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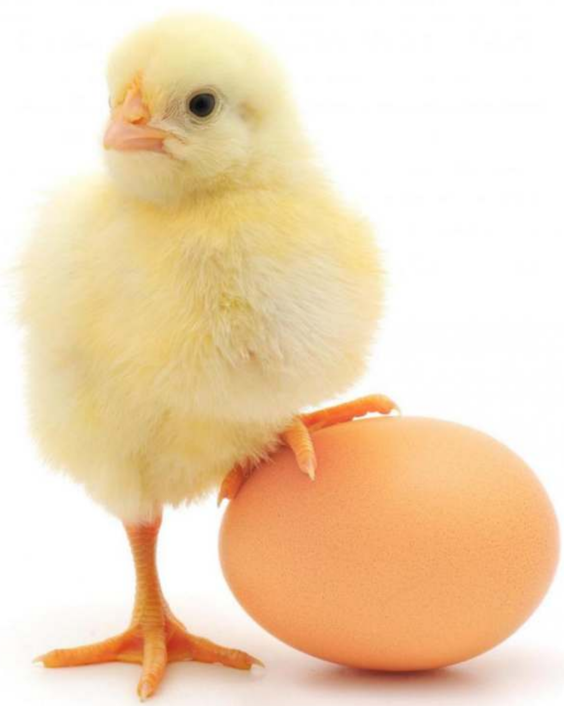

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Evaluation of Distillers Dried Grains with Solubles in Combination with Glycerin in Broiler Diets[1]

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Abstract: An experiment was conducted to evaluate the use of distillers dried grains with solubles (DDGS) combined with glycerin in broiler diets. In a 3×2 factorial arrangement, 600 one-day-old commercial strain Cobb 500 broilers were randomly assigned to experimental diets with 0, 15 and 30% DDGS of known composition; within each level of DDGS the diets contained 0 or 5% glycerin, respectively, from 0-42 days of age. Diets were formulated to meet digestible amino acid requirements and were fed in pelleted form. Each dietary treatment was replicated 4 times. Body weight gain and feed consumption were measured and carcass characteristics were evaluated at 42 days of age. Inclusion of 30% DDGS had no adverse effect on body weight of chicks; however birds fed diets with 30% DDGS had greater feed intake and poorer feed conversion than birds fed the control diet at most age periods. This was highly correlated to the reduced pellet quality of diets containing the high levels of DDGS. Birds fed diets with 30% DDGS also had significantly reduced dressing percentage compared to birds fed the control diet with no DDGS. However, there was no adverse effect on breast meat yield related to the higher levels of DDGS inclusion. Addition of 5% glycerin from biodiesel production to the diets had no significant effect on body weight, feed intake, or feed conversion. There was no significant effect of the addition of glycerin on dressing percentage or yield of various carcass parts. With one minor exception, there was no significant interaction between addition of glycerin and level of DDGS in the diet, even though pellet quality declined when glycerin was added to the diets. Overall, the results of this study demonstrates that 15% DDGS of known nutritional quality can be utilized in diets for growing broilers with no adverse effects provided diets are formulated on a digestible amino acid basis and meet the nutritional requirements of the broiler. Higher levels may be tolerated but there may be a loss in feed conversion unless pellet quality can be improved. A loss in dressing percentage at higher levels of DDGS has been consistently noted in this and previous studies. Incorporation of 5% glycerin from biodiesel production as a source of energy appears satisfactory.

Key words: Growth performance, carcass trait, glycerin, broiler, distillers dried grains with solubles

Introduction

Distiller dried grains with solubles (DDGS) is a coproduct obtained in the dry-milling process of corn to produce ethanol after fermentation with the yeast *Sacharomices cereviceae* (Olentine, 1986; Davis, 2001). The DDGS is a valuable source of energy, protein, phosphorus, water-soluble vitamins and minerals for animals. Previous research has shown that DDGS can be successfully fed to poultry (Runnels, 1966; Waldroup *et al.*, 1981; Parsons *et al.*, 1983; Olentine, 1986; Noll *et al.*, 2003). Glycerin is an important structural component of triglycerides and phospholipids. Glycerin as a byproduct of biodiesel production has been evaluated in diets for poultry and swine as a feed ingredient that provides energy for cellular metabolism (Campbell and Hill, 1966; Simon *et al.*, 1996, 1997; Barteczko and Kaminski, 1999; Cerrate *et al.*, 2006).

Glycerin and DDGS are both byproducts of biofuel production. Previous studies from our laboratory (Cerrate *et al.*, 2006) have demonstrated that 5% glycerin is an acceptable energy source in broiler diets. To our knowledge, no studies have been reported in which glycerin and DDGS have been used simultaneously. The objective of this study was to evaluate the combined use of glycerin and DDGS in diets for growing broilers.

Materials and Methods

Dietary treatments: Diets were formulated using digestible amino acid specifications suggested by a major poultry breeder[3] adjusted proportionally to the dietary energy level. No minimum crude protein level was specified. Supplemental sources of amino acid activity included methionine hydroxy analogue calcium salt, L-Lysine HCl, L-Tryptophan and L-Threonine. Total[4] and digestible[5] amino acid values for corn and soybean meal were obtained from tables provided by major amino acid producers. Nutrient values for DDGS were from a weighted average nutrient compilation (Waldroup *et al.*, 2007) with some modification. A sample of the

DDGS was subjected to amino acid analysis and IDEA analysis by laboratories specializing in these assays and total and digestible amino acid content of DDGS was based on these assays. Mineral assays were carried out in a commercial laboratory specializing in these assays. The nutrient matrix used for DDGS is in Table 1. Diets were developed for starter (0-14 days), grower (15-28 days) and finisher periods (29-42 days). Diets were formulated to contain 0, 15 and 30% DDGS, with and without the addition of 5% glycerin from biodiesel production. A dietary energy value was selected that provided approximately 1% supplemental poultry oil in the diet with no DDGS and no glycerin. Diets were maintained isocaloric as the level of DDGS and glycerin varied by the use of supplemental poultry oil. Metabolizable Energy values for the glycerin were calculated by using 95% of the Gross Energy value determined by bomb calorimetry. Sodium and potassium content of the glycerin was also determined and used in formulation. A lignin sulfonate pellet binder[6] was included in all diets at the rate of 0.4%, the maximum recommended level for this product. Defluorinated phosphate was the primary source of supplemental phosphate due to its known beneficial effects on pelleting. All diets contained complete vitamin and trace mineral mixes obtained from commercial sources. Pro-Pak (H. J. Baker and Bro, Stamford, CT), a blended animal 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 diets for the starter (0-14 days), grower (15-28days) and finisher (29-42 days) are in Table 2-4, respectively. Th e calculated nutrient composition is shown in Table 5-7 for the starter, grower and finisher diets, respectively. All diets were pelleted with steam. Starter diets were pelleted on a CPM Laboratory Model pellet mill using a 3/32" (2.38 mm) die while grower and finisher diets were pelleted on a CPM Master Model 30 hp pellet mill using a 3/16" (4.76 mm) die. Each diet was fed to four pens of 25 male broilers each.

Table 1: Nutrient values used for DDGS in formulation of diets

Nutrient	Unit	Value
Dry matter	%	89.36
Crude protein	%	28.53
Crude fat	%	8.89
Crude fiber	%	6.80
Calcium	%	0.05
Phosphorus	%	0.85
Nonphytate P	%	0.53
Metabolizable energy	Kcal kg^{-1}	2849.00
Digestible methionine	%	0.49
Digestible cystine	%	0.42
Digestible lysine	%	0.60
Digestible tryptophan	%	0.16
Digestible threonine	%	0.72
Digestible isoleucine	%	0.86
Digestible histidine	%	0.61
Digestible valine	%	1.16
Digestible leucine	%	2.89
Digestible arginine	%	1.08
Digestible phenylalanine	%	1.10

Table 2: Composition (g kg^{-1}) of broiler diets for 0-14 days of age

Ingredient	0-0	0-5	15-0	15-5	30-0	30-5
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00	25.00
DDGS	0.00	0.00	150.00	150.00	300.00	300.00
Glycerin	0.00	50.00	0.00	50.00	0.00	50.00
Yellow corn	596.20	541.59	477.38	422.74	358.16	303.23
Poultry oil	8.78	8.27	17.72	17.30	26.82	26.51
Soybean meal	328.24	334.53	289.60	295.62	251.00	257.05
Limestone	4.93	4.71	8.11	7.89	11.30	11.06
Defluorinated phosphate	16.57	16.77	13.21	13.40	9.84	10.05
Sodium chloride	2.98	2.41	2.80	1.79	2.18	1.31
Sodium bicarbonate	0.65	0.00	0.00	0.00	0.00	0.00
MHA-84	2.88	2.98	2.17	2.28	1.47	1.58
L-Threonine	0.49	0.52	0.30	0.33	0.10	0.14
L-Lysine HCl	2.03	1.97	2.46	2.40	2.88	2.82
Vitamin premix[2]	5.00	5.00	5.00	5.00	5.00	5.00
Mintrex P_Se[3]	1.00	1.00	1.00	1.00	1.00	1.00
Coban-60[4]	0.75	0.75	0.75	0.75	0.75	0.75
BMD-50[5]	0.50	0.50	0.50	0.50	0.50	0.50
Pel-Stik[6]	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

[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] 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, [4]Elanco Animal Health division of Eli Lilly and Co., Indianapolis, IN 46825, [5]Alpharma, Inc., Ft. Lee, NJ 07024, [6] Uniscope Inc., Johnstown CO 80534

Table 3: Composition (g kg^{-1}) of diets for 15-28days of age

Ingredient	0-0	0-5	15-0	15-5	30-0	30-5
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00	25.00
DDGS	0.00	0.00	150.00	150.00	300.00	300.00
Glycerin	0.00	50.00	0.00	50.00	0.00	50.00
Yellow corn	661.46	607.45	542.77	488.23	423.57	368.97
Poultry oil	10.26	9.61	19.16	18.70	28.23	27.80
Soybean meal	264.59	270.53	225.93	231.93	187.33	193.34
Limestone	4.90	4.67	8.08	7.86	11.27	11.04
Defluorinated phosphate	14.21	14.41	10.84	11.05	7.48	7.68
Sodium chloride	3.03	2.71	2.99	2.09	2.48	1.46
Sodium bicarbonate	1.02	0.00	0.17	0.00	0.00	0.00
MHA-84	2.15	2.26	1.45	1.55	0.74	0.85
L-Threonine	0.31	0.34	0.12	0.15	0.00	0.00
L-Lysine HCl	1.82	1.77	2.24	2.19	2.66	2.61
Vitamin premix[1]	5.00	5.00	5.00	5.00	5.00	5.00
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00	1.00
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]	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

[1]As shown in Table 2

Table 4: Composition (g kg^{-1}) of diets for 29-42 days of age

Ingredient	0-0	0-5	15-0	15-5	30-0	30-5
Pro-Pak[1]	25.00	25.00	25.00	25.00	25.00	25.00
DDGS	0.00	0.00	150.00	150.00	300.00	300.00
Glycerin	0.00	50.00	0.00	50.00	0.00	50.00
Yellow corn	702.00	648.21	584.07	529.68	465.07	410.47
Poultry oil	10.68	9.96	19.45	18.94	28.46	28.04
Soybean meal	225.00	230.85	185.66	191.65	147.04	153.05
Limestone	5.12	4.90	8.30	8.06	11.48	11.25
Defluorinated phosphate	12.80	13.00	9.44	9.64	6.07	6.28
Sodium chloride	3.05	2.89	3.01	2.27	2.66	1.64
Sodium bicarbonate	1.25	0.00	0.41	0.00	0.00	0.00
MHA-84	1.80	1.91	1.11	1.22	0.41	0.51
L-Threonine	0.35	0.38	0.16	0.20	0.00	0.00
L-Lysine HCl	1.70	1.65	2.14	2.09	2.56	2.51
Vitamin premix[1]	5.00	5.00	5.00	5.00	5.00	5.00
Mintrex P_Se[1]	1.00	1.00	1.00	1.00	1.00	1.00
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]	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

[1]As shown in Table 2

Birds and management: Male chicks of a commercial broiler strain[7] 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 hr light daily. Care and management of the birds followed recommended guidelines (FASS, 1999).

Measurements: All mixed diets were analyzed for crude protein, calcium, total P, sodium and total amino acids and were found to be in good agreement with calculated values. Pellet quality 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 and determining percent retained on a 2 mm screen. Body weights by pen and feed consumption were determined at 14, 28 and 42 days of age. The weight of dead birds was used to adjust feed conversion. At the end of the study, five representative birds per pen were processed using mechanical evisceration for dressing percentage and parts yield as described by Fritts and Waldroup (2006).

Table 5: Calculated nutrient content of diets for 0-14 days of age. Values in bold italic are at minimum specified level

Nutrient	0-0	0-5	15-0	15-5	30-0	30-5
ME Kcal kg^{-1}	3020.00	3020.00	3020.00	3020.00	3020.00	3020.00
Crude protein (%)	22.87	22.75	24.31	24.18	25.75	25.61
Calcium (%)	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***
Phosphorus (%)	0.74	0.73	0.75	0.75	0.76	0.76
Nonphytate P (%)	***0.50***	***0.50***	***0.50***	***0.50***	***0.50***	***0.50***
Sodium (%)	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***	0.26
Chloride (%)	0.25	0.21	0.25	0.18	0.21	0.15
DEB meq kg^{-1}	244.00	255.00	261.00	279.00	285.00	303.00
Met (%)	0.65	0.65	0.63	0.63	0.61	0.62
Lys (%)	1.36	1.36	1.39	1.39	1.42	1.42
Trp (%)	0.26	0.26	0.26	0.26	0.26	0.26
Thr (%)	0.89	0.89	0.91	0.91	0.94	0.94
Arg (%)	1.46	1.46	1.47	1.47	1.49	1.49
TSAA (%)	1.01	1.01	1.03	1.03	1.06	1.05
dMet (%)	0.56	0.56	0.53	0.53	0.50	0.51
dLys (%)	***1.20***	***1.20***	***1.20***	***1.20***	***1.20***	***1.20***
dTrp (%)	0.22	0.22	0.22	0.22	0.22	0.22
dThr (%)	***0.76***	***0.76***	***0.76***	***0.76***	***0.76***	***0.76***
dIle (%)	0.80	***0.80***	0.83	0.83	0.86	0.86
dVal (%)	0.92	0.91	0.98	0.97	1.04	1.04
dArg (%)	***1.31***	***1.31***	***1.31***	***1.31***	***1.31***	***1.31***
dTSAA (%)	***0.85***	***0.85***	***0.85***	***0.85***	***0.85***	***0.85***

Table 6: Calculated nutrient content of diets for 15-28days of age. Values in bold italic are at minimum specified level

Nutrient	0-0	0-5	15-0	15-5	30-0	30-5
ME Kcal kg^{-1}	3096.00	3096.00	3096.00	3096.00	3096.00	3096.00
Crude protein (%)	20.17	20.04	21.61	21.48	23.05	22.92
Calcium (%)	***0.90***	***0.90***	***0.90***	***0.90***	***0.90***	***0.90***
Phosphorus (%)	0.67	0.67	0.68	0.68	0.70	0.69
Nonphytate P (%)	***0.45***	***0.45***	***0.45***	***0.45***	***0.45***	***0.45***
Sodium (%)	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***	0.25
Chloride (%)	0.25	0.23	0.25	0.19	0.22	0.16
DEB meq kg^{-1}	218.00	224.00	232.00	248.00	254.00	273.00
Met (%)	0.55	0.56	0.54	0.54	0.52	0.52
Lys (%)	1.17	1.17	1.20	1.20	1.23	1.23
Trp (%)	0.22	0.23	0.22	0.22	0.22	0.22
Thr (%)	0.77	0.77	0.79	0.79	0.83	0.82
Arg (%)	1.26	1.26	1.28	1.28	1.29	1.29
TSAA (%)	0.88	0.89	0.91	0.91	0.93	0.93
dMet (%)	0.47	0.47	0.44	0.45	0.42	0.42
dLys (%)	***1.04***	***1.04***	***1.04***	***1.04***	***1.04***	***1.04***
dTrp (%)	0.19	0.19	0.19	0.19	0.18	0.18
dThr (%)	***0.66***	***0.66***	***0.66***	***0.66***	***0.66***	***0.66***
dIle (%)	0.70	0.70	0.73	0.73	0.76	0.76
dVal (%)	0.82	0.81	0.88	0.87	0.94	0.93
dArg (%)	***1.13***	***1.13***	***1.13***	***1.13***	***1.13***	***1.13***
dTSAA (%)	***0.74***	***0.74***	***0.74***	***0.74***	***0.74***	***0.74***

Table 7: Calculated nutrient content of diets for 29-42days of age. Values in bold italic are at minimum specified level

Nutrient	0-0	0-5	15-0	15-5	30-0	30-5
ME Kcal kg^{-1}	3140.00	3140.00	3140.00	3140.00	3140.00	3140.00
Crude protein (%)	18.50	18.37	19.91	19.78	21.35	21.22
Calcium (%)	***0.85***	***0.85***	***0.85***	***0.85***	***0.85***	***0.85***
Phosphorus (%)	0.63	0.63	0.64	0.64	0.65	0.65
Nonphytate P (%)	***0.42***	***0.42***	***0.42***	***0.42***	***0.42***	***0.42***
Sodium (%)	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***	0.25
Chloride (%)	0.25	0.24	0.25	0.20	0.23	0.17
DEB meq kg^{-1}	202.00	205.00	216.00	229.00	235.00	254.00
Met (%)	0.51	0.51	0.49	0.49	0.47	0.48
Lys (%)	1.06	1.06	1.09	1.09	1.12	1.12
Trp (%)	0.20	0.20	0.20	0.20	0.20	0.20

Table 7: Continued

Nutrient	0-0	0-5	15-0	15-5	30-0	30-5
Thr (%)	0.71	0.71	0.74	0.74	0.76	0.76
Arg (%)	1.14	1.14	1.15	1.15	1.16	1.17
TSAA (%)	0.82	0.82	0.84	0.84	0.86	0.86
dMet (%)	0.42	0.43	0.40	0.40	0.37	0.38
dLys (%)	***0.93***	***0.93***	***0.93***	***0.93***	***0.93***	***0.93***
dTrp (%)	0.17	0.17	0.17	0.17	0.16	0.16
dThr (%)	***0.61***	***0.61***	***0.61***	***0.61***	***0.61***	***0.61***
dIle (%)	0.63	0.63	0.66	0.66	0.69	0.69
dVal (%)	0.75	0.74	0.81	0.80	0.87	0.86
dArg (%)	***1.02***	***1.02***	***1.02***	***1.02***	***1.02***	***1.02***
dTSAA (%)	***0.68***	***0.68***	***0.68***	***0.68***	***0.68***	***0.68***

Statistical analysis: The data were subjected to factorial analysis (SAS Institute, 1991) with DDGS level and glycerin level as main effects along with the interaction of these 2 effects. Pen means were the experimental unit for growth performance while each bird was an experimental unit for processing variables as the birds were processed in random order. Mortality data were transformed to the square root of n + 1; data are presented as natural numbers. All statements of significance are based on $p \leq 0.05$.

Results

Through the use of supplemental amino acids, the diets containing the various levels of DDGS and glycerin met the requirements for digestible amino acids. As seen in Table 5-7, requirements for digestible lysine, threonine, arginine and total sulfur amino acids were at their minimum required levels in all diets. This resulted in diets with little excess amino acids that might impair performance and insured that diets with high levels of DDGS contained sufficient amounts of essential amino acids. In some early studies on the use of DDGS, diets were formulated on a total amino acid basis and may not have supplied adequate amounts of essential amino acids (Waldroup *et al.*, 1981; Dale and Batal, 2003; Lumpkins *et al.*, 2004) and may have contributed to the reduced performance at higher levels of DDGS.

The effect of dietary variables on pellet quality are shown in Table 8. The percentage of fines was affected by both level of DDGS and by addition of glycerin. Increasing levels of DDGS significantly increased the percentage of fines and the addition of 5% glycerin to the det also increased the percentage of fines in the diets. There were a higher percentage of fines in grower and finisher diets than in the starter diets; starter diets were pelleted using a 2.38 mm die while grower and finisher diets were pelleted with a 4.76 mm die. While the adverse effect of increased DDGS on pellet quality was anticipated, due to the higher level of supplemental poultry oil added to maintain the diets isocaloric as well as the high level of oil found in the DDGS, the adverse effect of glycerin was unexpected. The texture of the glycerin used in this trial was markedly different from that observed in our previous studies (Cerrate *et al.*, 2006). In our previous studies, the glycerin was relatively free-flowing and did not visibly appear to affect pellet quality, although no specific study was done to ascertain pellet quality. The product used in the present study was thick, viscous and had to be extensively heated before applying to the diets.

Table 8: Effect of level of distillers dried grains with solubles (DDGS) and glycerin on pellet quality of broiler diets

Feed type	(%) DDGS	(%) Glycerin	(%) Fines[1] Mean	SD	CV
Starter[2]	0	0	1.05	0.67	63.32
	0	5	5.38	1.02	18.93
	15	0	4.29	0.30	7.02
	15	5	10.52	1.14	10.85
	30	0	12.04	2.40	19.90
	30	5	14.10	1.22	8.62
Grower[2]	0	0	10.53	3.02	28.66
	0	5	32.71	7.68	23.50
	15	0	18.96	7.94	41.88
	15	5	31.02	8.91	28.72
	30	0	26.89	3.38	12.58
	30	5	38.78	6.38	16.44
Finisher[2]	0	0	12.83	6.34	49.40
	0	5	29.36	7.21	24.57
	15	0	26.60	11.55	43.43
	15	5	36.98	9.12	24.66
	30	0	42.64	16.68	39.11
	30	5	47.02	9.09	19.34

[1]Percent of pellets that pass through a 2 mm screen,
[2]Pelleted using a 2.38 mm die, [3]Pelleted using a 4.76 mm die

The effects of dietary DDGS and glycerin on live performance are shown in Table 9. At 14 days of age, birds fed the diets with 15 and 30% DDGS were actually significantly heavier than birds fed the basal diet with no DDGS. No significant differences in body weight were seen at 28 or 42 days of age between birds fed diets with different levels of DDGS. In some of our previous studies, inclusion of 30% DDGS resulted in a significant reduction in performance (Wang *et al.*, 2007b, 2007c); this may have been due to lack of formulating diets to supply all digestible amino acids as was done in the present study.

Table 9: Effect of level of distillers dried grains with solubles (DDGS) and glycerin on performance of male broilers (means of four pens of 25 birds per pen)

		Body weight (kg)			Feed Intake (kg bird^{-1})		
		14 days	28 days	42 days	1-14 days	1-28 days	1-42 days
0		0.382[b]	1.416	2.839	0.469[b]	2.013[b]	4.613
15		0.404[a]	1.438	2.885	0.476[b]	2.054[ab]	4.676
30		0.402[a]	1.437	2.804	0.503[a]	2.103[a]	4.719
SEM		0.005	0.017	0.033	0.008	0.022	0.056
	0	0.396	1.437	2.846	0.487	2.057	4.653
	5	0.396	1.423	2.840	0.478	2.057	4.685
	SEM	0.005	0.013	0.027	0.006	0.017	0.044
0	0	0.381	1.436	2.859	0.474	2.030	4.629
0	5	0.383	1.396	2.820	0.465	1.996	4.597
15	0	0.402	1.428	2.862	0.483	2.038	4.602
15	5	0.405	1.448	2.909	0.469	2.071	4.749
30	0	0.404	1.448	2.817	0.505	2.102	4.728
30	5	0.400	1.426	2.790	0.500	2.105	4.710
SEM	0.007	0.025	0.051	0.012	0.033	0.085	0.020
DDGS		0.007	0.530	0.260	0.010	0.020	0.380
Glycerin		0.950	0.460	0.870	0.310	0.970	0.610
DDGS x Gly		0.850	0.420	0.620	0.890	0.540	0.450

		Feed:Gainratio			ME Kcal kg^{-1} gain		
		1-14	1-28 days	1-42 days	1-14 days	1-28 days	1-42 days
0		1.373[a]	1.464	1.648[b]	1417[b]	4506	5130[b]
15		1.311[b]	1.471	1.644[b]	1437[b]	4528	5115[b]
30		1.389[a]	1.506	1.710[a]	1517[a]	4636	5319[a]
SEM		0.013	0.014	0.016	23.02	43.00	21.47
	0	1.371	1.472	1.659	1471	4530	5161
	5	1.345	1.489	1.676	1443	4583	5215
	SEM	0.010	0.011	0.013	19.37	34.22	40.96
0	0	1.389	1.455	1.643	1430	4477	5110
0	5	1.357	1.473	1.654	1404	4535	5149
15	0	1.335	1.469	1.631	1459	4520	5074
15	5	1.288	1.474	1.657	1415	4536	5155
30	0	1.388	1.493	1.703	1525	4594	5298
30	5	1.389	1.520	1.716	1509	4678	5340
SEM		0.007	0.021	0.025	34.92	65.23	78.08
DDGS		0.001	0.090	0.020	0.010	0.090	0.020
Glycerin		0.090	0.300	0.370	0.300	0.290	0.360
DDGS x Gly		0.410	0.840	0.940	0.900	0.850	0.940

[a,b]Means within a column having a common superscript do not differ significantly ($p<0.05$)

Feed conversion was significantly affected by level of DDGS at 14 and 42 days with a numerical ($p = 0.09$) difference at 28days. There was no significant difference in feed conversion between birds fed diets with 0 or 15% DDGS, while birds fed diets with 30% DDGS had significantly higher feed conversion than birds fed diets with 0 or 15% DDGS. Since the diets were calculated to be isocaloric, these same differences were reflected in caloric efficiency (ME kcal kg^{-1} gain) as well. This is in agreement with previous reports from our laboratory (Wang *et al.*, 2007a, 2007b, 2007c) and suggest that the energy value assigned to DDGS is overestimated. However, a portion of this loss in feed conversion may be due to the reduced pellet quality of diets containing 30% DDGS, as suggested by McKinney and Teeter (2004). Finding a means to produce a better quality pellet could markedly improve performance of broilers fed diets high in DDGS.

The inclusion of 5% glycerin to the diets had no significant effects on body weight, feed conversion, or calorie conversion at an age, in agreement with our previous research (Cerrate *et al.*, 2006). Feed conversion tended to be numerically higher for diets with glycerin, which may have been a reflection of the reduced pellet quality seen in diets containing glycerin; however these differences were not statistically significant. No interactions were observed between level of DDGS and the addition of glycerin to the diets.

The effects of level of DDGS and glycerin in broiler diets on carcass yield is shown in Table 10. Dressing percentage was reduced as the level of DDGS increased, with the dressing percentage of birds fed diets with 30% DDGS being significantly lower than that of birds fed the diet with no DDGS. Similar trends in reduced dressing percentage with higher levels of DDGS have been seen in previous studies from this

Table 10: Effect of level of distillers dried grains with solubles (DDGS) and glycerine on dressing percentage and parts yield of broilers at 42 days of age (means of four pens of five males)

			(%) of carcass weight		
DDGS (%)	Glycerin (%)	Dressing (%)	Breast	Wings	Leg quarters
0		74.61^{a}	30.24	10.60^{b}	28.04
15		74.15^{ab}	29.98	10.51^{b}	28.34
30		73.71^{b}	30.19	10.88^{a}	28.59
SEM		0.25	0.34	0.10	0.21
	0	74.24	30.20	10.66	28.26
	5	74.08	30.07	10.67	28.39
	SEM	0.20	0.28	0.08	0.17
0	0	74.97	30.57	10.53	27.76^{c}
0	5	74.26	29.92	10.67	28.33^{abc}
15	0	74.27	30.30	10.63	27.94^{bc}
15	5	74.03	29.66	10.40	28.74^{ab}
.30	0	73.47	29.74	10.84	29.08^{a}
30	5	73.95	30.63	10.93	28.09^{bc}
SEM	0.36	0.49	0.14	0.30	
ANOVA	Probability > F				
DDGS	0.03	0.85	0.02	0.17	
Glycerin	0.58	0.75	0.97	0.60	
DDGS x Glycerin	0.22	0.18	0.37	0.004	

laboratory (Wang *et al.*, 2007a, 2007b). Birds in this study were processed using mechanical evisceration so it was not possible to determine abdominal fat content, which may have been increased in diets with high DDGS. Further studies are needed to specifically determine reasons for the loss in dressing percentage due to higher levels of DDGS.

Breast meat yield did not differ among birds fed the different levels of DDGS. In previous studies from our laboratory, breast meat yield was reduced at higher levels of DDGS (Wang *et al.*, 2007a, 2007b, 2007c). In the present study, diets were formulated to provide for a wider array of essential amino acids and were formulated on a digestible amino acid basis to ensure adequate levels of all essential amino acids to sustain protein synthesis. There was no significant difference in yield of leg quarters among birds fed the different levels of DDGS, while birds fed diets with 30% DDGS had a higher wing yield than did birds fed diets with 0 or 15% DDGS.

Inclusion of 5% glycerin in broiler diets had no significant effects on dressing percentage or parts yield. There was no interaction between levels of DDGS and addition of glycerin for dressing percentage, breast yield, or wing yield. There was a significant interaction between level of DDGS and addition of glycerin for yield of leg quarters; addition of 5% glycerin resulted in a numerical increase in leg quarter yield when diets contained 0 or 15% DDGs but gave a significant reduction in leg quarter yield when the diets contained 30% DDGS.

Discussion

The results of this study are in agreement with previous reports from our laboratory that demonstrate that DDGS of known composition can be used at 15% in broiler starter, grower and finisher diets without loss of performance providing diets are formulated on a digestible amino acid basis to meet the needs for all essential amino acids (Wang *et al.*, 2007 a, b, c). 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 12-15% 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. 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.

It appears that one of the major problems that limit the use of high levels of DDGS in broiler diets is the reduction in pellet quality. Pellet quality is a concern at higher levels of DDGS 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 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).

Moreover, the present experiment was in agreement with Cerrate *et al.* (2006), who demonstrated that glycerin from biodiesel production can be effectively used in broiler diets at levels of 2.5 or 5%. In the present study birds fed diets with 5% glycerin did not differ significantly in performance from birds fed diets with no glycerin. Our study showed no negative effect of glycerin added to broiler diets, which was agreement with Simon *et al.* (1996) who stated that from the point of view of weight gain, feed intake and feed conversion ratio as well as N-balance a supplementation of 5-10% glycerol seems to be beneficial.

Conclusion: In conclusion, 15% DDGS of known composition and quality to broiler diets can be added in broiler diets with no loss in live weight gain, feed conversion, or adverse effects on carcass yield. Moreover, 5% glycerin could be added to the diets with no negative effects for broilers. The use of higher levels of DDGS without reduction in performance may be highly correlated to the ability to sustain pellet quality in such diets. Further research is needed in this area.

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