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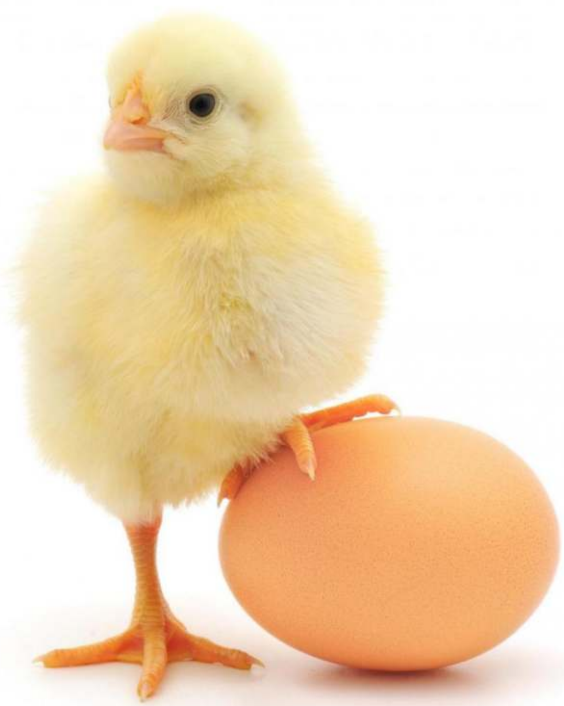

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Effects of Increasing Inclusion Rates of a Low-Fat Distillers Dried Grains with Solubles (LF-DDGS) in Finishing Broiler Diets

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Abstract: The objectives of this study were to determine the maximum inclusion rates of a low fat distillers dried grains with solubles (LF-DDGS) in broiler diets fed during the finisher I phase (28 to 42 d) and the finisher II phase (43 to 56 d) and the subsequent effects on live performance and carcass characteristics. These ages were specifically chosen to determine effects of feeding LF-DDGS to broilers grown to heavy weights (>3.0 kg). Experimental diets were formulated to contain 0, 8, 16, 18, 24, or 30% LF-DDGS for finisher I phase and 0, 18, 16 and 24% LF-DDGS for finisher II phase. Diets were formulated to be isocaloric and to meet or exceed the minimum nutrient requirements. Birds were fed common diets until d 27 or 41 and experimental diets were fed until d 42 and d 56, respectively. Upon completion of the experimental periods, all birds and feed were weighed to determine body weight, body weight gain, feed consumption and feed conversion ratio for the experimental periods. On d 43 and 57, after an overnight fast, 6 birds per pen were tagged, weighed and processed to determine hot carcass weight and abdominal fat pad. After a period of chilling, carcasses were deboned to determine breast and tender weights. For the Finisher I period, body weight gain (BWG) was significantly ($p<0.05$) decreased and FCR was significantly increased for birds fed diets containing 30% LF-DDGS. At 43 d, carcass yield was found to be significantly decreased ($p<0.05$) for birds fed 30% LF-DDGS when compared to birds fed no LF-DDGS. For the Finisher II period, there were no significant effects of LF-DDGS inclusion on live performance and resulting carcass parameters. These results indicate that finishing broilers (28 to 56 d) can tolerate up to 24% LF-DDGS in the later phases of production without any detrimental effects on live performance and carcass parameters.

Key words: Distillers dried grains with solubles, oil extracted, finisher phase, broilers

INTRODUCTION

Increased demand for renewable fuels has increased the production of dry-grind ethanol, greatly increasing the production of distillers dried grains with souble (DDGS). Current modifications to the process remove corn oil from DDGS to meet increasing demands and results in an oil extracted or lower fat content in DDGS (LF-DDGS) (Saunders and Rosentrater, 2009). The oil extraction process can now reduce the crude fat from 9.3 to as low as 2.1% (Ganesan *et al.*, 2009). Previous research has extensively studied the inclusion rates of conventional (full-fat, non-oil extracted) DDGS in broiler diets (Swiatkiewicz and Koreslski, 2008; Salim *et al.*, 2010). Several studies have aimed to determine the rates of inclusion of LF-DDGS in swine and their effects on live performance and carcass characteristics. Jacela *et al.* (2011) reported that increasing amounts of a solvent extracted DDGS (fat content of 4%) could be fed to nursery pigs up to 30% without any detrimental effects on overall performance but at inclusion rates greater than 20% reduced overall growth performance and increased negative effects on carcass quality in growing and finishing pigs. The fat quality decline in the finishing carcasses may have been due to increasing amounts of oil added to the diets to offset the lower metabolizable energy content of the LF-DDGS (Jacela *et al.*, 2011). Another study observed that feeding a medium-oil DDGS (ether extract of 7.63%) linearly decreased live performance and carcass traits when fed in swine diets up to 45% (Guney *et al.*, 2013). The use of LF-DDGS in broiler diets has not been studied extensively. Guney *et al.* (2013) reported that up to 20% LF-DDGS could be added to broiler starter diets without any detrimental effects on live performance. Previous research has already indicated older birds can tolerate higher amounts of DDGS in broiler diets (Lumpkins *et al.*, 2004; Wang *et al.*, 2007a, b; Loar *et al.*, 2010).

Recently, many broiler integrators are now raising birds to heavier weights (>3.0 kg) and extending the production period for the debone market. There has been extensive research on the nutrient requirement of these heavier broilers but none have aimed to determine the effects of including LF-DDGS in heavy broiler diets, especially in the later stages of production. Therefore, the objectives of this study were to determine the effects of feeding increasing levels of LF-DDGS (0 to 30%) from 28 to 42 d (finisher I) and 43 to 56 d (finisher II) in a commercial-type setting using diet compositions primarily used in the broiler industry.

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MATERIALS AND METHODS

Ingredient analysis and diet formulations: Low-fat DDGS that underwent oil extraction was obtained from a commercial source; nutrient composition of the LF-DDGS sample is presented in Table 1. The same LF-DDGS was used in both the finisher I and II phases. Prior to diet formulation, proximate analysis and total amino acid content were determined AOAC International (2006). Digestible amino acid content was determined using NIR methods. Briefly, samples were ground through a 1 mm sieve, allowed to equilibrate to room temperature in sealed bags for 20 min and then scanned on a standardized FOSS XDS NIR. The standardized septra was then uploaded to Adisseo's Precise Nutrition Evaluation Software (Adisseo, France SAS; www.Pne.adisseo.com) and analyzed for digestible amino acids. In addition, the sample of LF-DDGS was analyzed for metabolizable energy previously in our lab and was added to the nutrient matrix (2.615 kcal/kg; Table 1). A total of six dietary treatments were used to determine the maximum inclusion rates of LF-DDGS for broilers in the finisher I phase of production fed from 29 to 42 d of age. The LF-DDGS was included at 0, 6, 12, 18, 24 and 30% of the diet during the finisher I phase of the experiment. A total of four dietary treatments were used to determine the maximum inclusion rates of LF-DDGS for broilers in the finisher II phase of production fed from 43 to 56 d of age. The LF-DDGS was included at 0, 8, 16 and 24% of the diet during the finisher II phase of the experiment. The maximum for the finisher II was lowered because at inclusion rates greater than 24% the diets would not be balanced for nutrient requirements during the finisher II phase. For each experimental phase, two experimental diets were formulated: a corn-soybean meal base diet (0% LF-DDGS) and a summit diet (30% LF-DDGS for the finisher I and 24% for the finisher II) diet using least-cost diet formulation software (BRILL, Feed Management Systems, Inc., Brooklyn Center, MN). The compositions of the experimental diets are presented with calculated values in Table 2 and analyzed proximate values in Table 3. Experimental diets were formulated on a digestible amino acid basis to contain the same amount of nutrients and were formulated to meet or exceed NRC (1994) requirements for broilers 28 to 42 d and 43 to 56 d of age. In order to maintain the practicality of the diets, diets were not formulated to be isonitrogenous because it is not common practice in the industry to add purified amino acids such as Val. The summit and basal diets were then blended in different proportions to achieve the intermediate LF-DDGS levels as mash and then subsequently pelleted. Prior to d 28, all birds were fed common starter until d 14 and grower feed until d 27 and finisher feed until d 42. The common diets were formulated to contain corn, soybean meal and poultry by-product meal and met or exceeded nutrient requirements for birds in those phases (NRC, 1994). The common diets did not contain any type of DDGS or ethanol by-product. Starter and feed was crumbled and grower and finisher diets were pelleted. All feeds were manufactured at the USDA-ARS Poultry Research Unit's pilot feed mill. Diets were conditioned at 85°C and subsequently pelleted using a 40-hp pellet mill with die dimensions of 0.476 x 3.81 cm (California Pellet Mill, Crawfordsville, IN). All experimental diets were pelleted.

Table 1: Nutritional composition of the LF-DDGS

Dry matter (%)	89.70
Crude fat (%)	7.42
Crude protein (%)	28.22
Crude fiber (%)	6.30
Ash (%)	4.91
Apparent metabolizable energy (kcal/kg)	2.615
Total amino acid (%)	
TSAA	1.05
Arginine	1.28
Histidine	0.78
Isoleucine	1.09
Leucine	3.32
Lysine	0.97
Methionine	0.50
Phenylalanine	1.39
Threonine	1.09
Tryptophan	0.24
Valine	1.39
Total digestible content (%)	
TSAA	0.80
Arginine	1.16
Histidine	0.58
Isoleucine	0.89
Leucine	2.80
Lysine	0.49
Methionine	0.50
Phenylalanine	1.19
Threonine	0.72
Tryptophan	0.19
Valine	1.20

Animal husbandry: All animal care and use were approved by the ARS-USDA Institutional Animal Care and Use Committee at the Mississippi State location. Seven-hundred and ninety two male Ross x Ross 708 broilers were obtained from a commercial hatchery at day of hatch. Chicks were vaccinated for Marek's disease and Newcastle disease at the hatchery. Chicks were randomly allocated to 72 mini-pens of 11 birds per pen measuring 1.2 x 1.07 m in a tunnel-ventilated research facility to ensure a bird density of 0.1 m^2/bird. Mini pens were arranged in two groups of 36 with a center aisle separating the two down the building. Each group of 36 pens were then used for the different experimental periods at 28 to 42 d and 43 to 56 d. Air temperature was maintained at 33° and reduced as birds aged to a final temperature of 21°C. A 23L:1D lighting schedule was implemented with light intensity of 30 lx from 0 to 7 d of age, decreased to 10 lx from 8 to

21 d and further decreased to 3 lx from 22 to 56 d. All birds were fed common diets prior to their experimental periods. Starter crumbles were fed from 0 to 14 d, grower pellet from 15 to 27 d and for birds on the finisher II experimental diets were fed finisher pellet from 29 to 41 d of age. At the start of the experimental periods, on d 28 and 42, respectively, all birds were weighed to determine an initial weight for the experimental period. For the finisher I phase, each of the six dietary treatments was then fed to six replicate pens until d 42. For the finisher II phase, each of the four dietary treatments was then fed to nine replicate pens until d 56. Upon completion of the experimental periods at d 42 and 56, all birds and feed were weighed to determine final body weight, body weight gain and feed conversion ratio (FCR) for the experimental period. Incidence of mortality was recorded and weighed daily and FCR was adjusted for mortality. On d 43 and 57, six birds per pen were randomly selected for processing. Feed was removed for 12 h overnight prior to processing. Birds selected for processing were weighed to determine pre-processing live weights and then placed into coops and transported to the Mississippi State University pilot processing plant. Birds were electrically stunned, bled, scalded, mechanically picked and eviscerated. Whole hot carcass (without abdominal fat pad, giblets and neck) and abdominal fat pad surrounding the viscera were weighed. Carcasses were then split into front and back halves and placed on ice for 4 h. After chilling, the front halves were deboned to obtain fillet (pectoralis major) and tender (pectoralis minor) weights. Total breast weight was then subsequently calculated from the sum of the major and minor muscle weights. Yield, relative to live weight, was also determined.

Statistical analysis: Treatments were arranged in a randomized complete block design with pen location as the random blocking factor. Pen was considered the experimental unit comprising 11 birds per pen. The finisher I diets were fed to six replicate pens and the finisher II diets were fed to nine replicate pens per diet. All mortality and relative processing yield data were arcsine transformed. All treatment means were separated using the GLIMMIX procedure of SAS (2011). In addition, linear and quadratic trends were analyzed for increasing inclusion rates of LF-DDGS. Statistical significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

Live performance: Effects of LF-DDGS inclusion on live performance data for the finisher I (28 to 42 d) and finisher II (43 to 56 d) periods are presented in Table 4.

Table 2: Composition of the experimental diets fed to broilers during the finisher I and II phases of production

	Finisher I (28 to 42 d)		Finisher II (43 to 56 d)	
Ingredient (%)	0% LF-DDGS	30% LF-DDGS	0% LF-DDGS	24% LF-DDGS
Corn	67.52	47.97	71.11	53.86
Soybean meal	25.84	6.17	16.86	5.96
LF-DDGS	-	30.00	-	24.00
Poultry by product	1.92	11.38	9.20	11.77
Poultry oil	2.04	3.00	1.16	3.00
Limestone	0.79	0.49	0.65	0.51
Dicalcium phosphate	0.97	0.13	0.17	0.06
Salt	0.42	0.16	0.35	0.19
Vitamin/mineral premix[1]	0.25	0.25	0.25	0.25
DL-Methinonie	0.12	0.09	0.11	0.08
L-Lysine	0.11	0.34	0.13	0.30
L-Threonine	0.01	0.01	0.02	0.03
Calculated analysis				
Metabolizable energy (kcal/kg)	3.150	3.150	3.200	3.200
Crude protein (%)	19.40	23.47	20.15	22.92
Calcium (%)	0.66	0.66	0.66	0.66
Non-phytate phosphorus (%)	0.33	0.33	0.33	0.33
Sodium	0.20	0.20	0.20	0.20
Dig Lys	1.01	1.01	0.95	0.95
Dig Met	0.45	0.45	0.42	0.42
Dig TSAA	0.74	0.74	0.71	0.70
Dig Ile	0.66	0.66	0.69	0.69
Dig Thr	0.66	0.66	0.65	0.65
Dig Val	0.81	0.94	0.82	0.89

[1]Vitamin and mineral premix included the following per kilogram of diet: vitamin A (vitamin A acetate), 4,960 IU; vitamin D (cholecalciferol), 1,653 IU; vitamin E (dl-α-tocopherol acetate), 27 IU; menadione (menadione sodium bisulfate complex), 0.99 mg; vitamin B12 (cyanocobalamin), 0.015 mg; folic (folic acid), 0.8 mg; d-pantothenic acid (calcium pantothenate), 15 mg; riboflavin (riboflavin), 5.4 mg; niacin (niacinamide), 45 mg; thiamine (thiamine mononitrate), 2.7 mg; d-biotin (biotin), 0.07 mg; pyridoxine (pyridoxine hydrochloride), 5.3 mg, Mn (manganous oxide), 90 mg; Zn (zinc oxide), 83 mg; Fe (iron sulfate monohydrate), 121 mg; Cu (copper sulfate pentahydrate), 12 mg; I (calcium iodate), 0.5 mg and Se (sodium selenite), 0.3 mg

Table 3: Proximate analysis of the experimental diets with varying amounts of LF-DDGS fed to broilers in the finishing phases of production

Finisher I	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Ash (%)	Moisture (%)
0% LF-DDGS	19.53	9.61	2.36	5.08	9.61
6% LF-DDGS	20.61	9.46	2.60	5.01	9.46
12% LF-DDGS	22.12	9.07	2.84	5.21	9.07
18% LF-DDGS	22.80	8.97	3.18	4.83	8.97
24% LF-DDGS	22.84	8.81	3.05	4.72	8.81
30% LF-DDGS	23.15	8.35	4.11	5.59	8.35
Finisher II					
0% LF-DDGS	19.68	10.16	2.70	4.22	10.16
8% LF-DDGS	20.08	9.81	2.80	4.48	9.81
16% LF-DDGS	21.11	9.29	3.29	4.33	9.29
24% LF-DDGS	21.77	9.33	3.25	4.65	9.33

Table 4: Effect of LF-DDGS inclusion level on live performance of male broilers during the finisher I and II phases of production

	Finisher I (d 28 to 42)[1]				
% LF DDGS	28 d BW (kg)	42 d BW (kg)	BWG (kg)	Feed consumption (kg)	FCR (kg:kg)
0	1.563	3.163	1.600[a]	3.005	1.843[b]
6	1.555	3.182	1.638[a]	3.057	1.869[b]
12	1.556	3.158	1.571[a]	3.052	1.897[b]
18	1.575	3.164	1.564[a]	2.971	1.887[b]
24	1.575	3.135	1.564[a]	2.976	1.904[b]
30	1.550	3.087	1.418[b]	3.004	2.031[a]
Pooled SEM	0.021	0.042	0.043	0.052	0.026
p-value					
Main effect of DDGS	0.1498	0.6710	0.0281	0.7746	0.0006
Linear	-	0.1344	0.0099	0.4391	0.0039
Quadratic	-	0.3389	0.1048	0.8654	0.1588
	Finisher II (d 43 to 56)[2]				
% LF DDGS	42 d BW (kg)	56 d BW	BWG (kg)	Feed consumption (kg)	FCR (kg:kg)
0	3.204	4.654	1.450	3.003	2.080
8	3.186	4.695	1.474	3.136	2.088
16	3.216	4.674	1.421	3.020	2.074
24	3.229	4.699	1.435	3.058	2.081
Pooled SEM	0.018	0.040	0.049	0.043	0.034
p-value					
Main effect of DDGS	0.3919	0.7113	0.7450	0.0634	0.9838
Linear	-	0.4045	0.5289	0.8789	0.9251
Quadratic	-	0.8025	0.8954	0.6058	0.9729

[a-c]Means within a column without common superscripts are not significantly different ($p \leq 0.05$)

[1]6 replicate pens of 11 birds per pen. [2]9 replicate pens of 11 birds per pen

For the finisher I period, there were no significant differences in 42 d BW and FC, however, body weight gain (BWG) was found to be decreased (p = 0.0281) in birds fed the 30% LF-DDGS diets. These differences in BWG resulted in increased (p = 0.0006) FCR for birds fed the 30% LF-DDGS. Additional statistical analysis indicates a significant linear response in BWG (p = 0.0099) and FCR (p = 0.0039) to increasing LF-DDGS inclusion rates. This may indicate that feeding 30% LF-DDGS in finisher I diets may be too high. The proximate analysis of the experimental diets (Table 3) indicate the 30% LF-DDGS, as expected, had higher crude fiber content (4.11%) compared to the 0% LF-DDGS diet (2.36%). As monogastrics, broilers are unable to digest fiber effectively; this may have caused the decrease in BWG, despite the increase in crude protein observed for diets with increasing amounts of LF-DDGS. It has been suggested by previous studies that high inclusion rates of conventional DDGS may be marginally deficient in tryptophan, isoleucine and arginine, which may have caused the weight gain depression seen in birds fed 30% LF-DDGS in the finisher I phase (Wang *et al*., 2007b). Additionally, several reports have indicated that high levels of conventional DDGS inclusion may adversely affect pellet quality (Loar *et al*., 2010; Shim *et al*., 2011; Wang *et al*., 2007b). The beneficial effects of pelleting on broiler performance and feed conversion have been well discussed in the literature (Jensen *et al*., 1962; Nir *et al*., 1994; Briggs *et al*., 1999). Pellet quality was not measured in this current study, however, based on results obtained with conventional higher fat content DDGS, it would be expected that the LF-DDGS would have similar effects on pellet quality based on particle size and bulk density (Loar *et al*., 2010).

Wang *et al*. (2007a) indicated that diets containing 15% conventional DDGS could be fed from 1 to 42 d of age without any detrimental effects while diets with 30% DDGS had reduced body weight and elevated FCR when diets were formulated on a digestible amino acid basis. Previous research has indicated that broilers in the finishing phases of production could be fed up to 15% conventional DDGS (Lumpkins *et al.*, 2004). Shim *et al.* (2011) reported 42 d broilers showed improved performance for diets including DDGS up to 24% of the diet. The results of the current study indicate that even though the dietary energy of DDGS may be reduced through oil extraction methods, feeding a lower fat DDGS may have similar inclusion rate trends as a conventional DDGS. The previously reported studies stress that dietary energy and digestible amino acid levels should be maintained when formulating diets with a conventional DDGS (Waldroup *et al.*, 1981; Loar *et al.*, 2010; Wang *et al.*, 2007a, b). The results of the current study are in agreement with these previous results using conventional non-oil extracted DDGS and an oil-extracted DDGS, with live production being maximized at 18% LF-DDGS inclusion rate in birds at 42 d of age.

For the Finisher II phase (aged 43 to 56 d), there were no significant differences in live performance in diets fed with or without varying levels of LF-DDGS. This is in support of our hypothesis that older birds could tolerate higher levels of LF-DDGS compared to younger birds since there were no significant differences in 56 d BW, BWG, FC and FCR. The non significant results also indicate no detrimental effect of feeding high levels (up to 24%) of a fat extracted DDGS product during the finisher II phase of production.

Processing characteristics: Absolute processing weights and yields relative to live weight are presented in Table 5. Live weights and processing absolute processing weights at 43 d were not significantly different amongst the different dietary treatments. However, carcass yield (devoid of neck, giblets and fat) was increased (p = 0.0084) at 12% LF-DDGS inclusion when compared to the 24 and 30% LF-DDGS inclusion. However, this increased carcass yield was not found to be significantly different to a diet with 0% LF-DDGS added. This difference may be attributed to the increased protein in the 12% LF-DDGS diets (Table 3). At 57 d, processing weights and yields were not found to be significantly affected by LF-DDGS inclusion. These results indicate there were no significant differences in carcass characteristics from feeding a diet either with or without LF-DDGS and agree with previous studies that fed conventional DDGS to broilers (Loar *et al.*, 2010; Lumpkins *et al.*, 2004; Wang *et al.*, 2007a, b). Live performance in previous studies were found to be significantly different but resultant carcass data was unaffected by the inclusion of DDGS. Lumpkins *et al.*, (2004) reported that broilers fed an 18% conventional

Table 5: Effect of LF-DDGS inclusion level on carcass composition of 43 and 57 d male broilers

	D 43										
	Absolute wt (g)							Yield, relative to live weight (%)			
% LF DDGS	Live[2]	Carcass[3]	Fat	Fillet[4]	Tender[5]	Total breast[6]	Carcass	Fat	Fillet	Tender	Total breast
0	2625	1920	27	461	98	559	73.46[a]	0.98	17.49	3.73	21.22
6	2699	1970	28	481	100	581	73.21[ab]	1.04	17.77	3.69	21.48
12	2623	1914	28	471	98	569	73.52[a]	1.03	17.87	3.71	21.61
18	2722	1975	28	483	98	581	72.89[abc]	1.02	17.66	3.59	21.26
24	2577	1870	25	458	96	553	72.75[bc]	0.95	17.71	3.68	21.41
30	2598	1872	29	461	94	554	72.29[c]	1.08	17.61	3.59	21.22
Pooled SEM	52	38	1	12	2	14	0.176	0.145	0.156	0.084	0.158
p-value	0.1740	0.1156	0.3066	0.3862	0.4101	0.3778	0.0084	0.5241	0.8284	0.3109	0.7764
	D 57										
0	4614	3508	79	976	179	1155	75.57	1.63	20.94	3.83	24.79
8	4665	3467	77	964	178	1142	75.18	1.63	20.81	3.84	24.65
16	4595	3490	78	972	180	1152	75.74	1.67	20.98	3.89	24.88
24	4659	3520	80	988	182	1170	76.12	1.69	21.25	3.91	25.17
Pooled SEM	47	37	3	16	4	19	0.01	0.00	0.00	0.00	0.00
Main	0.6313	0.7719	0.7817	0.7684	0.9380	0.7830	0.8084	0.7958	0.8045	0.8647	0.7879
Linear	0.7217	0.7592	0.5971	0.5597	0.5789	0.5374	0.4717	0.3233	0.4445	0.4017	0.4010
Quadaratic	0.9060	0.3389	0.3198	0.3799	0.7842	0.4155	0.5682	0.8766	0.5327	0.9760	0.5660

[a-c]Means without common superscripts are significantly different ($p \leq 0.05$). [1]6 replicate pens of 6 birds processed, [2]After a 12 h overnight fast, [3]Hot carcasses without fat pad, giblets and neck, [4]Pectoralis major. [5]Pectoralis minor, [6]Summation of the pectoralis major and minor muscles

DDGS diet significantly affected overall growth performance in 42 d broilers but resultant carcass composition was not affected by the higher inclusion rates of DDGS. Including 18% DDGS significantly affected live performance for birds in the starter phase (0 to 16 d), but not the grower or finisher phases which partially explain the overall growth depression observed in that study (Lumpkins *et al.*, 2004). Loar *et al.* (2010) also reported no significant differences in processing yields in 42 d broilers fed conventional DDGS included at 8% of the diet.

Conclusion: In conclusion, broilers diets formulated with up to 24% LF-DDGS was found to have significantly higher BWG during the finisher I phase (28 to 42 d). Carcass yield was found to be significantly increased for 12% LF-DDGS inclusion rates when compared to diets formulated with higher LF-DDGS diets (>24% LF-DDGS inclusion), however, this was not different to a diet formulated with no LF-DDGS. For the finisher II period (43 to 56 d), there were no significant differences in live performance and processing characteristics and indicate that feeding older birds up to 24% LF-DDGS has no detrimental effects on broiler performance. Despite the reduced energy content of oil-extracted DDGS, it is concluded that including LF-DDGS in broiler diets may be similar to feeding a conventionally produced, non-fat extracted.

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