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Utilization of Distillers Dried Grains with Solubles (DDGS) in Broiler Diets Using a Standardized Nutrient Matrix[1]

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Abstract: An experiment was conducted to evaluate different levels of “new generation” distillers dried grains with solubles (DDGS) in broiler diets throughout a 49 d growing period, based a standardized nutrient matrix derived from a composite of literature values. Diets were formulated based on digestible amino acid content to typical U.S. poultry industry standards to contain 0, 5, 10, 15, 20, or 25% DDGS. Each dietary treatment was assigned to four replicate pens of 25 male chicks of a commercial broiler strain. Starter diets (0 to 14 d) were fed as crumbles; grower (14 to 35 d) and finisher (35 to 49 d) diets were fed as pellets. Bulk density (mass/volume) was determined on the crumbled or pelleted feeds. Body weights and feed consumption were determined at 14, 35 and 49 d of age. At the end of the study five representative birds per pen were processed to determine dressing percentage and parts yield. Increasing the DDGS in the diet generally reduced the weight per volume of feed. There were no significant effects of DDGS level on body weight; however chicks fed diets with 25% DDGS consumed significantly more feed and had poorer feed conversion compared to chicks fed the control diet with no DDGS. Birds fed 15 and 25% DDGS had significantly lower dressing percentage than did birds fed the control diet with no DDGS. Birds fed diets with 25% DDGS had significantly lower breast weight when expressed as percentage of live weight but not when expressed as a percentage of the carcass weight, compared to birds fed the control diet with no DDGS. Wing weight as percent of live weight and carcass weight was significantly greater for birds fed diets with 15% DDGS as compared to the control, while wing weight as percent of the carcass was significantly increased for birds fed the diet with 25% DDGS as compared to those fed the control diet with no DDGS. These results indicate that good quality DDGS could be used in broiler diets at levels of 15 to 20% with little adverse effect on live performance but might result in some loss of dressing percentage or breast meat yield.

Key words: Broilers, distiller’s grains, ethanol byproduct, alternative ingredients

Introduction

Distiller's dried grains with solubles (DDGS), a co-product of the dry-mill ethanol industry, are dried residue remaining after the fermentation of the corn starch by selected yeasts and enzymes to produce ethanol and carbon dioxide. Most (~98%) of the DDGS in North America comes from plants that ferment corn to produce ethanol for oxygenated fuels. The remaining 1 to 2% of DDGS is produced by the alcohol beverage industry. It has long been recognized that DDGS from the alcohol beverage industry is a valuable source of energy, protein, water-soluble vitamins and minerals for poultry (Couch *et al*., 1970; Jensen, 1978, 1981; Potter, 1966; Runnels, 1966, 1968; Scott, 1965, 1970; Waldroup *et al*., 1981; Parsons and Baker, 1983).

The increasing supply of DDGS from fuel ethanol production encourages the use of higher percentages than has typically been used in the past. Swine research results have indicated that “new-generation” corn DDGS (built after 1990) from U.S. Midwest ethanol plants has higher levels of apparent ileal digestible amino acids (Whitney *et al*., 2000), metabolizable energy (Spiehs *et al*., 1999) and available phosphorus (Whitney *et al*., 2001) than values published by NRC (1998). However, there is very limited research published regarding use of the ‘new-generation’ DDGS in broiler diets. Waldroup (2007) reviewed some major concerns regarding the use of DDGS in poultry diets and provided a standardized DDGS nutrient matrix derived from recently published data. The objective of this experiment was to evaluate the use of different levels of DDGS in broiler chicken production based on this nutrient matrix.

Materials and Methods

Experimental diets: Diets were formulated to meet nutritional standards typical of the U.S. poultry industry[3] to contain 0, 5, 10, 15, 20, or 25% DDGS. Diets were formulated on a digestible amino acid basis, utilizing 90% of current industry total amino acid levels in relation to dietary energy. Total and digestible amino acid values for corn and soybean meal were based on values suggested by a leading amino acid producer[4] adjusted to the moisture and crude protein content of the products used in the formulation of the diets. Nutrient values for DDGS were based on a composite of reported values (Waldroup, 2007) and are shown in Table 1. A blended animal protein[5] was added to all diets at 5%, a level typical of animal protein usage in the U.S. poultry

Table 1: Nutrient matrix for DDGS based on weighted averages of published data and analyzed data

Nutrient	Estimated	Analyzed[1]
Dry matter %	89.36	88.84
Crude protein %	26.45	26.16
Fat %	10.08	9.65
Fiber %	6.99	6.32
TME_n, kcal/lb	1293	----
Calcium %	0.07	0.04
Phosphorus %	0.77	0.84
Available phosphorus %	0.48	----
Potassium %	0.85	1.04
Sodium %	0.20	0.18
Arginine %	1.09	1.33
Histidine %	0.68	0.72
Isoleucine %	0.96	0.93
Leucine %	3.00	2.97
Lysine %	0.73	0.88
Methionine %	0.50	0.55
Cystine %	0.54	0.51
Phenylalanine %	1.31	1.27
Threonine %	0.96	0.98
Tryptophan %	0.21	----
Valine %	1.30	1.24
Serine %	1.07	1.26
Dig Arginine %	0.93	1.25
Dig Histidine %	0.58	-----
Dig Isoleucine %	0.78	0.88
Dig Leucine %	2.70	2.80
Dig Lysine %	0.50	0.78
Dig Methionine %	0.43	0.50
Dig Cystine %	0.42	0.47
Dig Phenylalanine %	1.15	------
Dig Threonine %	0.72	0.84
Dig Tryptophan %	0.18	0.20
Dig Valine %	1.05	1.08
Dig Serine %	0.88	-----

[1]Analyzed digestible amino acids derived by multiplying analyzed total amino acid values determined by ion-exchange chromatography (Ajinomoto Heartland Lysine, Chicago IL) by IDEA estimates of amino acid digestibility (Novus International, St. Louis MO)

industry. Diets were maintained isocaloric and isonitrogenous. All diets were fortified with complete vitamin and trace mineral mixes. Composition of diets for starter (0-14 d), grower (14-35 d) and finisher periods (35-49 d) are shown in Table 2, 3 and 4, respectively. Starter diets were crumbled, while grower and finisher diets were pelleted. Each of the dietary treatments was fed to four replicate pens of 25 birds each.

Housing and management: Male chicks of a commercial broiler strain[6] were obtained from a local hatchery where they had been vaccinated in ovo for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Twenty-five chicks were randomly assigned to each of 24 pens in a broiler house of commercial design. New softwood shavings served as litter over concrete floors. Each pen was equipped with two tube feeders and an automatic water font. Supplemental feeders and waterers were used during the first seven days. Temperature and airflow were controlled by automatic heaters and ventilation fans. Incandescent lights supplemented natural daylight to provide 23 hr light daily. Care and management of the birds followed recommended guidelines (FASS, 1999).

Measurements: The DDGS sample was analyzed for crude protein, fat, fiber, ash, Ca, total P, Na and total amino acid content by commercial laboratories specializing in these assays and was subjected to Immobilized Digestibility Enzyme Assay (IDEA™) analysis[7] to estimate amino acid digestibility. All mixed diets were analyzed for crude protein, Ca, total P, Na and total amino acids by the same commercial laboratories that analyzed the DDGS sample. Bulk density (mass per unit of volume) of mixed feeds was determined by weighing a predetermined volume of feed. Body weights by pen and feed consumption during intervals were determined at 14, 35 and 49 d of age. Birds that died were weighted to adjust feed conversion. At the end of the study five representative birds per pen were processed for dressing percentage and parts yield as described by Fritts and Waldroup (2006).

Statistical analysis: All the data were subject to one-way ANOVA analysis (SAS institute, 1991). Pen means were used as the experimental unit for growth performance, while each bird served as an experimental unit for processing variables as the birds were processed in random order. Contrast comparisons were made between each level of supplemental DDGS and the control level with no DDGS. All statements of significance were based on $p \leq 0.05$.

Results and Discussion

Analysis of the DDGS product used in this study indicated that the test product was equal or superior in nutrient content to the nutrient matrix used in formulating the diets (Table 1). Dry matter, crude protein, fat and fiber content of the test product were slightly less than the calculated value while total phosphorus content was slightly greater than calculated. Total and digestible lysine values for the DDGS product used in the study were considerably higher than the calculated values, indicating that the test product was not overheated during processing. Many of the key essential amino acids including arginine, methionine and threonine were equal or superior to the estimated value. Analysis of the mixed feeds (Table 5, 6 and 7) indicate that the nutrient composition of the mixed feeds was generally in good agreement with calculated values.

Increasing the amount of DDGS in the diet generally resulted in reduced bulk density, especially in starter

Table 2: Composition (g/kg) of broiler starter diets (0-14 d) with different levels of distillers dried grains plus solubles (DDGS) formulated on current industry standards

	DDGS inclusion, %					
Ingredients	0	5	10	15	20	25
DDGS	0.00	50.00	100.00	150.00	200.00	250.00
Yellow corn	577.93	552.15	526.40	500.65	474.90	449.16
Soybean meal	322.54	296.67	270.63	244.60	218.56	192.53
Poultry oil	19.09	20.22	21.38	22.52	23.68	24.84
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00
Ground limestone	6.43	7.27	8.10	8.95	9.78	10.62
Defluorinated phosphate	8.46	7.55	6.65	5.75	4.85	3.95
Sodium chloride	4.00	3.87	3.76	3.65	3.55	3.42
MHA-84	1.73	1.71	1.69	1.67	1.65	1.63
L-Threonine	0.07	0.21	0.37	0.52	0.67	0.82
L-Lysine HCl	0.00	0.60	1.27	1.94	2.61	3.28
Vitamin Premix[2]	5.00	5.00	5.00	5.00	5.00	5.00
Trace minerals[3]	0.50	0.50	0.50	0.50	0.50	0.50
Mintrex P_Se minerals[4]	0.50	0.50	0.50	0.50	0.50	0.50
Coban 60[5]	0.75	0.75	0.75	0.75	0.75	0.75
BMD 50[6]	0.50	0.50	0.50	0.50	0.50	0.50
Pel-Stik[7]	2.50	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

[1]H.J. Baker and Bro., 595 Summer Street, Stamford, CT 06901-1407, [2]Provides per kg of diet: vitamin A (from vitamin A acetate) 7715 IU; cholecalciferol 5511 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg, [3]Provides per kg of diet: Mn (from $MnSO_4 \cdot H_2O$) 50 mg; Zn (from $ZnSO_4 \cdot 7H_2O$) 50 mg; Fe (from $FeSO_4 \cdot 7H_2O$) 25 mg; Cu (from $CuSO_4 \cdot 5H_2O$) 5 mg; I from $Ca(IO_3)_2 \cdot H_2O$), 0.5 mg, [4]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 20 mg; Zn (as zinc methionine hydroxy analogue complex) 20 mg; Cu (as copper methionine hydroxy analogue complex) 10 mg; Se (as selenium yeast) 0.15 mg, [5]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825, [6]Alpharma, Inc., Ft. Lee, NJ 07024, [7]Uniscope Inc., Johnstown CO 80534

Table 3: Composition (g/kg) of broiler grower diets (14-35 d) with different levels of distillers dried grains plus solubles (DDGS) formulated on current industry standards

	DDGS inclusion, %					
Ingredients	0	5	10	15	20	25
DDGS	0.00	50.00	100.00	150.00	200.00	250.00
Yellow corn	635.56	609.82	584.07	558.32	532.57	506.82
Soybean meal	265.56	239.53	213.49	187.46	161.42	135.40
Poultry oil	20.31	21.46	22.62	23.77	24.92	26.08
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00
Ground limestone	5.62	6.45	7.29	8.13	8.97	9.81
Defluorinated phosphate	7.22	6.32	5.42	4.52	3.62	2.72
Sodium chloride	4.16	4.05	3.93	3.82	3.72	3.59
MHA-84	1.52	1.50	1.49	1.47	1.45	1.43
L-Threonine	0.11	0.26	0.41	0.56	0.71	0.86
L-Lysine HCl	0.19	0.86	1.53	2.20	2.87	3.54
Vitamin Premix[1]	5.00	5.00	5.00	5.00	5.00	5.00
Trace minerals[1]	0.50	0.50	0.50	0.50	0.50	0.50
Mintrex P_Se minerals[1]	0.50	0.50	0.50	0.50	0.50	0.50
Coban 60[1]	0.75	0.75	0.75	0.75	0.75	0.75
BMD 50[1]	0.50	0.50	0.50	0.50	0.50	0.50
Pel-Stik[1]	2.50	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 2

and grower diets (Table 8). In crumbled starter diets there was little difference in bulk density of diets with up to 20% DDGS while in pelleted grower diets there was a general linear decrease in bulk density as the amount of DDGS in the diet increased. In pelleted finisher diets, the diet with no DDGS inexplicably had the lowest bulk density, with bulk density increasing up to diets with 15% DDGS and then reduced in diets with 20 and 25%. Mraz *et al*. (1957) pointed out that neither energy value nor density of the ration was an adequate criterion of the

Table 4: Composition (g/kg) of broiler finisher diets (35-49 d) with different levels of distillers dried grains plus solubles (DDGS) formulated on current industry standards

	DDGS inclusion, %					
Ingredients	0	5	10	15	20	25
DDGS	0.00	50.00	100.00	150.00	200.00	250.00
Yellow corn	697.79	672.05	646.30	620.55	594.80	569.06
Soybean meal	203.91	177.88	151.84	125.80	99.78	73.74
Poultry oil	20.98	22.13	23.28	24.44	25.60	26.75
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00
Ground limestone	5.62	6.46	7.30	8.14	8.97	9.80
Defluorinated phosphate	5.93	5.03	4.13	3.23	2.33	1.43
Sodium chloride	4.34	4.22	4.11	4.00	3.88	3.77
MHA-84	1.03	1.01	0.99	0.97	0.95	0.94
L-Threonine	0.27	0.42	0.58	0.73	0.88	1.03
L-Lysine HCl	0.38	1.05	1.72	2.39	3.06	3.73
Vitamin Premix[1]	5.00	5.00	5.00	5.00	5.00	5.00
Trace minerals[1]	0.50	0.50	0.50	0.50	0.50	0.50
Mintrex P_Se minerals[1]	0.50	0.50	0.50	0.50	0.50	0.50
Coban 60[1]	0.75	0.75	0.75	0.75	0.75	0.75
BMD 50[1]	0.50	0.50	0.50	0.50	0.50	0.50
Pel-Stik[1]	2.50	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 2

Table 5: Calculated and analyzed (A) nutrient content of broiler starter diets with different levels of distillers dried grains plus solubles (DDGS) formulated on current industry standards

	DDGS inclusion, %					
Nutrients	0	5	10	15	20	25
ME, kcal/kg	3085.57	3085.59	3085.62	3085.59	3085.60	3085.65
Crude protein, %	22.44	22.44	22.44	22.44	22.44	22.44
Crude protein (A)[1]	22.99	22.14	22.62	22.32	22.63	22.55
Calcium, %	0.93	0.93	0.93	0.93	0.93	0.93
Calcium, % (A)	0.97	1.01	0.99	0.98	1.02	1.02
Nonphytate P, %	0.43	0.43	0.43	0.43	0.43	0.43
Phosphorus, %	0.66	0.66	0.66	0.66	0.66	0.66
Phosphorus, % (A)	0.67	0.68	0.65	0.69	0.68	0.68
Sodium, %	0.25	0.25	0.25	0.25	0.25	0.25
Sodium, % (A)	0.23	0.24	0.22	0.25	0.24	0.26
Met, %	0.57	0.57	0.58	0.58	0.58	0.58
Met (A)	0.53	0.53	0.54	0.54	0.54	0.55
Lys, %	1.33	1.33	1.33	1.33	1.33	1.34
Lys (A)	1.27	1.25	1.29	1.28	1.35	1.35
Trp, %	0.27	0.27	0.26	0.25	0.24	0.24
Thr, %	0.93	0.93	0.94	0.94	0.95	0.95
Thr (A)	0.87	0.86	0.89	0.89	0.91	0.93
TSAA, %	1.01	1.01	1.01	1.02	1.02	1.02
TSAA (A)	0.93	0.92	0.93	0.92	0.94	0.94
Isoleucine, %	0.97	0.95	0.94	0.92	0.90	0.89
Isoleucine (A)	0.93	0.88	0.89	0.86	0.88	0.85
Histidine, %	0.64	0.63	0.63	0.62	0.62	0.61
Histidine (A)	0.61	0.59	0.59	0.59	0.61	0.60
Valine, %	1.15	1.15	1.15	1.14	1.14	1.13
Valine (A)	1.10	1.07	1.10	1.07	1.10	1.08
Leucine, %	2.08	2.10	2.13	2.15	2.18	2.20
Leucine (A)	1.96	1.94	2.01	2.00	2.10	2.14
Arginine, %	1.56	1.51	1.46	1.41	1.36	1.32
Arginine (A)	1.50	1.43	1.44	1.41	1.43	1.39
Dig Met, %	0.54	0.54	0.54	0.54	0.54	0.54
Dig Lys, %	1.19	1.18	1.18	1.18	1.18	1.18
Dig Trp, %	0.24	0.24	0.23	0.22	0.21	0.21
Dig Thr, %	0.81	0.81	0.81	0.81	0.81	0.81
Dig TSAA, %	0.89	0.89	0.89	0.89	0.89	0.89

[1]A = analyzed value

Table 6: Calculated and analyzed (A) nutrient content of broiler grower diets with different levels of distillers dried grains plus solubles (DDGS) formulated on current industry standards

	DDGS inclusion, %					
Nutrients	0	5	10	15	20	25
ME, kcal/kg	3151.76	3151.76	3151.76	3151.72	3151.70	3151.75
Crude protein, %	20.31	20.31	20.31	20.31	20.31	20.31
Crude protein, % (A)[1]	21.46	21.36	21.49	21.43	21.24	21.38
Calcium, %	0.85	0.85	0.85	0.85	0.85	0.85
Calcium, % (A)	0.92	0.93	0.89	0.91	0.94	0.92
Nonphytate P, %	0.40	0.40	0.40	0.40	0.40	0.40
Phosphorus, %	0.62	0.62	0.62	0.62	0.62	0.61
Phosphorus, % (A)	0.61	0.60	0.63	0.61	0.62	0.62
Sodium, %	0.25	0.25	0.25	0.25	0.25	0.25
Sodium, % (A)	0.23	0.24	0.23	0.26	0.24	0.23
Met, %	0.53	0.53	0.53	0.53	0.54	0.53
Met % (A)	0.51	0.51	0.50	0.51	0.50	0.51
Lys, %	1.18	1.19	1.19	1.19	1.19	1.20
Lys % (A)	1.18	1.19	1.17	1.20	1.21	1.24
Trp, %	0.24	0.24	0.23	0.22	0.21	0.20
Thr, %	0.84	0.85	0.85	0.86	0.86	0.87
Thr % (A)	0.82	0.83	0.80	0.84	0.84	0.84
TSAA, %	0.93	0.93	0.94	0.94	0.94	0.95
TSAA % (A)	0.87	0.87	0.85	0.89	0.89	0.89
Isoleucine, %	0.85	0.84	0.83	0.81	0.80	0.78
Isoleucine % (A)	0.85	0.85	0.80	0.80	0.80	0.79
Histidine, %	0.58	0.58	0.57	0.56	0.56	0.55
Histidine % (A)	0.55	0.56	0.54	0.55	0.54	0.54
Valine, %	1.05	1.04	1.04	1.04	1.03	1.03
Valine % (A)	1.02	1.04	0.99	1.00	1.01	1.02
Leucine, %	1.92	1.95	1.97	2.00	2.02	2.05
Leucine % (A)	1.83	1.91	1.87	1.93	1.98	2.01
Arginine, %	1.38	1.33	1.28	1.23	1.18	1.13
Arginine % (A)	1.39	1.39	1.29	1.29	1.28	1.26
Dig Met, %	0.49	0.49	0.49	0.49	0.49	0.49
Dig Lys, %	1.06	1.06	1.06	1.06	1.06	1.06
Dig Trp, %	0.21	0.21	0.20	0.19	0.18	0.18
Dig Thr, %	0.73	0.73	0.73	0.73	0.73	0.73
Dig TSAA, %	0.82	0.82	0.82	0.82	0.82	0.82

[1]A = analyzed

growth-promoting value of a ration; a value based on the ratio of energy to volume was a better guide. As all diets in the present study were formulated to be isocaloric, a lower bulk density was associated with a lower energy: volume ratio as defined by Mraz *et al*. (1957). Similar effects of bulk density on performance have been observed by Shelton *et al*. (2005).

The effects of diets with various levels of DDGS on live performance and mortality are shown in Table 9. Body weight at any age was not significantly affected by the level of DDGS in the diet. Feed intake was not significantly affected by DDGS during the period of 0-14 d; however, at 35 and 49 d birds fed diets with 25% DDGS ate significantly more feed than did those fed the control diet with no DDGS. Feed conversion also tended to increase as the level of DDGS increased in the diet, with birds fed diets with 25% DDGS having significantly higher feed conversion for the 0-35 and 0-49 d periods than birds fed the control diet with no DDGS. This suggests that the Metabolizable energy value assigned to the DDGS might be an overestimate of its actual value; or may be a result of the reduced bulk density of the diets with the higher levels of DDGS. There was no significant effect of level of DDGS on mortality during the study.

The effects of diets containing different levels of DDGS on processing parameters are shown in Table 10. Compared to birds fed the control diet with no DDGS, birds fed diets with 15 or 25% DDGS had significantly lower dressing percentage; however birds fed diets with 20% DDGS did not differ significantly in dressing percentage compared to those fed the control diet. There was a significant reduction in breast meat as a percentage of live weight in birds fed the diets with 25% DDGS as compared to those fed the control diet with no DDGS. Breast meat as a percentage of carcass weight was numerically but not significantly reduced in birds fed diets with 25% DDGS compared to those fed the control diet with no DDGS. Wing weight as a percent of live weight and carcass was significantly increased in birds

Table 7: Calculated and analyzed (A) nutrient content of broiler finisher diets with different levels of distillers dried grains plus solubles (DDGS) formulated to current industry standards

	DDGS inclusion, %					
Nutrients	0	5	10	15	20	25
ME, kcal/kg	3217.85	3217.85	3217.85	3217.85	3217.85	3217.85
Crude protein, %	18.01	18.01	18.01	18.01	18.01	18.01
Crude protein %(A)[1]	18.88	19.02	18.87	18.72	19.01	18.94
Calcium, %	0.79	0.79	0.79	0.79	0.79	0.79
Calcium, % (A)	0.83	0.83	0.81	0.82	0.84	0.82
Nonphytate P, %	0.36	0.36	0.36	0.36	0.36	0.36
Phosphorus, %	0.57	0.57	0.57	0.57	0.57	0.57
Phosphorus, % (A)	0.56	0.56	0.58	0.59	0.56	0.58
Sodium, %	0.25	0.25	0.25	0.25	0.25	0.25
Sodium, % (A)	0.23	0.25	0.24	0.24	0.23	0.24
Met, %	0.46	0.46	0.46	0.46	0.46	0.46
Met, % (A)	0.46	0.45	0.47	0.45	0.45	0.44
Lys, %	1.03	1.03	1.03	1.03	1.04	1.04
Lys, % (A)	1.08	1.13	1.13	1.06	1.13	1.04
Trp, %	0.21	0.20	0.19	0.18	0.17	0.17
Thr, %	0.76	0.76	0.77	0.77	0.78	0.78
Thr, % (A)	0.73	0.75	0.78	0.74	0.75	0.73
TSAA, %	0.82	0.82	0.83	0.83	0.83	0.84
TSAA, % (A)	0.84	0.83	0.82	0.84	0.84	0.83
Isoleucine, %	0.74	0.73	0.71	0.70	0.68	0.67
Isoleucine, % (A)	0.77	0.75	0.73	0.75	0.67	0.69
Histidine, %	0.52	0.51	0.51	0.50	0.50	0.49
Histidine, % (A)	0.57	0.55	0.53	0.49	0.57	0.60
Valine, %	0.93	0.93	0.93	0.92	0.92	0.91
Valine, % (A)	0.96	0.94	0.92	0.89	0.85	0.82
Leucine, %	1.75	1.78	1.80	1.83	1.85	1.88
Leucine, % (A)	1.78	1.78	1.81	1.85	1.78	1.82
Arginine, %	1.18	1.13	1.08	1.03	0.98	0.93
Arginine, % (A)	1.27	1.27	1.22	1.21	1.14	1.13
Dig Met, %	0.42	0.42	0.42	0.42	0.42	0.42
Dig Lys, %	0.91	0.91	0.91	0.91	0.91	0.91
Dig Trp, %	0.18	0.17	0.17	0.16	0.15	0.15
Dig Thr, %	0.66	0.66	0.66	0.66	0.66	0.66
Dig TSAA, %	0.72	0.72	0.72	0.72	0.72	0.72

[1]A = analyzed value

Table 8: Bulk density (g/cm^3) of the experimental diets

	Starter[1]		Grower[2]		Finisher[2]	
DDGS inclusion, %	Mean	SD[3]	Mean	SD	Mean	SD
0	0.78	0.011	0.78	0.005	0.73	0.009
5	0.77	0.004	0.75	0.002	0.75	0.011
10	0.78	0.006	0.74	0.007	0.77	0.010
15	0.78	0.015	0.72	0.007	0.76	0.006
20	0.78	0.006	0.71	0.003	0.74	0.015
25	0.74	0.011	0.73	0.008	0.75	0.007

[1]Fed as crumbles, [2]Fed as pellets, [3]SD = Standard deviation

fed diets with 15% DDGS and significantly increased as a percentage of the carcass in birds fed diets with 25% DDGS. There was no significant effect of dietary DDGS on percentage of leg quarters as a percentage of live weight or carcass weight. These results are somewhat in contrast to the findings of Lumpkins *et al*. (2004) who fed diets with 0, 6, 12, or 18% DDGS through 42 days and observed no differences in yield when observing the selected carcass parts: front and back halves (white and dark meat areas), wings and breasts; however, the highest level fed in the cited study was 18%.

Waldroup *et al*. (1981) reported that when DDGS from beverage alcohol production was included in isocaloric broiler diets, up to 25% DDGS could be used without reduction in body weight or feed utilization. When included in diets in which the energy content was

Table 9: Effect of varying level of DDGS in broiler diets on live performance of male broilers (means of four pens of 25 birds per pen)

	DDGS inclusion, %							
Items	0	5	10	15	20	25	CV %	SEM
Body weight (kg)								
14 d	0.460	0.455	0.475	0.463	0.477	0.476	2.64	0.0062
35 d	2.365	2.370	2.360	2.330	2.312	2.341	1.98	0.0233
49 d	3.728	3.795	3.786	3.705	3.717	3.762	2.31	0.0432
Feed conversion (feed:gain ratio)								
0-14 d	1.334	1.370	1.331	1.341	1.316	1.348	5.13	0.0344
0-35 d	1.559	1.576	1.595	1.571	1.584	1.618*	1.90	0.0150
0-49 d	1.773	1.789	1.806	1.800	1.783	1.827*	1.77	0.0159
Feed intake (kg/bird)								
0-14 d	0.550	0.558	0.569	0.558	0.563	0.577	5.08	0.0143
0-35 d	3.612	3.660	3.687	3.586	3.583	3.709*	2.11	0.0384
0-49 d	6.521	6.703	6.751	6.577	6.540	6.785*	2.13	0.0708
Mortality (%)								
0-14 d	2.00	1.00	2.00	0.00	0.00	0.00	187.61	0.7817
0-35 d	6.00	2.00	3.00	2.00	1.00	3.00	121.13	1.7159
0-49 d	11.00	7.00	7.00	5.00	6.00	6.00	81.93	2.8674

*Differs significantly from 0% level based on single-degree comparisons (p<0.05)

Table 10: Effect of various levels of DDGS on processing parameters at 49 d (means of four replicate groups of five males each)

	DDGS inclusion, %							
Variables	0	5	10	15	20	25	CV	SEM
Dressing percentage, %	74.98	74.23	74.14	73.87*	74.22	73.60*	2.05	0.3484
Breast % of live weight	22.64	22.30	22.93	22.01	22.20	21.36*	8.26	0.4214
Wings % of live weight	7.87	7.90	7.76	8.14*	7.89	8.01	5.25	0.0955
Leg quarter % of live weight	22.62	22.60	22.80	22.80	22.10	22.53	5.92	0.3064
Breast % of carcass	30.18	30.02	30.92	29.80	29.91	29.01	7.66	0.5269
Wings % of carcass	10.50	10.65	10.48	11.02*	10.64	10.89*	5.43	0.1333
Leg quarter % of carcass	30.20	30.46	30.78	30.87	29.78	30.62	6.28	0.4388

*Differs significantly from 0% level based on single-degree comparisons (p<0.05)

allowed to decline as the level of DDGS was increased, there was a decline in performance at DDGS levels of 15% or more. For “new generation” DDGS Noll (2005) recommended a maximum dietary inclusion level of 10% corn DDGS for meat birds. Lumpkins *et al*. (2004) indicated that DDGS from modern ethanol plants was an acceptable feed ingredient for broiler diets and could be safely used at 6% in the starter period and 12 to 15% in the grower and finisher periods. Diets fed in the study by Lumpkins *et al*. (2004) were formulated on the basis of total amino acids, which might account for the birds' inability to use greater than 6% in the starter diet or more than 12 to 15% in grower and finisher diets. In the present study, the diets were formulated on the basis of digestible amino acid values and higher levels were tolerated. The sample of DDGS used in the present study was analyzed to contain slightly lower crude protein, fat and fiber content than the nutrient matrix used to formulate the diets but had higher total and digestible values for many essential amino acids, including lysine. Therefore, it could be considered as a high quality source of DDGS and may be the reason why higher levels of DDGS were tolerated in the present study.

The physical appearance, chemical composition and nutrient digestibility of DDGS can vary considerably depending on source and processing and drying procedures (Cromwell *et al*., 1993). Variations may exist among samples of DDGS for metabolizable energy, content and availability of essential amino acids (especially lysine), content and bioavailability of phosphorus and variation in sodium content. The acceptance of high levels of DDGS as seen in the present study may be associated with the apparent high nutrient quality of the sample used in the present study. Further research should be conducted to confirm this high inclusion rate with a range of DDGS samples and to evaluate the influence of DDGS on carcass composition, especially breast meat yield.

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