Korean Journal Of Agricultural Science

pISSN : 2466-2402
eISSN : 2466-2410

ANIMAL

Effect of anise flavor on the performance of sows and their litters with different weaning ages

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Abstract

This study was conducted to evaluate the effect of dietary supplementation of anise flavor on the performance of lactating sows and suckling pigs at different weaning ages. A total of 120 sows (Landrace × Yorkshire) were used in this experiment. Sows were fed with a commercial lactation diet (60 sows) or diet with flavor (60 sows) during days 100 to 114 of gestation period and the whole lactation period. Piglets were allotted to 2 dietary treatments based on their initial body weight (BW) using a 2 × 2 factorial arrangement of treatments with 2 levels of anise flavor (0 or 0.5 g/kg) and weaning periods (weaned at 21 day or 28 day after birth). Sows fed with flavor supplemented diets had higher ($p < 0.05$) back fat and average daily feed intake (ADFI) at weaning, lower ($p < 0.05$) back fat loss than those fed with non-flavor diets. Sows weaned at 28 day had higher ($p < 0.05$) weaning back fat and lower ($p < 0.05$) back fat loss than those weaned on 21 day. During weaning, piglet average daily gain (ADG), ADFI, digestibility of dry matter (DM), nitrogen (N), and gross energy (GE) and fecal score were affected by anise flavor, respectively. In conclusion, dietary flavor supplementation could increase feed intake of lactating sows, improve growth performance and reduce weaning stress of piglets, especially effective in the early weanling piglets. Meanwhile, interactive effects were observed about the piglet performance between weaning ages and anise flavor supplementation after weaning.

Keywords: flavor, litter and weaning pig, sow

OPEN ACCESS

Citation: Sun HY, Lei Y, Kim I. 2019. Effect of anise flavor on the performance of sows and their litters with different weaning ages. Korean Journal of Agricultural Science. https://doi.org/10.7744/kjoas.20190013

DOI: https://doi.org/10.7744/kjoas.20190013

Received: September 10, 2018

Revised: April 1, 2019

Accepted: April 19, 2019

Introduction

Feed intake and metabolic state during lactation influence weaning-to service-intervals (WSI), subsequent farrowing rates and total-born litter sizes (Bilkei, 1995). Therefore, an insufficient feed intake by sows during lactation is a serious problem, because sow requires large amount of energy for high milk production during lactation. During lactating period, low feed intake leads to greater body weight (BW) loss, reduced milk production, and reproductive problems that may lead to culling of the sow (Baidoo et al., 1992; Eissen et al., 2000). During the past years, due to genetic selection for large litter size, sows are facing heavy burden for milk production (Auldist et al., 1998). It has been reported that flavor increased feed intake of lactating sows and improved growth performance of piglets (Wang et al., 2014). However, the effectiveness of these feed additives has not been consistently observed. Some studies failed to demonstrate an effect of dietary flavor or sweeteners on performance of pigs (McLaughlin et al., 1983; Munro et al., 2000).

The age of weaning can be a major determinant of the total annual production and, ultimately, the profitability in modem swine production units. While a number of factors must be considered when determining optimal weaning age, including management capabilities, available facilities, and effects on the sow, the ability to maintain the health and performance of the weaned pig must be of major concern (Varley and Cole, 1976; Levis, 1990). Some authors noted that early weaning could enhance the reproductive performance of sows, efficient utilization of housing and reduce pathogen or antigens to piglets (Alexander et al., 1980; Harris, 2000) consequently making pig production more economical.

However, it has been widely reported that in pigs less than 30 days of age, enzymatic and secretory functions in the gastrointestinal tract may not yet be fully functional and/or may lack efficiency in degrading plant-based substrates (Tarvid et al., 1994). Mathew et al. (1996) found that greater fluctuations in bacterial populations, pH, and dry matter occur in pigs weaned at 21 day of age compared with pigs weaned at 28 day of age. It means pigs weaned at 28 day has more stable gut environment than the pigs weaned at 21 day. Sufficient feed intake is beneficial to the development of the intestine (McCracken et al., 1995; Pluske et al., 1996; Spreeuwenberg et al., 2001).

Feed intake closely relates with the development of the intestine, higher feed intake can promote the growth of intestine. Therefore, we hypothesize that anise flavor supplementation in the basal diet would improve the development of the intestine in weaning pig through the increase in feed intake. Thus, the objective of the present study was to test whether the supplementation of anise flavor (AF) would improve the growth performance, nutrient digestibility, and fecal score at different weaning age.

Materials and Methods

The experimental protocol used in this study was approved by the Animal Care and Use Committee of Dankook University.

The flavors used in the present study were provided by DadHank Biotechnology Corporation (Chengdu, China) as non-hygroscopic powder.

Experimental design, animals, and diets

A total of 120 sows (Landrace × Yorkshire), with an average BW of 236.7 kg (14 day before farrowing) were used in this experiment. Gestating sows were fed on a commercial lactation diet (60 sows) or diet with added anise flavor (60 sows) during 100 to 114 day of gestation. On 104 day of gestation, sows were moved into farrowing crates in an environmentally regulated farrowing house. The diets (Table 1 and 2) were formulated to meet or exceed the NRC (2012) nutrient requirements. Farrowing crates (2.1 m × 0.6 m) contained an area (2.1 m × 0.6 m) for newborn pigs on each side. Supplemental heat was provided for piglets using heat lamps (500 W), which maintained the temperature for newborn piglets constant at 35℃. Drinking nipples provided water *ad libitum* to the piglets. After farrowing, all piglets were cross-fostered to another sow in the same group. Each sow fostered ten piglets. All piglets received injections of 1 mL of iron dextran and the males were castrated 3 day after birth. No creep feed was given during the lactation period. The back fat of sows was measured 6 cm off the midline at 10th rib using a real-time ultrasound instrument (Piglot 105, SFK Technilogy, Herlev, Denmark). At the day before farrowing and 21 day after farrowing. During the lactation period, feed intake of the sow was recorded daily to determine the average daily feed intake (ADFI). On 21 day after farrowing, the BW of piglets was checked, and then the sows, fed diets with flavor and their litters, were selected to continue the following experiments. Piglets were allotted to 2 dietary treatments based on their initial BW using a 2 × 2 factorial arrangement of treatments with 2 level of anise flavor (0 or 0.5 g/kg) and weaning period (weaned at 21 day or 28 day after weaning). From 104 day of gestation until farrowing, sows were fed 2.5 kg of the experimental diet per day. On the day of parturition, sows were not offered feed. First day after farrowing, sows were fed with 1.5 kg experimental feed and 2.0 kg at the second day. Daily feed allowance increased gradually, one week after farrowing, sows were allowed *ad libitum* to the experimental lactation feed and water. All diets were provided in meal forms and divided into 2 daily meals.

Sampling and measurements

Sow body weight were checked on 7 day before farrowing, within a few hours after farrowing and at weaning. Individual all piglet BW and feed intake was assessed on 7 and 14 day after weaning for calculation of average daily gain (ADG) and ADFI. Chromium oxide (0.2%) was added to the diet as an indigestible marker (Fenton and Fenton, 1979) at each phase for 7 d before fecal collection to determine apparent total tract digestibility (ATTD) of dry matter (DM), nitrogen (N), and gross

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

Items	Gestation diet	Lactation diet
Ingredients (%)		
Corn	57.10	51.12
Soybean meal, 46% of crude protein	10.65	24.61
Wheat bran	12.00	4.00
Rapeseed meal	3.70	2.50
Rice bran	6.00	5.00
Tallow	3.59	6.05
Molasses	3.60	3.50
Dicalcium phosphate	1.52	1.64
Limestone	0.99	0.76
Salt	0.60	0.50
L-lysine HCl, 98%	0.05	0.12
Vitamin premix[y]	0.10	0.10
Mineral premix[z]	0.10	0.10
Calculated composition (%)		
Metabolizable energy (MJ/kg)	3.19	3.44
Crude protein	13.10	17.10
Crude fat	6.89	9.10
Lysine	0.65	1.00
Calcium	0.87	0.85
Phosphorus	0.76	0.73

[y] Provided per kilogram of complete diet: vitamin A, 10,000 IU; vitamin D3, 2,000 IU; vitamin E, 48 IU; vitamin K3, 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 B6, 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.

energy (GE). On the last 2 day of the experiment, fecal samples were collected from 2 pigs daily in each pen. All feed and fecal samples were stored at - 20℃ until analysis. Before chemical analysis, fecal samples were dried at 57℃ for 72 h, after which they were ground to pass through a 1-mm screen. All feed and fecal samples were analyzed for DM (Method 930.15; AOAC, 2007), CP (Method 990.03; AOAC, 2007), and crude fat (Method 920.39; AOAC, 2007). Chromium was analyzed via UV absorption spectrophotometry (Shimadzu UV-1201, Shimadzu, Kyoto, Japan). The GE was analyzed by an oxygen bomb calorimeter (Parr Instrument Co., Moline, USA). The ATTD was then calculated using the following formula according to Stein et al. (2006): Digestibility (%) = $\{1 - [(Nf \times Cd)/(Nd \times Cf)]\} \times 100$,where Nf = nutrient concentration in feces (% DM), Nd = nutrient concentration in diet (% DM), Cd = chromium concentration in diet (% DM), and Cf = chromium concentration in feces (% DM).

Detection of estrus was conducted twice per day from weaning onward, at 8:30 and 16:00 every day. A sow was considered to be in estrus when exhibiting a standing response induced by a backpressure test when in the presence of a boar.

Subjective diarrhea scores were recorded daily from birth 1 to 7 day by the same person and were based on the following: 1 = well form feces, 2 = sloppy feces, 3 = diarrhea (Marquardt et al., 1999). Scores were recorded on a pen basis following the

Table 2. Piglet diet composition (as-fed basis).

Ingredients	%
Digestible corn	22.62
Soybean meal	8.00
Soy oil	4.50
Whey	24.16
Fish meal	2.50
Fermented soybean meal	10.00
Coconut oil	4.17
Lactose	8.00
Plasma powder	4.00
Sugar	3.05
Isolated soybean protein	6.15
Dicalcium phosphate	1.25
DL-methionine	0.38
L-lysine.HCl	0.41
Threonine, 98%	0.13
Zinc oxide	0.30
Choline Cl, 50%	0.10
Vitamin premix[y]	0.10
Mineral premix[z]	0.18
Calculated composition (%)	
Digestible energy (MJ/kg)	16.74
Crude protein	22.00
Lysine	1.74
Metthionine	0.70
Calcium	0.81
Phosphorus	1.00

[y] Provided per kilogram of complete diet: vitamin A, 1,298 IU; vitamin D3, 260 IU; vitamin E, 2.4 IU; menadione (sodium bisulfate form), 143 μg; vitamin B12, 3.3 μg; riboflavin, 880 μg; d-pantothenic acid, 2.6 mg; niacin, 4.4 mg.
[z] Provided per kilogram of complete diet: Zn (as $ZnSO_4$), 150 mg; Fe (as $FeSO_4 \cdot 7H_2O$), 132 mg; Mn (as MnO_2), 20 mg; Cu (as $CuSO_4 \cdot 5H_2O$), 12 mg; Se (as $Na_2SeO_3 \cdot 5H_2O$), 0.31 mg; I (as KI), 0.79 mg.

observations of individual pig and signs of stool consistency in the pen. The score was reported as average daily diarrhea of individual pig score.

Statistical analysis

In this experiment, sow was considered as the experimental unit. Data were analyzed as a 2 × 2 factorial arrangement of treatments and no significant interactions were observed. Farrowing group was used as a block. Piglet birth weight was used as covariates for weaning weights during lactation. Lactation length was used as a covariate for the number of pigs weaned, survivability, and the weaning weight of sows and piglets. Variability of all the data was expressed as standard error (SEM) and a probability level of $p < 0.05$ was considered as statistically significant.

Results

Growth performance of sow and their litters

Sows fed flavor diet had higher ($p < 0.05$) ADFI and lower ($p < 0.05$) back fat loss than those fed non-flavor on 21 day. Fed flavor sows were also a tendency higher than non-flavor sows in weaning back fat ($p = 0.06$) (Table 3). The BW and ADG on 21 day of the piglets from sows with flavor diets were improved but no significant compared to those from the sows with no-flavor diets. Sows weaned on 21 day had higher weaning back fat thickness ($p < 0.05$) and lower back fat loss ($p < 0.05$) than the sows weaned on 28 day (Table 4).

During the first week after weaning, piglets fed with AF supplemented diets had higher ($p < 0.05$) ADG, ADFI, and gain to feed ratio (G : F) than those fed with non-AF diets (Table 5). Piglets weaned at 28 day had higher ($p < 0.05$) ADG, ADFI, and G : F than those weaned at 21 day. There was an interaction effect on ADFI ($p = 0.01$) observed between weanling period and flavor supplementation.

During the second week after weaning, piglets fed with AF supplemented diets had higher ($p < 0.05$) ADFI than those fed with non-AF diets. The ADG of piglets weaned on 28 day was higher ($p < 0.05$) than the piglets weaned on 21 day. Overall,

Table 3. Effect of flavor on performance during lactation of sows and their litters at 21 day.

Items	Treatment			
	-AF	+AF	SEM	p-value
Sow				
Parity	2.7	2.7	0.1	NS
Initial BW	236.6	237.0	1.9	NS
Parturition Back fat	22.9	23.0	0.5	NS
Weaning Back fat	17.7	18.5	0.4	0.06
Back fat loss	5.2	4.5	0.3	0.02
ADFI	5.0	5.4	0.1	0.002
Litters				
Initial BW (kg/pig)	1.2	1.2	0.30	NS
Weaning BW (kg/pig)	6.0	6.1	0.33	NS
ADG (g/day)	228	232	0.36	NS

-AF, sow fed diet without flavor; +AF, sows fed diet with flavor; ADFI, average daily feed intake; ADG, average daily gain; BW, body weight; SEM, standard error mean.

piglets fed with AF supplemented diets had higher ($p < 0.05$) ADG and ADFI than those fed with non-AF diets. The ADG and ADFI of piglets weaned on 28 day were higher ($p < 0.05$) than the piglets weaned on 21 day. Interaction effects ($p < 0.05$) were observed between weaning date and flavor supplementation in ADFI.

Nutrient digestibility

The results of nutrient digestibility is shown in Table 6. At 1st week after weaning, the digestibility of DM, N, and GE was enhanced ($p < 0.05$) by the supplementation of flavor. Pigs weaned on 28 day have higher digestibility of DM and N than the pigs weaned on 21 day. Interaction effects were observed between weaning date and flavor supplementation in GE digestibility at 1st week after weaning as well as DM and GE digestibility at 2nd week.

Fecal score

The result of fecal score is shown in Table 7. On 1, 2, 3, 6, 7 day and overall, the first week after weaning, fecal score of piglets weaned on 28 day was lower ($p < 0.05$) than those weaned on 21 day. On 1, 2, 5, 6, 7 day and overall of the first week after weaning, fecal score in AF supplemented groups was lower ($p < 0.05$) than in non-flavor groups. Overall, there was an interaction effect ($p = 0.02$) observed between weaning date and flavor supplementation in fecal score.

Table 4. Effect of weaning time on reproductive performance of sows.

Treatment	W28	W21	SEM	p-value
Body weight (kg)	236.9	237.4	6.01	NS
Parturition Back fat	23.5	23.1	0.18	NS
Weaning Back fat	18.0	18.4	0.53	< 0.001
Back fat loss	3.8	4.3	0.08	0.01
Estrus interval	5.1	5.5	0.12	NS

W28, weaning at 28 day; W21, weaning at 21 day; SEM, standard error mean; NS, no significant.

Table 5. Effect of flavor on growth performance of piglets and weaning age.

Treatment	W28		W21		SEM	p-value		
	-AF	+AF	-AF	+AF		Weaning	AF	Weaning × AF
Weaning BW (kg)	9.1	9.2	6.0	6.1	0.1	< 0.001	NS	NS
1 wk								
BW	10.9	11.2	7.4	7.9	0.1	< 0.001	0.01	NS
ADG	261	287	198	247	21	0.01	0.04	NS
ADFI	324	354	266	313	46	0.02	0.04	0.01
2 wk								
BW	13.4	13.8	9.2	10.1	0.1	< 0.001	< 0.001	0.04
ADG	357	363	257	317	33	< 0.001	NS	NS
ADFI	456	513	348	416	37	0.05	0.02	0.05
Overall								
ADG	309	325	228	282	15	< 0.001	< 0.001	0.05
ADFI	420	483	332	394	41	0.03	0.01	0.04

W28, weaning at 28 day; W21, weaning at 21 day; -AF, basal diet; +AF, basal diet + flavor. ADFI, average daily feed intake; ADG, average daily gain; BW, body weight; SEM, Standard error mean; NS, no significant.

Table 6. Effect of flavor on nutrient digestibility of piglets and weaning age.

Items	W28		W21		SEM	p-value		
	-AF	+AF	-AF	+AF		Weaning	AF	Weaning × AF
After weaning 1 wk								
Dry matter	86.56	87.17	84.23	85.75	0.74	0.03	0.04	NS
Nitrogen	85.27	86.21	81.16	84.46	0.36	0.01	0.01	NS
Gross energy	88.10	89.04	84.37	86.56	1.01	0.06	0.01	0.03
After weaning 2 wk								
Dry matter	82.31	84.57	80.62	82.44	0.67	0.04	0.09	0.02
Nitrogen	85.24	86.56	82.17	84.75	0.94	0.02	NS	NS
Gross energy	85.66	87.71	81.74	84.42	0.50	0.05	0.05	0.02

W28, weaning at 28 day; W21, weaning at 21 day; -AF, basal diet; +AF, basal diet + flavor. SEM, Standard error mean; NS, no significant.

Table 7. Effect of flavor on fecal score one week after birth in piglets and weaning age.

Items	W28		W21		SEM	p-value		
	-AF	+AF	-AF	+AF		Weaning	AF	Weaning × AF
D1	3.8	3.7	4.1	3.7	0.1	0.04	0.01	NS
D2	3.9	3.7	4.2	3.7	0.1	0.03	< 0.001	NS
D3	3.8	3.7	4.1	3.8	0.1	0.04	NS	NS
D4	3.6	3.5	3.9	3.5	0.1	0.22	NS	NS
D5	3.5	3.4	3.8	3.3	0.1	0.26	0.05	NS
D6	3.4	3.2	3.8	3.3	0.1	0.01	0.01	NS
D7	3.4	3.2	3.6	3.2	0.1	0.18	0.04	NS
Average	3.6	3.4	3.9	3.5	0.1	0.004	< 0.001	0.02

W28, weaning at 28 day; W21, weaning at 21 day; -AF, basal diet; +AF, basal diet + flavor. SEM, Standard error mean; NS, no significant.

Discussion

Lactating sows often do not consume enough feed to satisfy their energy and nutrition needs for milk production (Boyd et al., 2000; Trotier and Johnston, 2001), which is a serious problem in the swine nutrition, especially in the summer season because of the heat stress. During the past years, genetic selection for large litter size had increased the milk yield burden for lactating sows (Auldist et al., 1998). Meanwhile, lower appetite was observed in the sows due to the genetic selection for high growth and lean rate (Kerr and Cameron, 1996). Flavor has been reported to enhance feed intake and performance of lactating sow and weaning pig (Torrallardona et al., 2000; Johnston et al., 2003). In present study, feed intake of sows in flavor groups was higher than the sows without flavor groups which is consistent with the findings of Wang et al. (2014) who reported that flavor improved feed intake of lactating sows When feed intake is insufficient, sows catabolize body tissues to supply the energy and nutrients for the maintenance and lactating requirements. Flavor can improve growth performance of piglets by increasing feed intake of sow, finally resulting in a higher individual and litter weight of the piglets (Wang et al., 2014). This may be the reason of lower back fat loss observation in sows with flavor diet in our study. In current study, the weaning BW of piglets from sows with flavor diet was increased; meanwhile, the back fat loss of sow with flavor diet was lower than that of sow without flavor. It meant the nutrients, which promoted the growth of piglet were not from the body store, but from the enhancement of diet. Therefore, it is indicated that the supplementation of flavor in sow's die may increase the milk production.

The swine industry has shifted to earlier weaning to improve farrowing-crate utilization, increase numbers of pigs born per sow per year, improve piglet health, and increase the number of pigs produced at a facility in a year. Lactation length (weaning age) can impact both nursery growth and sow fertility and should be optimized so that producers can maximize profitability of their pork operations. Short lactations may negatively affect measures such as weaning-to-first-service interval (Le Cozler et al., 1997). Smith et al. (2008) demonstrated that sow estrus interval decreased with increasing lactation length. However, in our study, we found that there was no significant difference on the Estrus interval at different weaning days. This is in agreement with the report from Tantasuparuk et al. (2000) that lactation length has no effect on WSI and subsequent litter size. This discrepancy may be due to the difference in the breeds of sows used in different studies.

In current study, we also found that weaning piglets with flavor had a higher performance. There is some explanation responsible for this result. Animal can make use of chemosensory cues before birth, especially flavor cues from maternal diet that reach the fetuses through the amniotic fluid and/or blood stream (Oostindjer et al., 2010). Additionally, animal and their litters share similar genetics and same environment, which leads to similar physiological response to the types of feed (Morrow-Tesch and McGlone, 1990; Bilko et al., 1994). Maternal information may be transmitted to the offspring through fur, breath, or faces and this information can be used to select appropriate food types (Wang et al., 2014). Therefore, the piglets after weaning preferred to forge the feed, which had same flavor with the diet of sows.

It is observed that pigs weaned on 28 day had higher ADFI, ADG, and G : F than the pigs weaned on 21 day in our study, especially during the 1st week. It is difficult for piglets, which weaned at 3 to 4 weeks, to get used to intake of solid feed, some piglets refrain from eating for over 50 h (Bruininx et al., 2002). As the piglets grow up, the intestine will mature. The digestive enzyme in the older animal will be more than younger animal. The digestibility of nutrients has been observed to increase with age after weaning which parallels increased digestive enzyme activity (Leibbrandt et al., 1975). It was also proved in our study that the DM and N digestibility was higher in pigs weaned on 28 day than the pigs weaned on 21 day. There was an interactive effect found on the ADFI and GE digestibility between flavor supplementation and weaning age. The low nutrient intake during the first days after weaning is a major contribution to the impaired intestinal function and integrity generally observed after weaning (McCracken et al., 1995; Spreeuwenberg et al., 2001). Studies found that flavor feed to weaning piglets could stimulate feed intake or improve the performance of pig, especially at weaning or during the starter period (McLaughlin et al., 1983; Torrallardona et al., 2000). Therefore, the enhancement of feed intake might contribute to the development of intestine, and finally increase the nutrient digestibility.

Diarrhea after weaning is a multi-factorial problem. In our study, the fecal score was decreased by the addition of flavor. McCracken et al. (1995) reported that the ingestion of small amounts of food directly after weaning might be sufficient to prevent problems leading to diarrhea. Because of the administration of flavor, the feed intake was enhanced in an extent to promote the development of intestine, and finally decrease the fecal score. Meanwhile, there was also an interactive effect found on fecal score between weaning age and supplementation of flavor.

In conclusion, dietary flavor supplementation could increase feed intake of lactating sows and growth performance, nutrients digestibility of piglets. The disadvantage weaned on 21 day may be recovered by the supplementation of flavor to reach the same level as pigs weaned on 28 day.

Acknowledgement

This work was carried out with the support of "Cooperative Research Program for Agriculture Science and Technology Development (Project No. PJ011603)" Rural Development Administration, Republic of Korea.

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