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Effects of Timing and Amount of Feed Prior to Farrowing on Sow and Litter Performance Under Commercial Conditions

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Abstract

A total of 727 mixed parity (mean = 3.8) sows were used to evaluate the effects of timing and size of meals before farrowing on sow and litter performance. Upon entry to the farrowing house (d 113), sows were blocked by weight within parity and allotted to 1 of 3 feeding management strategies until farrowing: 1) 6.0 lb lactation diet (1.15% standardized ileal digestible lysine and 1,150 kcal/lb NE) once daily at 0700 h; 2) 4 daily meals of 1.5 lb (0100 h, 0700 h, 1300 h, 1900 h); 3) *ad libitum* lactation diet and encouraged to consume feed at 0100 h, 0700 h, 1300 h, and 1900 h. After farrowing, all sows were provided lactation diet *ad libitum* until weaning. Data were analyzed for treatment effects within parity category in a mixed model with block as a random effect. Feeding sows *ad libitum* before farrowing tended to reduce sow body weight loss ($P = 0.077$) and reduce backfat loss ($P = 0.003$) from entry into the farrowing house until weaning compared to sows fed 4 daily meals, with sows fed once daily intermediate. Litter gain from 24 h to weaning tended to be greater ($P = 0.064$) in sows fed *ad libitum* or 4 times daily prior to farrowing compared to sows fed one meal. Piglet weaning weight increased ($P = 0.050$) in sows fed *ad libitum* before farrowing compared to those fed one meal, with those fed 4 times daily intermediate. There was no evidence for difference in farrowing duration, stillborn rate, colostrum yield, or 24 h piglet survival regardless of treatment. However, from 24 h after farrowing to weaning, sows fed one daily meal prior to farrowing had an increased ($P = 0.012$) percentage of fall-behind pigs compared to sows fed *ad libitum*, and increased ($P = 0.027$) preweaning mortality compared to sows fed four daily meals, resulting in reduced ($P = 0.006$) weaned percentage compared to sows fed four daily meals. There was no evidence for difference ($P > 0.10$) in subsequent reproductive performance regardless of treatment. In conclusion, when sows were fed *ad libitum* from 2 to 3 days before farrowing there was an observed improvement in sow body weight and backfat maintenance, and piglet weaning weight during lactation. Increased frequency of meals prior to farrowing improved the survival of pigs to weaning compared to sows fed a single meal prior to farrowing.

Keywords

farrowing duration, lactation, piglet performance, survival, transition sow

Authors

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K-STATE Research and Extension

Swine Day 2020

Effects of Timing and Amount of Feed Prior to Farrowing on Sow and Litter Performance Under Commercial Conditions

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Summary

A total of 727 mixed parity (mean = 3.8) sows were used to evaluate the effects of timing and size of meals before farrowing on sow and litter performance. Upon entry to the farrowing house (d 113), sows were blocked by weight within parity and allotted to 1 of 3 feeding management strategies until farrowing: 1) 6.0 lb lactation diet (1.15% standardized ileal digestible lysine and 1,150 kcal/lb NE) once daily at 0700 h; 2) 4 daily meals of 1.5 lb (0100 h, 0700 h, 1300 h, 1900 h); 3) *ad libitum* lactation diet and encouraged to consume feed at 0100 h, 0700 h, 1300 h, and 1900 h. After farrowing, all sows were provided lactation diet *ad libitum* until weaning. Data were analyzed for treatment effects within parity category in a mixed model with block as a random effect. Feeding sows *ad libitum* before farrowing tended to reduce sow body weight loss ($P = 0.077$) and reduce backfat loss ($P = 0.003$) from entry into the farrowing house until weaning compared to sows fed 4 daily meals, with sows fed once daily intermediate. Litter gain from 24 h to weaning tended to be greater ($P = 0.064$) in sows fed *ad libitum* or 4 times daily prior to farrowing compared to sows fed one meal. Piglet weaning weight increased ($P = 0.050$) in sows fed *ad libitum* before farrowing compared to those fed one meal, with those fed 4 times daily intermediate. There was no evidence for difference in farrowing duration, stillborn rate, colostrum yield, or 24 h piglet survival regardless of treatment. However, from 24 h after farrowing to weaning, sows fed one daily meal prior to farrowing had an increased ($P = 0.012$) percentage of fall-behind pigs compared to sows fed *ad libitum*, and increased ($P = 0.027$) preweaning mortality compared to sows fed four daily meals, resulting in reduced ($P = 0.006$) weaned percentage compared to sows fed four daily meals. There was no evidence for difference ($P > 0.10$) in subsequent reproductive performance regardless of treatment. In conclusion, when sows were fed *ad libitum* from 2 to 3 days before farrowing there was an observed improvement in sow body weight and backfat maintenance, and piglet weaning weight during lactation. Increased frequency of meals prior to farrowing

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improved the survival of pigs to weaning compared to sows fed a single meal prior to farrowing.

Introduction

Farrowing duration has naturally increased as genetic selection has increased litter size by 0.2 pigs per year over the past three years.[4] Longer farrowing durations can have negative effects on sow health and survival of piglets during parturition and lactation. Increased farrowing duration has been associated with a greater risk for stillbirths.[5,6] This is likely due to the long farrowing process causing asphyxia of piglets resulting in stillbirths, or negatively impacting live born piglet growth and survivability beyond the first few hours of life.[7] It remains unknown if increased farrowing duration is caused by stillborn piglets blocking the birth canal, if the sow has depleted her energy stores during parturition and slows contractions, or if other genetic and environmental factors are resulting in increased farrowing duration.

Recent data from a commercial sow study[8] demonstrated that on average, parturition lasts for 4 hours, but can range from 30 minutes up to 12 hours to complete. A retrospective analysis was conducted to evaluate the timing of the last meal prior to parturition on farrowing duration and stillborn rate.[6] The authors concluded that when sows had been offered a meal 3 hours or less before parturition, sows had a shorter farrowing duration, decreased need for farrowing assistance, and reduced stillborn rate in comparison to sows that had been offered their last meal greater than 6 h prior to farrowing. They hypothesized that this was due to higher plasma glucose levels at the onset of farrowing which resulted in more energy to be readily available during the farrowing process. Longer farrowing durations have been associated with a number of factors including sow housing, sow backfat, sow constipation score, and the number of stillborn pigs.[5] Several peripartum feeding strategies have been investigated to reduce farrowing duration and stillborn rate with little to no benefit observed.

Currently, commercial farms utilize many different feeding management strategies once sows are moved into farrowing crates until the onset of parturition, such as feeding one set feed amount in the morning, feeding two smaller meals twice daily, *ad libitum*, or other combinations. To our knowledge, no previous study has focused specifically on number of meals, and feed availability from d 113 of gestation to parturition, and the effect on farrowing duration and piglet survival. Therefore, the objective of this study

[4] Stalder, K. J. 2018. Pork industry productivity analysis, National Pork Board, Des Moines, IA.

[5] Oliviero, C. M. Heinonen, A. Valros, O. Peltoniemi. 2010. Environmental and sow-related factors affecting the duration of farrowing. Anim. Repro. Sci. 119:85-91. Doi: 10.1016/j.anireprosci.2009.12.009.

[6] Feyera, T., T. F. Pedersen, U. Krogh, L. Foldager, and P. K. Theil. 2018. Impact of sow energy status during farrowing on farrowing kinetics, frequency of stillborn piglets, and farrowing assistance. J. Anim. Sci. 96:2320-2331. doi: 10.1093/jas/sky141.

[7] Herpin, P., J. Le Dividich, J. C. Hulin, M. Fillaut, F. De Marco, and R. Bertin. 1996. Effects of the level of asphyxia during delivery on viability at birth and early postnatal vitality of newborn pigs. J. Anim. Sci. 74:2067-2075. doi: 10.2527/1996.7492067x.

[8] Gourley, K. M., A. J. Swanson, J. C. Woodworth, J. M. DeRouchey, M. D. Tokach, S. S. Dritz, R. D. Goodband, and B. Frederick. 2019. 183. Effects of increasing duration of feeding high dietary lysine and energy prior to farrowing on sow and litter performance under commercial conditions. J. Anim. Sci. 97(Suppl. 2):103-104 (Abstr.) doi: 10.1093/jas/skz122.183.

was to determine the effect of amount of feed and frequency of feed delivery on the parturition process, sow and litter performance, and survivability of piglets.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment.

A total of 727 sows (Fast Large white × PIC Landrace) were used at a commercial sow farm in southern Minnesota (New Fashion Pork, Jackson, MN). During gestation, sows were housed in individual stalls. The farrowing house was equipped with individual crates, each containing a shelf feeder with a hopper for sows, nipple waterer for sows, and heat mat for piglets. On the day of gestation when sows entered the farrowing house (d 113 ± 2), sows were weighed and backfat was measured at the P2 position (Renco Lean Meter, S.E.C. Repro Inc., Quebec, Canada). At this time, sows were blocked by body weight within parity category (gilts, parity 1, and parity 2+) and allotted to 1 of 3 feeding management strategies. Treatments consisted of: 1) sows fed 6 lb (1.15% standardized ileal digestible lysine and 1,150 Kcal/lb NE) lactation diet once daily at 0700 h; 2) sows fed 6 lb lactation diet 4 times daily in 1.5 lb meals (0100 h, 0700 h, 1300 h, 1900 h); and 3) sows fed *ad libitum* lactation diet, made to stand, and encouraged to consume meals 4 times daily (0100 h, 0700 h, 1300 h, 1900 h). When sows entered the farrowing house (1300 h), treatments 2 and 3 sows were fed their first meal, whereas treatment 1 sows did not receive their first meal in the farrowing house until the following morning. Prior to entry to the farrowing house, sows were fed 4.5 lb of gestation diet daily. Diets were formulated to meet or exceed nutrient requirements (Table 1) and were manufactured at the New Fashion Pork feed mill in Estherville, IA.

All feeding strategies were administered via hand feeding from a feed cart equipped with a scale until the start of parturition. At the start of parturition, feed remaining in the feeder was weighed to calculate total feed consumed from entry to the farrowing house until parturition. Sows were not fed during parturition; however, upon completion of the farrowing process, all sows were fed lactation diet *ad libitum* until weaning. Pre-farrow feed intake was recorded for all individual sows and on a subsample of 310 sows during lactation.

During parturition, sows were continuously monitored for 24 h. When a piglet was born, time was recorded, pigs were dried off using a desiccant (Tech Dry; Techmix LLC., Stewart, MN) and paper towels. Umbilical cords were then tied and cut to approximately 4 inches in length. Additionally, pigs were given an individual ear tag for identification and weighed before placing them next to the sow. Stillborn and mummified fetuses were also weighed and birth time recorded. During parturition, farrowing assistance was provided after 30 to 45 min with no farrowing progress evidence from the time a previous pig was born. When provided, farrowing assistance was noted on the litter record. The farrowing process was complete when no new pig had been born after 1 h and placenta expulsion was observed. At 24 h after birth of the first piglet in each litter, piglets were individually weighed to calculate colostrum intake and colostrum yield. All piglets remained with their birth sow during the trial until weaning.

All piglet mortalities prior to 24 hours were recorded and classified as either 1) died at birth (died within an hour of birth) or 2) laid on (due to crushing by the sow). Due to the health status of the farm, no cross-fostering occurred, and no nurse sows were utilized. At 24 h, piglets less than 1.2 lb body weight were identified and euthanized according to farm protocol. Fall-behind pigs and mortalities were weighed, and the date was recorded for all litters from birth to weaning. Fall-behind piglets were classified as losing weight for multiple days during lactation or sustaining a life-threatening injury; they were removed from the sow and humanely euthanized.

On the day prior to weaning, all piglets were individually weighed to measure litter growth and litter weight coefficient of variation. On the day of weaning (d 21± 3), sows were weighed and backfat was measured at the P2 position. Sows were moved to individual gestation stalls and checked once daily for signs of estrus using a boar and back pressure test for 42 d post-farrowing. Wean to first service interval and d 30 conception rate were collected on a total of 562 sows that remained after culling due to age (n = 160), injury (n = 3), or infertility (n = 2). Farrowing rate, subsequent total born, born alive, and stillborn were collected by farm employees and accessed through the farm database (PigCHAMP; Ames, IA).

Calculations

Sow body weight post-farrowing was calculated using the equation,[9] where post-farrow maternal body weight (lb) = b + (0.897 × pre-farrow BW, lb) - (1.118 × total born, n) + (6.87 × days pre to post-farrow, d). The intercept (b) for parities 1, 2, 3, and 4+ were -5.93, 5.15, 11.90, and 32.31, respectively.

Colostrum intake was calculated using piglet 24 h weight gain, suckling duration, and birth weight.[10] Colostrum yield was calculated as the sum of the colostrum intake of the pigs in the litter. If a piglet died before 24 h, the assumption was that there was no colostrum intake by that piglet.

Time from loading into farrowing crates to the onset of farrowing was calculated as (date of farrowing - date of entry to farrowing house), in days. Time consuming meals prior to farrowing was calculated as (start time of parturition - time the first meal was delivered upon entry to the farrowing house), in hours. Time since last meal was calculated as (farrow start time - time of last meal), in minutes. Pig-to-teat ratio for each sow was calculated as number of born alive piglets divided by functional teats. Pre-farrow feed intake is the sum of feed consumed from entry to the farrowing house until the start of parturition. Total feed intake is total pre-farrow feed intake plus total lactation feed intake. Farrowing duration was calculated as the time from birth of first pig to birth of last pig. Average birth interval per sow was calculated as the actual interval between each piglet and then averaged for the sow. Percentage assisted was calculated by dividing the number of pigs sleeved per litter by the number of total born pigs per litter.

[9] Thomas, L. L., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. C. Woodworth, and J. M. DeRouchey. 2018. Partitioning components of maternal growth to determine efficiency of feed use in gestating sows. J. Anim. Sci. 96:4313-4326. doi: 10.1093/jas/sky219.

[10] Theil, P. K., C. Flummer, W. L. Hurley, N. B. Kristenen, R. L. Labouriau, and M. T. Sorensen. 2014. Mechanistic model to predict colostrum intake based on deuterium oxide dilution technique data and impact of gestation and prefarrowing diets on piglet intake and sow yield of colostrum. J. Anim. Sci. 92: 5507-5519. doi:10.2527/jas2014-7841.

Statistical Analysis

Data were analyzed using generalized linear mixed models where dietary treatment within parity category was a fixed effect, with random effect of block. Heterogeneous variance by treatment was tested for each variable and used if it significantly improved the model fit.

Sow BW, backfat depth, litter weights, mean piglet BW, litter gain, colostrum yield and intake, piglet BW CV, total born, litter counts, and feed intake were fit using a normal distribution. Farrowing duration and birth interval were log transformed to normalize data and then fit using a normal distribution. Wean to estrus interval was fit using a negative binomial distribution. Percentage born alive, stillborn, assisted, survived to 24 h, fall-behind, mortality, weaned, in estrus by d 7, conception rate, and farrowing rate were fit using a binomial distribution.

Covariates were used if they significantly improved the model fit. Residuals and the Bayesian Information Criterion were used as an indication of improved model fit. Entry weight was used as a covariate for sow weaning weight, sow entry backfat, and weight change from entry to weaning. Sow backfat at entry was used as a covariate for sow backfat at weaning and backfat change from entry to weaning. Parity was used as a covariate for total sow feed intake. Total born was used as a covariate for total born litter weight, and total born, born alive and 24 h mean piglet BW, and total born individual pig weight CV. Born alive was used as a covariate for born alive and 24 h litter weights and coefficients of variation. Both lactation length and born alive were used for litter weaning weight and mean piglet weaning weight. Pig-to-teat ratio was used as a covariate for litter gains, colostrum yield, and colostrum intake. Sow blood glucose was analyzed for a time × treatment interaction, and main effects of time and treatment using a repeated measures statement. Statistical models were fit using the lme function (lmer package of R, version 3.5.2). Results were considered significant at $P < 0.05$ and marginally significant at $0.05 \leq P < 0.10$.

Results and Discussion

Timing of Treatments

Time from loading to farrowing was 0.3 days shorter ($P = 0.005$) for sows fed *ad libitum* prior to farrowing, compared to sows that received one meal daily. As would be expected due to the feeding strategy design of the trial, time spent consuming meals prior to farrowing was shorter ($P = 0.001$) for sows fed 6 lb once daily compared to the other two treatments. As a result, time since last meal in relation to the start of parturition decreased ($P = 0.001$) in sows fed 1.5 lb every 6 hours or *ad libitum* compared to those fed 6 lb once daily. Total pre-farrow feed intake was increased ($P = 0.001$) in sows fed *ad libitum* compared to the other two feeding strategies. These results demonstrated that the feeding strategies had been applied successfully to the sows, in order to create differences in timing of meals and amount of feed provided prior to parturition.

Sow Body Weight, Back Fat, and Feed Intake

Sow BW and backfat were similar ($P > 0.10$) at the start of the trial (entry to the farrowing house). Calculated sow BW post-farrowing was similar ($P > 0.10$), which was expected due to no change in weight of conceptus or litter size from dietary treatments

applied for only 3 d prior to farrowing. Sow BW at weaning was marginally heavier (P = 0.077) in sows that had been fed *ad libitum* prior to farrowing, compared to sows that had been fed 1.5 lb every 6 h prior to farrowing. As a result, sows that consumed feed *ad libitum* prior to farrowing had reduced sow BW loss from post-farrow to weaning (P = 0.035) and tended to have reduced sow BW loss from entry to weaning (P = 0.077) compared to sows fed 1.5 lb every 6 h, with sows fed 6 lb once daily being intermediate. Similar to the changes observed for BW, sow backfat loss was reduced (P = 0.003) in sows fed *ad libitum* compared to sows fed 1.5 lb every 6 h, resulting in greater backfat at weaning (P = 0.003) in sows fed *ad libitum* prior to farrowing compared to sows fed 1.5 lb every 6 h, with sows fed 6 lb once daily intermediate. The reduction in backfat and BW loss is likely a result of increased feed consumption during the peripartum period (21.4 vs. 16.5 lb) and improved feed intake during the lactation period when sows were fed *ad libitum*. It is important to note that *ad libitum* feed intake prior to farrowing did not exceed 7 d. In previous studies that evaluated *ad libitum* or increased feeding strategies starting on d 90 of gestation, excess BW and backfat gain occurred which contributed to decreased feed intake and increased sow body lipid mobilization in lactation.

Sow lactation feed intake was numerically increased (P = 0.175) in sows fed *ad libitum* prior to farrowing. This combined with the difference observed in feed intake prior to farrowing, resulted in increased (P = 0.018) total feed intake per sow during time spent in the farrowing crate in sows fed *ad libitum* prior to farrowing compared to sows fed 6 lb once daily. This change in feed intake could be due to a change in feeding behavior by allowing sows to determine their feed intake prior to farrowing, rather than restricted feeding. In support of this, it has been observed that peripartal voluntary feed intake was greater in sows fed *ad libitum* compared to sows fed restricted amounts.[11]

Litter Characteristics at Birth, Farrowing Duration, and Piglet Survivability

There was no evidence that total born pigs, percentage of pigs born alive or stillborn were different (P > 0.10) due to feeding strategy (Table 3). There were differences (P < 0.001) in percentage of pigs assisted per sow. The sows fed *ad libitum* prior to farrowing had the highest percentage assistance, followed by sows fed once daily prior to farrowing, with those receiving 1.5 lb every 6 h having the lowest assistance rate. Farrowing duration, birth interval, and time to birth of 6th pig was similar (P > 0.05) across feeding strategies (Table 4). In the present study, farrowing duration averaged 3.5 h, which is much shorter than the average of 5.8 h observed by Feyera.[6] Total born was also lower in the present study (16.0 vs. 17.1 pigs) compared to Feyera.[6] We speculate that the lower total born in the present study resulted in a shorter mean farrowing duration, therefore limiting the number of sows experiencing farrowing fatigue due to pre-farrow fasting. Additionally, farrowing assistance was more frequent in the present study, which may have reduced the differences in stillbirths between treatments, whereas Feyera[6] allowed up to a 60 min birth interval before intervention.

Percentage of pigs that died at birth or were laid on within 24 h after birth were similar (P > 0.10) across treatments, which resulted in no evidence for difference (P > 0.10) in

[11] Cools, A., D. Maes, R. Decaluwe, J. Buyse, T. A. van Kempen, A. Liesegang, and G. P. Janssens. 2014. Ad libitum feeding during the peripartal period affects body condition, reproduction results and metabolism of sows. J. Anim. Reprod. Sci. 145:130-140. doi: 10.1016/j.anireprosci.2014.01.008.

survival to 24 h. Piglets that were euthanized at 24 h due to low birth weight, or injury were similar ($P = 0.110$) across treatments. Percentage of fall-behind pigs were reduced ($P = 0.012$) in sows fed *ad libitum* prior to farrowing compared to those fed once daily prior to farrowing, with those fed 1.5 lb every 6 h intermediate. Piglet moralities from 24 h to weaning were reduced ($P = 0.027$) in sows fed 1.5 lb every 6 h compared to those fed once daily prior to farrowing. Although litter size at weaning was similar across treatments, the total percentage of pigs weaned was increased ($P < 0.05$) in those fed 1.5 lb every 6 h prior to farrowing compared to those restricted to 6 lb once daily, with *ad libitum* fed sows being intermediate. This result suggests that feeding strategy prior to parturition may have an impact in the sow's ability to raise her piglets to weaning.

Litter Performance and Colostrum Production

Feeding strategies prior to farrowing tended to increase ($P = 0.053$) total born litter weight in sows fed 1.5 lb every 6 h compared to the other two feeding strategies. Born alive litter weight was heavier ($P = 0.046$) in sows fed 1.5 lb every 6 h compared to the other two feeding strategies. There was no evidence for difference ($P > 0.10$) in colostrum yield or intake, which resulted in similar 24 h litter weights and litter gain in the first 24 h. Litter weight at weaning and litter gain from 24 h to weaning was marginally increased ($P < 0.10$) in sows fed 1.5 lb every 6 h or *ad libitum* prior to farrowing compared to those fed 6 lb once daily.

Mean piglet BW was marginally greater in total born ($P = 0.055$) and greater in piglets born alive ($P = 0.045$) in sows fed 1.5 lb every 6 h prior to farrowing compared to those fed 6 lb once daily, with those fed *ad libitum* prior to farrowing intermediate. This resulted in marginally increased ($P = 0.088$) piglet weights at 24 h in sows fed 1.5 lb every 6 h compared to the other two feeding strategies. At weaning, pigs from sows fed *ad libitum* prior to farrowing were heavier ($P = 0.050$) compared to sows fed 6 lb once daily prior to farrowing. This may be explained by the numerically increased feed intake during lactation in sows fed *ad libitum* prior to farrowing, which resulted in greater milk output and improved piglet weaning weights.

Subsequent Reproductive Performance

After culling at weaning, a total of 562 females remained in the herd and were used to measure subsequent reproductive performance (Table 5). There was no evidence for difference ($P > 0.10$) in wean-to-estrus interval, percentage of females in estrus by d 7 or 20 after weaning, conception rate, or farrowing rate. It has been observed that if sows mobilize greater than 12% of body protein during lactation, there will be reduced embryo survival and decreased farrowing rate.[12] This would suggest that although there were differences in sow BW and backfat change during lactation, they were not great enough to elicit a negative effect in reproductive performance. Subsequent total born, born alive, and stillborn were similar ($P > 0.10$) across all pre-farrow feeding strategies.

In summary, it is important to consider the length of time of *ad libitum* feeding prior to farrowing, where the benefits in lactation feed intake, reduction in backfat loss, and improvements in litter growth can be observed. Feeding the lactation diet

[12] Clowes, E. J., F. X. Aherne, G. R. Foxcroft, and V. E. Baracos. 2003. Selective protein loss in lactating sows is associated with reduced litter growth and ovarian function. J. Anim. Sci. 81:753-764.

to sows *ad libitum* for an average of 3 d prior to farrowing increased weaning weight compared to sows fed once daily prior to farrowing. Sows limit-fed 4 times daily prior to farrowing had increased weaned percentage compared to sows fed one meal daily prior to farrowing. With levels of sow productivity in this study, there was no evidence the feeding strategies from entry to the farrowing house until parturition impacted farrowing duration, birth interval, or stillborn rate. As litter size continues to increase, nutritional or management strategies to help reduce farrowing duration and improve piglet survival to weaning should continue to be investigated.

Table 1. Dietary composition[1]

Ingredient, %	Lactation diet
Ground corn	46.30
Dried distillers grain with solubles	25.00
Soybean meal, 47.5% CP	21.30
Vegetable oil blend[2]	2.85
Limestone	1.38
Monocalcium P, 21%	0.93
Liquid energy[3]	0.75
Lysine HCl	0.52
Salt	0.28
Vitamin premix	0.25
L-Threonine	0.17
Choline chloride, 60%	0.10
L-Valine	0.06
L-Methionine	0.05
L-Tryptophan	0.03
Standardized ileal digestible (SID) amino acids, %	
Lysine	1.15
Methionine and cysteine:lysine	0.50
Threonine:lysine	0.65
Tryptophan:lysine	0.18
Valine:lysine	0.70
Isoleucine:lysine	0.56
Total lysine, %	1.30
Crude protein, %	20.1
Metabolizable energy, kcal/lb	1,506
Net energy, kcal/lb	1,150
Ca, %	0.77
P, %	0.66

[1]Lactation diets were fed upon entry to farrowing house, according to treatment feeding strategy. After farrowing, sows received lactation diet *ad libitum* until weaning.
[2]Build R2 (Feed Energy Company, Pleasant Hill, IA).
[3]XFE Liquid Energy; alcohol-based liquid product (XFE Products, Des Moines, IA).
[4] Provided per lb diet: 4,722 IU vitamin A; 202 IU vitamin D3; 16.5 µg vitamin D; 32 IU vitamin E; 113 mg vitamin C; 1.7 mg vitamin K; 18.6 mg niacin; 12.5 mg pantothenic acid; 0.8 mg folic acid; 1.0 mg thiamine; 3.7 mg riboflavin; 1.8 mg pyridoxine; 16.1 mg vitamin B12; 0.2 mg biotin; 100 mg Fe from Fe sulfate; 0.15 mg Se from Na selenite; 8.4 mg Cu from InteliBond C; 60 mg Zn from InteliBond Z; 15 mg Mn from Mn oxide; 0.55 I from calcium iodate; 0.20 mg Cr from Cr propionate; 226 FTU phytase.

Table 2. Timing and amount of feed delivered to sows prior to farrowing on sow performance[1]

Response	6 lb × 1 delivery	1.5 lb × 4 deliveries	*Ad libitum* × 4 deliveries	SEM	*P*-value
Count, n	242	245	240	--	--
Parity, n	3.8	3.8	3.9	--	--
Gestation length, d	115.5	115.5	115.4	0.08	0.323
Lactation length,[2] d	21.7	21.7	21.9	0.09	0.043
Time from loading to farrow,[3] d	3.2[a]	3.1[ab]	2.9[b]	0.08	0.005
Time consuming meals prior to farrow,[4] h	57.4[b]	70.9[a]	65.1[a]	1.94	0.001
Time from last meal to farrowing,[5] min	605[a]	196[b]	216[b]	25.6	0.001
Sow BW, lb					
Entry	573.8	572.6	573.7	3.91	0.734
Post farrow[5]	544.9	542.2	542.1	3.85	0.237
Weaning	524.0	520.5	527.8	2.41	0.077
Sow weight change, lb					
Entry to weaning	-52.5	-56.0	-48.7	2.41	0.077
Post farrow-weaning	-10.7[ab]	-11.4[b]	-8.4[a]	0.94	0.035
Sow backfat, mm					
Entry	13.4	13.8	14.0	0.24	0.179
Weaning	11.6[ab]	11.1[b]	11.8[a]	0.16	0.003
Sow backfat change, mm					
Entry to weaning	-2.2[ab]	-2.7[a]	-1.9[b]	0.16	0.003
Sow feed intake, lb					
Total pre-farrow feed intake[7]	16.5[b]	17.3[b]	21.4[a]	<0.69[10]	0.001
Lactation average daily feed intake[8]	10.8	11.0	11.3	0.21	0.175
Total feed intake[9]	255.7[b]	259.7[ab]	272.8[a]	<7.65[10]	0.018

[1]A total of 727 mixed parity sows were used from entry into the farrowing house (d 113 ± 2 of gestation) until weaning. Sows were weighed, blocked by parity category and weight, and allotted to treatment at time of entry to the farrowing house. Treatments consisted of: 1) control sows fed 6 lb lactation diet once daily at 0700 h; 2) sows fed 6 lb lactation diet 4 times daily in 1.5 lb meals (0100 h, 0700 h, 1300 h, 1900 h); and 3) sows fed *ad libitum* lactation diet and encouraged to consume meals every 4 times daily (0100 h, 0700 h, 1300 h, 1900 h).

[2]Tukey adjustment resulted in no mean separation.

[3]Days spent in farrowing crate prior to parturition = (farrowing date - load date).

[4]Number of hours sow received treatments prior to farrowing. Sows were loaded into farrowing crates at 1300 h each day, therefore sows consuming 1.5 lb meals and *ad libitum* sows received feed at loading. Sows receiving 6 lb once a day did not receive feed until the following morning.

[5]Time from last meal delivery to the birth of first pig.

[6]Calculated from equation by Thomas et al. (2018) (Thomas, L. L., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. C. Woodworth, and J. M. DeRouchey. 2018. Partitioning components of maternal growth to determine efficiency of feed use in gestating sows. J. Anim. Sci. 96:4313-4326. doi: 10.1093/jas/sky219.).

[7]Sum of feed consumed from loading to farrowing, measured on all sows.

[8]Lactation feed intake was measured on a subsample of 310 sows.

[9]Sum of feed consumed from loading to weaning, measured on a subsample of 310 sows.

[10]Heterogenous variance by treatment, highest SEM reported.

Table 3. Timing and amount of feed delivered prior to farrowing on litter performance[1]

Response	6 lb × 1 delivery	1.5 lb × 4 deliveries	*Ad libitum* × 4 deliveries	SEM	*P*-value
Litter characteristics					
Total born, n	16.1	15.7	16.0	0.23	0.351
Born alive, %	93.4	93.8	93.6	0.45	0.664
Stillborn, %	6.6	6.1	6.4	0.44	0.667
Assisted, %	16.1[b]	13.7[c]	19.6[a]	1.11	0.001
Litter size at 24 h, n	13.9	13.6	13.8	0.20	0.432
Litter size at weaning, n	11.2	11.3	11.2	0.15	0.752
Litter weight, lb					
Total born, 0 h	42.8	43.9	42.8	0.43	0.053
Born alive, 0 h	40.0[b]	41.3[a]	40.3[ab]	0.45	0.046
24 h	41.3	42.3	41.4	0.45	0.219
Weaning[2]	117.1	121.6	119.1	1.43	0.083
Mean piglet BW, lb					
Total born, 0 h	2.73	2.81	2.74	0.028	0.055
Born alive, 0 h	2.74[b]	2.83[a]	2.77[ab]	0.027	0.045
24 h	3.00	3.08	3.02	0.027	0.088
Weaning	10.59[b]	10.79[ab]	10.88[a]	0.096	0.050
Litter gain 0 to 24 h, lb	3.03	2.80	2.84	0.105	0.218
Litter gain 24 h to wean, lb	75.06	79.24	77.75	<1.362[6]	0.064
CV of individual pig weights, %					
Total born	23	22	23	0.40	0.218
24 h	23	22	23	0.40	0.143
Weaning	19	19	19	0.40	0.486
Colostrum yield,[3] kg/sow	5.7	5.7	5.6	0.17	0.471
Colostrum intake,[4] g/pig	418	422	415	<6.1[6]	0.606
Pig:teat[5]	0.98	0.97	0.98	0.015	0.832

[1]A total of 727 mixed parity sows were used from entry into the farrowing house (d 113 ± 2 of gestation) until weaning. Sows were weighed, blocked by parity category and weight, and allotted to treatment at time of entry to the farrowing house. Control sows fed 6 lb lactation diet once daily at 0700 h; sows fed 6 lb lactation diet 4 times daily in 1.5 lb meals (0100 h, 0700 h, 1300 h, 1900 h); sows fed *ad libitum* lactation diet and encouraged to consume meals 4 times daily (0100 h, 0700 h, 1300 h, 1900 h).

[2]Lactation length averaged 21.7 ± 3.3 d.

[3]Calculated based on equation from Theil et al. (2014) (Theil, P. K., C. Flummer, W. L. Hurley, N. B. Kristenen, R. L. Labouriau, and M. T. Sorensen. 2014. Mechanistic model to predict colostrum intake based on deuterium oxide dilution technique data and impact of gestation and prefarrowing diets on piglet intake and sow yield of colostrum. J. Anim. Sci. 92: 5507-5519. doi:10.2527/jas2014-7841.).

[4]Sum of individual colostrum intake for all pigs in the litter.

[5]Pigs per functional teat.

[6]Heterogenous variance by treatment, highest SEM reported.

Table 4. Timing and amount of feed delivered to sows prior to farrowing: effects on farrowing duration, birth order, and survival[1]

Response	6 lb × 1 delivery	1.5 lb × 4 deliveries	*Ad libitum* × 4 deliveries	SEM	*P*-value
Farrowing duration, min	209	200	214	2.26	0.226
Birth interval, min	13.6	13.7	14.3	1.07	0.448
Birth time of 6th pig, min	90.2	93.1	95.5	3.82	0.620
Outcome to 24 h[3]					
Died at birth,[4] %	1.3	1.4	1.3	0.22	0.839
Laid on, %	5.0	5.2	5.2	0.41	0.950
Survived to 24 h, %	93.6	93.3	93.4	0.44	0.912
Outcome to weaning[3]					
Euthanized at 24 h, %	2.5	2.1	2.8	0.31	0.110
Fall-behind, %	7.5[a]	6.3[ab]	5.9[b]	0.52	0.012
Dead, %	7.6[a]	6.1[b]	6.6[ab]	0.49	0.027
Weaned, %	74.3[b]	77.6[a]	76.1[ab]	0.80	0.006

[1]A total of 727 mixed parity sows were used from entry into the farrowing house (d 113 ± 2 of gestation) until weaning. Sows were weighed, blocked by parity category and weight, and allotted to treatment at time of entry to the farrowing house. Control sows fed 6 lb lactation diet once daily at 0700 h; sows fed 6 lb lactation diet 4 times daily in 1.5 lb meals (0100 h, 0700 h, 1300 h, 1900 h); sows fed *ad libitum* lactation diet and encouraged to consume meals 4 times daily (0100 h, 0700 h, 1300 h, 1900 h). Weaning occurred on d 21.7 (± 3.3 d) of lactation.
[2]Time from birth of first piglet to last piglet.
[3]Calculations use the count of the variable divided by born alive count. Analyzed as a binominal.
[4]Died within an hour after birth, includes low viable, deformed, and savaged pigs.

Table 5. Timing and amount of feed delivered to sows prior to farrowing on subsequent reproductive performance[1]

Response	6 lb × 1 delivery	1.5 lb × 4 deliveries	*Ad libitum* × 4 deliveries	SEM	*P*-value
Count, n	188	188	186	--	--
Wean to estrus interval,[2] d	4.6	4.0	4.3	<0.182[3]	0.162
Estrous by d 7, %	95.7	96.3	96.2	1.47	0.958
Estrous by d 20, %	97.3	99.4	98.9	1.17	0.204
Conception rate,[4] %	89.4	88.3	86.6	2.51	0.703
Farrowing rate,[5] %	85.1	87.8	85.0	2.62	0.673
Subsequent litter					
Count,[6] n	160	165	158	--	--
Total born, n	13.7	14.0	13.7	0.26	0.492
Born alive, %	93.4	93.3	92.8	0.55	0.809
Stillborn, %	6.6	6.7	7.2	0.59	0.809

[1]A total of 562 mixed parity sows remaining in the herd were used to collect subsequent reproductive performance. Sows were culled after lactation due to old age (n = 160), injury (n = 3), or infertile (n = 2).
[2]Sows were monitored for 42 d after weaning for signs of estrus.
[3]Heterogenous variance by treatment, highest SEM reported.
[4]Sows confirmed pregnant at d 30 divided by total number bred.
[5]Sows farrowed divided by total number bred.
[6]Sows that farrowed a subsequent litter.