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Effects of flaxseed oil supplementation on lactating sows and their offspring

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Abstract

This study was conducted on sows to evaluate the effect of flaxseed oil on the sows and their offspring's performance. Forty-eight (48) sows (Landrace × Yorkshire) and their offspring were assigned randomly to each treatment (Control and Control + flaxseed oil 0.5% [FX]). Body weight (BW), average daily feed intake (ADFI) and nutrient digestibility of the sows were estimated. Sow backfat thickness, days-to-estrus, and chest circumference were measured by different methods. In piglets, survival rate, the initial weight, weaning weight, and average daily gain (ADG) were calculated. Fecal scores of both the sows and piglets were recorded. Inclusion of FX did not influence ($p > 0.05$) the litter size, days-to-estrus, sow BW, ADFI and digestibility of nutrient throughout the experiment. Reduction in ($p < 0.05$) BW loss was observed with the FX supplementation in sows. Only the backfat thickness during the weaning period showed an increase ($p < 0.05$) by FX supplementation. Chest circumference was decreased ($p < 0.05$) in the FX group compared to the control. Sows fed the FX diet had a reduced ($p < 0.05$) fecal score only at weaning. Piglets' fecal score showed no significant differences for FX supplementation. However, the inclusion of FX brought about a higher ($p < 0.05$) birth weight, weaning weight, and average daily gain (ADG). In conclusion, our study suggests that FX has positive supplementary effects on a sow's body condition and its offspring's performance as a source of n-3 fatty acid.

Keywords: flaxseed oil, lactating sows, offspring, production performance

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Introduction

The growth and immune status of offspring highly depend on maternal colostrum yield and quality. Colostrum contains immunoglobulins and cytokines. To improve colostrum quality, improving maternal nutrition condition or intervention through the maternal diet can be a positive approach. In sow nutrition, fat plays an important role in energy supplementation. Among fat, in the diet, n-3 FA (fatty acid) is quite a concern. It has been reported that improved fetal development and neonatal vigor by n-3 FA supplementation in sows (Francine et al., 2010). Also, polyunsaturated fatty acids (PUFAs) are passable into the fetus from the placenta through the bloodstream. Even through the milk, it can be available to piglets (Sampels et al., 2011). PUFAs are also related to reproductive beneficial where n-3

FA is noticeable. PUFAs are more beneficial to the parturition and lactation period (Smits et al., 2011; Rosero, 2016). PUFA showed a better farrowing rate, reduced wean to estrus interval, and less culling rate in sows by PUFA supplementation (Rosero, 2016). Fish oil supplementation in sow diets resulted in higher n-3 PUFA in sow milk and blood serum of sow and their piglets (Fritsche et al., 1993). The addition of flaxseed or flaxseed oil into the pig diet is an effective way to increase n-3 FA and decrease the ratio between n-3 FA and n-6 FA. It can certainly increase the n-3 PUFA in sows (Juárez et al., 2011).

Collectively, the present study was designed to appraise the effects of feeding flax originated oil to gestating and lactating sows to evaluate its effect on sows along with the production performance of the piglets.

Materials and Methods

Animal care

The experimental protocols planned for this study were approved (DK-1-1935) by the animal care and use committee of Dankook University.

Animals and housing

To perform this study, a total of 48 crossbreed (Landrace × Yorkshire) sows from Dankook university experimental farm were included in this current study to explore the effect of flaxseed oil on the performance of mother sows and their offspring. All sows were artificially inseminated within one week. Pregnancy detection was performed by ultrasonography 25 d after mating. In pregnant sows, from d 28 of gestation, the same commercial gestation feed (Table 1) was fed to all sows.

Sows were relocated to an environmentally regulated farrowing house at d 107 of gestation. Sows with their offspring were divided randomly into 1 of 2 treatments. Feeding treatments were: 1) Control (CON); 2) Control + 0.5% flaxseed oil (FX: as replacement of tallow). Sows were given the same commercial gestation diet (Table 1) from d 28 to d 95 of gestation, and then, they were fed standard lactation feed (Table 1) to d 95 of lactation. On farrowing d 1 kg of standard lactation diet per sow was given and it was increased by 1 kg each day to ad libitum to prevent overconsumption. The feed supply was divided into 2 portions of daily meals. Individual slatted floor farrowing crates (2.4 m × 1.8 m) were allotted for each sow with its' offspring. Each crate included a piglet nest decorated with piglet drinking nipple and feeder, and the temperature was maintained at 31℃. Drinking nipples provided *ad libitum* water to the piglets. After birth, piglets were treated for umbilical cord treatment, tooth cutting, and ear-tagged for identification. On d 5, male piglets were castrated and 1 mL iron dextran was injected.

Sampling and measurements

Sows were individually weighed at d 28, 95, 110; d 1 after farrowing and d 24 after birth. The backfat thickness along with body weight of the sows was measured and recorded within a few hours soon after farrowing and again on the day of weaning (21 d). An ultrasound instrument (Piglot 105, SFK Technology, Herlev, Denmark) was used to measure the backfat thickness at 6 cm off the midline of the 10th rib. The daily feed intake of the sows was calculated by subtracting the feed refusal from feed allowance. With a measuring tape chest circumference of sows was measured during farrowing and

Table 1. Sow diet composition (as-fed basis).

Items	Gestation diet	Lactation diet
Ingredients (%)		
Corn	28.00	35.00
Wheat	22.80	18.50
Tapioca	2.00	2.00
Wheat bran	11.90	2.50
Rice bran	3.00	2.50
Soybean meal	5.10	18.90
Rapeseed meal	3.00	1.00
DDGS	7.50	5.00
Tallow	3.70	3.50
Molasses	2.00	4.00
Dicalcium phosphate	0.44	0.80
Limestone	1.57	1.33
Salt	0.45	0.45
L-Lysine HCl, 23%	0.80	0.12
Vitamin premix[y]	0.10	0.10
Mineral premix[z]	0.10	0.10
Calculated composition		
ME ($MJ \cdot kg^{-1}$)	14.11	14.52
CP (%)	14.30	17.40
Crude fat (%)	7.09	6.00
Lys (%)	0.72	1.00
Ca (%)	0.80	0.80
P (%)	0.59	0.57

DDGS, dried distillers grains; ME, metabolizable energy; CP, crude protein; Lys, lysine.

[y] Provided per kilogram of complete diet: Vitamin A, 10,000 IU; vitamin D_3, 2,000 IU; vitamin E, 48 IU; vitamin K_3, 1.5 mg; riboflavin, 6 mg; niacin, 40 mg; d-pantothenic, 17 mg; biotin, 0.2 mg; folic acid, 2 mg; choline, 166 mg; vitamin B_6, 2 mg; and vitamin B_{12}, 28 µg.

[z] Provided per kilogram of complete diet: Fe (as $FeSO_4 \cdot 7H_2O$), 90 mg; Cu (as $CuSO_4 \cdot 5H_2O$), 15 mg; Zn (as $ZnSO_4$), 50 mg; Mn (as MnO_2), 54 mg; I (as KI), 0.99 mg; and Se (as $Na_2SeO_3 \cdot 5H_2O$), 0.25 mg.

weaning. On the 15[th] day of lactation, 2% chromium oxide (Cr_2O_3) as an indigestible marker was added to the sow lactation diets for 6 days to estimate the apparent total tract digestibility of dry matter (DM). Fresh fecal samples were obtained from each sow. At -20℃ feed and fecal samples were kept until further analysis. Fecal samples were de-moisturized for 72 hrs at 70℃ and ground to pass through a 1 mm sieve. Following the procedures of AOAC (1998), DM and N were analyzed of the samples. Chromium presence in feed and fecal samples were analyzed by UV absorption spectrophotometer (Shimadzu UV-1201, Shimadzu, Kyoto, Japan) (Williams et al., 1962). Digestibility was calculated considering the chromic oxide as an indigestible marker.

Estrus detection was performed during the weaning period at 08.30 a.m. and 04.00 p.m. every day, physical indications of estrus such as vulva enlargement or reddening, and using human back-pressure were used. A sow was counted to be in estrus if she expressed a standing response prompted by a back-pressure test in the presence of a boar. Fecal scores of the sows were recorded at d 28, 95, 110 of gestation also in farrowing and during the weaning period following the fecal scoring category

(Hart and Dobb, 1988), where the scoring category was based on the moisture content.

The record of piglets born, stillborn, live and dead during lactation was updated regularly for each litter. On d 0, d 21 (weaning) each piglet body weight (BW) was measured to calculate average daily gain (ADG). At d 5 and weaning, fecal scores were also evaluated.

Statistical analyses

The statistical analysis was done by the GLM procedure of SAS with the Student's t-test (SAS Inst. Inc., Cary, NC, USA). The experimental unit was an individual sow or litter of piglets. The effect of treatment on average sow weight, the number of pigs per litter, litter weight was determined using initial value as covariates. The probability level of $p < 0.05$ was regarded as statistically significant.

Results and Discussion

Sow performance

The inclusion of flaxseed oil did not affect ($p > 0.05$) the litter size, sow body weight throughout the experiment (Table 2). But interestingly, a reduced ($p < 0.05$) body weight loss was observed with the flaxseed oil supplementation in sows. No difference ($p > 0.05$) was distinguished on the average daily feed intake (ADFI) between the two groups. The backfat thickness and loss of backfat thickness of the sows were not different ($p > 0.05$) between groups due to flaxseed oil supplementation during the gestation period. Flax oil supplementation distinguished an increase ($p < 0.05$) in sow's backfat thickness at the weaning period. It can be due to the extra availability of fat from flaxseed oil which caused more fat accumulation and reduced protein synthesis (Hoque et al., 2020). Days to estrus were not affected ($p > 0.05$) in our study due to flaxseed oil supplementation.

A decreased ($p < 0.05$) chest circumference of sows was observed with the flaxseed oil supplementation group compared with the control group. No difference was observed on the nutrient digestibility on the current study (Table 3). Sows fed flaxseed oil supplemented diet led to a reduced ($p < 0.05$) fecal score at weaning, but it did not affect ($p > 0.05$) the fecal score at d 28, 95, 110, and farrowing (Table 4).

Previous reports mentioned that n-3 fatty acids supplied through diet had a great impact on immune responses in pigs (Mitre et al., 2005; Zhan et al., 2009). Besides, the available unsaturated long-chain fatty acids could have integrated into the membranes of the body cells and affect the immune status of animals. It has been suggested that flaxseed oil supplementation as a source of n-3 fatty acid can cause the lymphocyte response which stimulates the cytokines production such as lymphocyte proliferation (Kelley et al., 1991; Calder et al., 2002).

In this study, the dietary supplementation of flaxseed oil greatly benefited the health condition of sows during pregnancy and after farrowing. FX supplementation reduced body weight loss along with back fat loss, proving that, the sows' body metabolism was greatly influenced by the omega-3 fatty acids supplied by flaxseed oil supplementation. FX supplemented group also has a better initial weight of piglets and continued to show higher body weight and average daily gain up to the weaning period. Such as the omega-3 fatty acids influence the effectivity of several specific metabolic and structural aspects within the body, α-linolenic acid (ALA) is described as mostly available fatty acid for normal β-oxidation, lead to

Table 2. Effect of supplementation of flaxseed oil on performance in lactating sows.

Items	CON	FO	SEM
Parity	1.3	1.4	0.1
Litter			
No. of pigs	11.1	11.1	0.2
Weaned pigs	10.9	11.0	0.2
Sow body weight (kg)			
d 28	169.5	171.7	4.3
d 95	200.0	200.5	4.2
d 110	218.2	219.5	4.8
Farrowing	197.0	196.0	4.4
Weaning	180.0	183.4	4.8
Body weight loss (kg)	17.0a	12.6b	1.6
ADFI (kg)			
Gestation	2.78	2.78	0.01
Lactation	7.10	7.08	0.04
Sow backfat thickness (mm)			
Gestation	23.6	24.2	0.5
Farrowing	25.8	26.5	0.4
Weaning	20.4b	21.9a	0.4
Backfat thickness loss (mm)	5.4	4.6	0.3
Days to estrus (d)	4.5	4.4	0.1
Chest circumference (cm)			
Initial	95.1	95.9	0.9
Weaning	106.2a	100.5b	1.4

CON, basal diet; FO, CON + 0.5% flaxseed oil; SEM, standard error; ADFI, average daily feed intake.
a, b: Means in the same row with different superscripts differ ($p < 0.05$).

Table 3. Effect of flaxseed oil supplementation on nutrient digestibility in lactating sows.

Items (%)	CON	FO	SEM
Dry matter	77.38	77.40	0.07
Nitrogen	78.06	78.24	0.07
Energy	77.76	77.67	0.10

CON, basal diet; FO, CON + 0.5% flaxseed oil; SEM, standard error of the mean.

Table 4. Effect of flaxseed oil supplementation on fecal score[z] in lactating sows.

Items	CON	FO	SEM
D 28	3.6	3.4	0.1
D 95	3.4	3.2	0.1
D 110	2.9	2.9	0.1
Farrowing	2.7	2.9	0.1
Weaning	3.6a	3.2b	0.1

CON, basal diet; FO, CON + 0.5% flaxseed oil; SEM, standard error of the mean.
[z] Fecal score: 1 = hard, dry pellets in a small, hard mass; 2 = hard, formed stool that remains firm and soft; 3 = soft, formed, and moist stool that retains its shape; 4 = soft, unformed stool that assumes the shape of the container; 5 = watery, liquid stool that can be poured.
a, b: Means in the same row with different superscripts differ ($p < 0.05$).

the production of energy (Cunnane and Anderson, 1997). Also, shark liver oil (omega-3 sources) supplementation in sows during gestation, improved the furrowing performance of the sows and their offspring (Mitre et al., 2005). However, shark liver oil contains eicosapentaenoic acid (EPA) and docosahexaenoic (DHA). As mentioned earlier, flaxseed oil is abundant in α-linolenic acid (C18:3n-3).

Around 8-20% of ALA is transformed into EPA (Burdge, 2004; Defilippis and Sperling, 2006). On the other hand, the conversion of ALA into DHA is lower, which is estimated to be around 0 - 9%. It has been stated that in humans the efficiency of ALA conversion to EPA is about 10 - 15% (Holub, 2002). The ALA conversion to DHA occurred with less than 1% efficiency (Whelan and Rust, 2006). Therefore, it is not enough to explain the benefits of ALA derived from flaxseed oil because of the low transforming efficiency of ALA to EPA and DHA. For this reason, we studied other beneficial effects of EPA from flaxseed oil.

As mentioned earlier, the gestation and lactation diet linoleic acid (LA; 18:2 n-6) comes from plant oils, such as corn oils, sunflower, cereals, animal fat, and wholegrain bread, whereas, ALA is available in green plant type vegetables such as flaxseed and rapeseed oils. However, linoleic acid (LA; 18:2 n-6LA) and α-linolenic acid (ALA; 18:3 n-3) are broken down by the same set of enzymes. So, competition is present amid these two fatty acids, with an excess presence of one may oppose the metabolism of the other. Moreover, arachidonic acid (ArA; 20:4 n-6) obtained from LA, can be transformed into the type-2 prostaglandins, while eicosapentaenoic acid (EPA; 20:5 n-3), attained from ALA can be converted to type-3 prostaglandins, which are biologically less potent (Needleman et al., 1979).

Therefore, we hypothesized that improvement in body weight loss and backfat thickness was occurred due to the beneficial effect of good immune metabolism with ALA from flaxseed oil. Improved immunity may cause good production performance (improved piglet growth) of sows and decrease the breakdown of their tissue in the present study. But interestingly, nutrient digestibility was similar between groups of this study. Here, the possible reason could be due to the individual differences between the sows.

Litter performance

Dietary flaxseed oil supplementation in sows did not affect ($p > 0.05$) the piglet's survival and fecal score throughout the experiments (Table 5). But interestingly, the inclusion of flaxseed oil led to a higher ($p < 0.05$) initial weight, weaning weight,

Table 5. Effect of flaxseed oil supplementation on the performance and fecal score[z] in piglets.

Items	CON	FO	SEM
Piglets performance			
Piglet survival (%)	97.90	99.10	0.80
Initial weight (kg)	1.29b	1.48a	0.03
Weaning weight (kg)	6.79b	7.43a	0.10
Average daily gain ($g \cdot d^{-1}$)	229b	247a	3
Fecal score			
D 5	4.90	4.60	0.10
Weaning	3.40	3.20	0.10

CON, basal diet; FO, CON + 0.5% flaxseed oil; SEM, standard error of the mean.

[z] Fecal score: 1 = hard, dry pellets in a small, hard mass; 2 = hard, formed stool that remains firm and soft; 3 = soft, formed, and moist stool that retains its shape; 4 = soft, unformed stool that assumes the shape of the container; 5 = watery, liquid stool that can be poured.

a, b: Means in the same row with different superscripts differ ($p < 0.05$).

and average daily gain in piglets than those without flaxseed oil supplementation.

It is proved from the current study that flaxseed oil feeding to the gestation and lactating sows significantly increased the birth weight of piglets compared with those without flaxseed oil supplementation, which is in agreement with the previous report (Baidoo et al., 2020), where the suggestion was increased piglet weaning weight could be observed with 5% flax added to diet of the sows around the gestation and lactation period.

Increased muscle glycogen and increased nutrient absorption in weanling pigs were reported where mother sows in gestation and lactation were fed n-3 PUFA (Gabler et al., 2007). It is well suggested that flaxseed oil is a good source of PUFA for the animal; therefore, the cause for the increased birth weight is probably due to flaxseed oil supplementation in this study. A greater growth rate was found in weaning piglets, which is consistent with another report (Mateo et al., 2009). That report acclaimed that the addition of n-3 fatty acid sows' diet assisted a higher ADG of their piglets than those deficits the supplementation.

An increment of piglet birth weights and weaning weights were caused by 5% flax supplemented sows during the gestation and lactation period (Baidoo et al., 2020). In addition, both n-3 fatty acids along with n-3/n-6 ratios were higher in carcasses and brains of 1-day old piglets by supplementation of flaxseed meal in sows (Farmer and Petit, 2009). According to previous findings, the incorporation of n-3 fatty acid in the sow diets could regulate the intestine function of newborn piglets and enhanced intestinal glucose absorption (Gabler et al., 2007). Several studies suggested that dietary sources of n-3 fatty acid increased the concentration of IgG in colostrum and milk (Mitre et al., 2005; Mateo et al., 2009) and led to a higher antibody and leukocytes transfer to piglets. Therefore, our study also confirmed the inclusion of flaxseed oil indeed has a beneficial effect on the sow and piglet.

Conclusion

In closing, our study proposed that FX with its positive effect on sow body condition and piglet's performance, can be a possible replacement of lipid/fat source in the sow diet.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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