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Use of Constant or Increasing Levels of Distillers Dried Grains with Solubles (DDGS) in Broiler Diets[1]

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Abstract: A study was conducted to evaluate the use of constant or increasing levels of Distillers Dried Grains with Solubles (DDGS) in diets for broilers. Diets were formulated for starter (0-14 d), grower (14 to 35 d) and finisher (35 to 42 d) periods to contain 0, 15, or 30% DDGS. Diets were formulated on digestible amino acid basis to meet current U.S. poultry industry nutrient levels and were maintained isocaloric and isonitrogenous. Varying levels of DDGS were fed during the study; with some birds receiving a constant level while others received increasing amounts as the bird aged. The DDGS levels used in the study were as follows (starter-grower-finisher, %): 1) 0-0-0; 2) 0-15-15; 3) 0-15-30; 4) 0-30-30; 5) 15-15-15; 6) 15-15-30; 7) 15-30-30; 8) 30-30-30. 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. Body weights and feed consumption were determined at 14, 35 and 42 d of age. At the conclusion of the study five representative birds per pen were processed for dressing percentage and parts yield. The results indicated that increasing DDGS levels had a trend to reduce the weight:volume ratio and visually decreased pellet quality. Diets containing 15% DDGS could be fed throughout the entire feeding period of 1 to 42 d of age with no adverse effects on live performance or carcass composition when diets were formulated on a digestible amino acid basis. Inclusion of 30% DDGS in the diet reduced the weight:volume ratio and markedly reduced pellet quality. Birds fed diets with 30% DDGS during the starter or grower periods had reduced body weight, elevated feed conversion and typically had reduced breast meat yield, compared to birds fed diets with 15% DDGS or birds fed the control diet with no DDGS. Feeding DDGS for the last seven days prior to slaughter after being fed diets with 15% during starter or grower period might possibly be acceptable in terms of body weight gain and feed conversion but still resulted in a significant reduction in breast meat yield. It is possible that some of the essential amino acids that were not considered in the formulation of the diets may become marginal or deficient in diets with 30% DDGS. Further studies are suggested to evaluate needs for these amino acids in diets with high levels of DDGS.

Key words: Alternative feeds, ethanol byproducts, distillers dried grains with solubles, broilers

Introduction

There are three types of residual co-products produced from the production of ethanol from grain. These include Distiller's Dried Grains (DDG), Distiller's Dried Solubles (DDS) and Distiller's Dried Grains with Solubles (DDGS). Among the three co-products, the DDS fraction is the richest source of vitamins, the lowest in fiber and the highest in fat, yielding approximately 91% DE value of the corn. DDGS, a common commercially available product, is a blend of DDS and DDG with the intermediate nutrient composition between DDS and DDG. Due to the U.S. energy policy, the supply of DDGS has increased tremendously because of recent expansion of ethanol production from grains.

There is some question as to acceptable usage levels of DDGS in broiler diets. Dale and Batal (2003) used 0, 6, 12 and 18% DDGS in a 42 d growout study and reported that 12% DDGS resulted in a slight decrease in performance during the starter period while 18% DDGS had a negative impact on body weight and feed conversion over the 42 d period. Lumpkins *et al*. (2004) indicated that DDGS from modern ethanol plants was an acceptable feed ingredient for broiler diets and suggested a maximum usage level of 6% in starter diets and 12 to 18% in grower and finisher diets. Results from a recent study in our laboratory (Wang *et al*., 2007) using DDGS from new ethanol production indicated that 15 to 20% could be included in a pelleted or crumbled broiler diet formulated on the basis of digestible amino acids using a standardized nutrient matrix derived from reported literature values. The objective of the current study was to evaluate the use of constant or increasing levels of DDGS in broiler starter, grower and finisher diets.

Materials and Methods

Diet formulation: Diets were formulated to meet nutritional standards typical of the U.S. poultry industry (Agri-Stats, Fort Wayne IN) to contain 0, 15, or 30% DDGS. Diets were formulated on a digestible amino acid basis, utilizing 90% of current industry total amino acid levels in relation to dietary energy. Metabolizable energy and crude protein values typical of the U.S. industry were specified. Amino acid minimums were expressed for digestible lysine, digestible TSAA and digestible threonine as these are commercially available in supplemental form. No other amino acid minimums were specified in formulation. Because of the reported variation in sodium content of DDGS (Spiehs *et al*., 2002; Batal and Dale, 2003; Parsons *et al*., 2006) a minimum level of 4.0 g/kg of sodium chloride was specified in addition to a minimum sodium content of 0.25% for all diets. Calcium and available phosphorus minimums were similar to industry average values.

Total and digestible amino acid values for corn and soybean meal were based on values suggested by a leading amino acid producer (Ajinomoto Heartland Lysine, Chicago IL) adjusted to the moisture and crude protein content of the products used in the formulation of the diets. Nutrient values for DDGS are shown in Table 1 and were a composite of reported values (Waldroup *et al*., 2007). A blended animal protein was added to all diets at 5%, a level typical of animal protein usage in the U.S. poultry industry. Diets were maintained isocaloric and isonitrogenous. All diets were fortified with complete vitamin and trace mineral mixes. Composition of diets is shown in Table 2 with the calculated analysis shown in Table 3. Starter diets were crumbled, while grower and finisher diets were pelleted.

Using the diets with three different levels of DDGS, eight dietary treatments were compared. These included 1) feeding constant levels of 0, 15, or 30% DDGS for the duration of the 42 d study; 2) feeding increasing levels of DDGS at each diet change. Each of the dietary treatments was fed to four replicate pens of 25 birds each. The dietary treatments were as follows:

	% DDGS		
Treatment	0-14 d	14-35 d	35-42 d
1	0	0	0
2	0	15	15
3	0	15	30
4	0	30	30
5	15	15	15
6	15	15	30
7	15	30	30
8	30	30	30

Housing and management: Male chicks of a commercial broiler strain (Cobb 500[3]) 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. New softwood shavings served as litter over concrete floors. Twenty-five chicks were randomly assigned to each of 32 pens in a broiler house of commercial design. 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).

Table 1: Suggested nutrient matrix for DDGS based on weighted averages of published data[1]

Nutrient	Amount	Actual
Dry matter %	89.36	90.12
Crude protein %	26.45	27.92
Fat %	10.08	9.42
Fiber %	6.99	6.47
TME_n, kcal/lb	1293	Nd
Calcium %	0.07	0.05
Phosphorus %	0.77	0.82
Available phosphorus %	0.48	Nd
Potassium %	0.85	1.05
Sodium %	0.20	0.18
Arginine %	1.09	1.12
Histidine %	0.68	0.68
Isoleucine %	0.96	1.13
Leucine %	3.00	2.77
Lysine %	0.73	0.83
Methionine %	0.50	0.55
Cystine %	0.54	0.52
Phenylalanine %	1.31	1.24
Threonine %	0.96	0.95
Tryptophan %	0.21	Nd
Valine %	1.30	1.43
Serine %	1.07	1.44
Dig Arginine % (88.9%)[2]	0.93	0.99
Dig Histidine %	0.58	Nd
Dig Isoleucine % (85.3%)	0.78	0.96
Dig Leucine % (91.0%)	2.70	2.52
Dig Lysine % (76.1)	0.50	0.63
Dig Methionine % (88.6%)	0.43	0.48
Dig Cystine % (82.0%)	0.42	0.43
Dig Phenylalanine %	1.15	Nd
Dig Threonine % (78.7%)	0.72	0.75
Dig Tryptophan % (88.4%)	0.18	Nd
Dig Valine % (83.8)	1.05	1.20
Dig Serine %	0.88	Nd

[1]Data source: Waldroup *et al*. (2007), [2]Values in parenthesis are digestibility estimates based on IDEA analysis

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[4] 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 42 d of age. Birds that died were weighted to adjust feed conversion. At the end of

Table 2: Composition (g/kg) of diets with different levels of DDGS

Ingredient	Starter 0-14 d			Grower 14-35 d			Finisher 35-42 d		
DDGS	0.00	150.00	300.00	0.00	150.00	300.00	0.00	150.00	300.00
Yellow corn	591.02	511.34	431.65	650.00	570.65	490.97	715.23	636.27	556.60
Soybean meal	311.06	234.65	158.24	252.76	176.29	99.87	189.55	113.00	36.58
Poultry oil	17.09	21.05	25.02	18.13	21.98	25.95	18.03	21.74	25.70
Pro-Pak[1]	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Defl. phos	8.52	5.82	3.11	7.30	4.59	1.88	6.01	3.30	0.60
Limestone	6.49	9.01	11.53	5.68	8.19	10.71	5.68	8.20	10.72
Salt	4.00	4.00	4.00	4.15	4.00	4.00	4.33	4.00	4.00
MHA-84	1.53	1.46	1.39	1.34	1.27	1.20	0.85	0.78	0.71
L-Lysine HCl	0.31	2.26	4.22	0.60	2.56	4.52	0.84	2.80	4.76
L-Threonine	0.23	0.66	1.09	0.29	0.72	1.15	0.48	0.91	1.33
Vitamin premix[2]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Pel-Stik[3]	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Mintrex P_Se[4]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Coban 60[5]	0.75	0.75	0.75	0.75	0.75	0.75	0.00	0.00	0.00
BMD 50[6]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
TOTAL	1000.00	1000.00	1000.00	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 7715 IU; cholecalciferol 5511 IU; vitamin E 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione 1.5 mg; folic acid 0.9 mg; choline 1000 mg; thiamin 1.54 mg; pyridoxine 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg, [3]Uniscope Inc., Johnstown CO 80534, [4]Provides per kg of diet: Mn (as manganese methionine hydroxy analogue complex) 40 mg; Zn (as zinc methionine hydroxy analogue complex) 40 mg; Cu (as copper methionine hydroxy analogue complex) 20 mg; Se (as selenium yeast) 0.3 mg; Novus International, St. Louis MO, [5]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825, [6]Alpharma, Inc., Ft. Lee, NJ 07024

Table 3: Calculated nutrient content of diets with different levels of DDGS. Values in bold are at minimum specified level

	Starter 0-14 d			Grower 14-35 d			Finisher 35-42 d		
Nutrient	0% DDGS	15% DDGS	30% DDGS	0% DDGS	15% DDGS	30% DDGS	0% DDGS	15% DDGS	30% DDGS
ME kcal/lb	1400.00	1400.00	1400.00	1430.00	1430.00	1430.00	1460.00	1460.00	1460.00
CP, %	22.44	22.44	22.44	20.31	20.31	20.31	18.01	18.01	18.01
Met %	0.58	0.58	0.59	0.53	0.54	0.54	0.46	0.47	0.47
Lys %	1.32	1.33	1.34	1.18	1.19	1.20	1.02	1.03	1.04
Trp %	0.27	0.25	0.22	0.24	0.21	0.19	0.20	0.18	0.15
Thr %	0.93	0.94	0.96	0.84	0.86	0.87	0.76	0.77	0.78
Ile %	0.95	0.90	0.86	0.84	0.79	0.75	0.72	0.67	0.63
His %	0.62	0.61	0.60	0.57	0.55	0.54	0.50	0.498	0.47
Val %	1.13	1.12	1.11	1.02	1.02	1.01	0.90	0.90	0.89
Leu %	2.05	2.13	2.21	1.89	1.97	2.04	1.71	1.79	1.87
Arg %	1.53	1.38	1.24	1.34	1.19	1.05	1.13	0.99	0.85
TSAA %	1.01	1.02	1.03	0.93	0.94	0.95	0.82	0.83	0.84
Dig Met %	0.54	0.54	0.54	0.50	0.50	0.50	0.43	0.43	0.43
Dig Lys %	1.18	1.18	1.18	1.06	1.06	1.06	0.91	0.91	0.91
Dig Thr %	0.81	0.81	0.81	0.73	0.73	0.73	0.66	0.66	0.66
Dig TSAA %	0.89	0.89	0.89	0.82	0.82	0.82	0.72	0.72	0.72
Ca %	0.93	0.93	0.93	0.85	0.85	0.85	0.79	0.79	0.79
Available P %	0.43	0.43	0.43	0.40	0.40	0.40	0.37	0.37	0.37
Sodium %	0.25	0.26	0.27	0.25	0.26	0.27	0.25	0.25	0.26

Table 4: Dietary bulk density (g/cm^3)

DDGS inclusion, %	Diet	Mean	SD
0	Starter	0.74	0.012
15	Starter	0.72	0.017
30	Starter	0.72	0.007
0	Grower	0.76	0.001
15	Grower	0.75	0.003
30	Grower	0.72	0.016
0	Finisher	0.76	0.018
15	Finisher	0.77	0.005
30	Finisher	0.73	0.010

the study five representative birds per pen were processed for dressing percentage and parts yield as described by Fritts and Waldroup (2006).

Statistical analyses: All the data were subject to one-way ANOVA analysis (SAS institute, 1991). Significant differences among means were separated using Duncan's multiple-range test option of the general linear model procedure. Pen means of growth performance were used as an experimental unit, while each bird was

Table 5: Influence of various levels of distillers dried grains plus solubles (DDGS) on performance of male broilers at 14 d of age

DDGS, %	N	Body weight (kg)	Feed intake (kg/bird)	Feed:gainratio	Mortality (%)
0	16	0.408	0.584	1.433[b]	1.00
15	12	0.412	0.588	1.425[b]	0.67
30	4	0.386	0.594	1.539[a]	4.00
SEM		0.009	0.012	0.032	1.213
P value		0.055	0.76	0.01	0.065
CV		4.46	4.04	4.38	194.07

[ab]Means with common superscripts do not differ significantly (p<0.05)

Table 6: Influence of constant or increasing levels of distillers dried grains plus solubles (DDGS) on performance of male broilers at 35d

DDGS, %S-G[1]	n	Body weight (kg)	Feed intake (kg/bird)	Feed:gainratio	Mortality (%)
0-0	4	2.115[a]	3.472[a]	1.643[c]	2.00
15-15	8	2.071[a]	3.451[a]	1.667[bc]	2.00
30-30	4	1.864[b]	3.241[b]	1.742[ab]	8.00
0-15	8	2.086[a]	3.453[a]	1.655[bc]	3.50
0-30	4	1.870[b]	3.255[b]	1.743[ab]	2.00
15-30	4	1.884[b]	3.332[ab]	1.769[a]	1.00
SEM		0.026	0.049	0.032	2.469
P value		<0.0001	0.001	0.01	0.38
CV		2.56	2.91	3.82	164.60

[1]S-G = Starter-Grower, [abc]Means with common superscripts do not differ significantly (p<0.05)

an experimental unit for processing variables as the birds were processed in random order. Mortality data were transformed to $\sqrt{n+1}$ for analysis; data are shown as natural numbers. All statements of significance were based on $p \leq 0.05$.

Results and Discussion

The nutrient composition of the DDGS sample used in this study was in fairly good agreement with the values used in formulation of the diets (Table 1). Based on the IDEA analysis the lysine digestibility of the present sample was 76% compared to the 68% value used in the composite analysis. The dietary bulk density decreased with the increasing DDGS inclusion in the broiler diet (Table 4). Mraz *et al*. (1957) pointed out that neither energy value nor density of the ration was an adequate criterion of the 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). Although pellet quality was not quantitatively assessed the visual pellet quality decreased as the level of DDGS increased. Diets with 15% DDGS pelleted reasonably well and were similar to that of the control diet with no DDGS; however, diets with 30% DDGS pelleted extremely poorly and had numerous fines even though a pellet binder was added to the diets. Due to the fermentation of the corn starch by selected yeasts and enzymes to produce ethanol, DDGS is not well gelatinized. Pelleting increases the bulk density of feed ingredients and improves flowability as compared to mash feed (Briggs, 1999). This increase in bulk density as DDGS levels increased was consistent with our previous experiment (Wang *et al*., 2007). The positive relationship between pellet quality and performance of broilers has been noted by many authors (Kilburn and Edwards, 2001; Greenwood *et al*., 2004, 2005; McKinney and Teeter, 2004).

The effects of varying DDGS levels on performance of broilers at 14 d are shown in Table 5. Birds fed diets with 15% DDGS did not differ significantly from those fed diets with no DDGS in body weight, feed intake, feed conversion, or mortality. Feeding diets with 30% DDGS resulted in body weight that was numerically reduced and closely approached a level of statistical significance (P = 0.055). Feed intake was not significantly affected by feeding diets with 30% DDGS but feed conversion was significantly worsened by the addition of 30% DDGS to the diet. There were no significant differences in mortality among the various treatment groups, although numerically increased in birds fed diets with 30% DDGS (P = 0.065).

When the birds were changed to grower diets, six different treatments were included (Table 6). There was no significant effect of feeding diets with 15% from 1 to 35 d or from 14 to 35 d on body weight, feed intake, feed conversion, or mortality, compared to feeding the control diet with no DDGS. Birds fed diets with 30% DDGS either from 1 to 35 d or from 14 to 35 d after previously receiving diets with 0 or 15% DDGS had significantly reduced body weight and increased feed conversion as compared to birds fed the control diet with no DDGS. Birds that were fed 30% DDGS after previously being fed diets with 15% DDGS in the starter period appeared to perform somewhat better than those that had been previously fed the diet with 0% DDGS, but still had significantly reduced performance. Birds that had been

Table 7: Influence of constant or increasing levels of distillers dried grains plus solubles (DDGS) on performance of male broilers at 42d

DDGS, % S-G-F[1]	n	Body weight (kg)	Feed intake (kg/bird)	Feed:gainratio	Mortality (%)
0-0-0	4	2.771[a]	4.775[a]	1.724[b]	4.00
15-15-15	4	2.658[a]	4.718[ab]	1.776[ab]	3.00
30-30-30	4	2.440[b]	4.495[c]	1.845[a]	8.00
0-15-15	4	2.701[a]	4.725[ab]	1.750[b]	4.00
0-15-30	4	2.716[a]	4.860[a]	1.790[ab]	4.00
0-30-30	4	2.467[b]	4.562[bc]	1.853[a]	3.00
15-15-30	4	2.694[a]	4.879[a]	1.812[ab]	2.00
15-30-30	4	2.526[b]	4.682[abc]	1.854[a]	4.00
SEM		0.041	0.065	0.029	2.784
P value		<0.001	0.003	0.02	0.88
CV		3.11	2.76	3.19	139.19

[1]S-G-F = Starter-Grower-Finisher, [abc]Means with common superscripts do not differ significantly ($p<0.05$)

Table 8: Influence of constant or increasing levels of distillers dried grains plus solubles (DDGS) on dressing percentage and parts yield of male broilers at 42 d

DDGS (%)			Parts yield % of carcass weight		
S-G-F[1]	n	Dressing Percentage (%)	Breast	Wing	Leg quarter
0-0-0	20	71.33[a]	27.51[a]	10.96[b]	29.08
15-15-15	20	71.05[ab]	27.13[ab]	10.07[b]	29.71
30-30-30	20	70.06[bc]	25.44[c]	11.50[a]	30.06
0-15-15	20	71.32[a]	27.41[a]	11.20[ab]	28.97
0-15-30	20	69.54[c]	27.60[a]	10.95[b]	29.38
0-30-30	20	69.56[c]	25.99[bc]	11.12[ab]	29.37
15-15-30	20	69.64[c]	26.10[bc]	11.18[ab]	30.12
15-30-30	20	69.22[c]	25.41[c]	11.51[a]	29.90
SEM		0.36	0.42	0.13	0.32
P value		<0.0001	<.0001	0.01	0.065
CV		2.32	7.12	5.17	4.76

[1]S-G-F = Starter-Grower-Finisher, [abc]Means with common superscripts do not differ significantly ($p<0.05$)

fed 30% DDGS from 1 d of age had numerically higher mortality that did those fed other diets, but due to the inherent high variability in mortality this was not statistically significant.

When the birds were changed to finisher diets, there were eight different treatments (Table 7). There were no significant effects of feeding diets with 15% DDGS from 1 to 42 d of age, or from 14 to 42 d of age after previously consuming the control diet with no DDGS, compared to performance of birds fed the control diet with no DDGS. When birds were fed diets with 30% DDGS from 1 d or from 14 d after previously been fed diets with 0 or 15% DDGS, there were significant adverse effects on body weight and feed conversion. However, birds fed diets with 30% DDGS only during the finisher period from 35 to 42 d after previously being fed diets with 0 or 15% did not differ significantly in performance from those fed diets with 0 or 15% DDGS, although numerical differences in body weight and feed conversion were observed.

The effects of the dietary treatments on processing characteristics are shown in Table 8. Birds fed diets with 15% DDGS from 1 d of age or from 14 to 42 d of age did not differ significantly in dressing percentage or yield of breast meat, wing, or leg quarters from birds fed the control diet with no DDGS. Birds fed diets with 30% DDGS from 1 or 14 d of age after previously being fed diets with 0 or 15% DDGS had significantly reduced dressing percentage and breast meat yield compared to those fed the control diet with no DDGS. Birds that had been fed diets with 30% DDGS during the finishing period after previously being fed 15% DDGS from 1 to 35 d had significantly reduced dressing percentage and breast yield compared to those fed the control diet with no DDGS; however, if no DDGS was fed during the starting periods birds fed diets with 15% DDGS during the grower period could be fed diets with 30% DDGS during the finishing period without a significant reduction in breast yield although dressing percentage continued to be reduced.

The results of the present study indicate that diets with 15% DDGS, formulated on a digestible amino acid basis, can be effectively used in broiler diets providing the DDGS is equivalent in nutrient value to the standardized nutrient matrix. Feeding diets with 30% DDGS during the starter or grower periods will result in adverse performance but might possibly be tolerated in finisher diets, at least for the seven-day period utilized in the present study. These results are in agreement with Waldroup *et al*. (1981) who reported that when DDGS from beverage alcohol production was included into broiler diets with the ME content held constant, 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 allowed to decline as the level of DDGS was increased, there was a decline in performance at DDGS levels of 15% or more.

In contrast, Dale and Batal (2003) suggested a maximum level of 6% DDGS from ethanol production in starter diets and 12% in grower-finisher diets, while Lumpkins *et al*. (2004) stated that DDGS from modern ethanol plants could be safely used at 6% in the starter period and 12 to 15% in the grower and finisher periods. Dale and Batal (2003) do not indicate whether diets were formulated on total or digestible amino acid basis while Lumpkins *et al*. (2004) indicated that diets were formulated on total amino acid basis. Wang *et al*. (2007) concluded that DDGS could be included in broiler diets at levels of 15% when formulated on a digestible amino acid basis. It has been noted that digestibility of several amino acids in DDGS is relatively poor, especially Lys and Thr (Batal and Dale, 2006; Fiene *et al*., 2006; Parsons *et al*., 2006; Fastinger *et al*., 2006; Waldroup *et al*., 2007). Failure to compensate for this reduced amino acid digestibility in formulating diets may inhibit the usage of high levels of DDGS in broiler diets.

In evaluating the formulas used in the current study (Table 2) it is likely that some amino acids other than those specified in the formulation of the diets may have become marginal or limiting in diets with 30% DDGS. While it is difficult to make direct comparison to NRC (1994) recommendations due to differences in dietary energy levels and time of feeding, it is possible that tryptophan, isoleucine and arginine may be marginal or deficient in diets with 30% DDGS. The marginal level of isoleucine may be exacerbated by the increasing levels of leucine in the diet (Waldroup *et al*., 2002), while the marginal level of tryptophan may be exacerbated by increasing levels of the large neutral amino acids Ile, Leu, Val, Phe and Tyr (Si *et al*., 2004). As greater amounts of DDGS become available and supplies of corn diminish, the poultry industry may be forced to use higher levels of DDGS. Further research is needed to evaluate the use of other synthetic amino acids or higher crude protein levels in diets with high levels of DDGS.

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