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Supplementing maternal sows' diet with 25-hydroxyvitamin D_3 increased milk profile and the health status of their young ones

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Abstract

A total of 10 sows (average body weight of 185.5 kg, Landrace × Yorkshire) and their progenies were utilized in this experiment. At first, sows were randomly allotted to 1 of 2 dietary treatments with 5 replicates of 1 sow and its litter per pen following a randomized complete block design. The test treatments were: Control (CON) basal diet and a basal diet supplemented with 0.036% of 25-hydroxyvitamin D_3 (25(OH)D_3). Sows fed diet supplemented with 25(OH)D_3 had no adverse effect on their reproduction performance such as body weight, average daily feed intake, body weight loss, and body weight loss difference during before farrowing, after farrowing, and at weaning. Piglets born from sows fed dietary 25(OH)D_3 showed significantly increased ($p < 0.05$) weaning weight and average daily gain. Sows fed diet supplemented with 25(OH)D_3 had high total solid (TS) colostrum concentration at week 1, however at the end of week 3 the TS level had decreased approximately 2%. We believe that the positive findings of the present study could establish a major constituent for the swine mammary secretions and provide a reliable groundwork for future experiments in animal husbandry.

Keywords: 25-hydroxyvitamin D_3, milk profile, reproduction performance, sows

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Introduction

A survey of swine research indicated that a substantial proportion of serum 25-hydroxyvitamin D_3 (25(OH)D_3) concentrations in pigs are below guidelines (Arnold et al., 2015). Concurrently, Upadhaya et al. (2022) reported that vitamin D plays a vital role in bone health of mammals by maintaining proper calcium (Ca) and phosphorus (P) homeostasis. Such Ca requirement needs to be significantly higher during gestation and lactation period as a result of milk production, growth, and development of the fetus (Ardeshirpour et al., 2015). Usually, vitamin D can be obtained through diet or produced from the body by exposing to ultraviolet B (UVB) radiation from sunlight. Endogenous synthesis is considered as the most available source of vitamin D (Upadhaya et al., 2021). However, the most swine barns were built in confinement where animals cannot expose to direct sunlight and this insufficient sunlight expose has eventually leads to decrease feed intake, high level of lameness, and impaired bone growth and muscle function (Pietrosemoli and Tang, 2020). To overcome all these issues, scientists and pig industrialists were prompted to find a suitable diet that could increase the production performance of sow and the growth status of their young ones.

A nutritional approach to the use of dietary supplementation with 25(OH)D_3, as an alternative source of vitamin D, has gained popularity due to its commercialization and more efficient absorbability. The addition of 25(OH)D_3 rather than its precursor vitamin D_3 can evade 25-hydroxylation reaction in the liver thereby indicating that dietary 25(OH)D_3 additive could rapidly increase the circulation of vitamin D status in animals. Emerging experiments have reported that maternal 25(OH)D_3 supplementation has increased reproduction performances, birth outcomes and promote vitamin D circulation in sows and their young ones (Zhang and Piao, 2021). Similarly, Zhou et al. (2016) addressed that adding same dose of 25(OH)D_3 supplementation to both sow and their offspring diet reveals better growth performance. On contrary, Flohr et al. (2015) reported that piglets born form sows fed 3,000 IU vitamin D_3 has no impact on their average daily gain. During the natural suckling period, sow milk provides a chief nutrient to their piglets. Besides, the composition and quantity of milk produced by sows are very important for the successful piglet production (Klobasa and Butler, 1987). Previously, Weber et al. (2014) reported that sows fed diet supplemented with 25(OH)D_3 showed increased vitamin D concentration in their milk profile. The first step of hydroxylation occurs in the liver, while the second occurs in the kidney. It was hypothesized that a synthetically produced 25(OH)D_3 could be readily available to the animal because it bypasses the first step in the conversion to 1, 25 dihydroxycholecalciferols. Therefore, the objective of the current study was to evaluate whether adding dietary 25(OH)D_3 to a basal diet of sow could increase their milk profile there by enhancing the health status of their offspring's.

Materials and Methods

The research protocol (DK-2-2302) was reviewed and approved by Animal Care and Use Committee of Dankook University, Cheonan, Korea. A total of 10 sows (average body weight of 185.5 kg, Landrace × Yorkshire) and their progenies were utilized in this experiment. At first, sows were randomly allotted to 1 of 2 dietary treatments with 5 replicates of 1 sow and its litter per pen following a randomized complete block design. The test treatments were: Control (CON) basal diet and a basal diet supplemented with 0.036% of 25(OH)D_3. The basal diets were formulated according to the nutritional requirements of NRC (2012) (Table 1), mixed with supplement and offered to sows from 114th day of lactation and continued until weaning (21 days). The test treatment was commercially purchased from Farmsco Co., Ltd. (Korea). Sow milk was the only source to piglets from birth to 21 days of weaning. On day 107 of pregnancy, all sows were weighed individually and moved to farrowing crates (2.1 × 0.6 m) and stayed there until weaning. Piglet's initial birth weight (individual), and total birth weight were measured, and litters were cross-fostered among treatment groups within 24 to 36 h after parturition. The number of alive, dead, and mummified piglets in each pen was calculated to determine the survival rate at farrowing period. One mL (per pig) intravenous iron dextran injection was given within 24 h of birth. The male piglets were castrated (5 days after postpartum).

Table 1. Basal diet composition (as-fed basis) for lactating sow.

Items	Value
Ingredients (%)	
Corn	41.93
Wheat	23.00
Wheat bran	8.31
Soybean meal (48%)	4.48
Dehulled soybean meal	12.96
Molasses	2.00
Soybean oil	3.40
Mono-calcium phosphate	1.20
Limestone	1.18
Magnesium oxide	0.02
Salt	0.50
Threonine (99%)	0.17
Methionine (99%)	0.02
L-lysine (78%)	0.31
Vitamin/Mineral premix[z]	0.40
Choline (25%)	0.12
Total	100
Calculated value (%)	
Crude protein	16.50
Metabolizable energy ($kcal \cdot kg^{-1}$)	3,300
Crude fat	5.71
Ca	0.76
P	0.65
Lysine	0.96
Threonine	0.65
Methionine	0.26

[z] Provided per kg of complete diet: 16,800 IU vitamin A; 108 mg vitamin E; 7.2 mg vitamin K; 2,400 IU vitamin D_3; 18 mg riboflavin; 80.4 mg niacin; 2.64 mg thiamine; 45.6 mg D-pantothenic; 0.06 mg cobalamin; 24 mg Mn (as $MnSO_4$); 12 mg Cu (as $CuSO_4$); 60 mg Zn (as $ZnSO_4$); 0.6 mg I (as $Ca(IO_3)_2$); 0.36 mg Se (as Na_2SeO_3).

Sampling and measurements

Reproduction performance of sow

To determine the body weight loss (BWL), individual sows body weight (BW) was measured at initial, pre- and post-farrowing, and at weaning (21 days). The backfat thickness (BFT) (6 to 8 cm from the midline of the 10th rib) of each sow was measured using piglet 105, SFK Tech real-time ultrasonic instrument (Denmark) at initial, pre- and post-pregnancy, and at weaning to determine the backfat thickness loss (BFTL). During gestation (phase 1, 2 and 3), lactation, and ovulation period, the feed intake and the leftovers were calculated to determine the average daily feed intake (ADFI) of the sows. Twenty-one days after weaning, sows were taken to the breeding room (22nd day) and rested for about 2 weeks. Later sows were exhibited to standing response caused by a back-pressure test in presence of matured Duroc boars (twice a day) for estrus detection.

Suckling pig performance

The initial (INO) and the final number (FNO) of piglets were recorded to calculate the survival ratio of piglets during lactation period. Individual piglet's BW was measured at initial and at weaning. The average daily gain (ADG) of the piglets was calculated by the birth weight (kg) - weaning weight (kg) / length of lactation (day) × 1,000. At the end of week 1, 2 and 3, the fecal score of suckling was evaluated according to Hu et al. (2012), scoring system: 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.

Milk profile of sow

At the end of week 2 and 3, 10 mL of milk samples were manually collected from the mammilla of sows using a sterile bottle and stored at 4℃. The fat, protein, lactose, solids not fat, total solids, and milk frozen point were determined using 133-B MilkoScan™ (FOSS Electric, Denmark) analyzer.

Data analysis

This experimental data was analyzed using the general linear model (GLM) procedure of SAS Institute Inc. (USA). T-test was performed to determine the effect of 25(OH)D_3 additive on sow and their offspring performance. Individual sow and their progenies were used as an experimental unit. $p < 0.05$ and $p < 0.10$ was considered as significant and trends, respectively.

Results and Discussion

Reproduction performance of sow

25(OH)D_3 is the main form of vitamin D_3 in vivo models. Notably, it has been employed as a functional supplement in animals to augment their physiological regulation (Zhou et al., 2016). Previously, DeLuca (1986) reported that 25(OH)D_3, upon absorption through the intestinal epithelium into the bloodstream and subsequent processing in the liver and kidneys, possesses the capability to modulate the absorption of Ca and P. This regulation facilitates the maintenance of optimal serum levels of Ca and P necessary for bone strength. A study by, Sandoval et al. (2022) addressed that growing pigs fed diet supplemented with 25% hydroxyvitamin D_3 had no adverse effect on the physiological indices. Similarly, Zhang and Piao (2021) reported that maternal sow fed 25(OH)D_3 had no effect on body condition. The aforementioned outcomes were agreed with the present study, in which sows fed diet supplemented with 25(OH)D_3 had no adverse effect on their reproduction performance such as BW, ADFI, BWL, and BWL difference during before farrowing, after farrowing, and at weaning (Table 2). The probable reason for this outcome could be due to the less availability of vitamin D in animals. From Upadhaya et al. (2021), study we speculate that adding 25(OH)D_3, the functional form of synthetic vitamin D_3, to the diet would increase the availability of vitamin D that can enhance the performance of sows and their litters.

Table 2. Effect of dietary 25-hydroxyvitamin D_3 additive on reproduction performance of lactating sows.

Items	CON	HyD	SEM	p-value
Parity	3.2	3.4	0.5	0.3511
Litter size				
Total birth (head)	13.5	13.6	0.5	0.2777
Mummification (head)	0.2	0.0	0.1	0.7382
Stillbirth (head)	0.3	0.1	0.2	0.9798
Total alive (head)	13.0	13.4	0.4	0.1848
SUR1 (%)	96.58	99.05	1.39	0.6643
Body weight (kg)				
Initial	188.8	188.7	11.0	0.6846
Before farrowing	217.2	218.6	11.4	0.3016
After farrowing	196.9	197.9	11.0	0.3249
Weaning	181.8	181.7	11.1	0.1938
Ovulation	185.2	185.7	11.1	0.2837
Body weight difference 1[y]	28.4	29.9	0.8	0.5631
Body weight difference 2[y]	20.3	20.7	0.6	0.1033
Body weight difference 3[y]	15.1	16.2	0.6	0.1061
Body weight difference 4[y]	3.4	4.0	0.4	0.9069
Backfat thickness (mm)				
Initial	16.0	16.0	0.8	0.6846
Before farrowing	18.7	18.7	0.6	0.3000
After Farrowing	19.7	19.6	0.7	0.8050
Weaning	17.3	17.1	0.7	0.1938
Ovulation	17.8	17.9	0.7	0.2837
Backfat thickness difference 1[z]	0.8	0.9	0.3	0.7406
Backfat thickness difference 2[z]	1.8	1.9	0.4	0.9619
Backfat thickness difference 3[z]	1.0	0.9	0.3	0.5367
Backfat thickness difference 4[z]	2.3	2.4	0.3	0.9115
Backfat thickness difference 5[z]	0.5	0.7	0.2	0.7851
Body condition score				
Initial	2.3	2.5	0.2	0.6846
Before farrowing	3.0	2.9	0.1	0.3000
After farrowing	3.0	2.8	0.1	0.0850
Weaning	2.7	2.7	0.1	0.1938
Ovulation	3.1	2.8	0.1	0.2837
ADFI (kg)				
Phase 1	2.57	2.59	0.01	0.2357
Phase 2	2.33	2.35	0.02	0.3480
Phase 3	2.65	2.66	0.04	0.5944
Lactation	6.34	6.56	0.19	0.8048
Estrus interval (d)	4.8	3.7	0.7	0.7679

CON (control), basal diet; HyD, 0.036% of 25-hydroxyvitamin D_3; SEM, standard error of the mean; SUR1, survival rate of number of alive pigs per number of totals born pigs; ADFI, average daily feed intake.

[y, z] Initial to before farrowing; before farrowing to after farrowing; after farrowing to weaning; weaning to ovulation.

Suckling pig performance

In the earlier research, Amundson et al. (2016) reported that inclusion of adequate amount of vitamin D supplement in sows has reduce the bone mineral density and bone abnormalities in their offspring. Similarly, Upadhaya et al. (2022) found that dietary 25(OH)D_3 supplement has improved growth performance of piglets. In line with the current findings, piglets born from sows fed dietary 25(OH)D_3 showed significantly increased weaning weight and average daily gain (Fig. 1). Whereas, there was no difference observed on fecal score of sows and their young ones, thus table was not included. The inconsistent results of different studies on the response to 25(OH)D_3 supplementation are explained by various factors. For instance, Zittermann et al. (2014) noted a dose-response relationship with circulating 25(OH)D_3 in a human review, stating that a vitamin D dose per kg BW has 34.5% of the variation. The proposed reason could be due to the type of pigs utilized, the type of diet used, and the amount of supplementation employed in those studies.

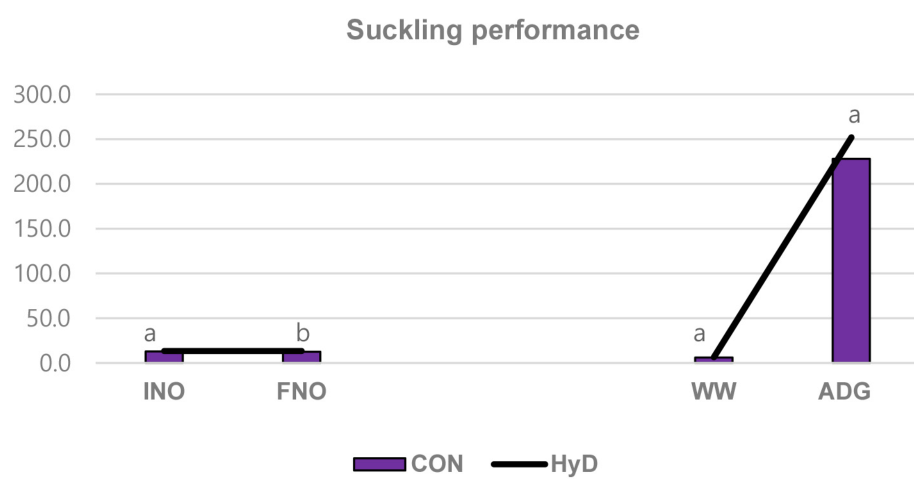

Fig. 1. Effect of 25-hydroxyvitamin D_3 (25(OH)D_3) supplementation on piglets. a, b: Denote statistically significant. INO, initial number of piglets; FNO, final number of piglets; WW, weaning weight; ADG, average daily gain; CON (control), basal diet; HyD, CON + 0.036% of 25(OH)D_3.

Milk profile of sow

Previous literature has mentioned that change from colostrum to mature milk has always accompanied by changes in the composition of porcine mammary secretions (Maciag et al., 2022). Besides, the fat content of milk gradually increased during the first 3 days of lactation and remained at a constant level until the third week of lactation and thus total solids (TS) and protein levels are usually high in colostrum while those of fat and lactose are comparatively low. The present study also reveals high TS colostrum concentration at week 1, however at the end of week 3 the TS level had decreased approximately 2% during the transition from colostrum to mature milk (Fig. 2). The probable reason for decrease in total protein, fat, lactose, and TS signals could be due to the transition of colostrum to normal milk.

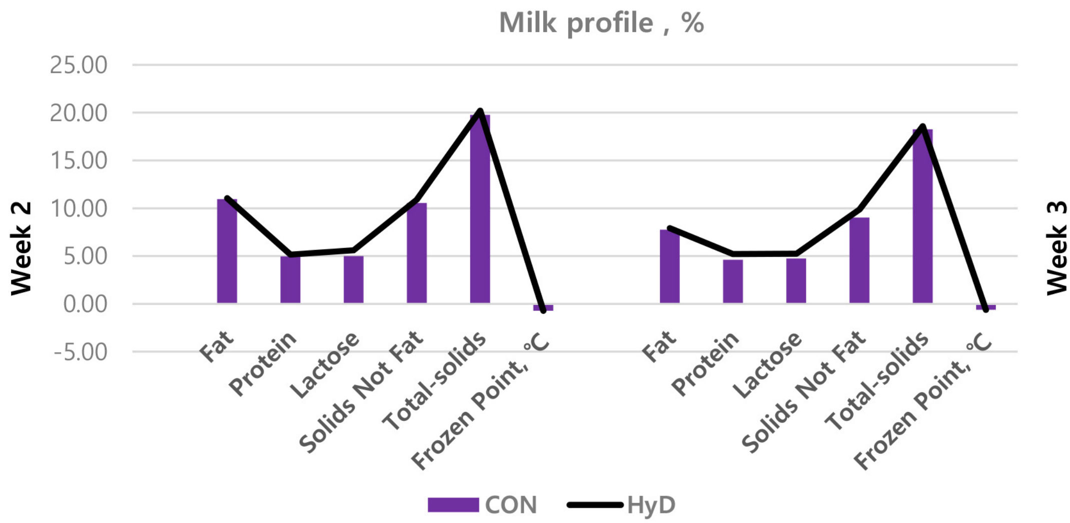

Fig. 2. At the end of week 3, dietary inclusion of 0.036% of 25-hydroxyvitamin D_3 (25(OH)D_3) showed decreased fat and total solids (%) content in sow milk profile. CON (control), basal diet; HyD, CON + 0.036% of 25(OH)D_3.

Conclusion

Our study demonstrates that inclusion of 0.036% of 25(OH)D_3 supplement to sow could enhance offspring performance without adverse effect on their reproductive performance. Moreover, the positive findings of our study establish a major constituent for the swine mammary secretions and provide a reliable groundwork for future experiments in animal husbandry.

Conflict of Interests

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

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