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Corn distillers dried grains with solubles in the feed of broilers and their effects on the performance, carcass yield, and gastrointestinal characteristics

[*Grãos secos de destilaria com solúveis na alimentação de frangos de corte e seus efeitos sobre o desempenho, rendimento da carcaça e características gastrointestinais*]

"Artigo Científico/Scientific Article"

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Abstract

This study was conducted to determine the effect of different levels of corn distillers dried grains with solubles (DDGS) in the diet of broilers, with regard to the performance, carcass yield, and gastrointestinal characteristics. A mixed lot of 700 one-day-old broilers from the COOB 500 lineage were used. It was distributed in a completely randomized design with five treatments, seven repetitions, and twenty broilers per experimental unit — ten male and ten female. The DDGS levels studied were inclusion of 4%, 8%, 12%, and 16% on experimental diets, plus the control treatment (0%). The period of 1–42 days were considered for performance evaluation. For performance, the following factors were evaluated weight gain (WG) (g/bird/day), ration consumption (RC) (g/bird/day), feed conversion (FC), medium weight (MW), productive efficiency index (PEI), and viability (V). At 42 days of age, two broilers from each lot were selected, weighed, and the ones with medium weight were identified from the experimental unit, for slaughtering and evaluation of cut yield, carcass, and gastrointestinal biometry. The evaluated parameters were submitted to variance analyses with a 5% probability, using the statistical program SAS-2012. The effects of the inclusion of DDGS were estimated through variable analyses via regression models and the contrasts by the Dunnett test, with a 5% probability. In the period of 1–42 days of production, the values of better performance obtained for the variables WG, FC, MW, and PEI were at levels of 7.28%; 10.60%; 12.10%, and 12.92%, respectively. There was a reduction in carcass weight, breast, and fat of the broilers, when using 12% and 16% of DDGS. Therefore, it indicated the inclusion of up to 11.02%, and 7.44% in the diet, so there was no loss on carcass yield and breast weight, respectively.

Keywords: co-products; ethanol; meat product; poultry; viscera

Resumo

Este estudo foi conduzido para determinar o efeito de diferentes níveis de grãos secos de destilaria de milho com solúveis (DDGS) na dieta de frangos de corte sobre desempenho, rendimento de carcaça e características gastrointestinais. Foi utilizado um lote misto de 700 frangos de corte de um dia da linhagem COOB 500, distribuídos em delineamento inteiramente casualizado com 5 tratamentos, 7 repetições e 20 frangos por unidade experimental, sendo 10 machos e 10 fêmeas. Os níveis de DDGS estudados foram 4; 8; 12, e 16% de inclusão nas dietas experimentais, mais o tratamento controle (0%). O período de 1 a 42 dias foi considerado para avaliação de desempenho. Para desempenho, avaliou-se ganho de peso (GP; g/ave/dia), consumo de ração (CR; g/ave/dia), conversão alimentar (CA), peso médio (PM), índice de eficiência produtiva (IEP) e viabilidade (V). Aos 42 dias de idade, dois frangos de cada lote foram selecionados com peso médio da unidade experimental, e identificados para abate e avaliação do rendimento de cortes, carcaça e biometria gastrointestinal. Os parâmetros avaliados foram submetidos a análises de variância com 5% de probabilidade por meio do programa estatístico SAS. Os efeitos da inclusão do DDGS foram estimados por

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meio de análises de variáveis via modelos de regressão e os contrastes pelo teste de Dunnett com 5% de probabilidade. Para as variáveis GP, CR, PM e IEP no período de 1-42 dias de produção, foram obtidos valores de melhor desempenho no nível de 7,28%; 10,60%; 12,10% e 12,92%, respectivamente. Houve redução do peso da carcaça, do peito e da gordura dos frangos com 12 e 16% de DDGS. Portanto, indica-se a inclusão de até 11,02% e 7,44% na dieta, para que não haja prejuízo no rendimento de carcaça e no peso do peito, respectivamente.

Palavras-chave: coprodutos; etanol; produto cárneo; avicultura; vísceras.

Introduction

The search for a fuel that is less pollutant increases the interest in ethanol. Beyond ethanol production, a co-product is emerging from this demand for biofuels, the corn distillers' dried grains with solubles (DDGS), or dried distillers' grain with corn solubles, which is obtained after the process of corn starch fermentation by yeasts and enzymes (Cortes Cuevas et al., 2012). These nutritive compounds present in its composition, a high content of proteins and fibers, associated with low costs, it is a source of protein, amino acids, energy, and phosphorus, among other nutrients (Lumpkins et al., 2004).

In animal production, corn and soybean meal are the principal inputs used as sources of energy and protein, respectively, both essential for the development of animals. In this context, DDGS can be an alternative source of nutrition in animal production, including poultry farming, with lower costs, and it seems to be very promising.

Throughout the years, Brazil has been projected as one of the biggest producers of chicken meat in the world. High demands of inputs on the broilers' diet justifies the usage of sub-products in the industry, to minimize diet costs, knowing that it represents around 70% of the expenditure on poultry production (Sakomura and Rostagno, 2007).

Centenaro et al. (2008) reported that among the food from the animal origin, chicken meat is considered healthier because it has less saturated fat and cholesterol content and a low cost. Given the above-mentioned factors, the objective was to evaluate the effect of the inclusion of various levels of corn DDGS on the performance parameters, carcass traits, and gastrointestinal characteristics.

Materials and Methods

The research took place at the broiler barn of the experimental farm of Animal Science and Agronomy of the Federal University of Mato Grosso (UFMT) campus, Cuiabá.

A completely randomized design was used, with five treatments, from which four had different inclusion levels and a control treatment, with seven repetitions, and 35 experimental units of 20 broilers each. Experimental diets were based on corn and soybean meal, formulated to reach the nutritional recommendations of the COOB 500 handbook (COOB, 2009). The amino acid content was based on AMINOD at ®5.0 (Fickler et al., 2016). The diets were isonutritive, presenting a nutritional composition of the ingredients based on the recommendations of Rostagno et al. (2011). The bromatological analysis from DDGS of corn was used to formulate the ration (Table 1).

The experimental treatments applied from the first day until the forty-second day of age (according to Table 2) were: T1 - Control diet with 0% of DDGS; T2 - Diet with 4% inclusion of DDGS; T3 - Diet with 8% inclusion of DDGS; T4 - Diet with 12% inclusion of DDGS; T5 - Diet with 16% inclusion of DDGS.

Performance evaluation

Weight gain, g/bird/day (WG); ration consumption, g/bird/day (RC), and feed conversion (FC) were evaluated according to the described methodology:

- Weight gain g/bird/day: medium weight gain per bird/day was determined through the weighting attained when the broilers arrived, on the first day and forty-second day of age. In the afternoon, the animals were weighed on scales with 50 kg capacity.
- Ration consumption g/bird/day: medium ration consumption was determined through the division of the difference between the offered ration during the phase and the leftovers weighted at the end of that phase, by the number of broilers in the lot. Leftover weighting was also done on the 50 kg scales. The mediums were totalized to result in the medium consumption of ration per bird in the lot.

- Feed conversion: Was calculated by division of the medium consumption of ration by the medium weight gain of the broilers in the studied plots.
- Mortality: Was observed daily for correction of consumption and feed conversion, taking into consideration broiler weighting and ration weighting on the day of mortality, according to what was described by Sakomura and Rostagno (2007).
- Viability: Viability analyses was calculated by the formula:

  Viability = 100 – mortality%
- Productive efficiency index (PEI): It was estimated through the following formula:

$$PEI = \frac{\text{Daily weight gain x Viability (\%) x 100}}{\text{Feed Conversion}}$$

Characteristics of the carcass yield and cuts

The yield of the mixed lot was analyzed by evaluating the feather weight, carcass weight, breast weight, thigh, upper thigh, wings, edible viscera (heart, liver, and gizzard) and non-edible viscera (proventriculus, duodenum, jejunum, ileum, cecum), and fat (abdominal fat).

The slaughtering and collection of samples was done for broilers that were 42 days of age. During this period, the broilers remained without food ration for eight hours; following which, they were selected and weighed. Two broilers (a male and a female) were identified from each lot, from among the experimental unit, with medium weight, with an interval of ±10% of medium weight, totalizing 70 slaughtered broilers.

Those broilers were desensitized by cervical dislocation and manually blooded through a cut in the jugular. After light scalding at the temperature of 56 degrees Celsius for two minutes, the broilers were taken to a rotate cylinder with plastic fingers to remove the feathers.

After feather removal, the broilers were once again weighed to obtain the weight of the feathers; then, they were manually eviscerated, and the carcasses were sent to the coolers for pre-cooling, from where they left at eight degrees Celsius. After the cooler, the carcasses remained in a stainless-steel treadmill with roles, so the excess water could be drained.

The carcasses were weighed on a scale with a capacity of 15 kg (Toledo, model: 9094) after the head, neck, and feet were removed. For the calculation of yield, the commercial cuts were divided into the breast, wings, thighs, upper thighs, edible viscera (liver, gizzard, and heart); and the non-edible viscera, which was divided into the proventriculus, small intestine (duodenum, jejunum, and ileum) and cecum. For the abdominal fat, all the retroperitoneal fat was considered, excluding what involves the gizzard.

Table 1. Bromatological analysis of corn distillers dried grains with solubles (DDGS).

Analysis	**Centesimal composition in mineral matter (%)**
Crude Protein (CP)	42.73
Ether Extract (EE)	1.66
Crude Fiber (CF)	18.37
Mineral Matter (MM)	1.87
Dry Matter (DM)	89.00
Non-nitrogenous extract (NNE)	47.73
Total digestible nutrients (TDN) (estimated)	79.09
Calcium (Ca)	0.13
Phosphorus (P)	0.53

All the viscera and abdominal fat were weighed on a semi-analytical scale BL series, brand: Shimadzu, BL 3200 H model, capacity of 3200 g. To scale the gizzard, all the food inside the organ was removed, keeping the keratin that involved it. The non-edible cuts (proventriculus, duodenum, jejunum, ileum, and cecum) were passed through a soft compression to eliminate the interior content; the clean tissue was weighted on a scale with 0.5 g precision, according to Valentim et al. (2017).

The percent of yield of the main cuts, edible and non-edible viscera, and abdominal fat were calculated by the relation between the medium weight of the representative cut of each repetition and the weight of the carcass according to the formula: Yield x = variable weight/Carcass weight* according to Valentim et al. (2017).

Gastrointestinal tract biometry

Identification of the compartment of the gastrointestinal tract was carried out in the following manner:

- Proventriculus: Is the tissue that comes before the gizzard is easily identified after exposition of the broiler's viscera.

- Gizzard: Is the muscle tissue that comes before the beginning of the small intestine.
- Duodenum: Is the part of the small intestine that goes from the end of the gizzard until the end of the duodenal handle that involves the pancreas. Jejunum: Follows the end of the duodenal loop until the Meckel's diverticulum.
- Ileum: Begins at the Meckel's diverticulum and prolongs itself until the ileum–cecum junction.
- Cecum: The dual cecum was identified as it was adhered by crimp at the end of the ileum.

The mensuration of each compartment was made after emptying the intestinal content. The measurement was through the use of a 30 cm ruler, with 0.1 mm precision. To obtain values of relative length, a segment of each segment was divided by the total length of the small intestine, and the results were multiplied by 100.

Statistical analysis

The parameters evaluated were submitted to variance analysis with 5% probability using the statistical program SAS (SAS Institute, 1990). Following this, the effects of the inclusion of DDGS were estimated by variable analysis via models of linear regression. The best adjustment was obtained for each variable. The contrasts were tested by the Dunnett test with 5% probability, comparing the treatment without the inclusion of DDGS of corn (control) and the others with DDGS (4%, 8%, 12%, and 16% of DDGS).

Results and Discussion

Analyzing the total phase of production (1 to 42 days), there was no influence ($p > 0.05$) on the performance variable, RC, and viability, as described in Table 3. The parameters of WG, FC, and PEI presented a square effect ($p < 0.05$), with the inclusion of levels of DDGS in the diet of the broiler. For the WG, FC, MW, and PEI variables, the best performance value was obtained at levels of inclusion of 7.28%, 10.60%, 12.10%, and 12.92%, respectively. For the Dunnet test ($p < 0.005$), there was a decline in the parameters of WG, FC, MW, and PEI, at levels of 12% and 16%, compared to the control treatment.

The PEI is the main indicator to measure performances in many meat broilers. This index measures the productive efficiency obtained during a major part of the broiler production, becoming the principal source of remuneration of companies with integrated poultry.

Bolu et al. (2012) indicated that inclusion of 10% of corn DDGS in broilers did not affect their WG and FC in the period between 22 and 42 days. On the other hand, Wang et al. (2007), who utilized levels of 30% inclusion of DDGS in diets for broilers, while they were growing, stated that the weight decreased, and the feed conversion was worse about the inclusion of 15% to the control diet.

To improve the usage of DDGS in the broilers' diet, the main concerns include variation in the levels of metabolizable energy and bioavailability of the levels of lysine, calcium, phosphorus, and sodium, and the variability in the sodium content (Latorre et al., 2017).

Jung et al. (2012) reported that up to 12% of DDGS in the diet does not interfere with the WG and FC; on the other hand, other negative effects occur in the feed efficiency due to protein digestibility.

A quadratic effect ($p < 0.005$) was observed in the variables of carcass weight and breast weight, which was able to include levels up to 11.02% and 7.44%, respectively (Table 4).

Regarding the Dunnet test ($p < 0.005$), there was a decline in the parameters of carcass and breast weights, at levels of 12% and 16%, in comparison to the control treatment. These results were indicative of possible bad protein digestibility of the DDGS, which resulted in a less muscular deposition. Applegate et al. (2009) narrated that the yield of the breast fillet of 42-day-old broilers had linear reduction with inclusion of levels of DDGS of sorghum, indicating a maximum of 12%, so the yield of this cut would not be affected.

The high content of crude protein of the DDGS can result in the excretion of nitrogen through the feces, which causes an increase in energy exigency to the amino acid catabolism and uric acid synthesis. Therefore, the quantity of liquid energy for synthesis and protein deposition decreases. Breasts represent around 50% of the total protein of the carcass; therefore, this cut is way more reasonable than another commercial cut in diet variation.

Table 2. Percentage composition of the experimental rations of broilers from 1 to 7, 8 to 35 e 36 to 42 days.

Ingredients (%)			**1 to 7 days**					**8 to 35 days**					**36 to 42 days**		
Levels DDGS (%)	0.0	4.0	8.0	12.0	16.0	0.0	4.0	8.0	12.0	16.0	0.0	4.0	8.0	12.0	16.0
Corn	51.20	49.70	48.20	46.80	45.40	54.91	53.88	52.90	51.46	50.36	59.17	58.1	57.0	55.58	54.44
Soybean meal	38.52	36.02	33.52	30.92	28.32	35.00	32.00	29.00	26.50	23.50	31.00	28.00	25.00	22.34	19.34
Limestone	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.82	0.82	0.82	0.82	0.82
Dicalcium phosphate	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Common salt	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
*Core	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.8	1.8	1.80	1.80
Starch	1.00	1.00	1.00	1.00	1.00	0.50	0.46	0.33	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Soy oil	3.51	3.51	3.51	3.51	3.51	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90	3.90
DDGS	0.0	4.0	8.0	12.0	16.0	0.0	4.0	8.0	12	16.0	0.0	4.0	8.0	12.0	16.0
L-Threonine (98.00%)	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.10	0.15	0.20	0.01	0.06	0.11	0.16	0.21
DL-Methionine (99.00%)	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
L-Lysine HCL (78.84%)	0.15	0.15	0.15	0.15	0.15	0.07	0.12	0.18	0.22	0.27	0.10	0.12	0.17	0.20	0.26
Nutritional composition calculated			**1 to 7 days**					**8 to 35 days**					**36 to 42 days**		
Metab. energy (kcal / kg)	3035	3035	3035	3035	3035	3108	3108	3108	3108	3108	3180	3180	3180	3180	3180
Crude protein (%)	22.0	22.0	22.0	22.0	22.0	20.00	20.00	20.00	20.00	20.00	19.00	19.00	19.00	19.00	19.00
Digestible lysine (%)	1.18	1.18	1.18	1.18	1.18	1.05	1.05	1.05	1.05	1.05	0.95	0.95	0.95	0.95	0.95
Digestible met.+cystine (%)	0.88	0.88	0.88	0.88	0.88	0.80	0.80	0.80	0.80	0.80	0.74	0.74	0.74	0.74	0.74
Tryptophan digestible (%)	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Digestible threonine (%)	0.77	0.77	0.77	0.77	0.77	0.69	0.69	0.69	0.69	0.69	0.65	0.65	0.65	0.65	0.65
Calcium (%)	0.90	0.90	0.90	0.90	0.90	0.84	0.84	0.84	0.84	0.84	0.76	0.76	0.76	0.76	0.76
Match available (%)	0.45	0.45	0.45	0.45	0.45	0.42	0.42	0.42	0.42	0.42	0.38	0.38	0.38	0.38	0.38
Sodium (%)	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Crude fiber (%)	2.96	3.09	3.21	3.33	3.46	2.84	3,13	3.41	3.70	3.99	2.69	2.99	3.27	3.56	3.85

DDGS: distillers dried grains with solubles. † EMAn values based on WPSA European Table of Energy Values for Poultry Feedstuffs (3rd edition, 1989). * Provides per kg of product: Calcium (max) 210g, Calcium (min) 170g, Phosphorus (min) 50g, Methionine (min) 22g, Vitamin A (min) 120000 IU, Vitamin D3 (min) 30000 IU, Vitamin E min) 400 IU, Thiamin (B1) (min) 35mg, Riboflavin (B2) (min) 130mg, Pyridoxine (B6) (min) 60mg, Vitamin B12 (min) 300mg, Vitamin K3 (Min) 1600mg, Zinc (min) 1380mg, Copper (min) 200mg, Colina (min) 400mg, Sodium (min) 26g, Manganese (min) (min) 160mg, Iron (min) 630mg, Iodine (min) 20mg, Selenium (min) 6mg, Fitase (min) 10000 FTU, Avilamycin 200mg, and Narasin + Navelbine 1000mg + 1000mg.

The negative effect of addiction to high levels of DDGS in a meat broiler's diet can be related to nutrient digestibility. According to Pinheiro et al. (2017), ingestion of excessive quantities of fiber feed can elevate the number of calceiform cells of the intestine, which are mucous producing cells, to facilitate the passing of the feed through the digestive tract, lowering the intestinal pH and size of the villi, causing reduction in the absorption of the nutrients, consequently reducing the deposition of muscular protein.

According to Wang et al. (2007), broilers fed with 15% and 25% of DDGS showed lower carcass yield than broilers that received the control diet, agreeing with the present study. Jung et al. (2012) research observed that inclusion of 20% of DDGS in the diet usually reduces breast yield, a fact that was perceived in this study.

Table 3. Medium ration consumption (RC), medium weight gain (WG), feed conversion (FC), medium weight (MW), viability, and productive efficiency index (PEI) of broiler fed with diet containing levels of distillers dried grains with solubles (DDGS) in the period of 1 to 42 days of age.

Parameter	Levels of corn DDGS (100 kg)					VC (%)	P-value
	0	4	8	12	16		
RC (g) ns	85.55	85.21	84.14	88.37	85.84	6.48	0.6972
WG (g) ^{2}	55.59	56.54	54.45	51.48*	51.65*	6.20	0.0238
FC ^{2}	1.53	1.44*	1.45*	1.58	1.57	4.87	0.0009
MW(g)^2	2071.21	2045.36	2133.43	1873.29*	1900.71*	6.61	0.0030
Viability ns	96.42	97.14	94.28	94.28	95.71	5.03	0.7396
PEI^2	368.34	383.83	352.71	337.69*	315.19*	9.63	0.0043

^{2}square effect (P<0,05); ^{3}Descriptive data analysis; *Significant at 5% of probability by the Dunnett test; VC: variation coefficient. ns: non-significant. Regression equation: Feed conversion $\hat{Y}$= 1,582829 - 0,95790x + 0,045153x^2; R^2= 62,42%; Weight gain $\hat{Y}$ = 56,614257-0,252482x -0,0173510x^2; R^2= 81,65%; ^{2}square effect (P<0,05); Regression equation: Medium weight: $\hat{Y}$= 2064,35+367,01-15,16x^2; R^2:55,30%. PEI $\hat{Y}$ = 385,401514 – 54, 84351x -2,128122x^2; R^2= 77,20%

Table 4. Feathers weight, carcass weight, breast weight, thigh weight, upper thigh weight, wings weight, carcass A %, carcass B %, breast %, thigh %, upper thigh %, wings % of broilers fed at the 42nd day with diets containing levels of distillers dried grains with solubles (DDGS).

Parameter	Levels of DDGS (100 kg)					VC (%)	P-value
	0	4	8	12	16		
Feathers weight (g) ns	137.64	129.29	168.07	143.64	147.50	16.89	0.6155
Carcass weight (g) ^{2}	1702.50	1683.07	1706.79	1493.21*	1526.36*	5.44	0.0001
Breast weight (g) ^{2}	557.5	538.92	551.07	490.09*	468.21*	5.06	0.0009
Thigh weight (g) ns	234.29	235.00	234.64	209.64	223.93	7.30	0.0517
Upper thigh weight (g)ns	223.93	221.07	219.29	198.93	210.71	6.36	0.0504
Wings weight (g) ns	168.57	161.43	165.00	147.86	155.36	3.06	0.1431
Carcass % ns	74.68	74.41	72.79	71.83	72.76	4.73	0.2192
Breast % ns	37.56	35.78	36.79	35.95	33.98	6.9	0.1230
Thigh % ns	15.019	14.663	14.605	15.319	15.645	5.07	0.4509
Upper thigh % ns	14.248	14.305	14.181	14.273	15.052	6.75	0.9085
Wings % ns	11.220	10.453	10.604	11.156	11.327	6.39	0.0896

^{1}linear effect (P<0,05); ^{2}square effect (P<0,05); VC: variation coefficient. ns: non-significant. *Significant at 5% of probability by the Dunnett test; regression equation: Carcass weight $\hat{Y}$= 1867,58-84,87x+3,85x^2; R^2: 66,64%. Breast weight $\hat{Y}$= Breast: 542,57 - 64x + 4,28x^2; R^2= 99,94%.

According to Boleli et al. (2002), feed introduced in the rations can stimulate changes in the mucosa by its physicochemical characteristics, mainly in response to substances and compounds that can act as anti-nutritional elements.

Conferring to Bastos et al. (2007), high quantities of soluble fibers can make the mucous act as a barrier to the action of digestive enzymes not releasing the diet's nutrients, which reflects in the development of the birds' organs and muscular tissues.

Regarding other variables, there was no observed difference among the levels used. Schone et al. (2017) did not find any effect on the yield of wings, thighs, and upper thighs, after testing five levels of inclusion of DDGS in two genders. Loar et al. (2009) also related that they did not observe differences in the yield of the carcasses and noble cuts.

Lumpkins et al. (2004), evaluating levels of DDGS of corn to broilers in levels of 0 to 18% did not observe any effect ($p > 0.005$) in the carcass %, obtaining a yield of around 70% in the different treatments. Data are similar to those in this experiment, which obtained values of 74.68%, 74.41%, 72.79%, 71.83%, and 72.7650%, at levels of 0%, 4%, 8%, 12%, and 16%, respectively, not showing any difference at the level of 5% of probability.

Cortes Cuevas et al. (2012), also evaluating the inclusion of DDGS in the ration of male and female broilers, did not observe significant effects by inclusion of DDGS on the carcass, breast, thigh, and wing yield.

Lukaszewicz and Kowalczyk (2014) concluded that the breast, muscle, and thigh weight was lower with the inclusion of 15% of DDGS, concluding that there was a negative effect with high inclusions of DDGS in the meat broiler's diet.

Levels of inclusion had no influence on the edible viscera at the level of 5% of probability, it was only the variable of abdominal fat that was affected by the tested treatments, and that was at a recommended level of 12.10% (Table 5).

Table 5. Heart, liver, gizzard, abdominal fat weight, and percentage of mixed broiler at 42 days fed with diets containing levels of distillers dried grains with solubles (DDGS).

	DDGS levels (100 kg)						
Parameter	0	4	8	12	16	VC (%)	P-value
Heart weight (g) ^{ns}	10.773	11.0807	10.6014	10.1536	9.8557	12.85	0.3742
Liver weight (g) ^{ns}	39.247	38.662	41.817	38.405	35.647*	10.88	0.0826
Gizzard weight (g) ^{ns}	34.155	31.6564	37.1600	34.1679	31.8521	9.70	0.139
Abdominal fat (g) ^{2}	20.210	20.459	21.337	18.736*	19.080	6.619	0.0030
Heart (%) ^{ns}	0.5182	0.5392	0.4976	0.5416	0.5191	12.13	0.9673
Liver (%) ^{ns}	1.8958	1.8887	1.9539	2.0570	1.8778	7.98	0.1269
Gizzard (%) ^{ns}	1.6510	1.5486	1.7452	1.8235	1.6710	8.02	0.6500
Abdominal fat (%)^{ns}	1.0726	1.0879	1.1036	1.0735	1.0223	11.90	0.8700

^{2}square effect (P<0,05); VC: variation coefficient. ns: non-significant. *Significant at 5% of probability by the Dunnett test; regression equation: abdominal fat $\hat{Y}$= 2062,75+36,71x-1,516x²; R²: 55,30%.

In the present study, fat weight was lower with the inclusion of greater levels of DDGS, and the inclusion of 16% was significant by the Dunnet test ($p < 0.05$). High fiber concentration could drop energy absorption, and as a consequence, the carcass fat deposition. A smaller fat content is a desirable attribute by consumers, seeing that they search for lower lipid content in the carcass, as it is associated with a healthy product (Centenaro et al., 2008).

In agreement with this research, Schone et al. (2017) found a reduction in the carcass yield in meat broilers; on the other hand, they found greater abdominal fat deposition in the female animals. There also found differences between the level of inclusion in the parameters of heart weight, obtaining smaller values at the level of 16%, with gizzard weight, being greater at the four evaluated levels, in comparison to the control treatment.

Vázquez et al. (2013) found a bigger size of liver in rabbit's fed with DDGS, but these results could be explained by the high content of fat in the samples of DDGS, a fact that was not observed in this experiment.

Fries-Craft and Bobeck (2019), studying 0%, 8%, 16%, and 24% of DDGS in broiler diets, stated that the only significant difference in carcass measurements between the treatments was observed for kilograms and percentage of fat in the carcass, which increased with the crescent inclusion levels of DDGS in the diets. The authors state that this increase could be justified by a larger lipid quantity in the DDGS used.

Loar et al. (2009) evaluated the effect of two levels (0% vs. 8%) of DDGS in an initial diet for broilers (0 to 14 days; 45 repetitions/treatment). After that, the same broilers were fed with a growing diet (14 to 28 days) with 0%, 5%, 7%, 15%, 22%, 25%, or 30% of DDGS, and it was concluded that raising of the inclusion level of DDGS during the growing phase resulted in a linear decrease ($p < 0.001$) in the liver's relative weight.

A small quantity of ether extract present in the DDGS used and the adequate balance of amino acids helped to explain the fact of not finding lower fat quantities with greater levels of DDGS. There were no differences found ($p > 0.05$) as shown in Table 6 for non-edible viscera weight.

Jung et al. (2012) verified that up to 12% of DDGS in the diet did not affect the heart and gizzard yield, but it tended to reduce the jejunum yield and duodenum weight, which was not verified in this study. Inclusion of up to 16% of DDGS did not prejudice the weight and yield of the proventriculus, duodenum, jejunum, ileum or cecum of the broiler, at 42 days. Abdel-Raheem et al. (2011) also indicate that there was no influence on the intestinal parameters by the corn and wheat DDGS.

Petkova et al. (2011), working with DDGS having high energy content, observed an effect on the size of the bird's liver, indicating that the excess lipids present made this organ increase its size so as to support a larger fat quantity. This fact could be explained by the iso-nutritive characteristics of the diets, because even though the DDGS had different amino acid values and energy in comparison to corn and soybean, there was no nutritional variation that could jeopardize the needs of the broiler with regard to viscera yield, knowing that there was amino acid supplementation according to each production phase. There was no effect found on the gastrointestinal tract (GIT) biometry of the broilers fed with diets containing DDGS levels, as shown in Table 7.

Table 6. Proventriculus, duodenum, jejunum, ileum and cecum weight and percentage of chicken at the 42nd day fed with diet containing levels of distillers dried grains with solubles (DDGS).

	DDGS levels (100 kg)						
Parameter	0	4	8	12	16	VC (%)	P-value
Proventriculus weight ns	8.573	8.104	9.0450	8.699	8.567	7.963	0.2675
Duodenum weight(g) ns	10.8750	11.5836	12.6521	12.0893	12.1021	19.69	0.8705
Jejunum weight(g) ns	18.2407	17.5443	20.7243	20.0429	19.3636	16.05	0.2843
Ileum weight(g) ns	18.1914	17.9064	18.7693	17.9471	17.5893	14.51	0.8497
Cecum weight(g) ns	14.9550	14.4507	16.5564	14.7636	14.0029	13.76	0.1323
% proventriculus ns	0.4161	0.3966	0.4374	0.4661	0.4575	12.17	0.1235
% duodenum weight ns	0.5319	0.5686	0.5948	0.6441	0.6358	19.85	0.5679
% jejunum weight ns	0.8889	0.8580	0.9718	1.0676	1.0144	14.40	0.0693
% ileum weigh ns	0.8790	0.8774	0.8764	0.9531	0.9254	12.37	0.5111
% cecum weight ns	0.7206	0.7094	0.7815	0.7860	0.7440	16.76	0.4197

VC: variation coefficient. ns: non-significant

Table 7. Length and percentage in relation to the gastrointestinal tract, duodenum, jejunum, and ileum total size of broiler at the 42nd day fed with diet containing levels of distillers dried grains with solubles (DDGS).

	DDGS levels (100 kg)						
Parameters	0	4	8	12	16	VC (%)	P-value
Duodenum (cm) ns	31.350	30.964	30.528	30.428	30.664	6.99	0.9677
Jejunum (cm) ns	72.442	72.528	74.107	71.850	72.614	6.92	0.8608
Ileum (cm) ns	77.364	78.078	78.750	75.135	74.935	7.14	0.4537
Total GIT(cm) ns	181.16	181.57	183.39	178.21	177.41	5.15	0.5924
Duodenum (%)ns	17.313	17.149	16.654	17.206	17.214	7.18	0.7777
Jejunum (%) ns	39.934	39.799	40.375	40.545	40.736	4.54	0.7911
Ileum (%) ns	42.752	43.050	42.970	42.248	42.049	4.32	0.6673

VC: Variation coefficient. ns: non-significant.

Świątkiewicz and Koreleski (2008) concluded in their study that the chemical, energetic, and amino acidic composition of the DDGS characterized it as a food rich in nutrients. However, the high quantity of fibers, around 72.95% of NDF, represent a limiting factor in its utilization in meat broiler feed, mainly in the initial phases where the digestive capacity and the enzymatic apparatus of the broilers is reduced and the soluble fiber utilization is totally limited.

For the variables WG, FC, MW, and PEI, in 1–42 days of production, the best performance values for the level of inclusion were, 7.28%, 10.60%, 12.10%, and 12.92%, respectively. There was a reduction of carcass, breast, and fat weight of broilers when using 12% and 16% of DDGS.

Conclusion

It indicates the inclusion of up to 11.02% and 7.44% in the diet, so it will not be a loss in the carcass yield and breast weight, respectively.

Conflict of Interest

The authors declare no conflict of interest.

Ethics Committee

The Ethics Committee approved the project in the Animal Usage Committee (CEUA) of UFMT under protocol number 23108.227104/2017-13.

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