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Evaluation of distillers dried grains with solubles to partially replace soybean meal in the diet of growing-finishing pigs

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ABSTRACT. This study was conducted to evaluate the effect of dietary supplementation with increasing levels of distillers dried grains with solubles (DDGS) on growth performance, nutrient digestibility, and carcass quality of growing-finishing pigs. The experiment was divided into 2 phases (Grower and Finisher) in a 16-week trial. A total of 120 [(Landrace × Yorkshire) × Duroc] growing pigs (BW; 22.02 ± 0.08 kg) were randomly assigned to control (CON) and treatment diets (TRT): CON – basal diet, DDGS 4% for growing pigs and 6% for finishing pigs; TRT1 – DDGS 10% for growing pigs and 12% for finishing pigs and TRT2 – DDGS 15% for growing and finishing pigs. Increasing dietary DDGS supplementation did not cause significant linear or quadratic responses in average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR). Furthermore, DDGS inclusion did not result in linear or quadratic effects on the digestibility of dry matter (DM), nitrogen (N), and digestible energy (E). Backfat thickness (BFT) tended to decrease (quadratic, $P = 0.057$) at week 16, whereas lean meat percentage (LMP) was unaffected by increasing DDGS levels in the diets. Thus, the addition of increasing DDGS levels (4–15%) to the basal diet showed no adverse effect on the growth performance, nutrient digestibility, and positively affected carcass quality of growing-finishing pigs, suggesting that DDGS (4–15%) inclusion exerted comparable effects to soybean meal, i.e. the main source of protein, thereby reducing feed cost.

Introduction

Soybean meal (SBM) is the primary protein source for farm animals, but it is also a relatively expensive feedstuff. Of the total costs, diet accounts for about 50% or even more in a swine production system. These feed costs constitute a high proportion of the energy variable in the swine industry (Noblet et al., 1994). Animal protein demand increases the acreage of soybean meal at the expense of tropical forests and can negatively affect the global environmental system (Fearnside, 2002). Moreover, the use of raw soybean seeds in pig production can hamper the quality, fat content, flavour, softness, and juiciness of the meat as it contains a large amount of oil (Fiedorowicz et al., 2016).

Due to rising grain costs, the demand for alternative feed ingredients such as distillers dried grains (DDG) and distillers dried grains with solubles (DDGS) is continuously increasing. The nutritional values of DDG and DDGS are 20–50% crude protein, 96% organic matter, 6% ether extract, and 15% crude fibre (El-Hack et al., 2019). DDGS are the main by-product of distillery plants and bioethanol production, containing high amounts of energy, crude protein (CP), and non-phytate phosphorous, making it a likely livestock feed for mono-gastric animals such as pigs and poultry (Widyaratne and

Zijlstra 2007; Foltyn et al., 2013). Various by-products from the rice processing industry, especially rice distilled dried grains with solubles (rDDGS), are potential sources of protein and can be used as a cost-effective substitute for soybeans in broilers (Dinani et al., 2018). Whitney et al. (2006) also suggested that legume seeds, rapeseed, and maize DDGS could replace SBM. DDGS are used as animal feed ingredients because of their elevated nutritional value, high availability, cost effectiveness, well-absorbed protein and fibre content, and low amounts of anti-nutrients.

According to the study conducted by Stein and Shurson (2009), DDGS with lower starch and higher oil concentrations may reduce fat and amino acid contents. Hence, using a large amount of DDGS (50%) may affect fat firmness and cause economic losses during the marketing of pigs. However, each 10% increase in the amount of DDGS in the ration can reduce the feed cost per 100 pounds by approximately 0.25–0.28 USD. Moreover, Kyawt et al. (2019) reported that adding up to 10% rice distillers dried grains (rDDG) to the diet can improve growth performance and reduce feed costs per kg body weight for growing pigs. Studies involving DDGS, conducted by Wu et al. (2016) and Curry et al. (2019), demonstrated that using 10% and 30% DDGS in pig diets did not differentiate pig performance. In contrast, high-protein DDGS were shown to negatively affect pig growth performance (Cemin et al., 2019). Rausch and Belyea (2006) reported that the inconsistent results in growth performance of growing pigs were possibly due to batch-to-batch differences in drying methods, residual sugar levels, and grain quality. Li et al. (2016) found that the apparent total tract digestibility (ATTD) of dry matter (DM) and gross energy (GE) was higher when swine diets were supplemented with 20% DDGS. In contrast, Ganchev et al. (2020) showed that DDGS reduced digestibility coefficients up to 40% in growing pigs. These authors also found that the digestibility of DDGS amino acids was lower compared to the grains from which they were produced, possibly due to the higher crude fibre content in DDGS. In pig nutrition, DDGS becomes an alternative feed source for SBM, as it contains three times more protein, fat, and fibre than other meals (Widyaratne and Zijlstra, 2007). According to the study of Stein and Shurson (2009), lactating sows could be fed diets containing up to 30% DDGS, which replaced soybean meal in a gestation sow diet without negatively affecting sow or litter performance. Woyengo et al. (2014) demonstrated that feed costs could be significantly reduced by using DDGS as an alternative source of energy and protein in pig rations.

DDGS production is increasing worldwide, but scientists have higher expectations for the future. Further research on the consistent utilization of DDGS is needed to benefit the animal feed industry. Therefore, we hypothesised that 4–15% DDGS supplementation to partially replace SBM could have a comparable and satisfactory influence on growth performance, nutrient digestibility, and carcass quality in growing-finishing pigs.

Material and methods

Sources of DDGS

Distillers dried grains with solubles (DDGS) used in our experiment were a commercial product purchased from Daehan feed (Incheon, South Korea). DDGS derivatives were used as animal feed and for the production of maize ethanol.

Experimental design and diet

This experiment was conducted at the experimental pig farm of the Dankook University using 120 growing-finishing pigs [(Landrace × Yorkshire) × Duroc]. Pigs were divided into one of three dietary treatments (completely randomised block design) for sixteen weeks according to body weight (BW) (average initial weight 22.02 ± 0.08 kg) and gender. The treatments were as follows: CON – maize-SBM-SM-PKM (soybean meal, sesame meal, and palm-kernel meal) basal diets supplemented with DDGS 4% for growing pigs and 6% for finishing pigs; TRT1 – DDGS 10% for growing pigs and 12% for finishing pigs; TRT2 – DDGS 15% for growing and finishing pigs, respectively.

Each treatment included eight replications, with five pigs per pen (three boars and two gilts). The formulation of the experimental diets met or exceeded the requirements of the NRC (2012) (Table 1). The experimental diets were administered in 2 phases: phase 1 (Grower, 0–8 weeks), phase 2 (Finisher, 8–16 weeks). A DDK-801 feed mixer (Daedong Tech, Anyang-si, South Korea) was used to mix the graded DDGS and CON diets. Each pen was equipped with an automatic feeder and nipple drinker, so that pigs had free access to feed and water. Ventilation was provided by a mechanical system with automatic regulation; artificial light was provided for 12 h a day. Temperature was maintained at about 30 °C and lowered by 1 °C every consecutive week.

Table 1. Composition of basal diet (CON) and diet supplemented with distillers dried grains with solubles (DDGS) fed to growing-finishing pig (as feeding basis)

Items	Phase 1 (Grower, 0–8 weeks)			Phase 2 (Finisher, 8–16 weeks)		
	CON	TRT1	TRT2	CON	TRT1	TRT2
Maize	64.195	60.445	58.855	66.765	62.815	65.385
Soybean meal	17.43	14.08	12.23	12.76	9.33	7.45
Sesame meal	2	2	2	2	2	2
DDGS (maize, USA)	4	10.79	14.63	6	12.94	14.93
Palm kernel meal	2	2	1.46	3	3	-
CMS	1.5	1.5	1.5	1.5	1.5	1.5
Lipid	4.2	4.4	4.5	3.9	4.2	3.8
Molasses	1.5	1.5	1.5	1.5	1.5	1.5
Limestone	1.06	1.1	1.12	1.08	1.12	1.16
MDCP	0.31	0.29	0.29	0.1	0.1	0.1
Salt	0.35	0.3	0.25	0.35	0.3	0.25
Methionine, 99%	0.14	0.12	0.11	0.05	0.04	0.04
Lysine, 50%	0.71	0.82	0.87	0.57	0.68	0.76
Threonine, 98.5%	0.14	0.15	0.16	0.09	0.1	0.71
Tryptophan, 20%	0.25	0.29	0.31	0.14	0.18	0.22
Vitamin mix[a]	0.1	0.1	0.1	0.1	0.1	0.1
Mineral mix[b]	0.1	0.1	0.1	0.08	0.08	0.08
Phytase	0.015	0.015	0.015	0.015	0.015	0.015
Total	100	100	100	100	100	100
Calculated value, %						
Moisture	13.29	13.18	13.16	13.34	13.22	13.36
CP	15.87	15.96	15.98	14.49	14.58	14.40
CF	7.17	7.61	7.85	7.13	7.68	7.30
Cf	2. 55	2.89	3.00	2.67	2.99	2.73
CA	4.55	4.64	4.65	4.27	4.37	4.25
DNSP	121	131	135	124	135	124
NE, kcal/kg	2471	2467	2468	2470	2470	2472
Ca	0.70	0.71	0.70	0.67	0.67	0.67
Total P	0.38	0.41	0.43	0.34	0.38	0.37
Total Lys	1.07	1.09	1.09	0.89	0.91	0.90

CMS – condensed molasses solubles, MDCP – monodicalcium phosphate, CP – crude protein, CF – crude fat, Cf – crude fiber, CA – crude ash, DNSP – digestible non starch polysaccharide, NE – net energy, Ca – calcium, Total P – total protein, Total Lys – total tysine; CON – basal diet, DDGS 4% for growing pigs and 6% for finishing pigs; TRT1 – DDGS 10% for growing pig and 12% for finishing pigs; TRT2 – DDGS 15% for growing and finishing pigs; [a] provided per kg of complete diet: IU: vit. A 15 000, vit. D_3 3 750, vit. E 37.5; mg: vit. K_3 2.55, thiamin 3, rivoflavin 7.5, vit. B_6 4.5, niacin 51, folic acid 1.5, biotin 0.2, Ca-pantothenate 13.5; µg: vit. B_{12} 24; [b] provided per kg of complete diet: mg: Zn 37.5 (as $ZnSO_4$), Mn 37.5 (as MnO_2), Fe 37.5 (as $FeSO_4 \cdot 7H_2O$), Cu 3.75 (as $CuSO_4 \cdot 5H_2O$), I 0.83 (as KI), Se 0.23 (as $Na_2SeO_3 \cdot 5H_2O$)

Sample measurements and chemical analysis

Body weight was measured at baseline and weeks 4, 8, 12, and 16 to calculate average daily gain (ADG). At the same time, feed consumption and feed residues were weighed to measure the average daily feed intake (ADFI) and feed conversion ratio (FCR) per pen. Chromium oxide (Cr_2O_3, 0.2%; Samchun, Gyeonggi-do, South Korea) was added to the diet as an indigestible marker before 7 days of faecal collection to measure digestibility according to the procedure of the Association of Official Analytical Chemists (AOAC, 2010). At weeks 4, 8, 12 and 16 of the experiment, fresh faecal samples were collected directly from at least two pigs from each pen by rectal massage to determine apparent dry matter (DM), energy (E), and nitrogen (N) digestibility by trained personnel.

All faecal and feed samples were placed in an icebox, transported to the laboratory, stored at −20 °C, and freeze-dried until final analysis. Prior to analysis, all specimens were dried in an oven at 70 °C for three days. The collected ground specimens were then sieved through a 1-mm screen sieve. Chromium oxide UV absorption spectrophotometry was analysed (Shimadzu UV-1201, Shimadzu and Kyoto, Japan) using the method of Williams et al. (2009). The energy in the samples was measured with an oxygen bomb calorimeter (Parr 6100 Instrument Co., Moline, IL, USA).The following formula was used to calculate the apparent total tract digestibility:

$$ATTD (\%) = [1 - \{(Nf \times C_d) / (N_d \times C_f)\}] \times 100,$$

where: N_f indicated concentration in faeces (% DM), N_d indicated nutrient concentration in diets (% DM), C_f indicated chromium concentration in faeces (% DM), and C_d indicated chromium concentration in diets (% DM).

According to the procedure described by Upadhaya et al. (2021), backfat thickness and lean percentage of the meat for all pigs (n = 40 per treatment) were calculated 5 cm to the right-hand side of the midline from three different sites (shoulder, mid-back, and loin just above the elbow, last rib, and last lumbar vertebra, respectively). During the experiment, a real-time ultrasound instrument (Piglog 105, SFK Technology, Herlev, Denmark) was used before the start of the trial and at the end of weeks 8 and 16. The mean value was calculated and applied for subsequent statistical analysis.

Statistical analysis

All data in this experiment were analysed according to a completely randomized block design using GLM SAS (Statistical Analysis System, Version 9.2); each pen was treated as an experimental unit, except for meat quality, where individual pigs were considered an experimental unit. Orthogonal polynomials were used to evaluate the linear and quadratic effect of increasing DDGS supplementation to the diet. The initial body weight was utilized as a covariate for ADG and ADFI. Data variability was expressed as SEM, with a *P*-value less than 0.05 considered statistically significant, and a *P*-value from 0.05 to 0.10 considered a trend.

Results

Growth performance

The effect of DDGS supplementation on growth performance of growing-finishing pigs is presented in Table 2. There was no difference ($P > 0.05$) between the experimental groups for BW, ADG,

Table 2. The effect of distillers dried grains with solubles (DDGS) supplementation on growth performance of growing-finishing pigs

Items	CON	TRT1	TRT2	SEM	*P*-value	
					linear	quadratic
BW, kg						
initial	22.02	22.02	22.01	0.01	0.9946	0.9969
week 4	39.50	39.81	39.61	0.35	0.9118	0.7300
week 8	61.21	61.72	60.67	0.73	0.5620	0.3399
week 12	84.95	85.61	83.70	1.25	0.3759	0.2969
week 16	111.25	112.30	109.41	1.79	0.3503	0.2376
Week 0–4						
ADG, g	625	635	629	12	0.8315	0.6006
ADFI, g	1326	1332	1330	10	0.8137	0.7510
FCR	2.134	2.100	2.123	0.040	0.8769	0.6317
Week 4–8						
ADG, g	775	783	752	18	0.2919	0.3278
ADFI, g	2031	2048	2023	39	0.8275	0.5431
FCR	2.627	2.626	2.690	0.050	0.4332	0.6442
Week 8–12						
ADG, g	848	853	823	20	0.2594	0.3483
ADFI, g	2463	2472	2418	45	0.4254	0.5231
FCR	2.907	2.904	2.940	0.055	0.5895	0.7102
Week 12–16						
ADG, g	939	953	925	21	0.5605	0.3309
ADFI, g	2565	2956	2938	48	0.6988	0.9378
FCR	3.160	3.105	3.181	0.059	0.7531	0.2528
Overall						
ADG	797	806	782	16	0.4067	0.2760
ADFI	2196	2202	2177	25	0.4698	0.5080
FCR	2.759	2.736	2.786	0.035	0.5413	0.3496

BW – body weight, ADG – average daily gain, ADFI – average daily feed intake, FCR – feed conversion ratio; CON – basal diet, DDGS 4% for growing pigs and 6% for finishing pigs; TRT1 – DDGS 10% for growing pig and 12% for finishing pigs; TRT2 – DDGS 15% for growing and finishing pigs; SEM – standard error of the mean; $P > 0.05$

Table 3. Effect of distillers dried grains with solubles (DDGS) supplementation on nutrient digestibility in growing-finishing pigs

Items, %	CON	TRT1	TRT2	SEM	*P*-value	
					linear	quadratic
Week 4						
DM	78.96	80.20	78.67	1.24	0.8649	0.3638
N	77.89	78.49	78.08	2.20	0.9419	0.8280
E	77.5	78.76	78.09	1.34	0.7408	0.5345
Week 8						
DM	76.26	76.40	75.96	0.38	0.5421	0.4821
N	75.08	75.18	75.05	1.24	0.9857	0.9442
E	74.62	74.83	74.47	1.18	0.9186	0.8158
Week 12						
DM	73.57	73.66	74.01	0.43	0.5273	0.8240
N	71.04	71.37	71.00	0.38	0.9500	0.5064
E	71.99	72.02	71.92	0.29	0.8589	0.8633
Week 16						
DM	71.76	71.12	72.30	0.95	0.7162	0.4804
N	71.37	70.16	72.53	1.39	0.5850	0.3346
E	71.58	70.41	72.52	1.01	0.5454	0.2302

DM – dry matter, N – nitrogen, E – energy; CON – basal diet DDGS 4% for growing pigs and 6% for finishing pigs; TRT1 – DDGS 10% for growing pig and 12% for finishing pigs; TRT2 – DDGS 15% for growing and finishing pigs; SEM – standard error of the mean; $P > 0.05$

ADFI and FCR during weeks 4, 8, 12, 16 and in the entire period. Additionally, increasing DDGS supplementation did not affect ($P > 0.05$) BW, ADG, ADFI, and FCR in pigs.

Nutrient digestibility

Dietary DDGS supplementation did not increase the ATTD of DM, N, and E during weeks 4, 8, 12, and 16. Moreover, increasing DDGS supplementation did not change DM, N, and E during the entire experimental period (Table 3).

Carcass quality

Our study found no statistically significant results for backfat thickness and lean meat percentage at weeks 8 and 16 (Table 4). However, increasing DDGS supplementation resulted in a tendency to reduce backfat thickness (quadratic, $P = 0.0575$) at week 16.

Table 4. Effect of distillers dried grains with solubles (DDGS) supplementation on back fat and lean meat percentag thickness in growing-finishing pigs

Items	CON	TRT1	TRT2	SEM	*P*-value	
					linear	quadratic
Initial						
BFT, mm	5.3	5.5	5.4	0.1	0.4642	0.4205
LMP, %	72.42	72.47	72.48	0.15	0.7206	0.9450
Week 8						
BFT, mm	12.6	12.8	12.1	0.2	0.1715	0.0897
LMP, %	59.56	59.60	59.35	0.15	0.3949	0.5110
Week 16						
BFT, mm	17.2	17.4	16.7	0.2	0.1230	0.0575
LMP, %	51.85	51.85	52.26	0.18	0.9104	0.8966

BFT – back fat thickness, LMP – lean meat percentag; CON – basal diet, DDGS 4% for growing pigs and 6% for finishing pigs; TRT1 – DDGS 10% for growing pig and 12% for finishing pigs; TRT2 – DDGS 15% for growing and finishing pigs; SEM – standard error of the mean; $P > 0.05$

Discussion

A variety of alternative feed additives have been marketed to boost pig immunity and to reduce adverse effects by regulating the intestinal microbiota (Liu et al., 2020). DDGS can be an alternative protein source for soybean meals because it contains low antioxidant levels, high nutritional value, and easily digestible protein. Earlier, DDGS was not used by farmers in non-ruminant animal breeding due its high fibre content, but in recent decades researchers have started to believe that it would be a satisfactory product for non-ruminant as well (Whitney et al., 2006).

Kyawt et al. (2019) demonstrated that dietary supplementation with up to 10% rice distillers dried grains (rDDG) increased BWG, decreased FCR, while FI (feed intake) remained unchanged. Cemin et al. (2019) reported that 0–40% high-protein distillers dried grains linearly decreased ADG and ADFI, thus high HP DDG levels negatively affected growth performance. Furthermore, Linneen et al. (2008) found that pigs fed diets containing 5–20% DDGS showed a linear decrease in ADG and ADFI, which was slightly contradictory to our findings. In addition, Świątkiewicz et al. (2016) reported that DDGS showed no significant effect on daily gain, feed utilization, which was consistent with the current study. Wang et al. (2016) demonstrated that replacing SBM with wheat DDGS linearly reduced ADG and feed efficiency (G:F), but ADFI was unaffected. In contrast, Lerner et al. (2019) reported that substituting DDGS with maize-soybean meal-based diets increased final BW and ADG, but decreased ADFI. In addition, outcomes of a related study by Curry et al. (2019), who observed that the addition of 30–40% DDGS showed no changes in ADG and ADFI, but significantly decreased feed efficiency (G:F). Similarly, the inclusion of 20–25% DDGS in the diets did not result in a significant difference in ADG and FCR in pigs and rabbits (Widyaratne and Zijlstra, 2007). The lack of changes in growth performance after DDGS application in growing-finishing pigs may be due to differences in animal types, palatability, grain quality, and doses of DDGS added to the diets.

Studies conducted by Kyawt et al. (2019) and Ganchev et al. (2020), who found that the incorporation of 30% maize DDGS into diets did not result in any changes in DM. The inclusion of wheat DDGS in the diet at the expense of SBM linearly reduced the apparent total tract digestibility coefficient (CATTD) of DM and gross energy (GE) (Wang et al., 2016). Risolia et al. (2019) suggested that DM digestibility was reduced by DDGS addition to dog diets supplemented with xylanase and protease. In contrast, increasing maize DDGS content in a broiler chicken diet elevated the apparent total tract digestibility of DM (Damasceno et al., 2020). Previously, Pedersen and Lindberg (2010), and Urriola and Stein (2010) found that DM digestibility was reduced by excess fibre in DDGS and faecal excretion. The latter authors showed that faeces excretion was increased and DM digestibility was significantly decreased. In the current study, the addition of 4–15% DDGS to the diet did not cause differences in digestibility. The presumed reason for the lack of stereotypic nutrient digestibility in growing-finishing pigs may be due to maize processing during the ethanol production process (grinding, heating, fermentation), which can alter the fibre structure and enzymes released by microorganisms, thereby causing partial breakdown of carbohydrate-lignin bonds.

Curry et al. (2019) demonstrated that the inclusion of DDGS in the feed resulted in a linear decrease in carcass traits. Linneen et al. (2008) found that with increasing DDGS levels in the diet, carcass weight and percentage yield decreased along with a reduction in backfat and fat-free lean. Likewise, Wu et al. (2016) reported that a diet containing 30% DDGS reduced carcass yield, LM area, and the percentage of fat-free lean, but did not exert any effect on backfat depth in comparison to a diet without DDGS. Świątkiewicz et al. (2016) and Kyawt et al. (2019) recorded no change in carcass traits after dietary supplementation of DDGS; however, our study demonstrated a trend towards reduced backfat thickness. Inconsistent findings concerning carcass quality may be due to an increase in DDGS content in different feed batches and energy intake by pigs.

Conclusions

The results of the present study indicated that replacing SBM with up to 15% DDGS in the basal diet had comparable effects on growth performance, nutrient digestibility and meat quality of growing-finishing pigs, suggesting the possibility of using DDGS as a suitable replacement for conventional protein sources in pig diets, which would provide the opportunity to formulate low-cost rations, as well as contribute to sustainable pig production.

Conflict of interest

The Authors declare that there is no conflict of interest.

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