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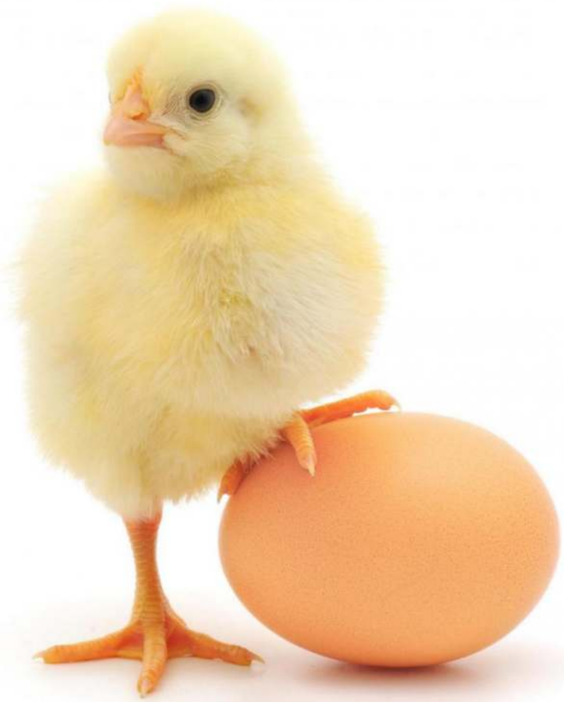

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Evaluation of Corn Distillers Dried Grains with Solubles in Broiler Diets Formulated to Be Isocaloric at Industry Energy Levels or Formulated to Optimum Density with Constant 1% Fat[1]

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Abstract: A feeding trial was conducted in various levels of corn distillers dried grains with solubles (DDGS) were fed in broiler diets formulated to be either isocaloric using metabolizable energy levels similar to current U.S. poultry industry levels or formulated to contain optimum density commensurate with 1% supplemental poultry oil. In each diet type, levels of 0, 15 and 30% DDGS were incorporated. This resulted in six dietary treatments with four pens of 25 males per treatment. Diets were developed for starter (0-14 d), grower (15-28 days) and finisher periods (29-42 days) and were formulated to meet digestible amino acid specifications of a major poultry breeder, adjusted to the energy content of the diet. Bulk density and pellet quality of mixed feeds were determined. At the end of the study, five representative birds per pen were processed for dressing percentage and parts yield determination. Pellet quality decreased with increasing level of DDGS used. There was little difference in pellet quality between diets with 0 or 15% DDGS but quality deteriorated severely in diets with 30% DDGS. Diets formulated to optimum energy had better pellet quality due to lower supplemental poultry oil. Over the 42 days study, birds fed diets with 30% DDGS had significantly lower body weight and significantly higher feed conversion than did birds fed the control diet with no DDGS. Birds fed diets with 15% DDGS did not differ significantly in 42 days BW or feed conversion from birds fed the control diet with no DDGS nor with the birds fed diets with 30% DDGS. It appeared that a portion of the reduced performance associated with the higher level of DDGS might have been associated with the reduced pellet quality and the bulk density of the diet, rather than any nutritional deficiency. Therefore, approaches to feed manufacturing that enhance pellet quality may enhance usage of higher levels of DDGS in broiler diets.

Key words: Broilers, DDGS, pellets, feed intake

Introduction

One of the fundamental concepts in formulating poultry diets is that nutrients from various ingredients are additive. That is, one unit of nutrient A from ingredient X plus one unit of nutrient A from ingredient Y should be equivalent to 2 units of nutrient A. Therefore, if proper nutrient values are assigned to each ingredient and the proper amount of nutrients are provided, almost any combination of ingredients should be satisfactory to support performance. However, this does not take into account problems such as antinutritional factors, bulkiness of ingredients that might inhibit feed intake, or influence of diet composition on pellet quality.

In recent studies in our laboratory (Wang *et al.*, 2007b, c) using digestible amino acid values in formulation of diets, we have determined that inclusion of 15% DDGS in broiler diets is acceptable, but feeding diets with 30% DDGS resulted in loss of performance if fed over an extended period of time. It was speculated in these studies that some essential amino acids not typically specified in formulation might be marginal or lacking, due to the high level of corn-derived protein in these diets. In addition, it is important that diets containing DDGS or other less digestible amino acids should be formulated on a digestible amino acid basis for best results (Rostagno *et al.*, 1995; Dari *et al.*, 2005). 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. Pellet quality is also a concern at higher levels of DDGS and may be partially responsible for reduction in performance. This is because there is little starch left in DDGS to contribute to particle bonding after fermentation to produce biofuel; in addition, the high oil content of DDGS also affects adhesion between particles because of its hydrophilic nature (Behnke, 2007). The objective of the present study was to evaluate a high level usage of DDGS in broiler diets formulated to more extensive digestible amino acid specifications and to evaluate factors that influence pellet quality such as supplemental fat levels and use of a high level of pellet binder.

Materials and Methods

Diet formulation: Diets were formulated using amino acid specifications suggested by a major poultry

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

Nutrient	Estimated	Analyzed[2]
Dry matter (%)	89.36	88.75
Crude protein (%)	26.45	27.69
Fat (%)	10.08	9.89
Fiber (%)	6.99	6.58
TME_n, kcal/lb	1293	ND
Calcium (%)	0.07	0.06
Phosphorus (%)	0.77	0.85
Available phosphorus (%)	0.48	ND
Potassium (%)	0.85	1.10
Sodium (%)	0.20	0.30
Arginine (%)	1.09	1.29
Histidine (%)	0.68	0.77
Isoleucine (%)	0.96	1.06
Leucine (%)	3.00	3.29
Lysine (%)	0.73	0.92
Methionine (%)	0.50	0.57
Cystine (%)	0.54	0.58
Phenylalanine (%)	1.31	1.38
Threonine (%)	0.96	1.00
Tryptophan (%)	0.21	0.20
Valine (%)	1.30	1.45
Serine (%)	1.07	1.17
Dig arginine (%) (83.90%)	0.93	1.08
Dig histidine (%)	0.58	ND[3]
Dig isoleucine (%) (81.60%)	0.78	0.86
Dig leucine (%) (87.90%)	2.70	2.89
Dig lysine (%) (65.10%)	0.50	0.60
Dig methionine (%) (86.10%)	0.43	0.49
Dig Cystine (%) (73.30%)	0.42	0.43
Dig phenylalanine (%)	1.15	ND
Dig threonine (%) (72.50%)	0.72	0.73
Dig tryptophan (%) (80.40%)	0.18	0.16
Dig valine (%) (80.10%)	1.05	1.16
Dig Serine (%)	0.88	ND

[1]Data source: Waldroup *et al.* (2007), [2]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), [3]ND: not determined

breeder[3]. These recommendations include specifications for both total and digestible amino a0cids. No minimum crude protein level was imposed during formulation. Supplemental sources of amino acid activity included methionine hydroxy analogue calcium salt, L-Lysine HCl, L-Tryptophan and L-Threonine. Digestible amino acid values for corn and soybean meal were derived from Table 1 provided by a leading supplier of amino acids[4] while nutrient values for DDGS were based on a weighted average nutrient compilation (Waldroup *et al.*, 2007). Diets were developed for starter (0-14 days), grower (15-28 days) and finisher periods (29-42 days).

Two different dietary series were compared. In the first series, an energy level was selected that was similar to current U.S. poultry industry diets. Test diets within this series were calculated to be isocaloric but the protein content of the diets varied in order to meet the amino acid requirements and the level of poultry oil increased as the quantity of DDGS increased. In the second dietary series, diets were formulated to be optimum nutrient density with 1% added fat to avoid high levels of supplemental fats in diets with high levels of DDGS. In this series of diets, amino acids were maintained in relation to dietary energy levels. As in the first series, the protein content of the diet varied in order to meet the amino acid requirements.

In order to enhance pellet quality, a lignin sulfonate pellet binder[5] was included in all diets at the rate of 8 lbs per ton of feed, the maximum recommended level for this product. Defluorinated phosphate was used as the primary source of supplemental phosphate due to its known beneficial effects on pelleting. All diets were fortified with complete vitamin and trace mineral mixes. Pro-Pak[6], a blended protein supplement that has been found to be consistent in nutrient content (Johnson and Waldroup, 1983) was added to all diets at the rate of 2.5% as a typical source of animal protein. Composition of isocaloric diets using industry energy levels is shown in Table 2 and calculated nutrient composition given in Table 3. Composition of diets formulated to be optimum density with 1% supplemental fats is shown in Table 4 with calculated nutrient composition shown in Table 5. Diets were pelleted with steam using a 3/16” (4.76 mm) die, starter diets were crumbled. Each diet was fed to four pens of 25 male broilers each.

Housing and management: Male chicks of a commercial broiler strain (Cobb 500) 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. 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 h 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, calcium, phosphorus and sodium by commercial laboratories specializing in these assays. Digestible amino acids in the DDGS sample were estimated by the IDEA® assay[7]. All mixed diets were analyzed for crude protein, calcium, total P, sodium and total amino acids and were found to be in agreement with calculated values. Four replicate four replicate samples of the finisher diet were analyzed for pellet quality. Bulk density of mixed feeds was

Table 2: Composition (g/kg) of isocaloric broiler diets formulated to typical industry energy levels using varying levels of Distillers Dried Grains with Solubles (DDGS)

	Starter 0-14 days			Grower 15-28 days			Finisher 29-42 days		
Ingredient	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)
DDGS	0.00	150.00	300.00	0.00	150.00	300.00	0.00	150.00	300.00
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Yellow corn	585.36	459.14	330.45	656.39	528.11	399.18	691.62	563.04	433.94
Poultry oil	24.10	34.59	45.52	20.87	31.63	42.64	23.92	34.82	45.88
Soybean meal 47.5%	325.21	291.74	260.01	260.60	228.85	197.15	223.88	192.14	160.47
Ground limestone	5.14	8.06	10.95	5.16	8.07	10.90	5.36	8.25	11.05
Defluorinated phosphate	16.67	13.70	10.72	14.29	11.31	8.33	12.88	9.89	6.91
Sodium chloride	3.43	3.10	2.77	3.73	3.40	3.07	3.91	3.58	3.25
MHA-84	2.00	1.34	0.79	1.19	0.57	0.16	0.84	0.29	0.00
L-Threonine	0.23	0.05	0.00	0.03	0.00	0.00	0.07	0.00	0.00
L-Lysine HCl	1.61	2.03	2.54	1.49	1.81	2.32	1.27	1.74	2.25
Vitamin premix[2]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Coban 60[3]	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
BMD 50[4]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mintrex P_Se[5]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pel-Stik[6]	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
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]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825, [4]Alpharma, Inc., Ft. Lee, NJ 07024, [5]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, [6]Uniscope Inc., Johnstown CO 80534

Table 3: Calculated nutrient content of isocaloric broiler diets formulated to typical industry energy levels using varying levels of Distillers Dried Grains with Solubles (DDGS)[1]

	Starter 0-14 days			Grower 15-28 days			Finisher 29-42 days		
Nutrient	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)
CP (%)	21.80	23.18	24.63	19.35	20.79	22.24	17.91	19.35	20.81
CP (%) (A)[2]	21.60	22.20	23.40	20.40	20.80	23.40	18.50	20.70	21.00
Ca (%)	**1.00**	**1.00**	**1.00**	**0.90**	**0.90**	**0.90**	**0.85**	**0.85**	**0.85**
Total P (%)	0.74	0.75	0.75)	0.67	0.68	0.69	0.63	0.64	0.65
Avail. P (%)	**0.50**	**0.50**	**0.50**	**0.45**	**0.45**	**0.45**	**0.42**	**0.42**	**0.42**
Na (%)	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
Cl (%)	0.27	0.25	0.23	0.29	0.27	0.25	0.29	0.28	0.26
DEB meq kg^{-1}	236.73	248.31	260.05	205.86	218.59	230.33	188.54	200.53	212.27
ME kcal lb^{-1}	**1400.00**	**1400.00**	**1400.00**	**1425.00**	**1425.00**	**1425.00**	**1450.00**	**1450.00**	**1450.00**
ME kcal kg^{-1}	3086.00	3086.00	3086.00	3141.00	3141.00	3141.00	3196.00	3196.00	3196.00
Met (%)	0.58	0.56	0.54	0.48	**0.46**	**0.46**	0.43	**0.42**	0.43
Lys (%)	**1.37**	1.38	1.40	**1.18**	**1.18**	1.20	**1.06**	1.08	1.09
Thr (%)	0.89	0.91	0.95	0.77	0.81	0.85	0.72	0.75	0.79
TSAA (%)	**0.98**	0.99	1.01	**0.85**	**0.85**	0.89	**0.78**	0.80	0.84
Dig Met (%)	0.55	0.52	0.50	0.46	0.43	**0.42**	0.40	0.38	0.39
Dig Lys (%)	1.24	**1.23**	**1.23**	1.06	**1.05**	**1.05**	**0.95**	**0.95**	**0.95**
Dig Trp (%)	0.23	0.23	0.23	0.20	0.20	0.20	0.18	0.18	0.18
Dig Thr (%)	**0.78**	**0.78**	0.80	**0.67**	0.69	0.71	**0.62**	0.63	0.65
Dig Ile (%)	0.84	0.86	0.88	0.73	0.76	0.78	0.67	0.69	0.71
Dig Val (%)	0.96	1.00	1.05	0.85	0.90	0.95	0.79	0.84	0.88
Dig Arg (%)	1.38	1.36	1.35	1.19	1.17	1.16	1.07	1.06	**1.05**
Dig TSAA (%)	0.88	**0.87**	**0.87**	**0.76**	**0.76**	**0.76**	**0.69**	**0.69**	0.71

[1]Values in bold face are at minimum recommended levels, [2]A = analyzed

determined by weighing a predetermined volume of feed. Pellet quality of finisher diets was determined by placing a weighed amount of feed (approx 500 g) in a Tyler Sieve Shaker[8] for 30 sec at a rate of 278 oscillations per min. The percentage of pellets retained on a 2 mm screen was used to determine pellet quality

Table 4: Composition (g/kg) of broiler diets formulated to optimum density with constant 1% added poultry oil using varying levels of Distillers Dried Grains with Solubles (DDGS)

	Starter 0-14 days			Grower 15-28 days			Finisher 29-42 days		
Ingredient	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)
DDGS	0.00	150.00	300.00	0.00	150.00	300.00	0.00	150.00	300.00
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Yellow corn	610.95	502.19	392.53	674.51	564.08	453.36	714.00	602.93	491.52
Poultry oil	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Soybean meal 47.5%	313.67	273.42	233.53	253.43	214.55	175.60	215.50	177.08	138.65
Ground limestone	5.23	8.22	11.17	5.23	8.19	11.07	5.46	8.38	11.18
Defl. phosphate	16.68	13.70	10.71	14.28	11.29	8.31	12.86	9.87	6.88
Sodium chloride	3.42	3.09	2.77	3.73	3.40	3.07	3.91	3.58	3.25
MHA-84	1.86	1.10	0.50	1.08	0.42	0.00	0.71	0.16	0.00
L-Threonine	0.22	0.00	0.00	0.01	0.00	0.00	0.04	0.00	0.00
L-Lysine HCl	1.65	2.03	2.54	1.48	1.82	2.34	1.27	1.75	2.27
Vitamin premix[2]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Coban 60[1]	0.75	0.75	0.75	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	0.50	0.50	0.50
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pel-Stik[1]	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

[1]As given in Table 1

Table 5: Calculated nutrient content of broiler diets formulated to optimum density with constant 1% added poultry oil using varying levels of Distillers Dried Grains with Solubles (DDGS)

	Starter 0-14 days			Grower 15-28 days			Finisher 29-42 days		
Nutrient	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)	DDGS (0%)	DDGS (15%)	DDGS (30%)
CP (%)	21.48	22.68	23.91	19.16	20.42	21.69	17.70	18.98	20.27
CP (%) (A)[2]	22.54	22.35	23.28	20.00	21.30	22.40	20.00	18.80	21.60
Ca (%)	**1.00**	**1.00**	**1.00**	**0.90**	**0.90**	**0.90**	**0.85**	**0.85**	**0.85**
Total P (%)	0.74	0.74	0.75	0.67	0.68	0.69	0.63	0.64	0.65
Avail. P (%)	**0.50**	**0.50**	**0.50**	**0.45**	**0.45**	**0.45**	**0.42**	**0.42**	**0.42**
Na (%)	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
Cl (%)	0.27	0.25	0.24	0.29	0.27	0.25	0.29	0.28	0.26
DEB meq kg^{-1}	232.73	242.38	251.47	203.63	214.08	223.52	186.01	195.89	205.53
ME kcal lb^{-1}	1373.00	1353.00	1332.00	1404.00	1383.00	1361.00	1423.00	1401.00	1379.00
ME kcal kg^{-1}	3027.00	2981.00	2935.00	3094.00	3047.00	2999.00	3135.00	3087.00	3038.00
Met (%)	0.57	0.53	**0.51**	0.47	**0.45**	**0.44**	0.42	**0.41**	0.42
Lys (%)	**1.34**	1.33	1.33	**1.16**	**1.15**	1.15	**1.04**	1.04	1.04
Thr (%)	0.88	0.89	0.92	0.76	0.80	0.83	0.70	0.74	0.77
TSAA (%)	**0.97**	0.96	0.97	**0.84**	0.84	0.86	**0.77**	0.78	0.83
Dig Met (%)	0.53	0.49	0.47	0.44	0.41	**0.40**	0.39	0.37	0.38
Dig Lys (%)	1.22	**1.19**	**1.17**	1.05	**1.02**	**1.00**	0.93	**0.92**	**0.90**
Dig Trp (%)	0.23	0.22	0.22	0.20	0.19	0.19	0.18	0.18	0.17
Dig Thr (%)	**0.77**	**0.76**	0.77	**0.66**	0.67	0.69	**0.61**	0.62	0.63
Dig Ile (%)	0.83	0.84	0.85	0.72	0.74	0.75	0.66	0.67	0.68
Dig Val (%)	0.94	0.98	1.02	0.84	0.88	0.92	0.78	0.82	0.86
Dig Arg (%)	1.35	1.32	1.28	1.17	1.14	**1.11**	1.05	1.03	**1.00**
Dig TSAA (%)	0.86	**0.84**	**0.83**	**0.74**	**0.73**	0.74	0.68	0.67	0.70

[1]Values in bold face are at minimum recommended levels, [2]A = analyzed

samples of each feed were analyzed for bulk density and Body weights by pen and feed consumption were determined at 14, 28 and 42 days of age. Birds that died were weighted to adjust feed conversion. At the end of the study five representative birds per pen were processed with automatic evisceration for dressing percentage and parts yield as described by Fritts and Waldroup (2006).

Statistical analysis: All the data were subject to ANOVA analysis as a 2×3 factorial arrangement of treatments (SAS Institute, 1991) with main effects of 2 diet types (isocaloric versus variable energy) and three levels of DDGS (0, 15 and 30%) and the interaction of diet type and DDGS levels considered. Pen means were the experimental unit for growth performance while each bird was an experimental unit for processing variables as they were processed in random order. All statements of statistical significance were based on $p \leq 0.05$.

Results and Discussion

The nutrient content of DDGS in current study used was equal or superior to that of the weighted average value (Table 1). The nutrient composition of experimental diets indicated that the diets typically were at minimum specified levels for total or digestible lysine and total or digestible TSSA and were frequently at minimum specified level for total and digestible threonine (Table 3 and 5). Other essential amino acids met or exceeded minimum specifications.

Inclusion of DDGS in the diets significantly influenced the physical quality of the diets. Dietary bulk density (g cm^{-3}) generally decreased as the amount of DDGS increased. This effect was less in diets formulated for variable energy with 1% poultry oil. There was also a significant effect of dietary treatment on pellet quality (Fig. 1). Diets formulated to optimum density with 1% added poultry oil had significantly fewer fines than did diets formulated to optimum density and diets with 0 and 15% DDGS had significantly fewer fines than did diets with 30% DDGS.

The ANOVA table showing the effects of the various dietary factors on different parameters is shown in Table 7. The effect of various DDGS levels in diets formulated to be isocaloric or optimum energy density on growth performance is shown in Table 8. Body weight was not significantly influenced by diet type. The level of DDGS had no significant effect on body weight at 14 or 28 days; at 42 days birds fed diets with 30% DDGS were significantly lighter than birds fed the control diet with no DDGS, while birds fed diets with 15% DDGS were intermediate between the diet with no DDGS and the diet with 30% DDGS. There was a trend ($p<0.10$) for an interaction between diet type and DDGS on body weight at both 28 and 42 days of age. The body weight of birds fed diets formulated to variable energy with 1% added poultry oil suffered little or no reduction while body weight of birds fed diets maintained isocaloric tended to decline as the level of DDGS increased. This may have been due in large measure to the change in pellet quality associated with the higher levels of poultry oil used to maintain diets isocaloric.

Feed intake tended ($p<0.10$) to be influenced by diet type, with birds fed diets formulated to variable energy consuming more feed than did birds fed diets formulated to be isocaloric. Because the variable energy diets were calculated to contain lower levels of metabolizable energy, this was not unexpected. There were no significant effects of DDGS level on feed intake and no significant interactions between diet type and level of DDGS.

Birds fed diets formulated to be isocaloric had numerically ($p = 0.06$) lower feed conversion at 14 days

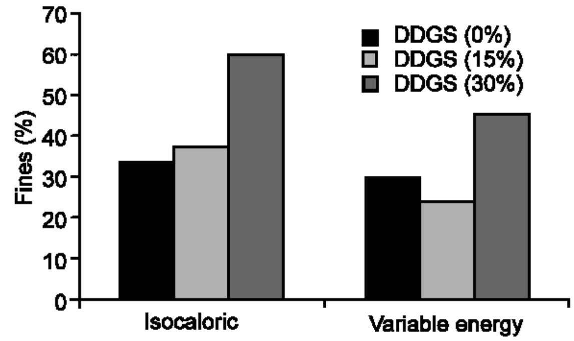

Fig. 1: Effect of level of DDGS and type of diet formulation on percent of pellets in broiler finisher diets that pass thorough a 2 mm screen

and significantly lower feed conversion at 28 and 42 day of age, compared to those fed the diets formulated to variable energy. Again, this was expected due to the lower metabolizable energy content of these diets. Increasing the level of DDGS numerically ($p = 0.06$) increased the feed conversion ratio at 14 days of age and significantly at 42 days of age. Birds fed diets with 30% DDGS had an overall 0-42 days feed conversion ratio that was significantly greater than that of birds fed the control diet with no DDGS; birds fed diets with 15% DDGS were intermediate. This may be in great measure an effect of the reduced pellet quality, as suggested by McKinney and Teeter (2004) and of the reduced dietary bulk density as suggested by Mraz *et al.* (1957).

Because of the differences in metabolizable energy between the different diet types and even among levels of DDGS in diets formulated to optimum density, evaluation of the efficiency by which birds utilized feed is better evaluated by comparing the conversion of overall dietary energy to gain (Saleh *et al.*, 2004; Leeson and Summers, 2005). No significant differences in total energy consumption (ME kcal/bird) were observed due to diet type or level of DDGS with no significant interactions between diet type and DDGS level. In addition, there were no significant differences in conversion of calories to gain related to diet type or to level of DDGS. There was a trend ($p<0.10$) of an interaction between diet type and DDGS level on calorie conversion at 28 and 42 days. The calorie:gain ratio tended to increase with level of DDGS in diets formulated to be isocaloric while it tended to remain constant or even decline as the level of DDGS increased when the diets were formulated to variable energy with constant 1% poultry oil. As noted above, this could be greatly influenced by differences in pellet quality. Although pellet quality declined in diets with 30% DDGS, the decline was significantly less when the diets were formulated to optimum density.

Mortality at 28 and 42 days was significantly less in birds fed diets formulated to variable energy as compared to

Table 6: Dietary bulk density (g/cm3) of diets formulated isocaloric or optimum density with 1% added poultry oil and different levels of distillers dried grains with solubles (DDGS). Starter diets are in crumble form while grower and finisher diets are pelleted

	Starter		Grower		Finisher	
Diet	Mean	SD	Mean	SD	Mean	SD
Isocaloric						
DDGS (0%)	0.74	0.006	0.78	0.014	0.80	0.020
DDGS (15%)	0.69	0.007	0.70	0.006	0.74	0.006
DDGS (30%)	0.67	0.015	0.68	0.013	0.66	0.014
Variable energy with 1% oil						
DDGS (0%)	0.74	0.001	0.73	0.022	0.78	0.021
DDGS (15%)	0.71	0.015	0.70	0.006	0.74	0.002
DDGS (30%)	0.71	0.028	0.67	0.007	0.75	0.005

Table 7: ANOVA of variables

	Probability > F			
Factor	CV	Diet type	% DDGS	Diet x DDGS
14 days BW	0.5344	0.7225	0.7513	2.47
28 days BW	0.5140	0.8959	0.0926	2.59
42 days BW	0.2233	0.0267	0.1049	1.84
0-14 days FI	0.1944	0.1756	0.7941	4.50
0-28 days FI	0.1069	0.7466	0.7336	3.00
0-42 days FI	0.0717	0.9943	0.5956	2.72
0-14 days FCR	0.0686	0.0637	0.7063	4.15
0-28 days FCR	0.0288	0.7225	0.4275	2.89
0-42 days FCR	0.0003	0.0092	0.4803	1.67
0-14 days mortality	0.0616	0.2412	0.3691	2.87
0-28 days mortality	0.0142	0.0268	0.0503	52.41
0-42 days mortality	0.0131	0.1049	0.0853	54.46
Dressing percentage,(%)	0.3897	0.5359	0.4421	2.23
Breast % of live weight	0.3104	0.2639	0.4646	6.84
Wings % of live weight	0.2929	0.6606	0.9673	4.34
Leg quarter % of live weight	0.9480	0.3806	0.9979	4.78
Breast % of carcass	0.3980	0.3477	0.1852	6.09
Wings % of carcass	0.5864	0.4103	0.8216	4.69
Leg quarter % of carcass	0.6419	0.1544	0.8230	4.75
% Fines	<.0001	<.0001	0.0007	6.34
0-14 days ME kcal bird^{-1}	0.7581	0.4999	0.6433	4.70
0-28 days ME kcal bird^{-1}	0.4460	0.9120	0.9614	3.07
0-42 days ME kcal bird^{-1}	0.3431	0.5811	0.9970	2.79
0-14 days ME kcal kg^{-1} gain	0.9285	0.2589	0.4280	4.43
0-28 days ME kca kg^{-1} gain	0.8532	0.9450	0.0925	2.95
0-42 days ME kcal kg^{-1} gain	0.8288	0.3102	0.0535	1.69

those fed isocaloric diets. At 28 days, mortality was significantly greater for birds fed diets with 30% DDGS as compared to those fed 0 or 15% DDGS. It must be emphasized that small numbers of birds were involved in these studies and the variability in mortality is very extensive as noted by the coefficient of variability of this measurement.

The effects of diet type and level of DDGS on processing parameters is shown on Table 9. There were no significant effects of diet type or DDGS level on dressing percentage or parts yield in this study, nor were there any significant interactions between diet type and DDGS level. In previous reports from our laboratory (Wang *et al.*, 2007 a,b,c) we have observed significant reductions in dressing percentage and in breast yield when diets contained more than 20% DDGS. Although differences were not significant in the present study, there were numerical reduction in dressing percentage and in breast yield when diets contained 30% DDGS as compared to the diet with no DDGS.

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 and the diets are formulated on a digestible amino acid basis. Feeding diets with 30% DDGS consistently during the growth period will result in adverse performance, probably related to the poor pellet quality resulting from such diets. 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

Table 8: Effect of formulating diets on an isocaloric or variable energy with 1% added poultry oil with different levels of distillers dried grains with solubles (DDGS) on performance of male broilers

	14 days BW (kg)			28 days BW (kg)			42 days BW (kg)		
	ISO	VAR	Mean	ISO	VAR	Mean	ISO	VAR	Mean
0	0.488	0.481	0.484	1.679	1.613	1.647	3.048	2.982	3.015[a]
15	0.486	0.482	0.484	1.654	1.653	1.653	2.998	2.937	2.968[ab]
30	0.479	0.481	0.480	1.627	1.659	1.643	2.912	2.955	2.933[b]
Mean	0.484	0.481		1.653	1.642		2.986	2.958	
DDGS (%)	--------- 0-14 d Feed/bird (kg) ---------			-------- 0-28 d Feed/bird (kg) ---------			--------- 0-42 d Feed/bird (kg) ---------		
0	0.627	0.651	0.639	2.511	2.533	2.522	5.267	5.307	5.287
15	0.655	0.660	0.657	2.519	2.573	2.546	5.238	5.347	5.293
30	0.658	0.677	0.667	2.507	2.589	2.548	5.201	5.389	5.295
Mean	0.646	0.663		2.512	2.565		5.235	5.348	
DDGS (%)	------- 0-14 d Feed: Gain ratio -------			------ 0-28 d Feed: Gain ratio -------			-------- 0-42 d Feed: Gain ratio -------		
0	1.423	1.502	1.462	1.539	1.618	1.578	1.755	1.808	1.782[b]
15	1.489	1.518	1.503	1.568	1.603	1.585	1.775	1.850	1.812[ab]
30	1.521	1.562	1.541	1.587	1.607	1.597	1.815	1.854	1.834[a]
Mean	1.477	1.527		1.564[b]	1.609[a]		1.782[b]	1.837[a]	
DDGS (%)	------- 0-14 days Mortality (%) -------			------- 0-28 days Mortality (%) ------			------- 0-42 days Mortality (%) -------		
0	3.00	3.00	3.00	5.00	3.00	4.00b	12.00	5.00	8.50
15	4.00	0.00	2.00	4.00	4.00	4.00b	5.00	6.00	5.50
30	6.00	3.00	4.50	11.00	4.00	7.50[a]	15.00	6.00	10.50
Mean	4.33	2.00		6.67[a]	3.67[b]		10.67[a]	5.67[b]	
DDGS (%)	------ 0-14 days ME kcal $bird^{-1}$ ------			----- 0-28 days ME kcal $bird^{-1}$ -----			----- 0-42 days ME kcal $bird^{-1}$ -------		
0	1932	1970	1951	7852	7793	7823	16655	16486	16571
15	1997	1967	1982	7851	7796	7824	16534	16359	16447
30	2028	1985	2007	7836	7721	7779	16429	16226	16328
Mean	1986	1974		7847	7770		16540	16357	
DDGS (%)	-- 0-14 days ME kcal kg^{-1} gain ---			--- 0-28 days ME kcal kg^{-1} gain ---			----- 0-42 days ME kcal kg^{-1} gain ---		
0	4389	4544	4467	4811	4976	4894	5549	5617	5583
15	4547	4524	4536	4886	4856	4871	5601	5660	5631
30	4692	4583	4638	4959	4790	4875	5733	5580	5657
Mean	4543	4551		4886	4875		5628	5620	

[ab]Means in row or column with common superscripts do not differ significantly ($p<0.05$)

Table 9: Effect of formulating diets on an isocaloric or variable energy with 1% added poultry oil with different levels of distillers dried grains with solubles (DDGS) on processing parameters at 42 days (means of four groups of five males each)

	Diet type		% DDGS			Isocaloric			Variable energy		
Variables	ISO	VAR	0	15	30	0	15	30	0	15	30
Dressing percentage, %	73.12	72.86	73.21	73.03	72.75	73.10	73.12	73.14	73.32	72.94	72.37
Breast % of live weight	21.73	21.40	21.87	21.53	21.30	22.24	21.72	21.23	21.49	21.34	21.36
Wings % of live weight	7.90	7.83	7.83	7.87	7.90	7.87	7.89	7.95	7.79	7.85	7.86
Leg quarter % of live weight	20.59	20.60	20.44	20.57	20.77	20.42	20.58	20.76	20.45	20.57	20.78
Breast % of carcass	29.72	29.35	29.87	29.47	29.27	30.43	29.69	29.03	29.31	29.25	29.51
Wings % of carcass	10.81	10.75	10.70	10.78	10.87	10.77	10.80	10.86	10.63	10.76	10.87
Leg quarter % of carcass	28.16	28.27	27.92	28.19	28.55	27.94	28.16	28.38	27.89	28.21	28.72

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 12-15% 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.* (2007b) 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.

Conclusion: A level of 15% DDGS of known composition is acceptable in broiler starter, grower and finisher diets formulated on the basis of digestible amino acids with no adverse effects on live performance or carcass characteristics. As the level of DDGS increases, problems with reduced dietary bulk density and poor pellet quality may result in reduced feed intake, poorer feed conversion and reduced body weight. Steps taken to improve pellet quality such as the use of effective binders, reduction in dietary fat, smaller die size and other approaches to provide better quality pellets may stimulate the use of higher levels of DDGS.

References

Batal, A.B. and N.M. Dale, 2006. True metabolizable energy and amino acid digestibility of distillers dried grains with solubles. J. Appl. Poult. Res. 15: 89-93.

Behnke, K.C., 2007. Feed manufacturing considerations for using DDGS in poultry and livestock diets. In: Proc. 5th Mid-Atlantic Nutrition Conference, Timonium, MD., pp: 77-81.

Dale, N. and A. Batal, 2003. Nutritional value of distillers dried grains and solubles for poultry. Pages 1-6 in: 19th Annual Carolina Nutrition Conference. Research Triangle Park, NC.

Dari, R.L., A.M. Penz, A.M. Kessler and H.C. Jost, 2005. Use of digestible amino acids and the concept of ideal protein in feed formulation for broilers. J. Appl. Poult. Res., 14:195-203.

FASS, 1999. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 1st rev. Edn. Federation of Animal Science Societies, Savoy IL.

Fastinger, N.D., J.D. Latshaw and D.C. Mahan, 2006. Amino acid availability and true metabolizable energy content of corn distillers dried grains with solubles in adult cecectomized roosters. Poult. Sci., 85: 1212-1216.

Fiene, S.P., T.W. York and C. Shasteen, 2006. Correlation of DDGS IDEA™ digestibility assay for poultry with cockerel true amino acid digestibility. In: Proc. 4th Mid-Atlantic Nutrition Conference. University of Maryland, College Park MD., pp: 82-89.

Fritts, C.A. and P.W. Waldroup, 2006. Modified phosphorus program for broilers based on commercial feeding intervals to sustain live performance and reduce total and water-soluble phosphorus in litter. J. Appl Poult. Res., 15:207-218.

Johnson, Z.B. and P.W. Waldroup, 1983. Statistical evaluation of production samples of a marine and animal protein blend. Feedstuffs, pp: 22-23.

Leeson, S. and J.D. Summers, 2005. Feeding programs for broiler chickens. In Commercial poultry production (3rd edn.). University books. Quelph, Ontario, Canada, pp: 229-296.

Lumpkins, B.S., A.B. Batal and N.M. Dale, 2004. Evaluation of distillers dried grains with solubles as a feed ingredient for broilers. Poult. Sci., 83:1891-1896.

McKinney, L.J. and R.G. Teeter, 2004. Predicting effective caloric value of nonnutritive factors: I. Pellet quality and II. Prediction of consequential formulation dead zones. Poult. Sci., 83: 1165-1174.

Mraz, F.R., R.V. Boucher and M.G. McCartney, 1957. The influence of the energy:volume ratio on growth response in chickens. Poult. Sci., 36: 1217-1221.

Parsons, C.M., C. Martinez, V. Singh, S. Radhadkrishman and S. Noll, 2006. Nutritional value of conventional and modified DDGS for poultry. Proc. Multi-State Poult. Nutr. Feeding Conf., Indianapolis IN.

Rostagno, H.S., J.M.R. Pupa and M. Pack, 1995. Diet formulation for broilers based on total versus digestible amino acids. J. Appl. Poult. Res., 4: 293-299.

Saleh, E.A., S.E. Watkins, A.L. Waldroup and P.W. Waldroup, 2004. Comparison of energy feeding programs and early feed restriction on live performance and carcass quality of large male broilers grown for further processing at 9-12 weeks of age. Int. J. Poult. Sci., 3: 61-69.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 Edition. SAS Institute, Inc., Cary, NC.

Waldroup. P.W., J.A. Own, B.E. Ramsey and D.L. Whelchel, 1981. The use of high levels of distillers dried grains plus solubles in broiler diets. Poult. Sci., 60: 1479-1484.

Waldroup, P.W., Z. Wang, C. Coto, S. Cerrate and F. Yan, 2007. Development of a standardized nutrient matrix for corn distillers dried grains with solubles. Int. J. Poult. Sci., 6: 478-483.

Wang, Z., S. Cerrate, C. Coto, F. Yan and P.W. Waldroup, 2007a. Utilization of distillers dried grains with solubles (DDGS) in broiler diets using a standardized nutrient matrix. Int. J. Poult. Sci., 6: 470-477.

Wang, Z., S. Cerrate, C. Coto, F. Yan and P.W. Waldroup, 2007b. Use of constant or increasing levels of distillers dried grains with solubles (DDGS) in broiler diets. Int. J. Poult. Sci., 6: 501-507.

Wang, Z., S. Cerrate, C. Coto, F. Yan and P.W. Waldroup, 2007c. Effect of rapid and multiple changes in level of distillers dried grain with solubles (DDGS) in broiler diets on performance and carcass characteristics. Int. J. Poult. Sci., 6: 725-731.

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