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Effect of lactation and nursery diets supplemented with a feed flavor on sow feed intake and lactation performance and subsequent weaned pig nursery performance

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ABSTRACT

A total of 105 sows (Line 241, DNA, Columbus, NE) were used across four batch farrowing groups to evaluate the effects of feeding a feed flavor in lactation diets on sow and litter performance. Sow groups 1 and 2 farrowed in an old farrowing facility during the summer months and groups 3 and 4 farrowed in a new farrowing facility during the winter months. Sows were blocked by body weight (BW) within parity on days 110 of gestation and allotted to 1 of 2 dietary treatments. Dietary treatments were a standard corn–soy-based lactation diet (control) or the control diet with the addition of a feed flavor at 0.05% of diet (Krave AP, Adisseo, Alpharetta, GA, USA). Farrowing facility environment had a large impact and resulted in many interactions with the feed flavor treatment. From farrowing to weaning, sows fed the feed flavor in the old farrowing house tended to have a higher ($P = 0.058$) lactation feed intake, while no difference in average daily feed intake (ADFI) was observed in the new farrowing house. Pigs weaned from sows fed with the feed flavor in the old farrowing facility had a higher ($P = 0.026$) BW at weaning and piglet average daily gain (ADG) from day 2 to weaning ($P = 0.001$) compared to piglets from sows not fed with the feed flavor; whereas the opposite occurred in the new farrowing house. Progeny from one farrowing group in the old farrowing facility was followed into the nursery. A total of 360 weaned pigs (DNA 241 × 600: initially 5.7 kg) were used in a 2 × 2 factorial in the nursery portion of the study to evaluate the effects of previous sow feed flavoring treatment (control vs. flavor) and nursery diets formulated with or without a feed flavor on growth performance in a 38-d trial. Nursery treatments were either a control diet or a diet containing a feed flavor (Delistart #NA 21, Adisseo). Offspring from sows fed with the flavor diet were heavier at weaning ($P < 0.001$) which was maintained throughout the study. Overall, progeny from sows fed with a diet containing a feed flavor had greater ($P < 0.05$) ADG, ADFI, and final BW during the trial. The presence of a feed flavor in the nursery did not improve overall nursery performance. In conclusion, when sow lactation feed intake was increased in the old farrowing house, pigs weaned from sows fed with the flavor diet were heavier ($P = 0.039$) at weaning compared to pigs weaned from sows fed with the control diet. Adding the feed flavor increased sow feed intake and piglet ADG in a warm environment, but not in a cool environment.

LAY SUMMARY

The use of feed flavors in swine diets has been thought to increase feed intake, leading to improvements in growth performance. However, the addition of feed flavors in the lactating sow and nursery piglet diets has shown variable results. The first objective of this study was to evaluate the effects of a new feed flavor product in the United States on sow and litter performance during lactation. The second objective was to determine the effect of supplementing a feed flavor with a similar flavor profile that was used in the sow lactation diet on performance during the nursery phase. Overall, lactation feed intake was increased for sows fed with the flavor diet compared to sows fed with the control diet, especially in the warm summer months. Piglets from sows fed with the flavor diet during the summer months had a higher weaning weight, which was maintained throughout the nursery period. Overall, no treatment differences in growth performance were observed between pigs fed diets with or without a flavor product in the nursery. However, offspring from sows fed with a flavor diet had a greater average daily gain, average daily feed intake, and body weight during the overall nursery period.

Key words: feed flavor, growth, lactation, nursery pig, sow

INTRODUCTION

Feed intake of sows during lactation is often below what is needed to meet the demands of milk production (Noblet et al., 1990). During lactation, an increase in feed intake has been shown to reduce backfat and sow body weight (BW) loss and increase litter weight gain (Eissen et al., 2003; Peng et al., 2007). Sow parity and weight, early lactation feed intake, environment, and lactation length affect total sow lactation feed intake (Koketsu et al., 1996). Studies have found that room temperature also greatly impacts feed intake, with an increased room temperature leading to decreased sow lactation feed intake (Black et al., 1993; Gourdine et al., 2006). Temperatures above the upper critical limit, 18 °C to 22 °C, will cause a decrease in metabolizable energy intake (Black et al., 1993; NRC, 2012) and can result in an increase in catabolism of stored fats to meet the energy demands of lactation

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(Noblet and Etienne, 1987). Decreased feed intake due to increased room temperature leads to a reduction in milk yield, lower piglet weaning weights, and increased sow BW loss (Quiniou and Noblet, 1999).

Feed flavors can stimulate feed intake by using enhanced taste and smell (Roura et al., 2008). The use of feed flavors in the sow lactation diet has been found to increase lactation feed intake, leading to increased milk production and litter weight gain when sows were housed in a tropical, humid environment (Silva et al., 2021). However, in other trials, no differences in feed intake were observed when a feed flavor was used in lactation diets (Charal et al., 2016). In nursery pigs, feed flavors have been shown to improve performance in the early postweaning phase and during heat stress conditions (Frederick and Van Heugten, 2006). Other studies have shown no differences in average daily feed intake (ADFI) throughout the nursery due to the inclusion of a feed flavor (Strek et al., 2008; Kim et al., 2019). It has been suggested that piglets can become familiarized with specific flavors used in sow diets because they can pass through the amniotic fluid and milk (Oostindjier et al., 2010). Thus, feeding flavors in nursery pig diets that are like those found in the sow lactation has resulted in increased ADFI and average daily gain (ADG) of nursery pigs (Oostindjier et al., 2010; Blavi et al., 2016). This early introduction to feed flavors can be beneficial for newly weaned pigs to entice feed intake and acceptance in the early postweaning period as well as reduce stress and increase postweaning performance (Oostindjer et al. 2011, 2014).

The variable responses observed when including feed flavors in the sow and nursery diet warrants the need for more research to evaluate their effects on sow and litter performance. The first objective of this study was to determine the effect of supplementing a feed flavor product in sow lactation diets on sow feed intake, sow weight and backfat change, and litter performance in production facilities and practices typical to the United States. The second objective was to determine the effect on nursery pig growth performance of supplementing a feed flavor (Delistart #NA 21, Adisseo) in nursery diets and to determine if pigs weaned from sows that were fed a feed flavor in lactation exhibited improved performance when a similar flavor profile is used in nursery diets. We hypothesized that including a feed flavor in sow diets would increase feed intake and performance of sows. We also hypothesized that piglets fed with diets with a similar flavor to that fed in the sow lactation diet would have the greatest improvement in feed intake and gain when compared to piglets fed with a standard corn–soybean meal diet.

MATERIALS AND METHODS

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This trial was conducted at the Kansas State University Swine Teaching and Research Center (Manhattan, KS, USA).

Sows

Animals, housing, and treatment. The study began in June 2021, with the first two groups (groups 1 and 2) of sows farrowing in June and July 2021. Groups 3 and 4 farrowed in November 2021 and January 2022. Groups 1 and 2 farrowed in an older farrowing facility (built in 1970) that was environmentally regulated using fans, cooling tubes to direct ambient air onto the sow, and drip coolers to cool sows, whereas groups 3 and 4 farrowed in a new farrowing facility (built in 2021) that utilized evaporative cooling system for incoming air to maintain target temperatures of 21 °C. Daily temperature and humidity measurements were taken at a rate of one measurement per hour during lactation using a USB Logger (EasyLog, EL-USB-2, Erie, PA, USA). The average temperature in the farrowing facility for the two groups that farrowed in the summer was 27.9 °C (standard deviation = 3.1 °C) and the average relative humidity was 62.2% (standard deviation = 10.5%; Table 1). The average temperature in the farrowing facility for the groups that farrowed in the winter was 23.3 °C (standard deviation = 0.8 °C) and the average relative humidity was 41.4% (standard deviation = 6.1%). Sows in groups 1 and 2 were housed in individual farrowing stalls that measured 1.5 × 2.1 m, that were equipped with a dry self-feeder with feed being delivered, as requested by the sow, through an automated feed system (Gestal Solo Feeder, Jyga Technologies, St-Lambert-deLauzon, Quebec, Canada).

Table 1. Farrowing facility environment temperature and humidity by group

	Farrowing facility environment[1]			
	Old/Summer		New/Winter	
	Group 1	Group 2	Group 3	Group 4
Temperature, °C				
Minimum	22.2	23.3	21.1	18.9
Maximum	34.4	37.2	25.6	25.0
Average	27.5	28.2	22.9	23.6
Standard deviation	3.0	3.1	0.7	0.8
Humidity, %				
Minimum	32.5	38.0	28.5	25.0
Maximum	79.5	84.0	66.0	54.0
Average	59.1	65.2	44.3	38.5
Standard deviation	11.2	9.8	6.3	5.8

[1]Two different farrowing facilities were used in this study. Sow groups 1 and 2 were farrowed in an older farrowing facility in June and July 2021, and groups 3 and 4 were farrowed in a new farrowing facility in November 2021 and December 2022.

Sows and piglets had access to a cup waterer. Sows in groups 3 and 4 were housed in individual farrowing stalls that measured 1.8 m × 2.4 m, that were equipped with a dry self-feeder with a similar automated feed system (Gestal Quattro Opti Feeder, Jyga Technologies, St-Lambert-deLauzon, Quebec, Canada). Sows and pigs had access to a pan waterer. Creep feed was not offered to piglets during the trial.

A total of 105 mixed parity sows (DNA 241, Columbus, NE, USA) and litters (DNA 241 × 600) were used. Sows were blocked by BW within parity and allotted to one of two dietary treatments in a completely randomized block design. Treatments included a standard corn–soybean-based lactation diet (control) or the control diet with the addition of 0.05% feed flavor (Krave AP, Adisseo) added at the expense of corn. The feed flavor had a sweet smell like bubblegum. All diets were formulated to meet or exceed the NRC (2012) requirement estimates and were manufactured at Hubbard Feeds (Beloit, KS, USA; Table 2). Sows were fed approximately 2.7 kg of their allotted diet from day 110 until farrowing (approximately day 116) and provided ad libitum access to feed throughout lactation with ad libitum access water granted throughout the feeding period.

Sows were moved to the farrowing facility on day 110 of gestation, at which time they were weighed, backfat was measured using an ultrasound probe (Renco Lean-Meater, Golden Valley, MN, USA), and caliper scores were recorded (Knauer and Baitinger, 2015). Backfat and caliper scores were measured at the last rib, with the backfat probe measurement taken 10 cm from the midline on both sides of the sow and then averaged to derive one composite measurement per sow. After farrowing and weaning, sow weights were recorded with backfat measurements and caliper scores also recorded at weaning. Feed was provided with the Gestal volumetric feeders and intake was confirmed by feed additions and weigh back of feed tubs at farrowing, day 10, and weaning.

The number of pigs born alive, stillborn, and born mummified were recorded for each sow throughout farrowing. Litters of piglets were cross fostered within treatment group to equalize litter size within 48 h of birth. Litter size and weight was recorded at farrowing, on days 2 and 10 after farrowing, and at weaning. Piglet survivability was determined by dividing the number of piglets weaned by the number of piglets after cross fostering. All piglet mortalities and causes of death were recorded. After weaning, sows were moved to individual gestation stalls and checked daily for signs of estrus using once daily exposure with a boar. The wean-to-service (WEI) interval of each sow was recorded.

Statistical analysis. Performance data were analyzed as a randomized complete block design using the lmer function from the lme4 package in R (Version 1.4.171, R Core Team, Vienna, Austria). Sow and litter were considered the experimental unit. Treatment, farrowing facility, and their interaction were fixed effects and block (representing sow BW within parity) and sow group were considered random effects. Litter born alive, stillborn, born mummified, and preweaning mortality were analyzed using a binomial distribution with a logit link function. The count of total born, total born alive, and litter size were analyzed using a Poisson distribution. Treatment comparisons were determined considering the interaction of the diet by farrowing facility environment (groups 1 and 2 vs. 3 and 4). Four sows on the flavor diet had to be taken off test due to refusing to eat the treatment diet, all were housed in the older farrowing facility during the summer months. Results are considered significant at $P \le 0.05$ and marginally significant at $0.05 < P \le 0.10$.

Nursery

Animals, housing, and treatment. A total of 360 weanling pigs (DNA 241 × 600: initially 5.7 kg) were used in a 38-d study. Weanling pigs were the offspring of sows fed with either a control diet or a diet containing the lactation feed flavor from day 110 of gestation through the end of lactation. Of the 389 total weaned pigs from the second sow group in the older farrowing facility during the summer months, 360 healthy pigs with no observable lameness or sickness were used to represent the overall population from both sow treatments. Pigs were weaned at approximately 19 d of age and placed into pens of 5 or 6 pigs balanced for gender and given either a control diet or a diet containing a different feed flavor (Delistart #NA 21, Adisseo), that had similar flavor compounds to the flavor used in the lactation portion of the study, at 0.05% of the diet added at the expense of corn. Treatments were arranged in a 2 × 2 factorial with main effects of sow treatment (control vs. flavor) and nursery treatment (control vs. flavor). There were 14 to 17 replications per treatment because of differences in the number of pigs weaned between the two sow treatments. Pens were 1.2 m × 1.2 m providing pigs with either 0.29 m^2 in pens with five pigs or 0.24 m^2 in pens with six pigs.

The treatment diets were fed in three phases. The basal phase 1 diet was manufactured at a commercial feed mill (Hubbard Feeds), and then evenly divided and the feed flavor or an equivalent amount of corn was added to the control diet at the OH Kruse Feed mill (Manhattan, KS, USA) after which diets were pelleted. Both phases 2 and 3 diets were manufactured as complete feed including the flavor product (Hubbard Feeds) and fed in a mash form. Phase 1 was fed until day 9 postweaning, phase 2 from days 9 to 24, and phase 3 from days 24 to 38. Phase 1 diets were formulated to 1.40% SID Lys, and phases 2 and 3 were formulated to 1.35% SID Lys. All other nutrients were formulated to meet or exceed the NRC (2012) requirement estimates.

Pigs and feeders were weighed on days 0, 3, 9, 17, 24, 31, and 38 to determine ADG, ADFI, and G:F. The phase 1 diet contained an indigestible marker, iron oxide, to help determine when pigs started to eat. Starting 10 h after weaning, fecal swabs were taken from all piglets with a cotton tip applicator to determine the percentage of pigs who consumed feed. The color of fecal swabs was used to determine eaters vs. noneaters, with a red tint defined as an eater. Pigs that tested negative on the first sampling were resampled every 12 h until all pigs were defined as eaters. Feeders were weighed every day for the first 8 d postweaning to determine feed disappearance during the early postweaning period (Figure 1). The percentage of pigs that lost weight from weaning to day 3 and from days 3 to d 9 was calculated based on initial weights determined at weaning.

Statistical Analysis Performance data was analyzed as a randomized complete block design for two-way ANOVA using the lmer function from the lme4 package in R (Version 1.4.171, R Core Team), with pen serving as the experimental unit. Sow treatment, nursery treatment, and the associated interaction were included in the model as fixed effects. The

Table 2. Diet composition (as-fed basis)[1]

Item	Lactation diet[1]	Nursery phase 1[2]	Nursery phase 2	Nursery phase 3
Ingredients, %				
Corn	64.50	44.50	58.41	64.74
Soybean meal	30.00	18.44	25.49	31.29
Milk, whey powder	–	25.00	10.00	–
Fish meal	–	4.50	–	–
Microbially-enhanced soy protein[3]	–	3.00	2.00	–
Corn oil	2.00	1.50	–	–
Calcium carbonate	0.90	0.30	0.90	0.85
Monocalcium P (21% P)	1.15	0.48	1.10	1.00
Sodium chloride	0.50	0.30	0.55	0.60
L-Lys-HCl	0.20	0.43	0.53	0.52
DL-Met	0.05	0.21	0.22	021
L-Thr	0.07	0.18	0.22	0.22
L-Trp	0.01	0.05	0.05	0.05
L-Val	–	0.12	0.14	0.13
Vitanim premix with phytase[4]	0.25	0.25	0.25	0.25
Trace mineral premix[5]	0.15	0.15	0.15	0.15
Sow premix[6]	0.25	–	–	–
Iron oxide	–	0.60	–	–
Feed flavor[7]	+/–	+/–	+/–	+/–
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standardized ileal digestibility AA, %				
Lys	1.07	1.40	1.35	1.35
Ile:Lys	67	57	55	55
Leu:Lys	140	111	112	114
Met:Lys	30	37	36	36
Met and Cys:Lys	56	57	57	57
Thr:Lys	63	63	63	63
Trp:Lys	20.7	20	20	20
Val:Lys	73	70	69	69
His:Lys	44	32	34	36
Total Lys, %	1.21	1.54	1.48	1.49
NE, kcal/kg	2,511	2,571	2,449	2,445
SID Lys:NE, g/Mcal	4.25	5.44	5.51	5.57
CP, %	19.9	21.1	20.5	21.2
Ca, %	0.77	0.69	0.77	0.69
P, %	0.63	0.66	0.65	0.61
STTD P, %	0.52	0.61	0.56	0.50

[1]Feed was manufactured by a commercial feed mill (Hubbard Feeds).
[2]Phase 1 diets were fed from days 0 to 9 (approximately 5.7 to 6.5 kg BW), phase 2 were fed from days 9 to 24 (approximately 6.5 to 11.0 kg BW), and phase 3 were fed from days 24 to 38 (approximately 11.0 to 19.7 kg BW).
[3]Access starter protein-V, Hubbard Feeds, Mankato MN.
[4]Ronozyme HiPhos GT 2700 (DSM Nutritional Products, Parsippany, NJ) provided 1,248 FTU/kg and an expected STTD P release of 0.14%. Provided per kg of premix: 1,653,468 IU vitamin A; 661,387 IU vitamin D; 17,637 IU vitamin E; 272 mg vitamin K; 3 mg vitamin B12; 4,082 mg niacin; 2,268 mg pantothenic acid; 680 mg riboflavin.
[5]Provided per kg of premix: 73 g Zn from Zn sulfate; 73 g Fe from iron sulfate; 22 g Mn from manganese oxide; 11 g Cu from copper sulfate; 0.20 g I from calcium iodate; 0.20 g Se from sodium selenite.
[6]Provide per kg of premix: 1,653,468 IU vitamin A; 8,818 IU vitamin E; 18 mg biotin; 181 mg folic acid; 45,359 mg choline; 4,082 mg carnitine, 0.79 g Cr.
[7]Krave AP in lactation diets and Delistart #NA 21 in nursery diets (Adisseo) were included at 0.05% in feed flavor diets, added at the expense of corn.

percentage of pigs defined as eaters were analyzed using a binomial distribution with a logit link function. Daily feed intakes from days 0 to 8 postweaning were analyzed using the lme function in R (Version 1.4.171, R Core Team) using an unstructured covariance matrix for repeated measures including fixed effects of sow treatment, nursery treatment, day, and all associated interactions. Room and pen nested within room were included in the model as random intercepts. Results were considered significant at $P \le 0.05$ and marginally significant at $0.05 < P \le 0.10$.

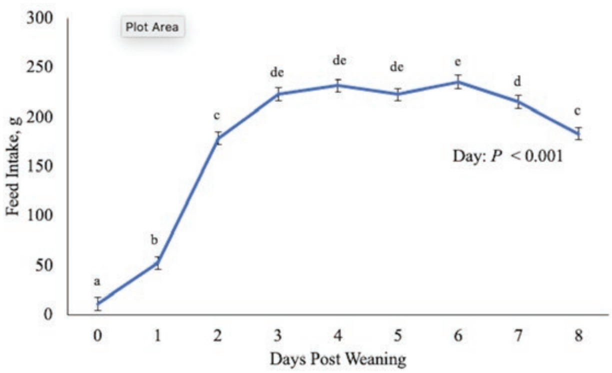

Figure 1. Days 0 to 8 postweaning average daily feed intake of piglets. Feeders were weighed daily for 8 d postweaning to determine daily feed intake in the early postweaning phase. Error bars represent +/-1 SEM. Data points that do share a common superscript differ ($P < 0.05$).

RESULTS

Sow

There were interactions observed between dietary treatment and farrowing facility environment for both sow and litter performance (Tables 3 and 4). There was a tendency ($P = 0.061$) for an interaction between sow treatment and farrowing facility environment on sow BW change from entry to farrow with sows fed with the control diet in the new farrowing facility during winter having less ($P < 0.05$) BW change compared to those fed with the flavor diet, whereas there was no difference ($P > 0.05$) between dietary treatment when sows were housed in the older farrowing facility during the summer months. An interaction was observed for sow ADFI from farrow to day 10 ($P = 0.048$) as well as tendency from farrow to wean ($P = 0.058$) where sows fed with the diet with the flavor had increased ($P < 0.05$) feed intake in the old farrowing facility in the summer months compared to sows fed with the control diet, whereas the opposite was observed when sows were in the new farrowing facility in winter months. A tendency for an interaction for WEI was observed ($P = 0.084$) where feed flavor reduced WEI in the old farrowing facility in the summer but increased ($0.05 < P < 0.10$) WEI in the new farrowing facility during the winter months. Even though an interaction was found, average WEI only ranged from 4.1 to 4.3 d for all treatments.

Interactions between dietary treatment and farrowing facility environment were found for litter size on dsys 2, 10, and weaning ($P < 0.05$) where litter sizes did not change in the old farrowing facility ($P > 0.05$), whereas in the new farrowing facility, sows fed diets with flavor had increased litter size. There was an interaction ($P = 0.026$) for litter weight on day 2 with litters from sows fed with the flavor diet in the new farrowing facility during winter having greater ($P < 0.05$) day 2 litter weight compared to those litters from sows fed with the control diet, there was no difference ($P > 0.05$) in day 2 litter weight when sows were housed in the old farrowing facility during the summer months. An interaction was observed for mean piglet body weight at weaning ($P = 0.026$) where piglet BW increased ($P < 0.05$) when sows were fed with the flavor diet in the old farrowing facility in summer months but decreased ($P < 0.05$) in sows fed with the flavor diet in the new farrowing facility in winter months when compared to the control sow litters. There was an interaction ($P = 0.001$) for piglet ADG from day 2 to weaning where piglets from sows fed the flavor diet had a greater ($P < 0.05$) ADG compared to piglets from sows fed the control diet in the old farrowing facility, but the opposite was observed in the newer farrowing facility. There was a tendency for an interaction ($P = 0.095$) for preweaning mortality from birth to day 2, where sows fed with the flavor diet tended to have greater piglet mortality ($P < 0.10$) when housed in the old farrowing facility during the summer months while no difference was observed in the new farrowing facility during the winter months. Lastly, an interaction ($P = 0.001$) was observed between treatment and farrowing facility environment on preweaning mortality from day 2 to weaning with piglets from sows fed the flavor diet having lower mortality ($P < 0.05$) when housed in the old farrowing facility in the summer months compared to piglets from sows fed the control diet, but higher mortality ($P < 0.05$) when housed in the new farrowing facility in the winter months.

In addition to the interactions, there were main effects observed for farrowing facility environment. There was a tendency ($P = 0.078$) for sows in the new farrowing facility during the cooler winter months to have a higher caliper score at weaning compared to sows housed in the old farrowing facility during the summer months. When sows and litters were housed in the older farrowing facility during the summer months, sow ADFI was lower ($P < 0.05$) overall. Total born was higher ($P = 0.036$) and day 0 litter size was higher ($P = 0.019$) in the older farrowing facility. Piglet BW was lower on day 10 ($P = 0.044$) and litter ($P = 0.019$) ADG was lower in the older farrowing facility during the summer months compared to the newer farrowing facility in the winter months.

Main effects were also observed for feed flavor treatment. When sows were fed with diets containing the feed flavor, overall lactation ADFI tended to be greater ($P = 0.093$). Sows fed with the control diet, tended ($P = 0.098$) to have a greater percentage of mummies. Day 10 piglet BW of piglets from sows fed with the flavor diet tended to be greater ($P = 0.087$) compared to piglets from sows fed control diets. Litter ADG tended ($P = 0.093$) to be greater for piglets from sows fed with the flavor diet overall.

Nursery

Progeny from sows fed with the feed flavor in lactation entered the nursery at a greater BW ($P < 0.001$; Table 5) than offspring from sows fed with the control diet and this BW advantage continued through the end of the study. There were no sow × nursery interactions for BW throughout the 38 d of the trial ($P > 0.10$).

There was no evidence of differences in ADG, ADFI, or G:F from weaning until days 3 postweaning for either sow dietary treatment or nursery flavor addition to diets. From days 3 to 9, pigs fed the flavor diet had increased ($P = 0.022$) G:F compared to those fed the diet without flavor. Offspring from sows fed the flavor diet had increased ADG ($P = 0.038$) and tended to have improved G:F ($P = 0.088$) from days 3 to 9. Overall, for phase 1 (days 0 to 9), there was no difference in ADG or ADFI between treatments but piglets fed with diets containing flavor tended to have increased G:F ($P = 0.078$).

During phase 2 (days 9 to 24), there was a tendency for a main effect of both sow ($P = 0.054$) and nursery ($P = 0.052$) treatment to impact ADG where piglets obtained from sows

Table 3. Interactive effects of lactation diets with or without a feed flavor and farrowing facility environment on sow performance[1]

	Farrowing facility environment[2]							
	Old/Summer		New/Winter			*P*-value =		
	Control[3]	Flavor	Control	Flavor	SEM	Flavor × farrowing facility	Flavor	Farrowing facility
Count, *N*	27	23	28	27				
Parity	2.5	2.5	2.5	2.5	0.42	0.376	0.266	0.997
Lactation length, d	19.0	19.1	18.8	19.2	0.20	0.525	0.908	0.491
Sow BW, kg								
Entry	262.9	265.9	261.9	262.9	11.00	0.762	0.640	0.949
Farrow	238.1	241.4	242.9	238.5	10.53	0.236	0.286	0.748
Wean	227.9	229.1	231.6	230.8	10.83	0.807	0.807	0.814
Sow BW change, kg								
Entry to farrow	−24.9	−24.4	−17.7	−24.5	2.77	0.061	0.208	0.073
Farrow to wean	−10.1	−11.6	−13.1	−7.7	2.81	0.189	0.317	0.414
Entry to wean	−35.0	−36.2	−30.6	−32.3	3.47	0.945	0.922	0.360
Sow back fat, mm								
Entry	15.2	14.8	15.5	15.4	0.42	0.686	0.566	0.575
Wean	13.5	12.8	14.0	13.7	0.44	0.707	0.473	0.370
Change (entry to wean)	−1.7	−1.9	−1.5	−1.7	0.36	0.973	0.821	0.668
Sow caliper score								
Entry	15.9	15.6	16.1	16.3	0.31	0.450	0.437	0.527
Wean	14.0	13.5	14.8	14.7	0.36	0.629	0.453	0.078
Change (entry to wean)	−1.9	−2.1	−1.3	−1.6	0.28	0.821	0.911	0.107
Sow ADFI, kg								
Prefarrow	2.8	2.9	2.7	2.8	0.12	0.890	0.908	0.216
Farrow to day 10	4.3[b]	4.7[b]	6.6[a]	6.3[a]	0.22	0.048	0.052	<0.001
Day 10 to wean	6.1	6.5	8.7	8.6	0.28	0.256	0.205	<0.001
Farrow to wean	5.1	5.5	7.6	7.4	0.21	0.058	0.052	<0.001
Overall	4.7	5.0	6.5	6.4	0.18	0.125	0.093	<0.001
Wean-to-estrus interval, d	4.2	4.1	4.1	4.3	0.09	0.084	0.171	0.326

[1]A total of 105 mixed-parity sows (Line 241, DNA, Columbus NE) and litters were used from day 110 of gestation until weaning.
[2]Two different farrowing facilities were used in this study. Sow groups 1 and 2 were farrowed in an older farrowing facility in June and July 2021, and groups 3 and 4 were farrowed in a new farrowing facility in November 2021 and December 2022.
[3]Sow treatment consisted of providing a control diet or the control diet with added Krave AP at 0.05% of diet (Adisseo) from entry into the farrowing facility (day 110 of gestation) until weaning.
[a,b]Means in the same row that do not have a common superscript differ ($P < 0.05$).

fed with the flavor diet had greater ADG compared to piglets from sows fed with the control diet and piglets fed with the diet without flavor had increased ADG compared to pigs fed with the flavor diet. A tendency ($P = 0.094$) for a main effect of sow treatment was found for ADFI with pigs from sows fed with the flavor diet having a greater ADFI. There was no differences for G:F during phase 2.

During phase 3 (days 24 to 38), there was a tendency ($P = 0.075$) for an interaction of sow and nursery flavor treatment for ADG where progeny from sows fed with flavor diets that were also fed with flavor in nursery diets had improved ADG compared to those that did not have flavor in nursery diets, whereas there was no difference between nursery treatments from piglets obtained from the sows fed with the control diet. There was a tendency ($P = 0.064$) for pigs from sows fed with the flavor diet to have an improved ADFI and pigs fed with the flavor diet having ($P = 0.010$) greater ADFI during phase 3. However, pigs fed with the flavor diet also had decreased ($P = 0.036$) G:F compared to pigs fed with the control diet without flavor.

For the overall period, days 0 to 38, piglets from sows that were fed with the feed flavor had increased ADG ($P = 0.038$), ADFI ($P = 0.043$), and BW ($P < 0.001$) when compared to piglets from sows that were fed with the diet without flavor. There were no overall differences in performance based on the presence or absence of feed flavor in the nursery diets.

No differences were found for early postweaning feed intake from days 0 to 8 postweaning due to nursery ($P = 0.326$) or sow ($P = 0.467$) treatment. Differences between days were observed ($P < 0.001$), with feed intake the highest 6 d postweaning (Figure 1). There was a tendency for a sow treatment by day interaction ($P = 0.061$) for feed intake postweaning (Figure 2). There was no difference in the number of hours it took pigs to begin eating after weaning based on nursery ($P = 0.714$) or sow ($P = 0.979$) treatment (Figure 3). The mean amount of time it took for the marker to be detectable in feces was 75 h (3.1 d) after weaning. There was a tendency ($P = 0.073$) for an effect of sow treatment on number of pigs that did not gain weight from days 0 to 3 with

Table 4. Interactive effects of lactation diets with or without a feed flavor and farrowing facility environment on litter performance[1]

	Farrowing facility environment[2]							
	Old/Summer		New/Winter			P-value =		
	Control[3]	Flavor	Control	Flavor	SEM	Flavor × farrowing facility	Flavor	Farrowing facility
Litter characteristics								
Total born, n	17.0	17.6	14.3	16.7	0.92	0.140	0.500	0.036
Born alive, %	90.2	91.0	90.4	88.5	0.02	0.354	0.438	0.911
Stillborn, %	6.8	8.2	6.3	9.5	0.01	0.527	0.967	0.790
Mummy, %	2.6	0.6	2.9	1.6	0.01	0.297	0.098	0.796
Litter size, n								
Day 0	15.3	15.9	12.8	14.8	0.76	0.246	0.691	0.019
Day 2	14.8[a]	14.8[a]	12.3[b]	14.3[a]	0.34	<0.001	0.012	<0.001
Day 10	14.0[a]	14.1[a]	12.1[b]	13.6[a]	0.26	0.002	0.063	<0.001
Wean	13.5[a]	13.7[a]	12.0[b]	13.4[a]	0.27	0.027	0.238	<0.001
Litter weight, kg								
Day 2	24.2[a]	24.4[a]	20.2[b]	23.1[a]	0.79	0.026	0.188	<0.001
Day 10	44.8	47.7	43.3	47.4	1.74	0.650	0.668	0.533
Wean	69.9	74.5	73.2	76.8	2.65	0.802	0.360	0.380
Mean piglet BW, kg								
Day 2[4]	1.6	1.7	1.6	1.6	0.06	0.613	0.642	0.879
Day 10	3.2	3.4	3.6	3.5	0.13	0.111	0.087	0.044
Wean	5.2[b]	5.5[a,b]	6.1[a]	5.8[a,b]	0.22	0.026	0.039	0.005
Litter ADG d 2 to wean, kg/d	2.40	2.62	2.82	2.80	0.12	0.162	0.093	0.019
Piglet ADG day 2 to wean, g/d	177[b]	194[a]	236[a]	212[a]	10.02	0.001	0.005	<0.001
Preweaning mortality, %								
Birth to day 2	2.8	6.2	3.4	3.2	0.01	0.095	0.038	0.680
Day 2 to wean	8.7[a]	6.4[a]	2.0[b]	7.4[a]	0.02	0.001	0.005	0.001

[1]A total of 105 mixed-parity sows (Line 241, DNA, Columbus NE) and litters were used from day 110 of gestation until weaning. Litters were cross fostered to equalize litter size up to 48 h postfarrowing within treatment group.
[2]Two different farrowing facilities were used in this study. Sow groups 1 and 2 were farrowed in an older farrowing facility in June and July 2021, and groups 3 and 4 were farrowed in a new farrowing facility in November 2021 and December 2022.
[3]Sow treatment consisted of providing a control diet or the control diet with inclusion of Krave AP at 0.05% of diet (Adisseo) from entry into the farrowing facility (day 110 of gestation) until weaning.
[4]Mean pig weight after cross fostering.
[a,b]Means in the same row that do not have a common superscript differ ($P < 0.05$).

fewer piglets from sows on the control diet not gaining weight when compared to piglets from sows on the flavor diet (Figure 4). From days 3 to 9, there was a tendency ($P = 0.079$) for an interaction between sow and nursery treatment with piglets from sows fed with the control diet that were fed nursery diets with flavor having increased percentage of pigs with no weight gain, but piglets from sows fed with the flavor diet had reduced percentage of pigs without weight gain when nursery diets contained flavor.

DISCUSSION

Feed flavors can be included in swine diets to stimulate feed intake through enhanced taste and smell (Frederick and Van Heugten, 2006). The use of feed flavors to increase feed intake has been variable in all production phases (McLaughlin et al., 1983). Silva et al. (2018, 2021) conducted two studies in tropical climates evaluating the same lactation feed flavor tested in our trial and observed similar outcomes to the summer portion of our study, including an increase in sow ADFI and piglet ADG. Other trials using different feed flavors have also observed similar responses (He et al., 2017; Wang et al., 2021). This association with increased sow feed intake and increased piglet and litter weight and ADG is expected (Koketsu et al., 1996; Eissen et al., 2003) and is the result of increased milk production which is the biggest factor for increased preweaning piglet growth (Solà-Oriol and Gasa, 2017). Counter to our observations, Silva et al. (2021) conducted a study in two different environmental conditions, defined as hot and cool, and concluded that the addition of a feed flavor in the sow lactation diet could increase sow feed intake regardless of temperature. Silva et al. (2018) observed that as the concentration of flavor (Krave AP; Adisseo) increased in the diet from 0.025% to 0.05%, feed intake increased, with sows fed with the 0.05% flavor diet having greater intake than sows fed with the control diet, with sows fed with 0.025% fed flavor being intermediate. Zhe et al. (2022) also conducted a study evaluating the effects of the same feed flavor (Krave AP; Adisseo) in the sow lactation diet compared to a control diet and found no differences in feed intake between treatments, although litters from sows fed with the diet containing the feed flavor had greater ADG than the control. Collectively, the data suggests that feed flavors have the potential to increase sow feed intake and litter gain,

Table 5. Interactive effects of sow and nursery pig diets supplemented with a feed flavor on growth performance of nursery pigs[1]

s	Sow treatment[2]							
	Control		Flavor			*P* =		
Nursery treatment[3]	Control	Flavor	Control	Flavor	SEM	Sow × nursery	Sow	Nursery
Body weight, kg								
Day 0	5.4	5.5	6.0	6.0	0.03	0.986	<0.001	0.140
Day 3	5.6	5.7	6.1	6.1	0.05	0.879	<0.001	0.482
Day 9	6.1	6.2	6.7	6.8	0.06	0.904	<0.001	0.147
Day 24	10.7	10.6	11.5	11.4	0.19	0.908	<0.001	0.359
Day 38	19.3	19.2	20.1	20.4	0.25	0.336	<0.001	0.687
Days 0 to 3								
ADG, g	63	63	47	43	15.4	0.863	0.118	0.846
ADFI, g	85	86	79	75	7.0	0.690	0.171	0.847
G:F g/kg	649	677	526	508	130.7	0.836	0.196	0.968
Days 3 to 9								
ADG, g	87	96	99	109	87.1	0.999	0.038	0.115
ADFI, g	217	212	228	217	11.7	0.687	0.228	0.246
G:F, g/kg	404	452	437	499	27.3	0.762	0.088	0.022
Phase 1 (days 0 to 9)								
ADG, g	79	85	82	87	6.9	0.906	0.711	0.370
ADFI, g	173	170	178	170	9.7	0.654	0.630	0.326
G:F, g/kg	453	495	455	504	26.2	0.886	0.829	0.078
Phase 2 (days 9 to 24)								
ADG, g	305	288	319	305	13.0	0.813	0.054	0.052
ADFI, g	462	448	485	467	18.1	0.876	0.094	0.184
G:F, g/kg	661	646	657	654	10.8	0.565	0.830	0.357
Phase 3 (days 24 to 38)								
ADG, g	573	568	571	602	12.3	0.075	0.111	0.210
ADFI, g	792	808	796	861	16.2	0.111	0.064	0.010
G:F, g/kg	724	703	719	701	11.8	0.859	0.677	0.036
Overall								
ADG, g	356	347	361	369	6.5	0.194	0.038	0.933
ADFI, g	523	521	534	550	10.3	0.360	0.043	0.479
G:F, g/kg	682	668	677	672	8.0	0.565	0.947	0.222

[1]A total of 360 weaned pigs (600 × 241, DNA, initially 5.7 kg) weaned at approximately 19 d of age were used in a 38-d nursery trial with 5 or 6 pigs per pen and 14 to 17 pens per treatment.
[2]Sow treatment consisted of providing a control diet or a feed flavor diet with inclusion of Krave AP at 0.05% of diet (Adisseo) from day 110 of gestation until weaning.
[3]Nursery treatment consisted of providing a control diet or a feed flavor diet with the inclusion of Delistart #NA 21 at 0.05% of diet (Adisseo) in phases 1, 2, and 3.

but there is no consistency across reports which warrants further investigation into the factors that need to be present for the benefit to be observed.

Voluntary feed intake of sows may be reduced by high environmental temperatures (NRC, 2012), which was observed in our study. The reduction in feed intake in a warmer environment agrees with the findings of Gourdine et al. (2006) and Silva et al. (2009) where warmer environmental temperatures decreased feed intake. Temperatures above the upper critical limit of 18 °C to 22 °C will decrease feed intake (Black et al., 1993; NRC, 2012). During the summer months, the average temperature in the old farrowing house was 27.9 °C, above the upper critical limit by almost 6 °C. Feed intake was significantly greater in the new farrowing house during the winter months when the average temperature was 23.3 °C.

In our study, sows lost BW and backfat from entry to weaning regardless of treatment or farrowing environment. Wang et al. (2014, 2021) and Silva et al. (2018) also fed lactating sows flavored diets and observed backfat losses regardless of treatment. The loss of backfat from entry to weaning indicates that sows were in a negative energy balance. He et al. (2017) observed that adding flavors to the lactation diet decreased sow weight loss. A greater loss of BW and backfat has been associated with larger litter size due to sow's mobilizing body reserves to meet the demands of milk production (Eissen et al., 2003). Sows housed in the old farrowing house fed with the flavor diet had a shorter WEI compared to sows fed the control diet, but the opposite was observed in the new farrowing house. However, only slight numerical differences in WEI were observed. Silva et al. (2018) found no differences in WEI; however, He et al.

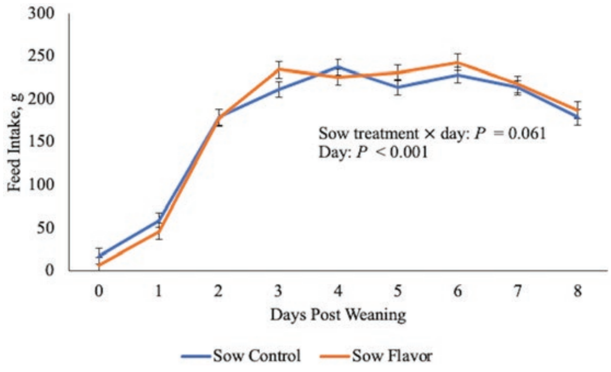

Figure 2. Days 1 to 9 postweaning average daily feed intake of piglets weaned from sows fed the control vs. the flavor treatment. Feeders where weighed daily for 8 days postweaning to determine daily feed intake in the early postweaning phase. Error bars represent +/-1 SEM.

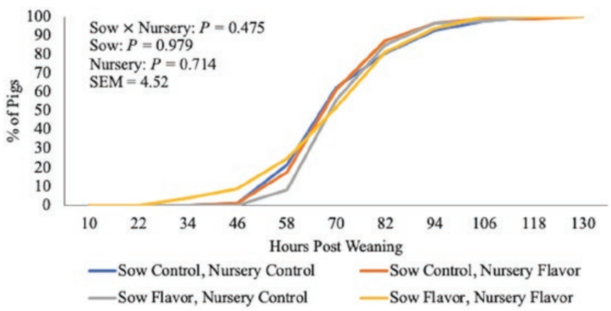

Figure 3. Percentage of pigs defined as eater by time after weaning as influenced by sow or nursery treatment. Fecal swabs were taken starting ~10 h postweaning and continued every 12 h after to define eaters vs. noneaters until all pigs were defined as eaters. Iron oxide was used as an indigestible marker and a red tint on the fecal swab was defined as eaters at each fecal swabbing timepoint was determined.

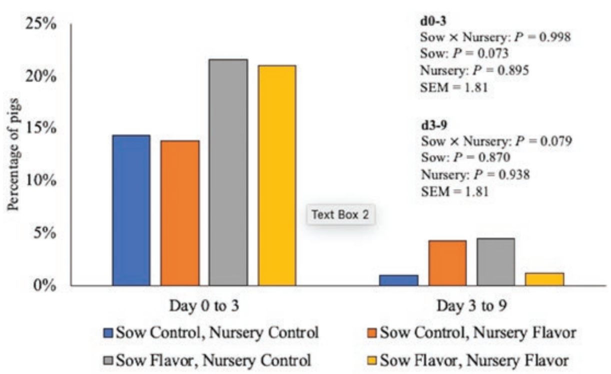

Figure 4. Percentage of piglets that did not gain weight from days 0 to 3 and 3 to 9 by treatment. Pigs were weighed on days 0, 3, and 9 to determine the percentage of pigs that did not gain weight from days 0 to 3 and from days 3 to 9.

(2017) observed a decreased WEI when sows were fed diets containing a flavor product.

In phases 1 and 2 in the nursery portion of the study, no differences in ADFI were observed due to dietary treatment, but in phase 3 pigs fed the flavor diet had increased ADFI. Conversely, Sulabo et al. (2010b) and Seabolt et al. (2010) observed increased feed intake during the early postweaning phase with no improvements in ADFI in later phases due to the inclusion of a feed flavor. Blavi et al. (2016) observed positive responses in overall ADFI when a feed flavor was included in the diet. Strek et al. (2008) observed no differences in ADFI throughout the nursery due to the inclusion of a feed flavor, but numerical differences showed an increase in ADFI for piglets fed with the feed flavor throughout the nursery phase. Kim et al. (2019) observed no differences in ADFI or G:F, but found a tendency for an increase in ADG when a feed flavor was included in the diet. In a second experiment, Kim et al. (2019) observed pigs fed with a flavor diet had greater ADG and a tendency for increased ADFI, but no differences in G:F using the same flavor product as the first experiment by Kim et al. (2019). Sulabo et al. (2010b) evaluated the effects of a feed flavor in a complex vs. simple diet. The results of the study indicated that the addition of a feed flavor in a complex diet increased postweaning feed intake but not in a simple diet. This demonstrates the variable response of the inclusion of feed flavor products on growth performance and the impact diet composition has on the response observed. No differences in overall ADG, ADFI, or G:F were observed due to the inclusion of the feed flavor in the nursery diet, which is in agreement with Strek et al (2008), Sulabo et al. (2010a), and Perez-Palencia et al. (2021) who also saw no differences in growth performance due to the inclusion of a feed flavor. Both ADG and ADFI were greater in pigs from sows fed with the flavor diet regardless of nursery dietary treatment in the current study, which was expected because they started the trial almost 0.5 kg heavier. These results are consistent with the results of Blavi et al. (2016), where the inclusion of a feed flavor in the sow lactation diet resulted in greater piglet growth performance postweaning regardless of nursery treatment.

We hypothesized that newly weaned pigs would begin eating feed faster if a flavor was included in the feed. However, as demonstrated in Figure 2, the time it took piglets to start eating postweaning, measured by how long it took the ingestible marker, iron oxide to be visibly noticed in the feces, was not affected by dietary treatment. Strek et al. (2008) also observed no differences in the time it took piglets to begin eating postweaning in diets with and without a feed flavor. Beaulieu et al. (2010) observed pigs that were weaned at a lighter weight lost less weight immediately postweaning compared to pigs that were weaned at a heavier weight, which was also observed in this study.

Improved ADFI and ADG in the early postweaning period have been previously observed due to early exposure to feed flavors preweaning (Yan et al., 2011; Wang et al., 2014). However, these studies provided exposure to the flavor through sow's milk and in creep feed. Yan et al. (2011) provided a feed flavor in the creep feed from day 5 of lactation to weaning and Wang et al. (2014) from day 7 of lactation to weaning, with the feed flavor also being fed in the lactation diet during both studies. Blavi et al. (2016) analyzed the presence of the flavor compounds in the sow milk and amniotic fluid. The flavor compounds were fed in the sow diet from day 73 of gestation to day 28 of lactation. It was found that the flavor compounds had a higher detection rate in amniotic fluid compared to milk. These findings could explain why there was not an interaction between sow diet and nursery diet, with piglets from sows fed the flavor diet that were fed the flavor diet in the nursery having a higher ADFI. The same flavor product may need to be included in the gestation diet or in creep feed to see a greater positive effect due to early introduction to flavors.

CONCLUSIONS

In conclusion, sows fed with the flavor diet in the old farrowing house during the summer months had a higher lactation feed intake. The differences in feed flavor response between farrowing facility environments suggest that adding the feed flavor to the lactation diet in situations where sow lactation ADFI is lower than optimal could lead to improvements in sow and litter performance. Offspring from sows fed with a diet containing a flavor had increased overall postweaning ADG, ADFI, and BW, which are all likely related to the increased weaning weight. Pigs fed the feed flavor during the nursery portion of the trial had increased ADFI for phase 3 of the study, but overall, no treatment differences were observed based on the presence of a feed flavor in nursery diets.

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