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Investigating Meat Quality of Broiler Chickens Fed on Heat Processed Diets Containing Corn Distillers Dried Grains with Solubles

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OPEN ACCESS

Received October 24, 2017

Revised February 20, 2018

Accepted March 7, 2018

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Abstract The present study investigated the effects of feed form and distiller's dried grain with solubles (DDGS) on meat quality and fatty acids profile of broiler chickens. A total of 720 broilers (Ross 308; average BW [body weight] 541±5.7 g) were randomly allotted to six treatments. Birds were fed three different feed forms (mash; SP, simple pellet; EP, expanded pellet) and DDGS (0 or 200 g kg⁻¹) in a 3×2 factorial arrangement. The addition of DDGS and EP to the diet resulted in increased shear force of breast meat. Moreover, DDGS inclusion in the diet reduced the concentration of stearic acid and behenic acid in thigh meat. Pelleting (SP and EP) of the diets increased palmitic acid content in the thigh, whereas the linolenic acid content decreased. The breast mass was higher with EP and SP diets than with the mash diet. Feed processing led to increased pectoralis muscle and drum mass compared to mash-fed chickens. In conclusion, our results demonstrated that EP decreased thigh linolenic acid and meat shear force. In addition, DDGS supplementation in broiler hampers meat quality by increasing the shear force.

Keywords feed processing, pellet, expansion, broiler chicken, fatty acids profile

Introduction

Feed processing, such as pelleting and expanding, are widely used in the animal feed industry for improved, efficient growth resulting from improved starch digestibility (Tran et al., 2008) and reduce feed wastage (Kim et al., 2016). Previous studies have reported that broiler chickens fed on pelleted diet have increased dressing, breast meat, and thigh mass (Wang et al., 2008). Moreover, expansion process technology is commonly used for producing pet diet; however, recently, expansion cooking technology has seen increased application in preparing broiler diets as well.

The reason for the widespread use of expanding pellet process is the greatly improved final feed form (Kim et al., 2016) as the inclusion of ingredients that are cost-effective or difficult to be made into pellets cannot easily compromise the form of pellet in final product. Conversely, in line with the recent increases in the amount of dried distiller's grains with solubles (DDGS) production as a co-product of the dry-mill ethanol industry, the use of DDGS in poultry diets has increased as well. Thacker et al. (2007) suggested that up to 15% DDGS can be successfully incorporated into diets fed to broiler chicks. In addition, high levels of DDGS compromise the physical form of the pellet (Shim et al., 2011). The physical form of the diet has a significant impact on meat yield (Brickett et al., 2007). Furthermore, it is safe to assume that high temperatures required in making DDGS could affect the nutritional quality. Schilling et al. (2010) reported that inclusion of 24% DDGS in the diet affected the meat quality, probably because of the altered fatty acids content. However, little is known on the effect of diet heat processing and dietary DDGS proportion on the meat quality of broilers. Therefore, in this study, we tested the hypothesis that diet heat processing and inclusion of DDGS in broiler diet affects the carcass traits, meat quality, and fatty acids composition.

Material and Methods

Experimental procedures

The protocol for the present experiment was approved by the Institutional Animal Care and Use Committee of Kangwon National University, Korea. This experiment was designed to evaluate the interaction of feed processing and DDGS on the growth performance of broilers. A total of 720 broilers (Ross 308; average BW [body weight] 541 ± 5.7 g) were randomly assigned based on BW and sex to 6 dietary treatments. A randomized complete block design with a 3×2 factorial arrangement of treatments Isocaloric and isonitrogenous diets were used to investigate the response of broiler chickens to two levels of DDGS (0 and 200 g/kg diet), in mash, simple pellet (SP) and expanded pellet (EP) forms. Each treatment had 6 replicate pens with 20 broilers (10 males and 10 females) per pen. Prior to the experiment, the birds were fed a standard broiler starter diet and management from d 1 to 14.

The mash diet was formulated to contain $3,150 \text{ kcal kg}^{-1}$ of ME, 210.0 (g/kg diet) CP, and 11.0 (g/kg diet) total lysine; supplemented with vitamins, minerals and AA to meet or exceed the nutrient requirements listed in Ross 308 nutrition specification (Aviagen, 2014). For the SP diet, the mash diet was steam conditioned to 75°C and pelleted using a 220 hp pellet mill (Model M12, Matador, Denmark) with a 2.8 mm die in diameter. The EP was produced by subjecting the mash diet to a 300 hp expander (Model M12, Matador, Denmark) with 180 amperes, a gap opening of 39% and temperature of 105°C . The expanded diet was further processed through a pellet mill similar to the one used for the SP diet. The experiment duration was 21 d, and the final BW was approximately 2.02 kg.

The birds were housed in rice hull-covered floor pens. Each pen was provided with a self-feeder and hanging bell drinker to allow free access to feed and water. The house temperature was 23°C and lighting was provided for 23 h/d.

Sample preparation

At the end of experiments, 72 birds (2 birds per replicate) were randomly selected and slaughtered by cervical dislocation. The whole slaughtering process was in the local slaughter floor of the laboratory, to avoid birds suffering from stress due to long transport time, according to the specifications outlined in the Korean legislation. After bleeding for 2 min, birds were scalded in water at 60°C for 2 min before feather plucking by a machine, evisceration, and tissue sample collection.

Fatty acids analysis

The fatty acids profile was measured using the previously reported methods by Kim et al. (2014). In brief, all layers of adipose tissue from the left side thigh were utilized for fatty acids determination. Total lipid was extracted from the adipose tissue samples with a chloroform and methanol (2:1, v:v) mixture and quantified gravimetrically. Fatty acids in each lipid were derivatized to methyl esters according to Lepage and Roy (1986). Separation of fatty acid methyl esters was achieved by gas chromatography (GC-17A, Shimadzu, Japan) equipped with 100 m fused-silica capillary column with i.d. of 0.25 mm, a 0.20 m film coating and SPTM-2560 column stationary phase (Sigma-Aldrich Co. LLC, USA), and flame ionization detector. Helium (purity 99.99%) carrier gas was employed as a carrier gas at a constant column flow of 1.0 mL/min. Oven temperature was maintained at 175°C for 30 min, increased at 5°C per min to 215°C, and then increased at 10°C per min to 235°C. Injector and detector temperature was maintained at 260°C. Methyl ester standards were used to identify sample fatty acid methyl esters.

Meat quality and meat portions

Drip loss was measured using approximately 2 g of meat sample according to the plastic bag method described by Honikel (1998). Cook loss was determined as described previously by Sullivan et al. (2007). Briefly, 5 g of breast meat were heat-treated in plastic bags separately in a water bath (100°C) for 5 min. Samples were cooled at room temperature. Cooking loss was calculated as (sample weight before cooking – sample weight after cooking)/sample weight before cooking×100. The pH value was determined using pH meter (IstekNeoMet 77P, Istek Inc, Korea). The shear force was measured using a texture analyzer (TA-XT2i, Stable Microsystems Ltd., UK) equipped with a 25 kg load cell, a Warner-Bratzler shear blade, and a test speed setting at 2.0 mm/s. Only the maximum force (kg) was taken into account.

After slaughter, carcass traits like pectoralis muscle, supracoracoideus, total breast, breast skin, abdominal fat, thigh, drum, wing and back measured. They are expressed as percent of the live weight. Breast meat was also collected and the meat color values were measured freshly. The breast meat was allowed to air-dry for 30 min and Minolta color values were measured for lightness (L*), redness (a*) and yellowness (b*).

Statistical analysis

Data generated in this experiment was analyzed as a 3×2 factorial arrangement in a completely randomized design. Pen was the experimental unit for statistical analysis. Broiler chickens were experimental units for measuring the fatty acids profile, meat portions, meat quality. The main effects of feed processing and DDGS, and their interaction were determined by mixed procedure of SAS statistical program (SAS Inst., Inc., USA). *P*-values≤0.05 were considered statistically significant.

Results and Discussion

Meat quality

The data for meat quality parameters are presented in Table 1, which indicate that meat drip loss and cooking loss were not affected by the DDGS level or processed feed. Our results indicated that drip loss was not significantly influenced by dietary DDGS or feed processing. These results are consistent with the reports of previous studies (Corzo et al., 2009; Jiang et al., 2014), which showed that DDGS supplementation in broiler diet did not negatively affect drip loss and cooking loss. However, the addition of 25% DDGS in broiler diet significantly decreased cooking loss (Min et al., 2009). Administration of

Table 1. Effects of feed processing on chicken breast meat quality from broiler diets with or without distiller's dried grain with solubles (DDGS) for 21 d

Items	DDGS (g kg ⁻¹)		SEM	Feed processing (FP)			SEM	P-value		
	0	200		M	SP	EP		FP	D	FP×D
Drip loss (%)	26.9	27.0	0.26	27.4	27.0	26.5	0.32	0.120	0.875	0.777
Cooking loss (%)	15.6	15.7	0.34	16.1	15.6	15.3	0.42	0.443	0.783	0.615
Shear force (kg·f)	2.18	2.27	0.02	2.15 ^b	2.23 ^{ab}	2.29 ^a	0.03	<0.01	<0.01	0.257
CIE L*	52.7	51.8	0.51	51.4 ^b	53.6 ^a	51.7 ^{ab}	0.62	0.037	0.249	0.020
CIE a*	5.45	5.76	0.31	5.38	5.55	5.90	0.37	0.612	0.471	0.872
CIE b*	15.5	15.3	0.45	14.9	15.4	15.9	0.55	0.433	0.807	0.502
pH 15 _{min}	6.66	6.73	0.04	6.71	6.69	6.71	0.05	0.935	0.245	0.653

Values with different superscripts with in a same row significantly differ ($p < 0.05$).

M, mash; SP, simple pellet; EP, expanded pellet; SEM, standard error of means; FP, feed processing; D, distiller's dried grain with solubles.

DDGS and EP diet significantly increased ($p < 0.01$) the shear force of breast meat, which is consistent with the report Schilling et al. (2010). Jiang et al. (2014) reported that higher level of DDGS in broiler diet increased the shear force of breast meat. Therefore, higher dietary DDGS levels led to poor meat tenderness. However, the shear force was < 30 N in all samples, indicating that it would still be acceptable to consumers (Corzo et al., 2009; Schilling et al., 2010). Our result showed that broilers fed EP diet showed increased shear force. The relationship between muscle shear force and processed feed has not been concretely established yet. There was an interaction between feed processing and DDGS level with meat lightness (L*), indicating a lighter breast meat color. However, Jiang et al. (2014) found that dietary DDGS had no effect on meat color. Conversely, our results indicated that meat color was significantly influenced by processed feed.

Fatty acids profile

The effect of DDGS content and processed feed on fatty acids profile of the thigh is presented in Table 2. On adding DDGS to the diet, C18:0 and C22:0 were both significantly decreased ($p < 0.05$). SP and EP diets increased the content of C16:0 in thigh meat, but decreased the ratio of linolenic acid ($p < 0.05$). Previous researches have demonstrated that the impact of 15% DDGS in the diet on fatty acids digestibility significantly increased polyunsaturated fatty acids and decreased that of short-chain fatty acids, and medium-chain fatty acids in the thigh meat of broiler chickens (Jiang et al., 2014); however, little is known about the effects of DDGS in expanded diet on the fatty acids profile of the thigh. The percentage of linolenic acid in the thigh decreased in EP diet-fed chickens. High-temperature conditions during feed processing can increase the hydrolysis of fatty acids; in particular, free fatty acids and polar lipids with double bonds have a higher potential for reacting under these conditions (Tran et al., 2008). Linolenic acid is a nutritious essential fatty acids with three double bonds, which makes it more vulnerable in high temperatures. The pelleting process may decrease linolenic acid in the diet, consequently leading to a lower linolenic acid percentage in the thigh.

Meat portions

Variable responses to meat portions were observed at the end of experiment (Table 3). No interactions ($p > 0.05$) between the FP and DDGS were detected for meat portions, but significant differences were observed in main effects ($p < 0.05$) of FP. The addition of DDGS did not change any of meat portions. Feed processing increased the percentage of pectoralis muscle

Table 2. Effects of feed processing on fatty acid profile of thigh meat in broiler diets with or without distiller's dried grain with solubles (DDGS) for 21 d

Items (%)	DDGS (g kg ⁻¹)		SEM	Feed processing			SEM	P-value		
	0	200		M	SP	EP		FP	D	FP×D
Octanoic (C8:0)	0.10	0.10	0.006	0.10	0.10	0.11	0.008	0.362	0.877	0.182
Decanoic (C10:0)	0.06	0.07	0.005	0.07	0.07	0.06	0.006	0.087	0.738	0.069
Lauric (C12:0)	0.29	0.28	0.007	0.28	0.30	0.28	0.009	0.394	0.151	0.886
Myristic (C14:0)	1.31	1.34	0.022	1.34	1.34	1.31	0.026	0.519	0.278	0.265
Palmitic (C16:0)	23.3	22.6	0.34	21.7 ^b	23.6 ^a	23.5 ^a	0.42	<0.01	0.180	0.477
Palmitoleic (C16:1c)	5.79	5.57	0.110	5.55	5.68	5.81	0.131	0.384	0.154	0.082
Stearic (C18:0)	8.53	8.06	0.130	8.32	8.25	8.32	0.162	0.951	0.016	0.964
Oleic (C18:1c9)	37.8	37.8	0.33	37.9	37.7	37.9	0.40	0.901	0.981	0.788
Linoleic (C18:2n-6)	22.1	23.0	0.48	22.8	22.9	22.1	0.59	0.521	0.225	0.920
Linolenic (C18:3n-3)	0.92	0.94	0.015	0.97 ^a	0.92 ^{ab}	0.90 ^b	0.019	0.035	0.250	0.111
Arachidonic (C20:4n-6)	0.09	0.10	0.004	0.10	0.09	0.10	0.005	0.556	0.138	0.391
Behenic (C22:0)	0.12	0.09	0.008	0.12	0.10	0.10	0.009	0.355	0.013	0.775
Erucic (C22:1)	0.08	0.07	0.005	0.07	0.09	0.07	0.006	0.060	0.321	0.881
Lignoceric (C24:0)	0.43	0.39	0.043	0.43	0.41	0.40	0.053	0.938	0.556	0.962

Values with different superscripts with in a same row significantly differ ($p<0.05$).

M, mash; SP, simple pellet; EP, expanded pellet; SEM, standard error of means; FP, feed processing; D, distiller's dried grain with solubles.

Table 3. Effects of feed processing on meat portions weight (% of live weight at processing basis) in broiler diets with or without distiller's dried grain with solubles (DDGS) for 21 d

Items	DDGS (g kg ⁻¹)		SEM	Feed processing			SEM	P-value		
	0	200		M	SP	EP		FP	D	FP×D
Carcass weight	63.5	63.2	0.70	62.3	62.9	64.8	0.86	0.123	0.721	0.478
Pectoralis muscle	21.6	21.1	0.47	19.7 ^b	21.7 ^a	22.7 ^a	0.58	<0.01	0.430	0.474
Supracoracoideus	2.39	2.54	0.090	2.64	2.28	2.48	0.117	0.099	0.263	0.140
Total breast	24.0	23.1	0.36	22.1 ^b	24.0 ^a	24.6 ^a	0.44	<0.01	0.085	0.705
Breast skin	2.40	2.50	0.061	2.46	2.31	2.49	0.076	0.476	0.378	0.668
Abdominal fat	1.61	1.53	0.078	1.45	1.59	1.67	0.096	0.244	0.477	0.826
Thigh	18.2	18.3	0.33	18.1	18.9	17.8	0.40	0.164	0.871	0.052
Drum	12.9	13.2	0.27	12.6 ^b	12.7 ^b	13.9 ^a	0.33	0.020	0.564	0.131
Wing	7.97	8.50	0.26	8.20	8.29	8.18	0.321	0.968	0.175	0.084
Back	20.7	21.8	0.33	20.3 ^b	21.5 ^{ab}	21.9 ^a	0.41	0.018	0.035	0.217

Values with different superscripts with in a same row significantly differ ($p<0.05$).

M, mash; SP, simple pellet; EP, expanded pellet; SEM, standard error of means; FP, feed processing; D, distiller's dried grain with solubles.

and drum but tended to decrease supracoracoideus muscle ratio compared with chickens fed mash-fed chickens ($p<0.05$). EP-fed chickens were found to have a higher ratio of back mass than mash-diet fed chickens ($p<0.05$). The higher portion for pectoralis muscle, drum, and back mass in chickens fed pelleted diets in the current study is in line with the result of Bricket et al. (2007). The current study showed that breast muscle yield tended to decrease in high DDGS treatment. The effects of various contents (%w/w) of DDGS on processing parameters on 49 d showed that breast muscle yield significantly decreased with increasing DDGS levels from 0% to 50% in a concentration-dependent manner (Wang et al., 2008). However, Shim et al. (2011) reported that processing measurement results were similar for chickens regardless of the DDGS content, and the only

significant difference among treatments was in carcass measurements, where the percentage of fat in the female carcasses increased with increasing DDGS content in the diet.

Conclusions

A content of up to 200 g/kg corn DDGS or EP in grower diet of broiler chicken decreased the shear force. The expansion process decreased the concentration of linolenic acid in the thigh. Therefore, expansion process and dietary DDGS may compromise the meat quality of broiler chickens.

Acknowledgements

This study was supported by 2017 Research Grant from Kangwon National University (No. D1001086-01-01).

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