant differences between treatments indicates that DDGS can be included at 15% in the diet of European quail without compromising intestinal health or integrity. These diets provide intestinal quality comparable to conventional diets based on corn and soybean meal.

3.3 Body chemical composition, protein and fat deposition rates, and carcass energy retention

Diets had no significant effect ($p > 0.05$) on body chemical composition (crude protein, ether extract, and mineral matter), protein and lipid deposition rates, or carcass energy retention (Table 5). A study investigating broiler chickens aged 1 to 42 days showed that, among the tested inclusion levels (0, 15%, and 30%), up to 15% DDGS could be added to diets without compromising performance or body composition[28], in agreement with the current results.

Table 5. Body chemical composition, protein and fat deposition rates, and carcass energy retention of 14- and 35-day-old broiler quail fed different diets.

Variable	Diet				SEM	p-value
	Control	DDGS	DDGS + Xyl	DDGS + DE		
14 days of age						
Crude protein (%)	66.11	69.21	68.22	69.72	0.157	0.4832
Ether extract (%)	11.41	13.13	13.40	12.39	0.073	0.3873
Mineral matter (%)	12.33	12.20	11.30	11.74	0.064	0.3869
Protein deposition (g day^{-1})	3.11	3.38	3.29	3.21	0.005	0.6518
Fat deposition (g day^{-1})	0.60	0.60	0.60	0.52	0.009	0.8724
Carcass energy (kcal g^{-1}, dry matter basis)	23.27	24.83	24.29	23.04	0.103	0.7665
35 days of age						
Crude protein (%)	66.12	63.34	63.79	62.95	0.199	0.4462
Ether extract (%)	17.93	21.03	19.28	18.89	0.296	0.2368
Mineral matter (%)	8.29	7.61	7.41	7.95	0.090	0.1106
Protein deposition (g day^{-1})	3.43	3.36	3.34	3.04	0.016	0.8287
Fat deposition (g day^{-1})	0.92	1.12	1.01	0.99	0.023	0.2014
Carcass energy (kcal g^{-1}, dry matter basis)	28.15	29.59	28.43	27.97	0.273	0.4459

Means in a row followed by different letters differ significantly at $p < 0.05$ by Tukey's test. Control, reference diet based on corn and soybean meal; DDGS, diet containing 15% DDGS; DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase; and DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer; SEM, standard error of the mean.

3.4 Carcass and cut yields

Research on DDGS inclusion in poultry diets has aimed to provide comprehensive insights into the effects on performance. Carcass and cut yields represent critical economic factors for evaluating dietary alternatives. These parameters are essential in determining whether a feed ingredient is viable, as cost savings are only meaningful if they do not negatively impact overall production outcomes—whether in meat or egg production—or compromise animal performance. Therefore, assessing carcass yield is fundamental to ensuring that dietary substitutions do not reduce the profitability of poultry farming.

There were no differences between treatments ($p > 0.05$) in the carcass and cut yields of European quail at 35 days of age (Table 6). Carcass yields were as follows: 57.28% in the control group, 58.86% in the 15% DDGS group, 59.99% in the DDGS + Xyl group, and 60.21% in the DDGS + DE group. Additionally, no differences were observed in cut (drum + thigh, breast, wings, and back) yields.

Table 6. Carcass and cut yields of broiler quail at 35 days of age according to diet.

Yield	Diet				SEM	p-value
	Control	DDGS	DDGS + Xyl	DDGS + DE		
Carcass (%)	59.28	58.86	59.99	60.21	0.198	0.1310
Drum + thigh (%)	26.91	25.53	26.61	27.79	0.136	0.1144
Breast (%)	44.63	45.73	46.07	45.37	0.118	0.2121
Wings (%)	10.52	10.48	10.22	10.60	0.026	0.7380
Back (%)	16.81	16.39	16.04	16.83	0.277	0.7180

Means in a row followed by different letters differ significantly at $p < 0.05$ by Tukey's test. Control, reference diet based on corn and soybean meal; DDGS, diet containing 15% DDGS; DDGS + Xyl, diet containing 15% DDGS and 0.01% xylanase; and DDGS + DE, diet containing 15% DDGS and 0.1% clay- and algae-based digestibility enhancer; SEM, standard error of the mean.

In agreement with the current study, previous research showed that the carcass and cut yields of broiler chickens fed diets containing different inclusion levels of DDGS (0, 6%, 12%, and 18%) did not differ[29]. Furthermore, the inclusion of up to 25% DDGS did not affect broiler performance or carcass yield[30]. Thus, a moderate addition of fiber in the diet of non-ruminants may improve productive viability without affecting bird performance[31]. In another study, it was found that 8% DDGS inclusion in broiler diets did not cause changes to carcass yield or weight gain[32].

3.5 Cost analysis of experimental diets

As demonstrated in Table 7, the inclusion of 15% DDGS in the starter diet led to a reduction in diet price per kilogram (R$0.19) compared with the basal diet. The reference diet had a greater quantity of soybean meal, whose price per kilogram was R$1.68 higher than that of DDGS. For the grower diet, such substitution was also viable, resulting in a R$0.10 savings for every kilogram of feed produced.

Table 7. Cost analysis of feed ingredients for starter and grower diets of European quail.

Ingredients	Starter diet		Grower diet		Price per kg
	Control	15% DDGS	Control	15% DDGS	
Corn grain	68.11	60.96	83.11	71.27	1.63
Soybean meal	149.85	117.62	122.18	96.60	2.94
DDGS[1]	0.00	18.90	0.00	18.90	1.26
Dicalcium phosphate	17.92	17.92	20.91	21.66	12.45
Limestone	0.06	0.06	0.02	0.02	0.18
Common salt	1.35	1.32	1.39	1.35	2.95
Soybean oil	17.62	19.25	18.04	21.76	4.65
L-Lysine HCl	9.80	9.80	14.70	21.56	49.00
DL-Methionine	24.64	25.2	24.08	21.28	56.00
L-Threonine	5.20	5.20	6.40	6.80	40.00
Butylated hydroxytoluene	0.20	0.20	0.20	0.20	20
Vitamin–mineral premix	30.33	30.33	30.33	30.33	75.84
Total cost[2] (BRL)	325.08	306.76	321.36	311.73	
Price/kg (BRL)	3.25	3.06	3.21	3.11	
Price/kg[3] (USD)	0.62	0.58	0.61	0.59	

[1] DDGS, dried distillers' grains with solubles.
[2] Cost per 100 kg of feed.
[3] Exchange rate on the day of analysis: 1 USD = 5.32 BRL

Industrial co-products have proven to be a valuable alternative in terms of economic viability, particularly when included at appropriate levels in poultry diets. In the current study, the inclusion of 15% DDGS did not negatively affect the performance of broiler quail. From an economic perspective, this inclusion level resulted in feed cost savings of about R$0.20 per kilogram in the starter phase and R$0.10 per kilogram in the grower phase, confirming the feasibility of corn DDGS in quail nutrition.

Similar findings were reported for other co-products. For example, the gradual inclusion of sorghum DDGS in broiler diets reduced feed costs[33]. Although the study was based on a different species, it was found that a 15% inclusion level yielded comparable outcomes: savings of R$0.15 and R$0.12 were achieved per kilogram of feed during the starter (1–14 days of age) and grower (15–34 days) phases, respectively, of broiler chicken.

4. Conclusion

It is concluded that up to 15% DDGS can be included in grower diets for European quail to increase economic returns without affecting growth, carcass yield, or body chemical composition. There was an estimated savings of R$18.36 in the starter phase and R$9.73 in the grower phase for every 100 kg of feed produced compared with the conventional corn- and soybean meal-based diet. Exogenous additives (xylanase and enzyme cofactor) did not exert significant benefits in broiler performance in either phase.

Conflict of interest statement

The authors declare no conflict of interest.

Data availability statement

Data will be made available on request to the corresponding author.

Author contributions

Conceptualization: M. A. P. Barbosa, S. M. Marcato, and D. de O. Grieser. Data curation: V. R. C. de Paula and C. E. Stanquevis. Project administration: M. A. P. Barbosa, S. M. Marcato, and M. I. Benites. Methodology: M. A. P. Barbosa, M. I. Benites, D. R. de Aquino, and P. A. de S. Ezidio. Supervision: S. M. Marcato and D. de O. Grieser. Writing - Review & Editing: M. A. P. Barbosa and S. M. Marcato.

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