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Effect of Distillers Dried Grains with Solubles on Quality Traits and Fatty Acid Composition of Pork Belly

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MR and SP planned the study. SK executed experimental work, compiled the data and wrote the article. AF performed statistical analysis.

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ABSTRACT

The aim of this study was to investigate the effects of dietary distillers dried grains with solubles (DDGS) on growth performance, meat quality and fatty acid composition of pork belly. A total of 50 gilts and 50 barrows (initial BW 26±6.3 kg) were randomly allotted to 2 diets including a corn-based control diet and control plus 9% DDGS. After 105 d administration of experimental diets, growth performance, pork quality traits, and fatty acid composition in loin were analyzed. No significant difference in growth performance and quality traits of pork loin between control and DDGS was observed. Fatty acid composition in pork belly, however, was significantly affected by DDGS treatment. Levels of palmitoleic acid (C16:1) and oleic acid (C18:1) which are positively associated with meat flavor, were greater (p<0.05) in DDGS compared to control group. Supplementation of DDGS increased (p<0.05) the level of conjugated linoleic acid, which has been reported to reduce body fat accumulation, when compared with control group. Taken together, these data indicate that DDGS can be utilized as a feed additive and has beneficial effects on unsaturated fatty acid formation in pork without deleterious effect on growth performance.

INTRODUCTION

Swine industry is recently facing a crisis driven by increased feed costs and environmental issues. Agri-byproducts including dried distiller's grains with solubles (DDGS) have received increased attention as an alternative feed stuff with lower ration cost. According to Renewable Fuel Association (RFA), 80% of the total DDGS produced in 2011 was utilized in the manufacturing of feed for ruminants, 10% for swine and 9% for poultry industry (RFA, 2011). Addition of only 10% DDGS can replace 5.7% corn and 4.2% soyabean meal subject to the inclusion of 0.1% crystalline lysine in the animal diet (Stein, 2007). DDGS has been used in animal feed on account of its valuable proteins and high concentration of energy in the form of high fat content (Belyea *et al*., 2010). The major constituents of the feed stock like protein, fats, fiber, minerals remains unaffected during process of fermentation and are restored in DDSG with higher concentrations (Han and Lue, 2010). Nutritional value and chemical composition of DDGS is associated with the processing procedure, feed stock composition and species, the amount of condensed solubles used, fermenting microbial strains *etc*., (Kittiporn, 2009; Liu, 2011). In addition to the standard reference values of NRC (NRC, 1994; NRC, 1998), diverse nutrient compositions of various feed ingredients have been reported (Belyea *et al*., 1998; Kim *et al*., 2008; Liu, 2009). It, therefore, is recommended to have analysis of DDGS before the feed formulation. With almost similar levels of protein and ME, 10-30% of corn replacement with DDGS in livestock and poultry feed has been evaluated successfully (Kent and Wright, 2002). Moreover, being relatively cheaper it has been remained as a point of price consideration for replacement of expensive ingredients of swine feed (Hoffman and Baker, 2011). However, administration of DDGS can reduce the saturated fatty acid biosynthesis due to its high content of polyunsaturated fatty acids (PUFAs), especially linoleic acid (Madsen *et al*., 1992). The higher the concentration of PUFAs biosynthesis in the body the softer will be the fat of the pork (Wood *et al*., 2003). Consequently, hardness of the back-fat or pork belly will

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be reduced (Hugo and Roodt, 2007). Firmness of pork fat is one of the important factor contributing overall quality, shelf life and flavor of the pork (Nishioka and Irie, 2006). Gilts are more susceptible to deleterious effect of DDGS since they possess relatively softer bellies compared to those of barrows. Hence, the amount of DDGS added in diets is limited for growing pigs. The inclusion of 30% DDGS in diets fed to growing pigs resulted in improved pig performance but increase in unsaturated fatty acids, low iodine value and softer belly cannot be compromised (Pompeu *et al*., 2009). However, addition of 10% showed no harmful effect on the hardness of overall fat and efficient source of protein and energy (Widmer *et al*., 2008) . It is, therefore, recommended that 8~10% DDGS can be included in diets fed to sows, growing and growing-finishing pigs. However, precise functional effects of DDGS on fatty acid composition of pork belly still remained unknown.

Therefore, the objective of this study was to analyze the effect of administration of DDGS during growing-finishing phase on pig growth, meat quality and fatty acid composition of pork loin.

MATERIALS AND METHODS

The procedures and protocols followed for this study were approved from The Institutional Animal Care and Use Committee of the National Institute of Animal Science South Korea.

Experimental design and animals

In a 105 days efficacy study, 70 days old offspring of sows [(Landrace × Yorkshire) × Duroc], each with an initial body weight (BW) of 27.62±5.82 kg was used to evaluate effects of DDGS supplementation on growth performance and carcass fat composition. A total of 100 pigs were randomly allotted by initial BW to control and DDGS supplemented groups (5 replicate pens per treatment, 5 barrow and 5 gilts per pen).

Experimental diets

Three types of feed including creep, growing and DDGS were obtained from the National Livestock Cooperatives Federation's OEM. Results of proximate analysis of composite samples of all types of feeds is given in Table I. Pigs were fed appropriate diets based on our previous study (Jeong *et al*., 2015) and NRC requirements (NRC, 2012). Dietary treatments consisted of corn-soybean based meal containing 9% DDGS. Inclusion level of DDGS in diets was determined based on data from the pilot experiment (data not shown). Animals used to fed experimental diets twice a day (9 and 17 h) freely access to water throughout the experiment, housed in an environmentally controlled grower-finisher commercial research facility with slotted floor pens in Korea.

Table I.- Chemical composition of experimental diets fed to growing pigs.

Item	Control feed[1]	DDGS[2]
Moisture (%)	11.72	12.30
Crude protein (%)	16.21	25.28
Crude fat (%)	8.15	8.66
Crude fiber (%)	3.60	7.71
Crude ash (%)	3.89	4.12
Ca (%)	0.55	0.58
P (%)	0.52	0.76

[1] Diets were formulated to contain 3,435 kcal/kg of ME, 1.10% total Lys, 0,65% Ca, and 0.55% total P for pigs weighing 27 to 40 kg. [2] Distillers dried grain with solubles.

Performance and carcass data

Pigs were monitored regularly to ensure proper health, feeders were inspected frequently for smooth functioning and feed allotments were recorded daily on pen basis. Feed in the feeders was weighed daily for feed intake analysis. Feed conversion ratio was calculated dividing feed intake by total weight gain. Before exsanguination the pigs were fasted overnight, transported to a local (Dong-A) livestock packing center and stunned electrically to render them unconscious. Carcass measurements were obtained after chilling for 24 h at 4°C. Meat graders were used for the assessment of carcass quality and yield following methods provided by Livestock Quality Assessment (LQA, 2007). Loin muscles 12th and 13th rib section, and primal valley were removed from of left side of each carcass for quality characteristics and fatty acid composition, respectively. Samples were collected in vaccum bags, transported immediately to the laboratory and kept frozen until used for analysis. The percentage loss in weight of a cube of meat carcass (3×3×3 cm) incubated for 48 hours at 4ºC was determined as the drop loss. While the percentage loss in weight of a standardized sample of meat (3×3×3 cm) cooked for 90 s on an electric grill with double pans (Nova EMG-533, 1,400 W, Evergreen enterprise, Seoul, Korea) until the internal temperature reached to 72ºC was taken as the cooking (heat) loss (Goni and Salvadori, 2010; Jama *et al*., 2008).

Surface color values L* (Lightness), a* (Redness) and b* (Yellowness) followed by Commission Internationale de l'Eclairage (CIE) were measured on Minolta colorimeter (Model CR-410, Minolta Co. Ltd., Japan). The averaged value of measurements from five randomly selected locations at the carcass meat was used for the statistical analysis (Trinderup *et al*., 2015).

Chemical and fatty acid composition

Chemical composition including moisture, ash, crude protein and fat contents were analyzed according to the AOAC (AOAC, 2000; n=10 per each treatment). Briefly, Crude fat, fiber and proteins were estimated following Soxhlet extraction system (SZC-D, Nanbei, China), acid base digestion and Kjeldahl (Tecator Kjeldahl Auto 1030 Analyzer; Foss, Warrington, UK) method, respectively. Fatty acids were analyzed using Gas Chromatography (Clarus 500, Perkin Elmer, Shelton, USA). Fatty acid methyl esters (FAME) were prepared from total lipids extracts of pork belly as described previously (Choi *et al*., 2016). Briefly, 3 g meat sample pulverized in liquid nitrogen was homogized in Polytron (PT-MR-2100, Switzerland) with methanol:chloroform (1:2, vol/vol) and filtered through Whatman filter paper No. 4. The extracted FAME was mixed with acetyl chloride; 200 µL, 6% potassium carbonate; 8 mL, benzene:methanol (1:4, vol/vol); 2 mL and isooctane; 1 mL and, centrifuged at 1,500 rpm for 10 min. Supernatant (1 µL) was loaded with the split ration of 100:1 at 250°C on fused silica capillary column (Supleco Sp-2560, 0.25mm I.D) equipped with gas chromatography (Clarus 500, Perkin Elmer, Shelton, USA). The oven temperature was set initially at 170°C for 5 min and then was increased to 220°C (2°C/min) and held for 40 min. The flame ionization detector (FID) detected the signal at 270°C.

Statistical analysis

Data were analyzed using SAS software (SAS Institute, USA) with pen as the experimental unit, and student t-test was used to compare differences between means. Significance was defined at $p<0.05$ (Mendelhall and Sincich, 2016).

RESULTS AND DISCUSSION

Growth performance

Results revealed that least square means of initial BW and its variation were not statistically different between control and DDGS group. No significant difference in average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) between control and DDGS group was observed (Table II). This is not surprising considering that DDGS contains concentrated crude protein, fats, minerals and many essential amino acids beyond the level found in maize or soya bean meals (Spiehs *et al*., 2002) therefore pig performance has been observed better below 30% inclusion of DDGS in most of the studies. These results are consistent with the previous data (Whitney *et al*., 2006) showing that supplementation of 30% DDGS reduced growth performance but inclusion of 0, 10 or 20% DDGS in diets of growing-finishing pigs did not adversely affect overall growth performance. In another study similar results were noted when growing-finishing pigs were fed diet with substitution of soyabean and corn with 30% DDGS (Stein and Shurson, 2009). However, discrepancies still exist in growth performance among studies in growing pigs. Pigs fed 30% DDGS showed decreased ADG (Whitney *et al*., 2006; Feoli *et al*., 2007), but those fed 20% DDGS had an improved efficiency in growth without changes in ADG or ADFI (Dedecker *et al*., 2005). Differences in feed intake and growth performance may be related to the specific source of DDGS used in these experiments. Moreover, at higher concentrations of DDGS in feed, lysine becomes deficit up to a level that may acts as a limiting factor and after heat processing in feed manufacturing can interfere with the digestibility in swine gut (Shelby *et al*., 2008) while fiber on the other hand exceeds the limits usually at higher concentrations of DDSG affects the rate of metabolism and release of energy (Kerr and Shurson, 2013).

Table II.- Growth performance, average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR) in pigs fed diets containing distillers dried grain with solubles (DDGS).

Item	Control	DDGS	*p-value*
Number of pigs	50	50	NA
Number of pens	5	5	NA
Initial BW (kg)	26.34±6.32[1]	28.4±5.31	0.2482
Final BW (kg)	112.72±9.52	118.30±5.34	0.1276
BW gain (kg)	90.56±4.33	89.77±6.90	0.6862
ADG (kg)	0.80±0.12	0.76±0.45	0.1630
ADFI (kg)	2.18±0.09	2.67±0.99	0.1720
FCR	3.10±1.05	2.97±0.78	0.8507

[1] Mean ± SE.

Non-significant behavior of ADFI in the current results suggested that inclusion of said dose of DDGS in the diet offered to grower-finisher pigs has no influenced the palatability. Therefore, inclusion of 9% DDGS into diet can be achieved without any deleterious effect on pig and seems to be an acceptable feed ingredient. It can be used as a substitute for corn and soybean meal without defective effect on growth performance in grower-finisher pigs. Further study will be necessary to specify the levels of important nutrients including fats, proteins and amino acids of various sources of DDGS.

Carcass characteristics

DDGS fed animals showed numerically higher slaughter and hot carcass weights (HCW) compared to control, while back-fat depth remained unaffected. Similarly, carcass yield grade was not significantly different between treatments. Only numerically different, dressing percentage of DDGS group was lower than that of control group (Table III). The current study is in concomitant with results of many of the studies conducted earlier (Stein and Shurson, 2009; Stein, 2007; Xu *et al*., 2010; Cromwell *et al*., 2011). In a similar study, 12th rib fat and overall carcass weight has been found in steers fed with 20% distillers grains solubles instead of 40% (Mateo *et al*., 2004). However, it is generally believed that the carcass weight reduces at the rate of 0.03% per 1% increase of DDGS in the diet (Shurson, 2011) but some studies have confirmed that withdrawal of DDGS six weeks prior to slaughtering limits the reduction of carcass weight. Moreover, only one study each for reduction of back-fat (Widmer *et al*., 2008) and % carcass lean (Gaines *et al*., 2007) has been reported so far. Decrease in dressing percentage may be contributed to supplementation of DDGS which includes higher level of fiber than control diet. During fermentation process, starch is converted into ethanol while fiber remains unaffected. Hence, DDGS increases overall percentage of fiber in the feed. Consequently the weight of the large intestine increases (Agyekum *et al*., 2012).

Table III.- Carcass characteristics of pigs fed diets containing distillers dried grain with solubles (DDGS) at 110 kg BW.

Item	Control	DDGS	*p-value*
Number of pigs	50	50	NA
Slaughter wt (kg)	112.72±9.52*	118.30±5.34	0.1276
HCW (kg)	88.85±1.56	89.92±1.84	0.7942
Dressing (%)	78.82±0.00	76.01±0.00	0.1690
Back-fat depth (mm)	24.77±0.94	24.00±1.04	0.2709
Yield grade score	1.76±0.19**	1.66±0.26	0.2505

* Mean ± SE.

High fiber content of DDGS in the current studies might increase intestinal growth and thickened the gut wall, resulting reduced carcass yield percentage. Therefore, reducing dietary fiber levels in DDGS prior to marketing might improve the carcass yield. However, more studies are required to find out the exact role of fiber in reducing the carcass yield, timing and level of reduction.

Meat quality

Chemical composition, cooking characteristics, and meat color were not affected by dietary DDGS supplementation in pigs at 110 kg BW. Moisture, content of crude protein and crude fat, pH, cooking- and drip- loss did not differ among treatments but DDGS supplementation tended to increase moisture and crude fat in carcass. CIE color of L, a, b, and, Chroma and hue levels were not different among treatments (Table IV). Concomitant to this result, previous studies (Leick *et al*., 2010; Ying *et al*., 2013) showed no effect of DDGS inclusion level on Minolta L*, a*, and b* values. No effect was found in Minolta L*, a*, and b* or on subjective scores of color, marbling, and firmness by DDGS treatment (Lee *et al*., 2013). However, there was a decrease in *Longissimus* muscle marbling and firmness scores (Xu *et al*., 2010) and Minolta b* (Widmer *et al*., 2008) as DDGS inclusion level increased. Increase in lipid oxidation can changes the color of meat. These findings are important in terms of consumer's attraction as color is one the important indices which determines the acceptability of pork meat (Mancini and Hunt, 2005). The fact that DDGS did not affect the values of CIE, Chroma and hue suggested that consumers would not be able to notice the difference between pork meat from pigs in control and DDGS group. However, feeders still need to use caution in use of DDGS and further study is necessary to identify the specific mechanisms by which DDGS inclusion affects meat color.

Table IV.- Chemical composition, cooking characteristics, and meat color of pigs fed diets containing distillers dried grain with solubles (DDGS) at 110 kg BW.

Item	Control	DDGS	*p-value*
Number of pigs	50	50	NA
Moisture (%)	73.39±0.51[1]	74.23±0.36	0.1324
Crude protein (%)	22.56±0.21	21.04±0.23	0.6378
Crude fat (%)	1.94±0.28	2.54±0.40	0.6891
Cooking loss (%)	22.34±0.32	22.89±0.31	0.2542
24-h LM pH	5.40	5.36	0.9785
Drip loss (%)	4.35±0.15	5.41±0.30	0.3231
CIE[2]			
L*	56.35±1.90	55.87±0.90	0.376
a*	11.10±0.58	10.32±0.58	0.8790
b*	6.12±0.47	5.99±0.21	0.9983
Chroma	12.33±0.73	11.34±0.56	0.6987
hue	30.20±0.75	29.23±0.95	0.4987

[1] Mean ± SE.
[2] International Commission on Illumination. L*, lightness; a*, redness; b*, yellowness.

Table V.- Fatty acid composition in lipid of belly fat of pigs fed distillers dried grain with solubles (DDGS).

Item	Control	DDGS	p-value
Number of pigs	50	50	NA
Lauric acid (C12:0) (%)	1.28±0.25[1]	0.96±0.16	0.7870
Myristic acid (C14:0) (%)	0.82±0.19	0.52±0.17	0.8765
Palmitic acid (C16:0) (%)	27.44±1.45	26.78±1.35	0.5431
Palmitoleic acid (C16:1) (%)	1.37±0.27[a]	1.52±0.31[b]	0.0452
Stearic acid (C18:0) (%)	11.57±1.21	12.23±1.59	0.3456
Oleic acid (C18:1 *cis*-9) (%)	34.31±0.92[a]	36.11±0.23[b]	0.0421
Vaccenic acid ($C_{18:1}$-t_{11}) (%)	0.01±0.33	0.01±0.35	0.8424
Linoleic acid (C18:2n-6) (%)	25.38±1.40	23.37±3.08	0.7890
Conjugated linoleic acid ($C_{18:2}$-t_{10},c_{12}) (%)	0.001±0.0002[a]	0.003±0.0002[b]	0.0252
SFA[2]	41.11±2.22	40.49±2.56	0.3476
UFA[3]	61.07±2.11	61.01±2.32	0.1232
IV[4]	0.66±0.02	0.66±0.10	0.8452

[a,b] Different letters within a row indicate statistically significant difference (P<0.05).
[1] Mean ± SE.
[2] Saturated fatty acids.
[3] Unsaturated fatty acids.
[4] Iodine Value (Saturated to unsaturated fatty acids ratio).

Fatty acid composition

The effects of DDGS supplementation on fatty acid composition in belly fat are shown in Table V. Supplementation of 9% DDGS in pig diet did not affect the levels of saturated fatty acids including lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0) and unsaturated fatty acids including vaccenic acid (C18:1-t11) and linoleic acid (C18:2). However, dietary DDGS treatment increased (p<0.05) some of unsaturated fatty acids including palmitoleic acid (C16:1), oleic acid (C18:1), and conjugated linoleic acid (CLA; C18:2-t10, c12). Adding unsaturated fat to pig diets has been shown to increase poly-unsaturated fatty acid (PUFA) level in pork (Miller *et al*., 1990; Xu *et al*., 2010). Since DDGS contains about 10% fat and most of which consists of large amount of PUFA (linoleic acid, 60%). Increase in PUFA level in belly fat would presumably occur in pigs fed DDGS in our current study (Lea *et al*., 1970). This result is also meaningful because palmitoleic and oleic acids show a strong correlation with meat flavor so that DDGS supplementation might have a positive role in improvement of palatability of pork meat. Furthermore, with growing concerns in health, customers prefer to purchase pork with high unsaturated fatty acid (UFA) content. In this regard, high PUFA and CLA content with their various biological activities could address some of the consumer concerns about meat-related health problems. This result might stem from the higher content of linoleic acid (C18:2) included in DDGS. The relationship between the process of transformation and metabolism of the linoleic acid and CLA content needs to be further investigated. Iodine Value is the ratio of poly unsaturated fatty acids to saturated fatty acids which is directly associated with the thickness of belly. The higher is the IV of a fat the higher will be its melting point and vice versa which can also be associated with pork belly thickness (Lawrence, 1974). In the current studies DDGS in the diet did not influence the IV of fatty acid profile of swine fat (Table I). The current results again support our above finding that belly thickness was not influenced with 9% replacement of DDGS with corn and soybean in the feed.

CONCLUSIONS

Taken together, results of the current study indicate that DDGS can be utilized as a feed additive and has beneficial effects on unsaturated fatty acid formation in pork meat without deleterious effect on carcass characteristics and growth performance. Moreover, meat from the animals fed on upto 9%DDGS have better ratio of unsaturated fatty acids and flavor as compared to that of the animals fed diet having no DDGS, hence threat of coronary heart diseases associated with saturated fatty acids can be mitigated. The work explains how animals can be manipulated for the production of meat according to the desired characters by establishing feed composition. However, more investigations are required to establish the mechanism how DDGS affects sensorial, chemical and quality characteristics of the meat.

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Conflict of interest statement

We declare that we have no conflict of interest.

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