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Effect of omega-3 fatty acid supplementation in salmon oil on the production performance of lactating sows and their offspring

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Abstract

Salmon oil (SO) could be used as a great source of ω-3 fatty acids in pig diet. The purpose of the study was to investigate the SO effect on production performance of sows and their offspring. 48 lactating sows (Landrace × Yorkshire) from Dankook University experimental farm were used in this study. Sows were conceived using either guided natural mating or by artificial insemination. Pregnancy diagnosis was confirmed by ultrasonography on day 25 after mating. Sows and their offspring were assigned randomly to 1 of 2 treatments. Treatments included: 1), control (CON); 2), control + SO 0.5% (CS). The inclusion of SO did not affect ($p > 0.05$) the litter size throughout the experiment. No difference ($p > 0.05$) was observed on the average daily feed intake (ADFI), chest circumference, estrus interval and sow backfat thickness between CON and SO treatments. Dietary SO supplemented diet reduced ($p < 0.05$) body weight loss during lactation compared with control treatment. Pigs fed SO supplemented diet did not affect ($p > 0.05$) the fecal scores during lactation compared with those fed control treatments. Sows fed SO supplemented diet led to a higher ($p < 0.05$) initial weight, weaning weight and average daily gain of piglets than those fed control diets. No difference ($p > 0.05$) was observed on piglet survival and fecal scores throughout the experiment. Inclusion of SO could reduce the body weight loss of sows and improves piglet growth during lactation, indicating SO has beneficial effects for pigs.

Keywords: lactating sows, piglets, production performance, salmon oil

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Introduction

With the development of the pork industry, a great attention has been focused on the beneficial roles of various fatty acids while formulating pig-diets. Studies have already suggested that long chain poly unsaturated fatty acids (PUFA) is important for the visual and neural development of the neonate (Innis, 2007). It is well suggested that omega-3 (ω-3) fatty acids can improve the immunity of pig, especially the major unsaturated long-chain fatty acids, which could be substituted for fish oil, or flax seed and canola oils or marine microalgae (Kibria and Kim, 2019). A Study documented that the fatty acids could be released from the phospholipids to undergo enzymatic degradation to the eicosanoids, which is considered as short live lipid derived mediators (Gabler et al., 2009). Aforementioned study also suggested that the eicosanoids have profound effects on biological response and are responsible for many beneficial effects even during acute inflammation.

Moreover, marine oils were used as supplementation in gestating and lactating sows as well as weaning piglets for certain beneficial effect on the growth performance in pigs and survival of their offsprings because those also contain fatty acids (Kim et al., 2006; Kibria and Kim, 2019). Gabler et al. (2007) also suggested that inclusion of n-3 fatty acid (ω-3 fatty acids are also called n-3 fatty acids) in sow diet could increase the muscle glycogen content in weaning pigs. Therefore, it is suitable to suggest that providing salmon oil to the sows could greatly increase the production performance of sows and their offspring. Our study especially concerned about the use of salmon oil, which is the fish oil extracted from salmon containing a higher concentration of ω-3 polyunsaturated fatty acid.

Collectively, the objective of the current study was to determine the salmon oil effect on the production performance of lactating sows and their litter performance.

Materials and Methods

The experimental protocols employed in this study were approved by the Animal Care and Use Committee of Dankook University.

Experimental animals, diets, and design

A total of 48 lactating sows (Landrace × Yorkshire) from Dankook University pig farm were used in this current study to investigate the salmon oil (SO) effect on the production performance of sows. Sows were mated by either natural mating under supervision or by artificial insemination. Pregnancy of each sow was confirmed by the ultrasonography on d 25 after mating or insemination.

From d 28 of gestation, all sows of control and treatment were fed same commercial gestation diet. Sows and their offspring were assigned randomly to 1 of 2 treatments. Treatments included: 1) control (CON); 2) control + salmon oil 0.5% (SO: as replacement of tallow). Sows were fed on a same commercial gestation diet from d 28 to d 95 of gestation, and from d 95 gestation, they were fed standard lactation feed from the d 95 of lactation. At d 107 of gestation, sows were moved to the farrowing crates in an environmentally regulated farrowing house. On farrowing day sows were received 1 kg of standard lactation diet by NRC (2012) recommendation and increased feed by 1 kg each day until *ad libitum* to avoid overconsumption from the beginning (Table 1).

Feed allowance was divided into 2 daily meals. Sows and their offspring were individually housed in farrowing crates (slatted floor; 2.4 × 1.8 m). This space included a piglet nest which was electrically maintained at 31℃, a piglet drinking nipple, and a piglet feeder placed on a dimpled rubber matting to collect any spillage from the feed. Drinking nipples provided water *ad libitum* to the piglets. After birth, piglets were handled for tooth cutting, umbilical cord treatment, and ear tagged for labeling. All piglets received injections of 1 mL of iron dextran and the males were castrated on d 5 after birth.

Table 1. Composition of the experimental sow diets (as-fed basis).

Items	Gestation diet	Lactation diet	
		CON	SO
Ingredients (%)			
Corn	35.54	39.20	39.20
Wheat	28.80	18.50	18.50
Tapioca	2.00	2.00	2.00
Wheat bran	11.90	2.50	2.50
Rice bran	3.00	2.50	2.50
Soybean meal	5.10	18.90	18.90
Rapeseed meal	3.00	1.00	1.00
DDGS	7.50	5.00	5.00
Salmon oil	-	-	0.50
Tallow	3.70	3.50	3.00
Molasses	2.00	4.00	4.00
Dicalcium phosphate	0.44	0.80	0.80
Limestone	1.57	1.33	1.33
Salt	0.45	0.45	0.45
L-Lysine HCl, 23%	0.80	0.12	0.12
Vitamin premix[y]	0.10	0.10	0.10
Mineral premix[z]	0.10	0.10	0.10
Calculated composition (%)			
ME ($MJ\cdot kg^{-1}$)	14.11	14.52	14.52
CP	14.30	17.40	17.40
Crude fat	7.09	6.00	6.00
Lys	0.72	1.00	1.00
Ca	0.80	0.80	0.80
P	0.59	0.57	0.57

CON, basal diet; SO, salmon oil; DDGS, distillers dried grains with solubles; 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.

Sampling and measurements

Sows were weighed at d 28, 95, 110 and 115 (d 1 after farrowing) and d 24 after birth (weaning). The backfat thickness and body weight of the sows were measured within a few hours after farrowing and on the day of weaning (21 d). The backfat thickness (6 cm off the midline at the 10th rib) measurements were taken using a real-time ultrasound instrument (Piglot 105, SFK Technology, Herlev, Denmark). The daily feed intake (FI) of the sows was determined as the difference between feed allowance and the refusals collected before feeding. Chest circumference of sows was measured at farrowing and weaning using a tape. At the 15th day of lactation, chromium oxide (Cr_2O_3, 2 $g\cdot kg^{-1}$) was added to the diets as an indigestible marker for 6 days to determine the apparent total tract digestibility of DM. Fresh fecal samples were obtained from each sows. All fecal and feed samples were stored at -20℃ until analyzed. Fecal samples were dried and ground to pass through a 1-mm screen, after which the feed and fecal samples were analyzed for DM and N according to the Association of Official Analytical Chemists (AOAC, 2007). Gross energy was calculated by using a bomb calorimeter (Parr 6400 Bomb Calorimeter, Parr Instrument Co., Moline, USA). Following the method described by Williams et al. (1962) Chromium was analyzed by UV absorption spectrophotometry (Shimadzu UV-1201, Shimadzu, Kyoto, Japan). Digestibility was calculated using chromic oxide as an indigestible marker.

Detection of estrus was conducted twice per day from weaning onward, at 8:30 am and 4.00 pm every day, other signs of estrus such as vulva swelling or reddening, or reaction to human back-pressure were used. A sow was considered to be in estrus when exhibiting a standing response induced by a back pressure test. Fecal scores of the sows were measured at d 28, 95, 110, after farrowing and weaning according to Hart and Dobb (1988), where the severity of diarrhea from each pig were scored by determining the moisture content. Briefly, fecal scores were 0, normal, firm feces; 1, possible slight diarrhea; 2, definitely unformed, moderately fluid feces; and 3, very watery and frothy diarrhea.

The total number of piglets born, live, stillborn and dead during lactation was recorded for each litter. Individual piglet body weight (BW) was assessed on d 0, d 21 (weaning) to calculate average daily gain (ADG). Fecal scores were also evaluated at d 5 and weaning.

Statistical analysis

Data were analyzed using the General Linear Models procedure of SAS (SAS Institute Inc., Cary, NC, USA). The individual sow as well as litter of piglets was used as the experimental unit. The effect of treatment on average sow weight, numbers of pigs per litter, litter weight were determined using initial value as covariates. The probability level of $p < 0.05$ was regarded as statistically significant.

Results and Discussion

Sow performance

Dietary salmon oil supplementation reduced ($p < 0.05$) the body weight loss during lactation compared with control treatment. However, the inclusion of salmon oil did not affect ($p > 0.05$) the litter size throughout the experiment (Table 2). No difference ($p > 0.05$) was observed on the parity, sow body weight, average daily feed intake (ADFI), chest circumference, estrus interval and sow backfat thickness between CON and SO treatments. Nutrient digestibility and fecal scores of sows which fed salmon oil supplemented diet were not affected ($p > 0.05$) during lactation compared with those fed control treatment (Table 3 and Table 4).

It is evident from the current study that the inclusion of salmon oil in sow diet seemed to be benefited the health status of the sows, in which the body weight loss of sows during lactation was reduced ($p < 0.05$) by the salmon oil supplementation. It is well accepted that the sows cannot satisfy their nutrient requirement from feed during lactation, so they have to mobilize their tissue to provide nutrients to piglets. Therefore, reduction of the body weight loss is normally considered as natural health marker of sows during lactation. Previously, Mitre et al. (2005) had demonstrated that n-3 fatty acids supplemented diet had a great impact on immune response in pigs, and suggested that the major unsaturated long-chain fatty acids could incorporate in the cell membranes of the body and subsequently affect the immune status of animal that was later found successful (Zhan et al., 2009). Reilly et al. (2008) also suggested that the inclusion of ω-3 fatty acids could influence the nutrient digestibility by maintaining the function and structure of the small intestine, and its digestive capacity of the guts. After farrowing, a rapid increase in ADFI of sow is important because the energy requirement for milk production is very high (Noblet et al., 1990). A low ADFI during lactation leads to greater BW loss, decreased milk production and reproductive problems that may lead to culling of the sow (Baidoo et al., 1992; Eissen et al., 2009). Consequently, it is important to identify sows that have a behavior favorable to piglet survival during farrowing, and that also have the potential to rapidly increase the ADFI during lactation. However, in our current study, there is no significant difference of feed intake between treatments. Although, the nutrient digestibility was not significantly increased by the salmon oil supplementation, it numerically increased the nutrient digestibility compared with the control treatments.

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

Items	CON	SO	SE	p-value
Parity	2.0	1.9	0.1	0.6623
Litter				
No. of pigs	11.8	11.6	0.2	0.6451
Weaned pigs	11.5	11.4	0.2	0.7828
Sow body weight (kg)				
d 28	154.2	153.5	2.1	0.8535
d 95	199.9	205.5	1.9	0.1686
d 110	216.7	221.5	2.1	0.3106
Farrowing	200.5	202.1	2.0	0.7651
Weaning	188.3	192.3	2.0	0.4376
Body weight loss (kg)	12.3a	9.6b	0.7	0.0127
ADFI (kg)				
Gestation	3.05	3.04	0.01	0.8609
Lactation	6.29	6.24	0.02	0.7154
Sow backfat thickness (mm)				
Gestation	23.4	23.0	0.5	0.6348
Farrowing	24.4	24.8	0.5	0.6976
Weaning	22.1	22.4	0.6	0.8051
Backfat thickness loss (mm)	2.3	2.4	0.3	0.8091
Days to estrus (d)	4.4	4.4	0.1	1.0000
Chest circumference (cm)				
Initial	100.9	101.1	0.8	0.9341
Weaning	101.1	99.1	0.8	0.5213

CON, basal diet; SO, CON + 0.5% salmon oil; SE, 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 salmon oil supplementation on nutrient digestibility in lactating sows.

Items (%)	CON	SO	SE	p-value
Dry matter	73.03	74.32	0.62	0.0975
Nitrogen	74.83	75.07	0.75	0.7849
Energy	72.47	73.57	0.62	0.3551

CON, basal diet; SO, CON + 0.5% salmon oil; SE, standard error.

Table 4. Effect of salmon oil supplementation on nutrient digestibility in lactating sows[z].

Items (%)	CON	SO	SE	p-value
D 28	3.7	3.5	0.1	0.2891
D 95	3.7	3.5	0.1	0.3867
D 110	3.6	3.6	0.1	1.0000
Farrowing	3.6	3.5	0.1	0.3968
Weaning	3.5	3.3	0.1	0.1520

CON, basal diet; SO, CON + 0.5% salmon oil; SE, standard error.
[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.

As mentioned previous, several studies (Calder, 2001; Wallace, 2001; Jupp et al., 2007) reported that common characteristics of chronic inflammatory diseases such as inflammatory bowel disease is excessive production of arachidonic acid-derived eicosanoids. Moreover, Bagga et al. (2003) and Robinson and Stone (2006) concluded that eicosapentaenoic acid (EPA) derived from salmon oil could inhibit eicosanoid synthesis from arachidonic acid (ArA) competitively. Therefore, EPA is known for its anti-inflammatory properties. Also, the eicosanoids derived from EPA are less inflammatory or even anti-inflammatory, compared with eicosanoids derived from ArA. With these reports, we hypothesized that good immune effects of EPA from salmon oil supplementation, influenced beneficial effects of BW loss during lactation. Tryptophan metabolism is also involved in the response to a stressful event in pigs (Sève et al., 1991; Koopmans et al., 2005; Guzik et al., 2006). Tryptophan concentration differs according to the age and the physiological status of the pig. The metabolism of growing pig is oriented toward increasing the BW, whereas the metabolism of the lactating sow is oriented toward mobilization of body reserves that can provide energy and nutrients for mammary gland development and milk production Tryptophan can be metabolized in different pathways; one of the pathway is protein synthesis through the hydroxylase pathway. The other pathway is the kynurenin pathway, which is the major route for Tryptophan catabolism. In excess or under inflammatory conditions, the catabolism of Trp begins through activation of the enzyme indole amine 2, 3 dioxygenase (Melchior et al., 2004; Melchior et al., 2005).

Therefore, it is suitable to conclude that such as EPA derived from the salmon oil supplementation benefited the sow's health condition by some other endogenous function such as immune status, tryptophan catabolism and digestibility, which may consequently reduce the mobilization of its own body during lactation and explained the reduced body weight loss of sows observed in the present study.

Litter performance

Sows fed salmon oil supplemented diet led to give birth to the piglets with higher ($p < 0.05$) initial weight, weaning weight and average daily gain than those fed control diets (Table 5). No difference ($p > 0.05$) was observed on the piglet survival and fecal scores throughout the experiment.

Baidoo et al. (2003) had previously suggested that increased piglet weaning weight could be observed with 5% flax supplementation in the diet of the sows throughout gestation and lactation. Mateo et al. (2009) suggested that ω-3 fatty acid supplementation in sows led to a higher ADG of piglets than those without supplementation. As stated previously, salmon oil is also a rich of PUFA and could be used as an ω-3 fatty acid source for the animal, therefore, it is suitable to suggest that the inclusion of salmon oil in sow diets could increase the growth rate of piglets in the current study. Indeed, sows fed salmon oils supplemented diet greatly increased the growth rate of the piglet in the present study. Gabler et al. (2007) reported an increased muscle glycogen and improved nutrient absorption in weanling pig from sows fed ω-3 PUFA in gestation and lactation. Several studies suggested that dietary marine sources of ω-3 fatty acid increased concentration of IgG in colostrums and milk (Mitre et al., 2005; Mateo et al., 2009) and led to a higher antibodies and leukocytes transfer to piglets. Gabler et al. (2007) also suggested that the inclusion of ω-3 fatty acid in sows diets increased intestinal glucose absorption in newly weaned piglets indicated that the intestinal function in piglets could be modulated via utero manipulation of the sow diets.

Table 5. Effect of salmon oil supplementation on performance and fecal score in piglets^{z}.

Items	CON	SO	SE	p-value
Piglets performance				
Piglet survival (%)	97.8	98.3	0.40	0.7066
Initial weight (kg)	1.17b	1.38a	0.03	0.0002
Weaning weight (kg)	7.00b	7.67a	0.10	0.0004
Average daily gain ($g \cdot d^{-1}$)	243b	262a	4.00	0.0047
Fecal scores				
d 5	4.60	4.70	0.10	0.7600
Weaning	3.00	3.00	-	-

CON, basal diet; SO, CON + 0.5% salmon oil; SE, standard error.
^{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 ($p < 0.05$).

In the current study, although we did not investigate the IgG and glucose concentration in piglet, we hypothesized that the reason for the salmon oil supplementation could be the aforementioned beneficial effects demonstrated. However, it is interesting to note that Farmer et al. (2010) did not observe any improvement in the piglet growth rate when fish oil was supplemented in sow diets. The reason is likely to be the different oil (flaxseed oil and salmon oil) or some other feed formulation factors associated with each studies.

Conclusions

In conclusion, our results suggested that the inclusion of salmon oil as the source of ω-3 fatty acids, could reduce the body weight loss of sows during lactation and improves the growth rate of piglet by improving initial weight or birth weight and weaning weight of piglets significantly ($p > 0.05$), indicating salmon oil could be used as a great source of feed supplementation or additive for the lactating sows and also for the piglets.

Conflict of Interests

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

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