International Journal of Animal and Veterinary Advances 3(3): 205-211, 2011
ISSN: 2041-2908

Received: March 07, 2011 Accepted: April 20, 2011 Published: June 10, 2011

Effects of Feeding Different Levels of Corn Dried Distillers Grains with Solubles on Growth Performance, Carcass Yield and Meat Fatty Acid Composition in Broiler Chickens

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Abstract: A randomized complete design with 6 replicates of 10 birds per treatment (n = 60) was utilized to evaluate the effects of feeding corn dried distillers grains with solubles (CDGS) on growth performance, carcass yield and breast muscle fatty acid composition of chickens. A total of 300 male broilers (Cobb 500) were fed with different levels of CDGS (0% - control, 5, 10, 15 and 20%) in starter (age 0 to 21 day) and grower (age 21 to 42 day) diets, and weight gains and feed intakes were recorded. All diets were formulated isocaloric and isonitrogenous which met or exceeded the NRC requirements. At the end of the experiment (42 day) eight birds from each treatment were slaughtered to measure the dressing percentage, carcass parts yield and fatty acid profile of breast meat (from the left carcass side). Birds fed 5% CDGS had better ($p<0.05$) feed conversion ratio than those fed 10, 15 or 20%, but were not different ($p>0.05$) from control. There were no differences ($p>0.05$) in overall weight gain, feed intake, dressing percentages and carcass parts yields (% of carcass weight) among treatments. There were greater ($p<0.05$) percentages of linoleic acid (18:2 *n-6*) and elevated ($p<0.05$) polyunsaturated to saturated fatty acid ratios in chicken breast meat with increasing dietary CDGS. In conclusion, incorporating 5% of CDGS in the broiler diet did not affect ($p>0.05$) the growth performance and carcass yield. However, increasing the dietary CDGS increased ($p<0.05$) the percentage of linoleic acid and polyunsaturated to saturated fatty acid ratio in chicken breast meat.

Key words: Broiler chickens, corn distillers dried grains with solubles, growth performance, meat fatty acid composition

INTRODUCTION

Corn Distillers Dried Grains with solubles (CDGS) is a co-product after corn starch is fermented for ethanol fuel using dry milling technology (Davis, 2001; Butzen and Haefele, 2008). It contains all the nutrients remaining in the corn kernel in which the non-starch nutrients are three times concentrated of the original nutritional value of the corn (Davis, 2001). Hence, CDGS contains good source of energy, protein and available phosphorus (P). With the new processing technologies used in recently built ethanol plants the nutrient profiles of CDGS have improved and such CDGS became available for feeding livestock (Noll *et al.*, 2007).

One of the biggest challenges in using CDGS as a source of feed is the variation in nutrient concentrations among CDGS sources and processing plants (Cromwell *et al.*, 1993; Spiehs *et al.*, 2002; Belyea *et al.*, 2004). The high variability among sources was found especially for concentrations of lysine, methionine and minerals (Swiatkiewicz and Koreleski, 2008). Fastinger *et al.* (2006) noted that the lysine concentration in five different sources of CDGS ranged from 0.48 to 0.76%. These differences could be attributed to variation in original grain composition, efficiency of starch fermentation during ethanol production and fermentation scale up, different amount of solubles added back, and drying procedures (Swiatkiewicz and Koreleski, 2008). In addition, CDGS contains considerable amount of anti-nutritional factors such as arabinoxylan (Kim *et al.*, 2008) and its high fibre (8.8-10.2%) could affect the nutrient utilization in poultry and so limit the CDGS dietary inclusion. The high fibre can also decrease the nutrient digestibility of other dietary ingredients (Spiehs *et al.*, 2002).

Earlier work showed that feeding low level of CDGS (approximately 5%) in broiler diets improved weight gains (Day *et al.*, 1972) and a higher inclusion level was

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not detrimental to growth performance when metabolizable energy and lysine level were constant and sufficient in the broiler diets (Waldroup *et al.*, 1981; Parsons *et al.*, 1983). More recently, the 'new generation' of CDGS was utilised in poultry feed; incorporating 5% CDGS in broiler starter diet and up to 12 to 15% in grower diet had no negative impact on production parameters (Lumpkins *et al.*, 2004; Choi *et al.*, 2008), while higher inclusion levels at 15 to 25% CDGS decreased dressing percentage and breast meat yield (Wang *et al.*, 2007; Lumpkins *et al.*, 2003). Corzo *et al.* (2009) reported a greater percentage of linoleic acid and total Polyunsaturated Fatty Acids (PUFA) when 8% CDGS was added in broiler diets. This finding was further confirmed by Schilling *et al.* (2010) and Choi *et al.* (2008) who showed that increasing CDGS level in broiler diets significantly increased the concentration of linoleic acid, PUFA and Unsaturated Fatty Acids (UFA) in chicken meat.

Most of the previous work on CDGS in poultry involved that from the United States. Variations in geographic locations of growing corn and different processing methods could result in differences in nutrient content of CDGS. Thus the objective of the present experiment was to determine the effects of different dietary levels (5, 10, 15 and 20%) of a Chinese CDGS source on the broiler growth, carcass yield and meat fatty acid composition.

MATERIALS AND METHODS

Diets and animal management: The CDGS used in the present experiment was obtained from a corn-based ethanol plant in Jilin Province, China. It had a golden yellow colour, a coarse appearance, and a distinctively sweet smell. A dried sample of CDGS was ground and analysed for Dry Matter (DM), Crude Protein (CP), Ash, Ether Extract (EE), Crude Fibre (CF), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Gross Energy (GE), Amino Acids (AA), Calcium (Ca) and P (Table 1) following the procedure outlined by AOAC (2007). Five starter and five grower diets were prepared and fed to chicks at age 0 to 21 d and 21 to 42 d, respectively (Table 2). Corn-soybean meal-based diets without CDGS served as controls, while the remaining four diets in both age groups contained CDGS at levels of 5, 10, 15 and 20%, respectively. All diets were isocaloric and isonitrogenous formulated to meet or exceed the NRC (1994) requirements, and were offered in mash form.

The study was conducted at the Poultry Research Unit, Department of Animal Science, Universiti Putra Malaysia during the period of January to February 2009. A total of 300 male day-old chicks of a commercial broiler strain (Cobb 500) were obtained from a local hatchery and randomly distributed into 30 cages with 6 replicate cages per treatment (10 chicks per cage) in a complete randomized design. The cages were in a conventional open-sided house with cyclic temperatures (minimum 24ºC and maximum 35ºC). Equal number of birds was fed one of five diets containing 0 (control), 5, 10, 15 or 20% of CDGS. The chicks were vaccinated against Newcastle disease at 7 d via eye drop and received 24 h of light daily. They had free access to feed and water throughout the experiment. Individual body weights and feed intakes were recorded weekly, and mortalities were recorded daily.

Table 1: Chemical composition (% as fed) of Corn Distillers Dried Grains with solubles (CDGS) from China

Nutrient	CDGS
Dry matter (%)	91
Gross energy (kcal/kg)	4369
Crude protein (%)	29
Crude fat (%)	6.4
Crude fiber (%)	10
Ash (%)	4.6
Neutral detergent fiber (%)	52.3
Acid detergent fiber (%)	23.3
Calcium (%)	0.02
Phosphorus (%)	0.49
Lysine (%)	0.89
Methionine (%)	0.53
Threonine (%)	1.73
Arginine (%)	0.98
Tryptophan (%)	0.19

Measurements at Slaughter: At 42 d of age, live weights were determined after a 12-h of fasting and eight birds from each treatment group were randomly selected for slaughter. The abdominal fat pad was dissected and weighed as described by Griffiths *et al.* (1977) and Cahaner *et al.* (1986). Carcass yield, abdominal fat percentage, and whole breast, thigh-drumsticks and wings yields were determined. Carcase weight yield was calculated as percentage of live weight. The skin of the left breast was removed and the exposed *Pectoralis superficialis* was stored at -20ºC for fatty acid analysis.

Fatty acids: The fat was extracted from breast muscle according to Folch *et al.* (1957) as modified by Rajion (1985). Transmethylation of the extracted fatty acids to their Fatty Acid Methyl Esters (FAME) were carried out according to AOAC (2007) and subsequent methyl esters were quantified by gas chromatography (Agilent 7890N). The chromatography column temperature program initiated runs at 100ºC for 2 min, warmed to 170ºC at 10ºC/min, held for 2 min, warmed to 220ºC at 7.5°C/min, and then held for 20 min to facilitate optimal separation. The injector temperature was programmed at 250ºC and the detector temperature was 300ºC. Identification of fatty acids was carried out by comparing relative FAME peak retention times of samples to standards obtained from Sigma (St. Louis, MO, USA). The normalized percentage of total fatty acids was used to determine the differences in fatty acid composition (Alfaia *et al.*, 2006).

Table 2: Composition of the starter and grower experimental diets without (control) and with different percentages of corn distiller dried grains with solubles (CDGS)

	Starter diets (chicks age 0 to 21 d)					Grower diets (chicks age 21 to 42 d)				
Item	Control	5% CDGS	10% CDGS	15% CDGS	20% CDGS	Control	5% CDGS	10% CDGS	15% CDGS	20% CDGS
Ingredient, % as fed										
Corn grain	37.39	35.02	32.65	30.27	27.88	49.31	46.93	44.56	42.16	39.61
SBM[1]	41.58	38.94	36.31	33.67	30.97	36.80	34.17	31.54	28.82	27.97
CDGS (China)	-	5.000	10.00	15.00	20.00	-	5.000	10.00	15.00	20.00
Rice bran	9.99	10.02	10.04	10.06	10.14	2.81	2.83	2.85	2.95	1.39
Palm oil	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Limestone	1.19	1.24	1.29	1.34	1.39	1.19	1.24	1.29	1.34	1.38
Dical. phosphate	1.22	1.17	1.11	1.06	1.01	1.31	1.25	1.2	1.15	1.09
Sodium chloride	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Premix[2]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
DL-Methionine	0.22	0.21	0.20	0.20	0.19	0.18	0.18	0.16	0.16	0.13
L-Lysine HCL	-	-	-	-	0.02	-	-	-	0.03	0.03
Calculated composition										
ME, (kcal/kg)	3,050	3,050	3,050	3,050	3,050	3,200	3,200	3,200	3,200	3,200
Crude protein, (%)	22.2	22.2	22.3	22.3	22.4	20.3	20.3	20.4	20.4	21.0
Lysine, (%)	1.37	1.32	1.28	1.23	1.20	1.21	1.17	1.12	1.10	1.10
Methionine, (%)	0.51	0.51	0.51	0.53	0.53	0.42	0.43	0.43	0.44	0.44
Crude fibre, (%)	4.17	4.44	4.70	4.97	5.24	3.01	3.27	3.54	3.80	4.02
Crude fat, (%)	9.13	9.43	9.74	10.0	10.3	8.16	8.46	8.76	9.07	9.18

[1]Soybean meal, 42% crude protein; [2]Premix provided the following (per kilogram of diet): vitamin A, 2300 IU; vitamin D3, 400 IU; vitamin E, 1.8 mg; vitamin B12, 3.5 mg; riboflavin, 1.4 mg; panthotenic acid, 2 mg; nicotinic acid, 7 mg; pyridoxine, 0.25 mg; folic acid, 0.15 mg; menadione, 0.3 mg; thiamin, 0.15 mg; manganese oxide, 35 mg; ferrous sulfate 35 mg; zinc oxide, 30 mg; copper sulfate, 60 mg; cobalt carbonate, 5 mg; potassium iodine, 0.6 mg; selenium vanadate, 0.09 mg

Table 3: Analyzed fatty acid composition of the experimental diets and of pure corn distillers dried grains with solubles (CDGS) (% of total fatty acids)

Analyzed fatty acid[1]	Control	5% CDGS	10% CDGS	15% CDGS	20% CDGS	Pure CDGS
Total SFA	37.39	36.92	36.54	36.25	36.14	21.96
C8:0 (Caprylic)	0.06	0.06	0.06	0.04	0.07	0.08
C10:0 (Capric)	0.02	0.02	0.02	0.02	0.02	0.02
C12:0 (Lauric)	0.27	0.28	0.27	0.27	0.26	0.02
C14:0 (Myristic)	0.77	0.75	0.74	0.73	0.71	0.07
C14:1 (Myristoleic)	0.04	0.04	0.03	0.03	0.03	0.11
C15:0 (Pentadecanoic)	0.04	0.04	0.04	0.04	0.04	0.10
C16:0 (Palmitic)	31.39	30.91	30.58	30.33	30.08	16.67
C18:0 (Stearic)	3.67	3.62	3.57	3.58	3.54	2.62
C19:0 (Nonadecanoic)	0.09	0.10	0.09	0.09	0.09	0.06
C20:0 (Arachidic)	0.95	1.01	1.01	1.01	1.06	1.99
C24:0 (Lignoceric)	0.12	0.13	0.14	0.13	0.14	0.33
Total MUFA	40.94	40.69	40.40	39.99	39.43	23.86
C16:1 (Palmitoleic)	0.16	0.16	0.17	0.16	0.16	0.16
C17:1 (Heptadecenoic)	0.08	0.08	0.07	0.05	0.05	0.15
C18:1 (Oleic)	40.43	40.17	39.90	39.52	38.95	23.09
C15:1 (*cis*-10-Pentadecanoic)	0.03	0.04	0.03	0.04	0.04	0.06
C20:1 (Eicosenoic)	0.19	0.20	0.20	0.20	0.20	0.29
Total PUFA *n-3* (α-Linolenic)	0.42	0.42	0.42	0.43	0.43	0.45
Total PUFA *n-6* (Linoleic)	21.26	21.97	22.64	23.34	24.00	53.73
Total UFA	62.61	63.08	63.46	63.75	63.86	78.04
n-6 : *n-3* ratio	50.99	51.76	53.66	54.70	56.37	120.12
UFA:SFA ratio	1.67	1.71	1.74	1.76	1.77	3.55
PUFA:SFA ratio	0.58	0.61	0.63	0.66	0.68	2.47

[1]: SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; UFA = unsaturated fatty acids

Statistical analysis: Data were analysed as a completely randomized design and subjected to one-way ANOVA using the GLM procedure of SAS software (SAS Institute, 2004). Duncan multiple range test was used to determine significance of differences among treatment means. The differences were declared significant at $p<0.05$.

RESULTS AND DISCUSSION

All the previously reported nutrients in CDGS were about two to three times more concentrated than in corn grain, except for GE and AA that were similar to those in corn grain (Spiehs *et al*., 2002). The nutrient composition of the CDGS used in the present experiment (Table 1) was different to those in USA (average nutritive value of 49 samples) analyzed at the University of Minnesota (UMN, 2009). It though had higher CF (10% *vs* 7.4%), and lower crude fat (6.4% *vs* 11.2%) and total P (0.49% *vs* 0.79%). However the presently used CDGS had higher NDF (52.3% *vs* 32.2%) and ADF (23.3% *vs* 11.9%), but lower GE (4369 kcal/kg *vs* 4900 kcal/kg) than that reported by Fastinger *et al.* (2006). The above differences in nutrient content were due to different geographic locations (China *vs* US) and processing methods used for production of ethanol (Belyea *et al*., 2004).

There was a slight change in fatty acid composition of diets when the level of CDGS increased (Table 3). Total Saturated Fatty Acids (SFA) and Monounsaturated Fatty Acids (MUFA) were reduced (1 and 1.5%,

Table 4: Growth performance of broilers fed starter (chicks age 0 to 21 d) and grower (chicks age 21 to 42) diets without (control) and with different percentages of Corn Distiller Dried Grains with solubles (CDGS)

Item	Control	5% CDGS	10% CDGS	15% CDGS	20% CDGS
Weight gain, g/bird					
0 to 21 d	804±13.3^{a}	1152±11.3	1.41±0.05	809±9.46 ^{a}	1130±20.0
22 to 42 d	1491±28.8	2949±26.6	1.98±0.04^{b}	1538±21.0	3038±38.5
0 to 42 d	2305±34.2	4108±29.9	1.78±0.03^{b}	2347±24.8	4170±41.0
Feed intake, g/bird					
0 to 21 d	1.40±0.02	808±11.6^{a}	1174±17.5	1.42±0.04	782±19.4^{b}
22 to 42 d	1.97±0.02^{b}	1470±25.2	3157±94.1	2.11±0.04^{a}	1513±22.4
0 to 42 d	1.77±0.01^{b}	2281±30.7	4333±105	1.88±0.02^{a}	2288±28.4
Feed conversion ratio, g fed/g gain					
0 to 21 d	1130±20.4	1.42±0.03	767±13.4^{b}	1122±22.8	1.47±0.04
22 to 42 d	3143±51.9	2.08±0.03^{a}	1471±21.7	3076±32.1	2.09±0.03^{a}
0 to 42 d	4281±44.3	1.87±0.03^{a}	2244±27.3	4198±37.9	1.87±0.02^{a}

^{a,b}: Means within each row with no common superscripts differ significantly (p<0.05)

respectively) but the polyunsaturated fatty acids (PUFA) were increased (2.7%) across the experimental diets. The marked differences among diets were due to the higher content of linoleic acid in CDGS (53.5%) which affected the overall PUFA content in diets. In the current experiment, dietary PUFA to SFA ratio increased with the dietary polyunsaturation.

The birds in the present experiment fed diets with 15 and 20% of CDGS showed poorer (p<0.05) weight gains at age 0-21 than the other dietary groups. Thereafter, weight gains were not affected (p>0.05) by diet. Lumpkins *et al*. (2004) observed that higher level of CDGS (12 and 18%) depressed weight gains in the starter period but not at 42 d of age when chicks were fed isocaloric and isonitrogenous diets containing 12% CDGS (Table 4). The authors indicated that younger birds were less tolerant to high levels of CDGS, but grower chicks could efficiently use higher levels of CDGS. The present findings are in agreement with those of Lumpkins *et al.* (2004) and Wang *et al.* (2007) that different dietary levels of CDGS (0 to 20%) had no significant effect on feed intake. Diets in the present experiment were isocaloric, thus all chicks needed to consume a similar amount of feed to meet their metabolic energy requirement. On the contrary, Alenier and Combs (1981) reported that pullets showed preference for diets with 10% CDGS as compared to a corn-soy diet. However, genetic variation in dietary selection has been reported in poultry (Forbes and Shariatmadari, 1994).

Although there was no significant difference in weight gain and feed intake, birds fed diets with 10, 15 and 20% CDGS had poorer (p<0.05) Feed Conversion Ratio (FCR) than the other groups. The overall FCR of chickens fed diets with 0 and 5% CDGS were similar. Lumpkins *et al.* (2004) suggested that the safe inclusion level of CDGS was 6% in starter diets and 12-15% in grower and finisher diets. Wang *et al.* (2007) formulated diets based on digestible amino acid levels and found that dietary inclusion up to 25% of CDGS had negligible effect on body weight but resulted in poorer FCR. Our present finding showed that safe inclusion level of CDGS was only 5%, which is probably due to the different quality between Chinese and US sources of CDGS. Several authors reported the variability of nutrient content and digestibility of CDGS among different source and processing plants (Cromwell *et al.*, 1993; Spiehs *et al.*, 2002; Belyea *et al*., 2004). The Chinese CDGS used in the present experiment contained higher NDF (52.3%) and ADF (23.3%) when compared to US sources (Fastinger *et al.*, 2006) with lower NDF (32.2%) and ADF (11.9%). Wen *et al*. (2010) also found that ADF content in Chinese CDGS was higher than in that from North America, and the increase in the ADF content in CDGS was found to correlate with weight gains (Cromwell *et al*., 1993). The concentration of non-starch polysaccharide (NSP) was not determined in the present experiment, however, it was found that CDGS contained 11-13.5% of arabinoxylan out of 22.7% of total NSP (Ward *et al.*, 2008; Kim *et al.*, 2008). Hence, feeding chicks with higher level of CDGS (>10%) is believed to decrease the digestibility of starch, protein and fat (Choct and Annison, 1990) and thereby limits the maximum inclusion of CDGS in the broiler diet. The exposure of CDGS to high ambient temperature however, may have adversely affected protein and amino acid digestibilities of complete diets (Wallis and Balnave, 1984) or individual feed ingredients (Zuprizal *et al.*, 1993). Nevertheless, Lumpkins *et al*. (2004) attributed the poorer FCR among birds fed increasing levels of CDGS to increase in the dietary protein of corn origin and decrease in the dietary protein from soybean meal which caused marginal lysine deficiency. The diets were different in lysine level (Table 2), where the level of lysine content was decreased when increasing levels of CDGS. Hence, it is possible cause of poorer growth performance at 21 day-old chicks with higher inclusion CDGS in broiler starter diets.

There were no differences (p>0.05) among treatments in dressing percentage and parts yields of carcass (Table 5). However, dressed carcass weight of broilers fed with 5% CDGS was higher (p<0.05) than in those fed with 15 and 20% CDGS. The present findings are in agreement with those of Lumpkins *et al.* (2004). On the other hand, Wang *et al.* (2007) reported that broilers fed 15 or 20% CDGS showed some losses in dressing

Table 5: Dressing percentage and carcass parts yields of broilers fed diets without (control) and with different percentages of corn distiller dried grains with solubles (CDGS)

		Yields, %[1]			
Diet	Dressing percentage	Breast (bone-in)	Thigh-drumstick	Wings	Abdominal fat
Control	75.4±0.5	34.1±0.8	39.0±0.6	9.94±0.24	1.00±0.11
5 % CDGS	75.2±0.6	34.2±0.8	38.6±0.5	10.03±0.26	1.35±0.22
10 % CDGS	75.8±0.5	35.2±0.8	38.1±1.2	9.90±0.25	1.20±0.16
15 % CDGS	75.3±0.4	32.8±0.6	39.0±0.8	10.29±0.13	1.41±0.22
20 % CDGS	74.5±1.3	32.6±0.5	39.3±0.5	10.62±0.24	1.01±0.17

[1]Percentage of hot carcass weight

Table 6: Fatty acid profile of breast meat of broilers fed diets without (control) and with different percentages of corn distillers dried grains with solubles (CDGS)

Fatty acid[1]	Control	5% CDGS	10% CDGS	15% CDGS	20% CDGS
Total SFA	38.13±0.52	37.04±0.87	34.17±0.87	36.22±1.11	36.49±1.01
C8:0 (Caprylic)	0.56±0.11	0.68±0.08	0.47±0.11	0.59±0.11	0.39±0.04
C10:0 (Capric)	1.86±0.17[a]	0.73±0.17[b]	0.86±0.14[b]	1.96±0.51[a]	1.89±0.30[a]
C14:0 (Myristic)	0.51±0.04[ab]	0.62±0.03[a]	0.62±0.04[a]	0.46±0.06[b]	0.47±0.05[b]
C15:0 (Pentadecanoic)	0.60±0.06	0.47±0.12	0.53±0.12	1.03±0.19	0.71±0.18
C16:0 (Palmitic)	23.44±0.17[a]	24.04±0.30[a]	23.08±0.24[ab]	21.97±0.44[c]	22.30±0.51[bc]
C18:0 (Stearic)	11.16±0.40	10.49±0.62	8.59±0.86	10.20±0.77	10.39±0.64
Total MUFA	33.87±0.81	34.34±1.73	37.35±0.34	33.38±1.88	32.53±1.72
C14:1 (Myristoleic)	0.76±0.22[b]	0.47±0.09[b]	0.74±0.12[b]	1.27±0.22[a]	1.20±0.19[a]
C16:1 (Palmitoleic)	1.38±0.13	1.32±0.16	1.52±0.24	1.09±0.15	1.07±0.20
C17:1 (Heptadecenoic)	1.09±0.03	0.99±0.11	0.66±0.12	0.97±0.15	0.92±0.09
C18:1 (Oleic)	30.65±0.63	31.56±0.69	34.40±2.28	29.61±2.07	29.34±1.80
Total PUFA	27.99±0.55	28.62±0.94	28.48±1.59	30.39±0.89	30.98±0.95
C18:2 *n-6* (Linoleic)	18.29±0.30[b]	19.54±0.21[a]	20.13±0.47[a]	20.45±0.60[a]	19.49±0.55[a]
C20:3 *n-6* (Eicosatrienoic)	1.63±0.13	1.30±0.13	1.01±0.18	1.28±0.15	1.15±0.12
C20:4 *n-6* (Arachidonic)	8.05±0.38	7.70±0.99	7.19±1.55	8.72±1.09	10.31±1.29
Total Unsaturated	61.87±0.52	62.96±0.87	65.83±0.87	63.78±1.11	63.51±1.01
UFA:SFA ratio	1.63±0.03	1.71±0.06	1.94±0.08	1.78±0.10	1.76±0.08
PUFA:SFA ratio	0.73±0.02[c]	0.77±0.01[bc]	0.83±0.03[ab]	0.84±0.02[a]	0.85±0.02[a]

[a,b,c]: Means within each row with no common superscripts differ significantly ($p<0.05$); [1]SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; UFA = Unsaturated fatty acids

percentage and breast meat yield. The authors, however, did not maintain constant dietary ME. Thus, the energy content declined as the level of dietary CDGS increased (Waldroup *et al*., 1981).

The breast meat of chicks fed 15 and 20% CDGS had significantly higher capric acid (C10:0) but lower myristic acid concentrations than those fed 5 and 10% CDGS (Table 6). Feeding birds 15 and 20% CDGS significantly reduced the level of palmitic acid in breast meat when compared to the other treatments. Ponte *et al.* (2008) reported that palmitic acid was the most abundant saturated fatty acid in chicken breast meat. Reduction in palmitic acid concentration in chicken meat with increasing level of CDGS has been reported by Schilling *et al.* (2010) and Choi *et al.* (2008) who also observed that low dietary inclusion of CDGS did not alter the palmitic acid concentration in chicken meat.

On the contrary, the concentration of myristoleic acid (C14:1) in breast meat was significantly increased with higher level of CDGS at 15 and 20% in the present experiment. There was no significant difference in the total fatty acids (SFA, MUFA and PUFA) in chicken breast meat among treatments. This finding was similar to others showing that the dietary polyunsaturation level of fat does not influence intramuscular lipid content (Scaife *et al.*, 1994; Crespo and Esteve-Garcia, 2001).

Irrespective of level, feeding chicks with CDGS significantly increased the linoleic acid (C18:2 n-6) concentration in breast meat when compared to control in the present experiment. Increasing the dietary level of CDGS over 10% significantly elevated the PUFA:SFA ratio in the breast meat. However, Schilling *et al.* (2010) observed a significant linear increase in linoleic acid and PUFA in thigh meat as CDGS concentration increased in broiler diet. These discrepancies could be attributed to the higher proportion of phospholipids to neutral lipids (higher C-18 SFA than C-18 mono- or di-PUFA) in breast than thigh muscle (Marion and Woodroof, 1965). Besides, there was a slight change in the dietary linoleic acid when increasing the inclusion rate of CDGS (Table 2). Thus, tissue concentration probably responds in lesser extent to dietary changes which alter the fatty acid composition in breast meat (Cortinas *et al.*, 2004). In addition, fiber content of CDGS can influence the fat digestibility (Choct and Annison, 1990) and limit the deposition of fatty acid in chicken meat. Thus, the effect of increased dietary CDGS on linoleic acid content in breast meat in the present experiment was less significant than reported by Schilling *et al*. (2010).

CONCLUSION

The present results showed that incorporating 5% of CDGS in broiler diet has minimal effects on growth performance and carcass yield of chicks. There was a significant increase in the percentage of linoleic acid and PUFA:SFA ratio in chicken breast meat when the dietary CDGS was increased to between 10 to 20%.

ACKNOWLEDGMENT

Funding for this project was provided by Alltech Biotechnology Corporation Limited (Kentucky, USA). The authors would like to thank M. Ivan for critical reading of the manuscript.

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