FORMULATING POULTRY DIETS WITH DDGS – HOW FAR CAN WE GO?

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Summary

Current feeding trials have examined the use of low and moderate levels of distillers dried grains with solubles (DDGS) inclusion in broiler and turkey diets. In broilers, up to 15% DDGS in grow/finish diets is possible. In market tom turkeys, up to 20% DDGS in grow/finish diets is possible in diets with normal protein content and under conditions where feed intake is maximized. Variability of nutrient content is of concern as risk increases with higher inclusion rates but this variation can be reduced somewhat by using a limited number of sources to provide the material. Some of the nutrient variability in DDGS may be due to addition of different levels of solubles to the wet grains prior to drying. Varying the addition of the solubles to the grains affected particle size, color, and content of fat and minerals. Use of high levels of DDGS will change the amino acid and mineral nutrient profile as well as the amounts of ingredients being used.

Introduction

Expansion of the ethanol industry in the late 1990’s brought about increased supplies of corn DDGS (distillers dried grains with solubles) sparking interest by feed companies and nutritionists to examine the use of this corn co-product in poultry diets. Although DDGS is not a “new” product, research on feeding of DDGS generated from recently built ethanol plants was not available. Because of cost, availability or quality concerns, the product was not used at all in poultry diets or the use levels were kept conservative with levels above 5% considered high. In the last six months, however, the increase in price of both corn and soybean meal has re-kindled interest in exploring utilization of higher levels of DDGS (levels in excess of 10%).

Concerns regarding the use of DDGS still remain quite often that of variability in nutritional and physical characteristics, nutrient quality of the product, and levels of use in poultry diets. This paper will explore the considerations of using higher levels of DDGS in poultry diets based on its nutrient characteristics and the response of poultry to the feeding of high levels of DDGS from published studies.

Feeding Trials with DDGS in Meat Type Poultry

Chicken Broilers

Waldroup *et al.* (1981) fed up to 25% DDGS in two sets of diets where energy level was allowed to decline (variable) and the other set where diet ME was kept constant at 3200 kcal/kg with the use of supplemental fat (“fixed”). Diets were formulated without supplemental lysine using NRC ingredient specifications in corn-soybean meal based diets and diets were fed as mash. The ratio of nutrients to dietary energy in the variable regimen was kept constant. Diets were fed during 0-21 da and 21-42 da of age. In the diets of fixed energy, BW was not affected by DDGS inclusion level nor was feed efficiency during 0-42 days. In the variable dietary energy regimen, BW was reduced when DDGS was included at levels of 15% or greater. Feed efficiency (gain:feed) was reduced likewise when inclusion levels were 15% or greater. The authors also measured feed density (g/liter). Diets containing 25% DDGS were less dense with density decreasing by 6.9% and 5.4% in the starter and grower diet, respectively. The results of this study indicated that up to 25% of DDGS could be fed with adjustments to the diet energy level. However, broiler growth has changed considerably since this publication and diets were formulated to meet the lysine requirement with intact protein which may have prevented other amino acids from limiting growth.

More recent trials were conducted by Lumpkins *et al.* (2004). Inclusion level of 15% DDGS was examined in diets of low and high-density starter diets. Another trial examined levels of 0, 6, 12, and 18% in diets formulated to be isocaloric and isonitrogenous in starter, grower, and finisher diets. Diets were formulated on a total amino acid basis and supplements of lysine and methionine were used. The base diet was primarily composed of corn-soybean meal with poultry fat used to obtain the desired diet ME level. The DDGS product used was derived from corn used in ethanol production. The product contained 27% crude protein, 9.8 % fat, and total lysine of .85% (as fed basis). Lysine digestibility was determined to be 75% indicating it to be a high quality product. No negative effects on performance were noted by inclusion of DDGS (15%) in the high density starter diets. In the low density diets, feed efficiency (gain:feed) was reduced early (7 and 14 da) when fed diets with 15% DDGS. In the second trial, the feeding of 18% DDGS was found to decrease BW at 16 da of age, an effect which carried over to BW at 42 da of age. Feed efficiency was also worsened during 0-16 da at the high level of DDGS inclusion (18%). No treatment differences were observed during 17-31 da or 0-42 da for feed efficiency. The authors concluded that an 18% level of inclusion was too high for use in starter diets and that a marginal lysine deficiency may have caused the decrease in performance.

Market Turkeys

In market hens, Roberson (2003) found that level of inclusion and matrix values for DDGS (corn derived) influenced performance of grow/finish market hens. In the first study, four levels of DDGS were fed (0, 9, 18, and 27%). DDGS was incorporated into corn-soybean based diets and supplements of lysine, methionine, and threonine were used. Diets were formulated on a digestible amino acid basis and an energy value of 2870 kcal/kg was used for DDGS ME. In the second trial, diets were formulated on a total amino acid basis to meet 110% of the NRC (1994) amino acid requirements and an energy value of 2805 kcal/kg was assigned to the DDGS. Inclusion levels were 7 and 10% of the diet. In the first study, BW at 105 da was decreased linearly with DDGS inclusion. Feed/gain tended to increase with DDGS inclusion ($P<.10$). A higher incidence of pendulous crops and greater litter moisture was noted with the 27% inclusion level as compared to diets with 0 or 9% DDGS. In the second trial, growth and feed efficiency were similar among treatments. The acceptable performance with DDGS in the second trial was attributed to the use of higher amino acid specifications to overcome concerns with lysine digestibility and the lowering of the energy level of DDGS from 2870 to 2805 kcal/kg.

In market turkeys, previous studies have indicated that up to 10% DDGS could be incorporated into corn-soy diets containing moderate amounts of poultry byproduct meal (PBM) in grow/finish diets for heavy toms and formulated using digestible amino acids (Noll *et al.*, 2002, 2003) . Diets were formulated on a digestible amino acid basis using AME energy values of 2810-2860 kcal/kg for DDGS. In the three studies, comparing the DDGS feeding regimen with the control diet indicated no difference in live performance relative to market body weight and feed conversion (Table 1).

Table 1. Corn DDGS and performance of heavy tom turkeys.

Experiment	Age Period	Season	PBM Level	Treatment	DDGS Level	BW, 19 wks	Feed/Gain Cumulative for study period
	(wks)		(%)		(%)	(lbs)	
1. Noll *et al.*, 2002	5-19	Winter	8-5	Control	0	41.6	2.44
				DDGS	12-8	41.9	2.48
2. Noll *et al.*, 2003	8-19	Winter	8-6	Control	0	42.4	2.62
				DDGS	11-8	42.6	2.64
3. Noll, 2003	11-19	Spring	7-6	Control	0	40.5	2.67
				DDGS	10	40.2	2.63

Lysine digestibility coefficients for DDGS for Exp. 1, 2, and 3 were 78, 64, and 64%, respectively.

As prices or supplies permit, higher levels may be appropriate assuming performance doesn't suffer. Feeding levels of 15 and 20% resulted in performance similar to the control (Table 2) (Noll *et al.*, 2004). However, in a subsequent feeding trial, conducted such that the trial finished in early summer, growth of turkeys fed 20% DDGS was decreased in comparison to the control (Noll *et al.*, 2005).

Table 2. High levels of corn DDGS and performance of heavy tom turkeys.

Experiment	Age Period	Season	PBM Level	Treatment	DDGS Level	BW, 19 wks	Feed/Gain Cumulative for study period
	(wks)		(%)		(%)	(lbs)	
4. Noll *et al.*, 2004	8-19	Winter	7-5	Control	0	38.6	2.80
				DDGS	10	38.9	2.80
				DDGS	15	39.0	2.80
				DDGS	20	38.7	2.80
5. Noll *et al.*, 2005	6-19	Summer	8-5	Control	0	38.5	2.53
				DDGS	10	38.3	2.52
				DDGS	20[1]	37.7	2.55

[1]Contrast testing indicated the 20% inclusion level to be different from the control (P<.05).
Lysine digestibility coefficient for DDGS for Exp. 4 and 5 was 72%.

The difference in the results of feeding higher levels of DDGS between the two trials was attributed to season and protein level of the base diets. The one trial was conducted during the winter where feed intakes would be maximized under cool rearing conditions. Supplemental threonine was not used. The other trial was conducted under summer rearing conditions where feed intake was limiting and supplemental threonine was used to reduce diet crude protein levels.

Dietary Considerations in Feeding High Levels of Corn DDGS

DDGS Characteristics

Several studies have indicated that variability in composition and quality exists in DDGS. When high levels of inclusion are being used, the risk associated with nutrient variability becomes greater. Variability in composition was found in several nutrients. In a study conducted at the University of Minnesota (Ergul *et al*., 2003; Noll *et al.*, 2003), samples of corn DDGS were collected to determine their nutrient composition and variation among and within sources. Samples (N=20) were obtained from five commercial ethanol plants. Means (as fed basis) for ash, DM, fat, fiber, protein, starch, and sugars were 4.0, 88.3, 10, 5.7, 27.6, 4.7, and 2.3%, respectively. Sources varied in fat, protein, and ash content ($P < 0.01$). Amino acid content also differed among sources with the exception of Ser ($P < 0.05$). Respective means for methionine, cystine, lysine, arginine, tryptophan, valine, threonine, and isoleucine were 0.49, 0.52, 0.74, 1.08, 0.22, 1.32, 0.98, and 0.96%. Lysine content was the most variable across all samples (CV=11.2%) followed by cystine (CV=11.3%) and tryptophan (CV=11.1%). Within source, the CV for lysine averaged 4.6%. Respective means for Mg, Na, P, K, Cl, S, and Ca were 0.31, 0.11, 0.73, 0.95, 0.17, 0.65, and 0.03%. Mineral content also varied among sources, with sodium being the most variable among all samples (CV=33%) and was highly variable within sources. Sources of DDGS differed ($P < 0.05$) in digestibility coefficients for lysine, cystine, threonine, and arginine (71, 77, 72, and 93%, respectively). Sources differed ($P < 0.05$) in true digestible essential amino acid content except tryptophan. A wide range (0.38 to 0.65%) existed especially for true digestible lysine. Analyses of DDGS indicated that differences in composition are related to source of production during the time period of sample collection. However, within source, composition was found to be relatively consistent with the exception of sodium content. Batal and Dale (2003) also found a large range in sodium content over 12 samples of DDGS (.09-.44%, average value .23%). For most nutrients then, obtaining material from one source should help minimize variation among batches of materials.

Because lysine is a first or second limiting amino acid in poultry diets and because of its susceptibility to heat damage during the drying process, lysine digestibility will be a major concern in use of DDGS. Other studies have also reported variation *among* sources in lysine content and digestibility. Table 3 summarizes information from three different studies regarding true lysine digestibility as determined in cecectomized roosters. On average, true digestibility for lysine was in excess of 70% but some individual samples showed low digestibility. If one would take an extreme example where digestible lysine content of DDGS ranged between .39 to .65%, a 20% inclusion level of DDGS would result in a difference of .06% dietary lysine.

Table 3. Lysine content and digestibility of DDGS.

Source	No. of Samples	Mean Lysine Content (%)		Mean Lysine Digestibility Coefficient (%)	
		Average	Range	Average	Range
Ergul *et al*., 2003[1]	20	.74	.59-.89	71	59-84
Batal and Dale, 2006[2]	8	.71	.39-.86	70	46-76
Fastinger *et al*., 2006[1]	5	.64	.48-.75	76	65-82

[1]As fed basis. [2] Adjusted to 86% DM.

TMEn was also evaluated in these studies. On an 86% DM basis, TMEn ranged from 2490 to 3190 kcal/kg with an average of 2820 for 17 samples (Batal and Dale, 2006) as determined with conventional roosters. The authors attempted to develop a predictive equation for TMEn based on fat, fiber, protein, and ash content. Fat content was the best predictor of TMEn content, but the overall R^2 was quite low (R^2=.29). Adding fiber, protein, and ash to the regression model moderately improved the prediction equation (R^2=.45). In the study by Fastinger *et al.* (2006), on an as fed basis, TMEn ranged from 2484 to 3014 kcal/kg with an average of 2871 for the five samples. In this study, the sample with the lowest energy value was associated with the sample having the poorest amino acid digestibility as well. As reported by Abe (2005), TMEn as determined with young turkeys was not affected by source and averaged 2833 kcal/kg agreeing with the value obtained by Batal and Dale (2006). A recent trial tested the assignment of a metabolizable energy value to DDGS (Noll *et al*., 2005). A grow-finish trial was conducted with turkeys to confirm the appropriate energy value of DDGS to use in diet formulation. Commercial male turkeys (Large White, Hybrid strain) were fed diets varying in level of DDGS (10 or 20% DDGS) and formulated using different levels of MEn assigned to the DDGS during 6 to 19 wks of age. The ME assignments were (kcal/kg): previously determined TMEn in young growing turkeys of 2980; previously determined AMEn with young turkey poults of 2760; and, the NRC (1994) book value of 2480. The basal diet was composed of primarily corn, soybean meal, poultry byproduct meal and .05% supplemental threonine. Diets were formulated on a digestible amino acid basis. A control diet with no DDGS was included. Diets varying in ME assignment did not affect turkey body weight. When the TMEn value was used in formulation, cumulative 6-19 wk f/g was poorer as compared to the NRC value (2.56 vs. 2.52) ($P<.05$). Determination of energy by TMEn resulted in an overestimation of the energy value of the DDGS when using feed efficiency as the response criteria. While there was no difference in response for the NRC or AMEn energy value, use of the lower NRC energy value could have a large effect on diet cost.

Corn derived DDGS can be an economic source of available phosphorus (P). Previous studies have indicated the phosphorus availability of DDGS to be greater than that of phosphorus in corn, the availability of which is estimated at 28% (NRC, 1994). Lumpkins and Batal (2005) obtained P bioavailability estimates of 54 and 68% with chicks. Martinez-Amezcua *et al*. (2004) found P bioavailability was related to heat processing such that P availability increased from 75 to 87% for a sample of DDGS that was autoclaved. Bioavailability of phosphorus in three other sets of DDGS was 75, 82 and 102%. In a follow-up study, Martinez Amezcua and Parsons (2007) demonstrated that heating or autoclaving DDGS increased P bioavailability; however, digestibility of lysine was decreased. Kalbfleisch and Roberson (2004, 2005) found relatively high availabilities for P, in excess of 85% for DDGS using a turkey poult bioassay. Martinez-Amezcua *et al*. (2006) found additions of phytase and citric acid in a diet containing 40% DDGS released additional P, improving P availability of the DDGS from 62 to 72%. While the high bioavailability of P could reduce overall diet P content, the large range in bioavailability prevents accurate assignment of P bioavailability.

Many things can contribute to this source of variability, such as corn composition, solubles addition, and drying conditions. Variable solubles addition to the wet grains prior to drying could effect the nutrient composition of the dried product and perhaps change the dynamics of the drying process to affect product quality. To examine the effect of the solubles addition, a pilot study was conducted in cooperation with an ethanol plant in Minnesota (Noll *et al.*, 2007). Batches of corn distiller dried grains were produced with varying levels of solubles (syrup) added back to the wet grains (mash). The batches produced contained syrup added at approximately 0, 30, 60, and 100% of the maximum possible addition of syrup to mash. Actual rates of syrup addition were 0, 12, 25, and 42 gal/minute. The different combinations of mash and syrup were dried at the plant. Drying temperature decreased with the decrease in rate of solubles of addition. Digestible amino acids were determined in cecectomized roosters and true metabolizable energy (TMEn) in intact young turkeys. Regression analyses and correlation coefficients (Pearson) were conducted to determine the extent of the relationship between the level of solubles added and the resulting nutrient content. Particle size was greatly affected with larger and more variable particle size observed with the highest level of solubles addition. The larger particles (“syrup balls”) were readily apparent in the 100% batch. Content of fat and ash increased with solubles addition (Table 4). The TMEn content increased with solubles addition. Mineral content, especially for magnesium, sodium, phosphorus, potassium, chloride, and sulfur increased as the level of solubles addition increased. Protein and amino acid content showed very little change in the various products. True amino acid digestibility coefficients of the essential amino acids tended to be negatively correlated with solubles addition. The results indicate that solubles addition has the largest effect on particle size, color, and contents of fat (and thus TMEn) and minerals.

Table 4. Solubles addition and characteristics of the resulting DDGS.

		Solubles Addition (gal/min)					Statistics	
		42	25	12	0		Correlation (Pearson) with solubles addition	P value
Product Characteristics								
Color (CIE Scale)								
L*		46.1	52.5	56.8	59.4		-.98	.0001
a*		8.8	9.3	8.4	8		.62	.03
b*		35.6	40.4	42.1	43.3		-.92	.0001
Moisture (%)		13.8	10.7	9.75	9.52		.93	.06
Nutrient (%, DM basis)								
Protein		32.0	32.5	32.6	32.0		.03	NS
Fat		10.5	9.22	9.14	7.97		.96	.04
Fiber		6.5	10.08	7.76	9.17		-.51	NS
Ash		4.62	3.72	3.58	2.58		.97	.03
TMEn, kcal/kg		3743	3002	2897	2712		.94	.06
P, ppm		9116	7669	6636	5315		.99	.002

DDGS and Diet Composition

Incorporation of high levels of DDGS into market turkey and broiler diets can result in potential excesses and deficiencies of several nutrients. Broiler and turkey grower diets formulated with different levels of DDGS show the same trends (Table 5). Use of corn, soybean meal, dicalcium phosphate, and DL-methionine are decreased while supplemental lysine, fat, and calcium carbonate are increased as inclusion level of DDGS increases. Mineral content also changes with decreases in potassium and increases in sulfur content. Protein content increased slightly although changes would be greater if diets were formulated on an amino acid basis. Changes in sodium and chloride content can occur. With phosphorus, in the broiler diets, 20% DDGS resulted in no dicalcium phosphate use. If higher use levels of animal by product are desired, phosphorus levels will become excessive or the amount of DDGS would need to be decreased. The replacement of soybean meal protein with corn protein was associated with declines (total amino acid basis) in tryptophan, arginine, and isoleucine. Content of leucine and valine increased.

Production of pelleted feed containing DDGS may have negative effects on feed mill performance. Koch (2006, 2007) presented information on energy usage and pellet quality when adding DDGS in combination with other ingredients. Production of pellets from mixtures of Durum wheat and DDGS resulted in increased energy usage and decreased pellet quality (PDI) with increasing additions of up to 50% DDGS with wheat. Pelleting of a swine diet containing 10% DDGS decreased energy cost but also decreased pellet quality in comparison to pelleting the diet without DDGS.

Table 5. Inclusion of DDGS and diet composition.									
		Turkey Grower Diets, 8-11 wks of age[1]					Broiler Grower Diets[2]		
		DDGS Level, %					DDGS Level, %		
Ingredient (%)		0	20	30	40		0	10	20
Corn		54.65	45.24	40.54	35.83		63.14	56.19	51.26
Soybean meal		33.77	23.22	17.95	12.67		27.52	24.28	19.04
Poultry byproduct		4.00	4.00	4.00	4.00		5.00	5.00	5.00
DDGS		0.00	20.00	30.00	40.00		0.00	10.00	20.00
Dical. Phosphate		1.25	0.73	0.47	0.22		0.29	0.02	0.00
Ca. Carbonate		0.83	1.20	1.38	1.57		0.47	0.64	0.69
Dl met .99		0.17	0.13	0.11	0.09		0.23	0.22	0.20
L-Lys HCl		0.06	0.23	0.31	0.39		0.00	0.01	0.10
Thr		0.00	0.00	0.00	0.00		0.03	0.00	0.00
Animal fat		4.53	4.69	4.77	4.84		2.58	3.01	3.17
Other		++	++	++	++		++	++	++
Nutrient (%)									
Protein		22.06	22.13	22.16	22.19		20.44	21.14	21.17
ME, kcal/kg		3150	3150	3150	3150		3150	3150	3150
Met + Cys		0.82	0.82	0.82	0.82		0.87	0.87	0.87
Lys		1.28	1.28	1.28	1.28		1.10	1.10	1.10
Arg		1.42	1.30	1.25	1.19		1.29	1.29	1.23
Tryp		0.23	0.20	0.18	0.16		0.21	0.20	0.18
Val		1.01	1.03	1.04	1.05		0.92	0.97	0.98
Thr		0.79	0.79	0.79	0.79		0.75	0.75	0.75
Leu		1.74	1.94	2.04	2.14		1.32	1.77	1.88
Iso		0.90	0.88	0.86	0.85		0.81	0.83	0.82

[1]Formulated based on total amino acid requirements (NRC, 1994) adjusted for 3 wk periods.

[2]Formulated based on total amino acid specifications-medium density (Kidd *et al* ., 2004).

The use of high levels of both animal byproduct and DDGS could replace a considerable quantity of soybean meal protein. A trial was conducted to examine different inclusion levels of poultry byproduct meal (PBM) and DDGS and their combined effect on market tom performance during 5-19 wks of age (Noll *et al*., 2006). Large White male turkey poults (Nicholas strain) were randomly assigned to pens (10/pen) at 5 wks age and fed one of the following diet treatments (T): 1. Corn and soybean meal control; 2. As T1 with PBM (8%); 3. As T1 with PBM (12%); 4. As T1 with DDGS (10%); 5. As T1 with DDGS (20%); 6. As T 2 and T4; 7. As T2 and T5; 8. As T3 and T4; and, 9. As T3 and T5. Diets were formulated using digestible amino acids. Diet protein level was established by using intact protein to meet the digestible NRC threonine at 100% of the NRC recommendation. All diets were supplemented as needed with lysine and methionine to meet the specific NRC recommendations for these amino acids. The ratio of calcium:phosphorus was maintained at 2:1 to accommodate the higher levels of phosphorus in the diets containing high levels of PBM and DDGS. Each diet was fed to 10 replicate pens. The experimental design was a completely randomized block design with a factorial arrangement of PBM and DDGS inclusion levels. At 19 wks of age (Table 4), dietary treatment significantly affected 19-wk body weight and feed efficiency (5-19 wks) (P<.001).

Table 6. Market tom performance and inclusion of alternative protein sources.							
		Body Weight (lbs)				Feed/Gain	
Trt #	Diet Description	11 wks		19 wks		5-19 wks	
1	Corn-Soy Control	19.12	a	44.49	a	2.50	cd
2	As 1 + 8% PBM	18.58	b	43.95	ab	2.47	cd
3	As 1 + 12% PBM	18.35	bc	43.77	abc	2.46	d
4	As 1 + 10% DDGS	19.20	a	44.47	a	2.51	bc
5	As 1 + 20% DDGS	18.91	a	44.41	a	2.51	c
6	As Trt 2 & 4	18.58	b	43.99	ab	2.50	c
7	As Trt 2 & 5	17.87	d	42.85	c	2.56	a
8	As Trt 3 & 4	18.06	cd	43.56	abc	2.45	d
9	As Trt 3 & 5	18.06	cd	43.09	bc	2.55	ab
	Statistics						
	Treatment P value	0.0001		0.0001		0.0001	
	Treatment LSD (P<.05)	0.34		0.96		0.05	

Diets containing PBM (8 or 12%) or DDGS (10 or 20%) were not significantly different from the control. BW of turkeys fed diets containing PBM (8 or 12%) in combination with 20% DDGS was less than that of the control by 3.3%. A significant interaction existed for inclusion of PBM and DDGS (P<.02) for feed efficiency. Feed/gain of turkeys fed diets containing PBM (8 or 12%) or DDGS (10 or 20%) were not significantly different from the control. However, the feed/gain increased for turkeys fed diets containing PBM (8 or 12%) in combination with 20% DDGS and were significantly different from the control by 5 to 6 points. The decrease in performance was suspected to be due to an amino acid deficiency or an excess of the calcium and phosphorus in the diets.

Formulating diets with high inclusion levels of DDGS will need to consider potential excesses and deficiencies of certain amino acids and minerals. Phosphorus content of DDGS, while of good bioavailability, may limit its use particularly in combination with animal by product meals. Higher levels of use may result in unacceptable pelleting conditions and high supplemental fat levels.

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