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Impact of 25-hydroxyvitamin D_3 on productive performance of gestating sows

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Abstract

The primary goals of this research were to evaluate the impact of diet supplemented with 25-hydroxyvitamin D_3 (Hy･D®) on sow's body condition and reproduction performance. A total of sixteen multiparous sows [(Landrace × Yorkshire), average parity = 3.79 ± 0.32] and their litters were randomly allotted to 2 treatments to give 8 replicates per treatment. Diet treatments were randomized to receive a non-active (ND) or active 25-hydroxyvitamin D_3 (AD) diet (0.36 mg cholecalciferol/g) during pregnancy. The results of this experiment were observed at the gestation of d 58 - 75, d 76 - 95, d 96 - 110, and d 111 - 115. A corn-soybean meal-based diet was formulated to meet or exceed the nutrient requirements recommended by NRC (2012). Results indicated that the sows' farrowing duration was shortened (4.71, 5.38 h), and the average number of mummified fetuses decreased significantly ($p < 0.05$) in AD treatment compared with ND treatment (0.1, 0.5) while birth weight was significantly ($p < 0.05$) improved (1.44, 1.18 kg). There were no significant effects on body weight, backfat thickness, and fecal score during the gestation of sows in different phases ($p > 0.05$). And the total birth, stillbirth, live birth, and survival rates of the litter did not change ($p > 0.05$). The results of this study suggest that the farrowing duration of sow pigs will be shortened and the number of mummies will be decreased while their litters' body weight may be improved, if fed active 25-hydroxyvitamin D_3 (0.36 mg/g) during pregnancy phase.

Keywords: 25-hydroxyvitamin D_3, litters, reproduction performance, sow pigs

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Introduction

Vitamin D belongs to the steroid hormone family. It is a secosteroid that is metabolically activated and degraded through the actions of three cytochrome P450 hydroxylase enzymes (John et al., 2002). Vitamin D is important for two reasons: 1) It is needed for the proper absorption of calcium (Waldroup et al., 1963; Norman et al., 1987). Amundson's (2016) study indicated that sows improved their femur's mechanical properties when Vitamin D was added to their diet; 2) Research found that vitamin D receptors in cells were involved in the immune response and that activated dendritic cells produce vitamin D hormone. Those results suggest that vitamin D could exert immune regulatory effects (Cutolo and Otsa, 2008). A diet with vitamin D supplementation potentially attenuates immune responses of pigs challenged with rotavirus (Zhao et al., 2014; Tian et al., 2016) and viral infections such as influenza (Urashima et al., 2010; Kim et al., 2016), respiratory tract infections (Hansdottir et al., 2010), and HIV (Teichmann et al., 2003).

Vitamin D has two main forms, 25-hydroxyvitamin D (25-OH-D_3) and 1,25-dihydroxyvitamin D_3 (1.25-$(OH)_2$-D_3) eventhough the key pointly is 25-OH-D_3 in this paper (Hollis and Wagner, 2004; Holick and Chen, 2008; Zhao et al., 2014). In previous study, Cashman et al. (2015) conducted two experiments using pigs and laying hens, and found that the diet supplemented with 25-OH-D_3 resulted in improved pork products and eggs compared to basal diet. The results of Fritts and Waldroup's (2003) study revealed that the body weight of broilers fed the 25-OH-D_3 were significantly greater than those of birds fed 1,25-dihydroxyvitamin D_3. Also, Flohr et al. (2016a) found that the sows and weaning pigs had better growth performance when fed diet supplement with 25-OH-D_3 compared to basal diet. The objective of this study was to evaluate the impact of 25-OH-D_3 on performance and reproduction of pregnant sows and their litters.

Materials and Methods

The experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Dankook University.

Source of 25-hydroxvitamin D

The 25-hydroxyvitamin D_3 (Hy･D®) used in the experiment was provided by a commercial company (DSM-Bright Science, Brighter living, Holland).

Experimental design, animals, and housing

A total of 16 sows (Landrace × Yorkshire, average parity = 3.79 ± 0.32) and their litters were used in a 58-d experiment. On day 58 of gestation, sows were assigned to two diet treatments to give 8 replicates per treatment based on parity number according to a randomized complete block design. Diet treatments were randomized to receive a non-active (ND) or active 25-OH-D_3 (AD) diet (0.36 mg cholecalciferol/g) during pregnancy. This experiment included four phases: phase 1 (d 58 - 75 of gestation); phase 2 (d 76 - 95 of gestation); phase 3 (d 96 - 110 of gestation); and, phase 4 (d 111 - 115 of gestation). During gestation, sows were housed individually in stalls of 2.00 × 0.60 m^2. The stall had partly slatted floors that consisted of a 0.80 m concrete solid floor and a 1.05 m concrete slatted floor. Approximately 10 days before the expected time of parturition, sows were moved to farrowing rooms, each with 2.20 × 1.60 m^2. The concrete solid floor was equipped with a floor heating system. Cross fostering of piglets took place within 2 days from parturition and occurred only among sows of the same experimental treatment. All rooms were equipped with auto-controlled heating and mechanical ventilation systems. During the experiment, the sows were cared for according to animal welfare legislation.

Diets and feeding

The pigs were fed with corn-soybean based diets (Table 1). The diet treatments received a non-active 25-OH-D_3 (ND) or active 25-OH-D_3 (AD) diet (0.36 mg cholecalciferol/g). From d 58 of gestation until parturition, sows were fed 0.36 mg/g of ND or AD in their respective experimental diets and had no extra vitamin D_3 in the basal diet. On the day of parturition, the sows were not offered the feed. All diets were provided in meal form twice daily and sows had free access to drinking water throughout the experimental period. Diets were formulated (Table 1) to meet or exceed the nutrient requirements of gestating and lactating sows (NRC, 2012).

Table 1. Composition of experimental diets (as basal diet).

Items	
Ingredient (%)	
Corn	60.22
Soybean meal (45.4% crude protein)	27.72
Limestone-coarse (S)	1.05
Salt	0.6
Calcium phosphate	1.4
DL-Methionine	0.2
L-Lysine	0.55
Vitamin premix[y]	0.2
Cholin 50%	0.08
Mineral premix[z]	0.1
L-Tryptophan-10%	0.03
Animal Fat	4.75
L-Threonine 98.5%	0.2
Glucose-90%	0.4
Molasses	2.5
Calculated nutrition compositions (%)	
Dry matter	87.52
Metabolic energy (kcal/kg)	3421.43
Crude Protein	17.55
Calcium	0.85
Phosphorus	0.3
Sodium	0.39
Total Lysine	0.9
Total Methionine	0.37

[y]Provided per kilogram of complete diet: vitamin A, 10 000 IU; vitamin D_3, 0.36 mg/g (ND: non-active of 25-hydroxyvitamin D; AD: active of 25-hydroxyvitamin D); 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 B12, 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.

Data collection and measurements

The body weights of the sow pigs were measured individually at d 58, d 75, d 95, d 110 of gestation (before farrowing), and at d 115 (after farrowing), while the backfat thickness of pigs was measured 6 cm off the midline at the 10th rib using a real-time ultrasound instrument (Pilot 105, SFK Technology, Herlev, Denmark). The duration of farrowing duration was recorded. The litter's body weights, total number of births, stillbirths, mummified foetuses, and survival rates per litter were measured after birth.

Statistical analysis

Data were statistically analyzed by ANOVA, using the general linear model (GLM) procedure of the SAS program (SAS Inst. Inc., Cary, NC, USA), for a randomized complete block design. Mean values and standard error of means (SEM) are reported. Statistical significance was set at $p < 0.05$.

Results

Body condition

The effects of diet supplementation of 25-OH-D_3 on growth performance in pregnant sows are shown in Table 2. Although it was not statistically significant, the farrowing duration of sows appeared to be numerically shorter in AD treatment than in ND treatment ($p > 0.05$). There was no significant difference in body weight and backfat thickness between different phases of the gestation of sows ($p > 0.05$).

Table 2. Effect of 25-hydroxyvitamin D_3 on body condition in pregnant sows[x].

Items[y]	ND	AD	SEM[z]
Parity	3.88	3.71	0.32
Litter			
Total birth	11.9	11.3	0.7
Farrowing duration (hours)	5.38	4.71	0.13
Body weight difference (kg)			
d 58 to d 75	11.9	13.2	1.7
d 76 to d 95	1.7	2.2	0.5
d 96 to d 110	12.3	14.6	1.9
d 111 to d 115	20.5	19.9	1.4
Backfat thickness difference (mm)			
d 58 to d 75	1	0.6	0.2
d 76 to d 95	0.1	0.4	0.2
d 96 to d 110	0.1	0	0.1
d 111 to d 115	0.8	0.6	0.1

[x]Sixteen multiparous (average parity = 3.79 ± 0.32), 8 replicates per treatment.
[y]Abbreviation: ND, basal diet with non-active of 25-hydroxyvitamin D_3 (0.36 mg/g); AD, basal diet with active of 25-hydroxyvitamin D_3 (0.36 mg/g).
[z]SEM = Standard error of means.

Reproduction performance

The effects of diet supplementation with 25-OH-D_3 on piglet birth performance are shown in Table 3. The number of mummies was significantly reduced in AD treatment compared with ND treatment ($p < 0.05$) while the birth weight was significantly improved ($p < 0.05$). However, the total birth, stillbirth, piglets born live, and survival rate of the litter had not been changed ($p > 0.05$).

Table 3. Effect of 25-hydroxyvitamin D_3 on reproduction performance in piglets[x].

Items[y]	ND	AD	SEM[z]
Litter			
Total birth	11.9	11.3	0.7
Stillbirth	0.5	0.3	0.2
Mummy	0.5a	0.1b	0.1
Live birth	10.9	10.9	0.6
Survival rate (%)	92.2	96.3	2.5
Body weight (kg)			
Birth weight	1.18a	1.44b	0.03
Birth weight per litter	14.02	16.04	0.93

[x]Sixteen multiparous (average parity = 3.79 ± 0.32), 8 replicates per treatment.
[y]Abbreviation: ND, basal diet with non-active of 25-hydroxyvitamin D_3 (0.36 mg/g); AD, basal diet with active of 25-hydroxyvitamin D_3 (0.36 mg/g).
[z]SEM = Standard error of means.
a, b: Means in the same row with different superscripts differ ($p < 0.05$).

Discussion

In swine nutrition, litter is known about the vitamin D requirements for reproductive processes and body condition (Lauridsen et al., 2010). Modern swine production practices limiting Ultra-Violet Ray light exposure for natural synthesis of vitamin D. With practically all vitamin D provided from the diet, Vitamin D sufficiency should be expected, especially in sows (Alexander et al., 2016). The vitamin D statuses of mothers and newborns are directly correlated (Verhaeghe et al., 1994). During pregnancy and lactation, mothers require significant amounts of calcium to pass on to the developing fetus and suckling neonate, respectively. Given the dependence of adult calcium concentrations and bone metabolism on vitamin D, one might anticipate that vitamin D sufficiency would be even more critical during pregnancy and lactation. However, maternal adaptations during pregnancy and lactation, fetal adaptations provide the necessary calcium of vitamin D status relatively independently (Kovacs and Christopher, 2008; Park et al., 2016).

Some research indicated that vitamin D has a positive effect on bone-health in litters. Bone abnormalities were resulted and bone mineral density (BMD) was reduced in offspring from sows fed diets with inadequate vitamin D (Amundson et al., 2016). And Amundson's same study suggested that bone mineral density and relative mRNA expressions of genes had also been improved by more vitamin D in the diet (8,125 μg/kg or 43,750 μg/kg). Characterization of lesions associated with an accidental omission of vitamin D in sow diets and hypovitaminosis D induced kyphosis in young pigs. Amundson (2016) indicated that kyphosis was induced by feeding vitamin D deficient diets to sows during gestation and lactation and subsequent nursery diets deficient in vitamin D, with marginal deficiencies in Ca and P.

Previous studies reported that 25-OH-D_3 could significantly increase serum 25-OH-D_3 concentrations in gilts and newborn piglets and that improved maternal vitamin D status by diet supplementation with 25-OH-D_3 can promote prenatal and postnatal skeletal muscle development of pigs (Zhou et al., 2016). Litter performance and new born piglets' body weights may be affected by vitamin D status (Shaw et al., 2002; Lauridsen et al., 2010; Burild et al., 2015; Flohr et al., 2016b). In the present study, we found that the number of mummies had been significantly reduced for sows supplemented with active 25-OH-D_3 (0.36 mg/g). This result agrees with a previous study (Lauridsen et al., 2010), which showed that the number of stillborn piglets was decreased with high doses of 25-OH-D_3.

Previous work has shown that deficient maternal 25-OH-D_3 status had no effect on body condition of sows pig (Tabatabaei et al., 2014). Similarly, the present results showed that maternal 25-OH-D_3 did not influence the performance of sows except for an increased body weight of piglets born alive in the group with active 25-OH-D_3 supplementation compared with non-active of 25-OH-D_3 group. The new born piglets' body weights were increased, probably because bone density was improved by 25-OH-D_3. Finch et al. (2010) reported that offspring of vitamin D-deficient sows had lower body weight, body length than those of the vitamin D-sufficient sows, regardless of supplementation. However, some studies indicated that maternal performance and litter characteristics were largely unaffected by 25-OH-D_3 diet treatments (Flohr et al., 2016b).

Conclusion

From present study results, we can summarize that sow pigs had shortened farrowing duration and decreased the number of mummies while their litters' body weights were improved, when fed active 25-hydroxyvitamin D_3 (0.36 mg/g in the basal diet) in the pregnancy phase.

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