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3 **Effect of different feeding levels during three short periods of gestation on sow and litter**
4 **performance over two reproductive cycles**
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23 **Abstract**

24 The present study investigated the effects of different feeding levels during 3 short periods of
25 gestation on sow and litter performance. A total of 160 multiparous sows were allotted to 1 of 4
26 dietary treatments using a randomized complete block design with initial body weight (BW) and
27 backfat (BF) as the blocking criteria. All sows were fed one common corn-soybean meal-based
28 diet with the amount of $1.0 \times$ maintenance energy intake ($100 \times \text{BW}^{0.75}$ kcal ME/d) throughout
29 gestation except 3 periods of 7 d when dietary treatments were imposed on d 27, d 55 and d 83 of
30 gestation. During the 3 short periods, sows were fed 1 of 4 different feeding levels: 0.5, 1.0, 1.5
31 and $2.0 \times$ maintenance energy level (0.5M, 1.0M, 1.5M and 2.0M, respectively). Results showed
32 that both BW gain (16.12, 24.74, 30.62 and 36.71 kg, respectively) and BF change (-0.27, 0.99,
33 1.49 and 2.45 mm, respectively) from d 27 to 109 of gestation increased linearly ($P < 0.01$) with
34 the increase of gestation feeding levels. In contrast, with the rise of gestation feeding levels,
35 lactation BW gain (14.31, 9.84, 7.09 and 3.50 kg, respectively) decreased linearly ($P < 0.01$),
36 while BF loss during lactation (-0.79, -0.92, -1.12 and -1.57 mm, respectively) increased linearly
37 ($P = 0.05$). It was estimated that requirements of 1.20M, 0.66M and 0.65M feeding levels were
38 needed to maintain a constant BW during these 3 short periods. Additionally, average daily feed
39 intake during lactation (7.05, 7.00, 6.91 and 6.52 kg, respectively) tended to decrease linearly (P
40 $= 0.09$) in response to the increase of gestation feeding levels. Furthermore, piglet birth weights
41 increased linearly ($P < 0.01$) with the increase of gestation feeding levels, while piglet weaning
42 weights were similar ($P > 0.10$) among treatments. Subsequent reproductive performance was
43 not affected ($P > 0.10$) by feeding levels during the previous reproductive cycle. In conclusion,
44 increasing feeding levels during 3 short periods of gestation increased BW and BF gains during
45 gestation and caused less BW gain and more BF loss during lactation due to the reduction of

lactation feed intake in response to increasing gestation feeding levels. Increasing feeding levels during 3 short periods of gestation increased piglet birth weight, but did not affect piglet weaning weight. The feeding strategies in the current reproductive cycle did not impact subsequent reproductive performance. The data indicated that the current maintenance energy requirement of gestation sows may be underestimated or overestimated depending on gestation periods.

Key words: Feeding levels; sow performance; litter performance

Abbreviations: BW, body weight; BF, backfat; ADG, average daily gain; ADFI, average daily feed intake

1. Introduction

Nutritional strategies have been the research focus to improve reproductive performance of sows for several decades. It was previously thought that a feeding regime which could allow an adequate body weight gain accounted for the maternal weight gain, developing fetus and placenta with no detrimental effects on reproductive performance would improve overall energetic efficiency of reproduction (Frobish et al., 1973). However, modern crossbred sows, which have increased potential of large litter size and high lean mass (Whittemore, 1996), have been shown to gain adequate body weight over the reproductive cycle while simultaneously losing considerable fat mass (Yang et al., 1989; Dourmad et al., 1991), which may compromise subsequent reproductive performance (Yang et al., 1989).

In the past several decades, numerous studies have been conducted to investigate effects of energy concentrations (Buitrago et al., 1974; Dourmad et al., 1996; Heo et al., 2008; Hoppe et al., 1990) and protein levels (Mahan and Mangan, 1975; Mahan, 1998) during gestation on sow and litter performance. Additionally, feeding levels during different stages of gestation (Cromwell et

al., 1989; Heo et al., 2008; Hoving et al., 2011; Musser et al., 2006; Weldon et al., 1994a) and whole gestation (Dourmad et al., 1991; Mahan, 1998) over one or several reproductive cycles have also been studied to evaluate their effects on sow and litter performance. These studies consistently showed that increasing feeding levels during gestation increased sow body weight gain during gestation, but the sows consuming higher feeding levels during gestation lost more body weight and backfat during lactation, with inconsistent results for litter performance. However, we are not aware of any research on investigation of feeding levels during several short periods during gestation on sow and litter performance. Therefore, the objective of this study was to determine effects of different feeding levels during 3 short periods of gestation on sow and litter performance and its impact on the subsequent reproductive performance.

2. Materials and Methods

The Institutional Animal Care and Use Committee of University of Minnesota approved the experimental protocol of this study.

2.1. Animals and Management

The present experiment was conducted at the University of Minnesota - Southern Research and Outreach Center, Waseca, MN. The experiment started on February 4, 2014 and ended on November 13, 2014. A total of 160 multiparous Large White x Danish Landrace crossbred sows (TOPIGS 20, TOPIGS Inc., Winnipeg, Manitoba, Canada) consisted of 4 different batches were used in this study. After breeding, all sows in each batch stayed in the individual stalls (2.1 m length x 0.6 m width x 0.6 m height) for about 35 d; then pregnancy check was conducted for all these bred sows; after pregnancy check, all the pregnant sows were moved to the same group pen (13.1 m length x 6.9 m width x 0.7 m height) with electronic sow feeders (3.7 m length x 0.5 m

width x 0.7 m height) in the center. Another pregnancy check was conducted 2 wk later on these sows in the pen to confirm the pregnancy. During gestation, all sows were fed their respective gestation diets with different amounts of feed during different periods of gestation. On d 109 of gestation, sows were moved into the farrowing rooms with environment controlled systems and housed in individual farrowing crates (2.13 m length × 0.66 m width × 0.97 m height). All sows were fed 2.27 kg lactation diets beginning from d 109 to the date of farrowing. After parturition, the amount of feed was increased gradually to allow for *ad libitum* feed intake from d 5 until weaning at about d 19 of lactation. After weaning, sows were moved to the environmental controlled gestation room with individual stalls. Estrus was checked on the daily basis. Sows were bred via artificial insemination on 2 consecutive days. From weaning to breeding, sows were fed 2.0 kg gestation diet. Sows were allowed free access to water throughout the experimental period and remained in the study and the subsequent reproductive performance was recorded. Sows were culled according to the Standard Operation Procedure of the Swine Research Facility.

In each batch, 2 sows of parity 3 with similar BW and BF from each treatment were selected before farrowing. New born piglets from these sows were weighted immediately and notched individually after the last piglet within each litter was farrowed. These piglets were also weighed individually at weaning. Piglets from other sows were processed within 24 h after birth according to the standard piglet management procedure of the facility, such as iron shot, tail docking and navel cut and disinfection. Cross-fostering was conducted within 48 h after birth within dietary treatment to equalize litter size around 11 or 12 piglets per litter. Heat lamps were provided for newborn piglets for 48 h and piglets had access to heat pad from birth to weaning.

Physical castration was conducted on all male piglets between 5 and 9 d of age. No creep feed was provided during lactation and all piglets were weaned at about d 19 of lactation.

2.2. Dietary Treatments and Experimental Design

At d 27 of gestation, sows in each batch were allotted to 1 of 4 experimental treatments using a randomized complete block design by initial body weight (BW) and backfat (BF) at breeding and balanced by parity among treatments. The experiment started from d 27 of gestation throughout the gestation and lactation period. All sows were fed one common corn-soybean meal-based basal diet (Table 1) with the amount of $1.0 \times$ maintenance energy intake ($100 \times \text{BW}^{0.75}$ kcal ME/d, NRC, 2012) throughout the gestation period except 3 periods of 7 d dietary treatments imposing at d 27, d 55 and d 83 gestation. During these 3 periods, sows were fed 1 of 4 different feeding levels based on maintenance energy intake: 1) $0.5 \times$ maintenance level (0.5M); 2) $1.0 \times$ maintenance level (1.0M); 3) $1.5 \times$ maintenance level (1.5M); 4) $2.0 \times$ maintenance level (2.0M). Gestation diet and lactation diet (Table 1) met or exceeded NRC (2012) nutrient recommendations.

After breeding, all sows in each batch stayed in the individual stalls for about 35 d until pregnancy check; then the pregnant sows were moved to the same group pen. All sows were remained in the group pen until d 109 of gestation. Each batch, around 45-50 sows were transferred to group pens with the dimension of 13.1 m length x 6.9 m width x 0.7 m height and each pen was equipped with 4 nipple drinkers and fully slatted concrete floor. An electronic sow feeder (Osborne Industries, Osborne, Kansas, USA) was installed in the center of the pen. Excluding the space occupied by the electronic sow feeder, each sow in the group pens had the floor space allowance of 1.8 m^2 . The feed intake in the group pen system was manipulated

through different feeding curves, which were set in the program in the computer. Each pen had 24 h feeding cycle on the daily basis. Sows in the group pens were equipped with the transponders in their left ears. Each time only 1 sow was allowed to enter the electronic sow feeder. Once the sow entered the electronic sow feeder, the entrance was locked so that other sows could not enter the feeder. The system sensed the transponder in that sow's ear and determined the feed curve assigned to that sow. Once the sow finished her daily amount of feed, the door would open automatically and other sows would push her out. Individual stalls (Crystal Spring Hog Equipment, Ste. Agathe, Manitoba) were equipped with individual feeders and nipple drinkers. Each stall was located on the fully slatted concrete floor. The feed intake of sows in the individual stalls was managed via setting different feed drops with different volumes, which was calibrated, monthly by weighing the feed to assure correct weight and volume of feed. All the sows in the individual stalls were fed at 7:30 am each day.

2.3. Data Collection and Chemical Analysis

2.3.1. Sow and Litter Performance

Sow BW was recorded and BF thickness was measured using ultrasonic detection machine (Preg-Alert Pro, Renco Corp., Minneapolis, USA) on both the left and right sides at the P2 position (6.5 cm from the dorsal mid-line at the level of the last rib) on d 27, 34, 55, 62, 83, 90, 109 of gestation, within 24 h after farrowing and at weaning to measure the BW and BF change during gestation and lactation periods. During lactation, farrowing date, litter size (number of total piglets born, born alive, after cross-fostering and at weaning), piglet deaths were recorded. Litter weight at birth, after cross-fostering and at weaning was also recorded. Feed intake was recorded on daily basis until weaning. Prewaning mortality of piglets within litter was

calculated using the live born piglets died before weaning divided by the number of live born piglets. Litter weight gain and piglet average daily gain (ADG) were also calculated. Average daily feed intake (ADFI) was calculated using the summation of daily feed intake divided by the lactation period. Within-litter variation of liveborn piglet birth and weaning weights were calculated using the notched piglets. Subsequent reproductive performance was also recorded for each previous gestation feeding level treatment.

Protein and fat mass on d 27, d 109 of gestation, post-farrowing and weaning was estimated using the prediction equation of Dourmad et al. (1997). The corresponding changes of protein and fat mass during gestation and lactation were calculated.

2.3.2. Chemical Analysis

Concentrations of dry matter (method 934.01; AOAC, 2006), crude protein (method 984.13; AOAC, 2006), ether extract (method 920.39; AOAC, 2006), neutral detergent fiber (NDF, method 973.18; AOAC, 2006), acid detergent fiber (ADF, method 973.18; AOAC, 2006) in gestation and lactation diets were analyzed in University of Minnesota's Southern Research and Outreach Center's Swine Research Lab. Concentrations of calcium (method 958.01; AOAC, 2006), phosphorus (method 958.01; AOAC, 2006) and amino acid (method 982.30; AOAC, 2006) were analyzed in Experiment Station Chemical Laboratories (University of Missouri, Columbia, MO).

2.4. Statistical Analysis

SAS 9.4 (SAS Inst. Inc., Gary, NC) was used in all data analysis. Individual sow served as the experimental unit. The LSMEANS statement was used to calculate the least square means.

177 Tukey-Kramer adjustment was used for multiple comparisons of the least square means.
178 Covariates was used to adjust the least square means of response and presented as a footnote for
179 each table. Pooled SEM was calculated for each measurement. A probability of $P < 0.05$ was
180 considered as significant and $0.05 < P < 0.1$ was declared as a trend.

181 The GLIMMIX procedure was used to analyze all the data. Dietary treatment was considered as
182 the fixed effect. Batch and block within each batch were considered as random effects. Sow BW
183 and BF measured on d 27, 55, 83, 109, post-farrowing and at weaning were considered as
184 repeated measurements in time. Different covariance structure candidate models were examined
185 and the best fit model was selected for each measurement based on Akaike Information Criterion
186 (AIC) and Bayesian Information Criterion (BIC) values. Model examination results indicated
187 that heterogeneous first-order autoregressive (arh(1)) and heterogeneous Toeplitz (toeph) were
188 the best covariance models for sow BW and BF measurements, respectively. The SLICE option
189 by time was used to test the effect of dietary treatments at each of the different time points.

190 Sow BW change, BF change, ADG, feed intake and gain to feed ratio calculated for the 3 short
191 periods were also considered as repeated measurements. After model testing, the best covariance
192 structure models selected using the aforementioned technique for sow BW change, BF change,
193 ADG, feed intake and gain to feed ratio were all arh(1). The SLICE option by period was used to
194 test the effect of dietary treatments at the 3 short periods.

195 For litter performance of both reproductive cycles, the data of litter weight and average piglet
196 weight at birth and weaning, and average daily gain of piglets were analyzed in the default
197 normal linear regression model. Count data, such as number of liveborn, total born, after cross-
198 fostering, death and wean piglets were analyzed using Poisson regression model, while zero-

inflated Poisson regression model was used to analyze the numbers of stillborn and mummies.

Furthermore, the binomial regression model was used to analyze pre-weaning piglet mortality.

The CORR procedure was used to examine the Pearson correlation coefficients among sow performance parameters during gestation and lactation. Additionally, the REG procedure was used to establish the simple linear regressions and determine the effects of sow BW gain during gestation on sow BW change during lactation, sow BF change during gestation on sow BF loss during lactation, and sow BF post-farrowing on lactation average daily feed intake.

The LIFETEST procedure was used to examine the retention rate of sows among the 4 feeding levels during gestation periods. Logrank test was used to compare the retention rate among the 4 feeding levels.

3. Results

3.1. Effects of feeding levels on sow performance

At the initiation of the experiment (d 27 of gestation), there were no differences ($P = 0.80$ and 0.56 , respectively) for sow BW and BF thickness (Table 2). There were also no differences for sow BF thickness on d 55 and 83 of gestation ($P = 0.70$ and 0.29 , respectively). However, sows on 2.0M feeding level had higher ($P = 0.05$) BW at d 55 of gestation than those on 0.5M feeding level, and sows on 1.5M and 2.0M feeding levels had greater ($P < 0.01$) BW on d 83 of gestation compared with those on 0.5M feeding level. On d 109 of gestation, post-farrowing and at weaning, both BW and BF thickness were greater ($P < 0.05$) for sows on 1.0M, 1.5M and 2.0M feeding levels compared with those on 0.5M feeding level. Additionally, sow BW and BF thickness on d 83, 109 of gestation, at post-farrowing and weaning increased linearly ($P < 0.05$) with the rise of feeding levels.

221 From d 27 to 109 of gestation, sow BW gains on 1.0M, 1.5M and 2.0M feeding levels were
222 higher ($P < 0.01$) than sows on 0.5M feeding level, and sows on 1.5M and 2.0M feeding levels
223 had greater ($P < 0.01$) BF thickness change in comparison with those on 0.5M feeding level.
224 Both gestation BW gain (16.12, 24.74, 30.62 and 36.71 kg, respectively) and BF change (-0.27,
225 0.99, 1.49 and 2.45 mm, respectively) from d 27 to 109 of gestation increased linearly ($P < 0.01$)
226 with the rise of feeding levels during the 3 short periods. In contrast, sows on 0.5M feeding level
227 during 3 short periods of gestation gained more weight during lactation compared with those on
228 the other three feeding levels, and sows on 2.0M feeding level during 3 short periods of gestation
229 lost more BF during lactation than those on 0.5M feeding level. Lactation weight gain (14.31,
230 9.84, 7.09 and 3.50 kg, respectively) decreased linearly ($P < 0.01$), while BF loss during lactation
231 (-0.79, -0.92, -1.12 and -1.57 mm, respectively) increased linearly ($P = 0.05$) with the increase of
232 feeding levels during 3 short periods of gestation. Additionally, ADFI during lactation tended (P
233 = 0.10) to be higher for sows on 0.5M feeding level during 3 short periods of gestation than
234 those on 2.0M feeding level. With the rise of feeding levels during gestation, ADFI during
235 lactation (7.05, 7.00, 6.91 and 6.52 kg/d, respectively) tended to decrease linearly ($P = 0.09$).
236 Furthermore, both net BW gains and BF changes from d 27 of gestation to weaning were greater
237 ($P < 0.01$) in sows fed 1.0M, 1.5M and 2.0M during gestation in comparison with these
238 counterparts fed 0.5M. Both net BW gains and BF changes from d 27 of gestation to weaning
239 increased linearly ($P < 0.01$) with the rise of feeding levels during 3 short periods of gestation.
240 There were also no differences ($P = 0.78$) among 4 different feeding levels in terms of wean to
241 estrus interval. Survival analysis revealed that there were no differences among the 4 feeding
242 levels in terms of sow retention rate from d 27 until farrowing (Figure 1).

The results of feeding levels during 3 short periods of gestation on sow performance during these 3 periods are presented in Table 3. For all the 3 periods, sow performance parameters were greater in sows on 1.0M, 1.5M and 2.0M feeding levels in comparison with those on 0.5M feeding level in terms of BW change, BF change, ADG, feed intake and gain to feed ratio. Additionally, sows fed 1.5M and 2.0M feeding levels had higher BW change, BF change, ADG, feed intake and gain to feed ratio than sows fed 1.0M feeding level. With the rise of feeding levels, sow performance parameters increased linearly ($P < 0.01$) in terms of BW change, BF change, ADG, feed intake and gain to feed ratio. Furthermore, sow BW change, ADG, feed intake and gain to feed ratio increased significantly ($P < 0.01$, data not shown) with the advancement of gestation periods. However, there was no period effect ($P = 0.22$, data not shown) on sow BF change.

3.2. Effect of feeding levels on litter performance

There were no differences ($P > 0.10$) among 4 feeding levels in terms of numbers of liveborn, stillborn, total born, after cross-fostering, death and weaning, and litter weight at birth and weaning (Table 4). Number of mummies was higher ($P = 0.01$) in sows fed 1.0M feeding level than sows fed 2.0M feeding level. Gestation length was shorter ($P = 0.02$) in sows on 0.5M feeding level in comparison with sows on 2.0M feeding level. As a result of weaning at same day, lactation length was longer ($P < 0.01$) in sows on 0.5M feeding level in comparison with sows on 2.0M feeding level. Additionally, average weight of liveborn piglets at birth from sows on 1.0M, 1.5M and 2.0M feeding levels were higher ($P = 0.05$) than sows on 0.5M feeding level. After adjusting using gestation length, average weight of liveborn piglets at birth from sows on 1.0M, 1.5M and 2.0M feeding levels also tended to be higher ($P = 0.08$) than sows on 0.5M feeding level. Furthermore, no differences ($P > 0.10$) were found among the 4 feeding levels in terms of

average daily gain and pre-weaning mortality of piglets. There were also no differences ($P > 0.10$) among the 4 feeding levels in terms of coefficient of variation of piglet weights within litter at birth and weaning (Table 5).

In terms of subsequent litter performance (Table 6), increasing feeding levels during 3 short periods of gestation did not ($P > 0.10$) affect the litter size, litter weight and average weight of piglets at birth and weaning, as well as average daily gain of piglets, in the subsequent reproductive cycles.

3.3. Predicted sow body compositions during gestation and lactation

At the initiation of the experiment (d 27), there were no differences ($P > 0.10$) among 4 different feeding levels in terms of predicted protein and fat mass (Table 7). At the end of gestation (d 109) and post-farrowing, sows on 1.0M, 1.5M and 2.0M feeding levels had greater ($P < 0.01$) protein and fat mass than those on 0.5M feeding level. However, sow predicted protein mass at weaning was similar ($P > 0.10$) among the 4 feeding level, while predicted fat mass continued to be higher ($P < 0.05$) in sow on 1.5M and 2.0M feeding levels compared with those on 0.5M feeding level. Additionally, gains of sow protein (2.94, 4.05, 4.93 and 5.63 kg, respectively) and fat (3.12, 6.65, 8.75 and 11.23 kg, respectively) mass from d 27 to 109 of gestation increased linearly ($P < 0.01$) with the rise of gestation feeding levels. In contrast, protein mass gain (2.24, 1.73, 1.04 and 0.62 kg, respectively) during lactation decreased linearly ($P < 0.01$), while fat mass change (0.80, -0.18, -0.72 and -2.36 kg, respectively) during lactation increased linearly ($P < 0.01$) with the rise of feeding levels during 3 short periods of gestation.

3.4. Relationship among sow performance parameters

Gestation BW gain was negatively ($r = -0.52$, $P < 0.01$, Figure 2) correlated with lactation BW gain (Table 8). Gestation BF change was inversely ($r = -0.49$, $P < 0.01$, Figure 3) correlated with lactation BF loss. Additionally, ADFI during lactation was negatively ($r = -0.35$, $P < 0.01$, Figure 4) correlated with sow BF thickness at post-farrowing.

For an extra increase of 1 kg sow BW gain during gestation (from d 27 to 109 of gestation), lactation BW gain decreased by 0.51 kg (Table 9, Equation 1), while for an extra increase of 1 mm sow BF change during gestation, sow BF loss during lactation increased by 0.27 mm (Equation 2). Additionally, for an extra increase of 1 mm sow BF at post-farrowing, ADFI during lactation decreased by 80 g (Equation 3).

4. Discussion

4.1. Effects of feeding levels on sow performance

4.1.1. Sow BW and BF changes during gestation and lactation

The current experiment demonstrated that increasing feeding levels during 3 short periods of gestation caused a dramatic increase of BW and BF changes during these 3 short periods and from the initiation of the study (d 27 of gestation) to farrowing. The greater BW and BF gains during gestation resulted in less BW gain and higher BF loss during lactation, which was consistent with the previous literature (Baker et al., 1969; Hoppe et al., 1990; YOUNG et al., 1990; Dourmad et al., 1991). Interestingly, most of the aforementioned literature reported that sows lost considerable amount of BW and BF during lactation. In the present experiment, however, sows from all the gestation feeding levels gained different amount of BW during lactation and the amount of BW gain during lactation was inversely proportional to BW gain during gestation. It was estimated from the current study that sow BW gain during lactation

decreased by 0.51 kg for an extra kg of BW gain during gestation. Similarly, Dourmad et al. (1991) also illustrated an inverse relationship between gestation BW gain and lactation BW loss and found that every extra kg of BW gain during gestation was associated with 0.46 kg of lactation BW loss. It should also be noted that lactation BF loss increased linearly with the rise of feeding levels during 3 short periods of gestation, despite the fact the lactation BW increased in all dietary treatment, which indicated the limitation of the feeding strategy based only on the target of BW gain (Dourmad et al., 1991).

An apparent reduction of slope in the gestation BW gain from d 27 to 109 of gestation (8.62 kg/0.5M change vs. 5.88 kg/0.5M change) occurred at 1.0M feeding levels. This suggests that feed utilization for BW gain was more efficient at 1.0M feeding level than higher feeding levels. One possible explanation for the apparent decrease of feed utilization for sow BW gain in higher feeding levels may be that maternal fat synthesis may have increased relative to protein synthesis when feeding levels exceeded 1.0M.

BW changes during 3 short periods increased linearly with the rise of feeding level. By extrapolation of BW changes to zero based on the equations from Table 3, 1.20M, 0.66M and 0.65M feeding levels were needed to maintain a constant BW during these 3 short periods, respectively. These results indicate that the current maintenance energy requirement of gestation sows may be underestimated or overestimated depending on gestation periods and the maintenance energy requirement may not be constant during gestation periods. More detailed research is needed to warrant this finding.

4.1.2. Lactation feed intake

330 Numerous studies have demonstrated the negative relationship between gestation feeding levels
331 and lactation feed intake (Baker et al., 1969; Dourmad et al., 1991; Weldon et al., 1994). It was
332 suggested that the decrease of lactation feed intake was associated with the increased body
333 composition, especially BF thickness at farrowing (Dourmad et al., 1991). It was estimated from
334 the present study that for 1 mm more BF thickness at farrowing, average daily feed intake during
335 lactation decreased by 80 g. Dourmad et al. (1991) reported that the reduction of lactation feed
336 intake in response to BF thickness at farrowing was most pronounced during the first week of
337 lactation and estimated that the relationship between backfat thickness at farrowing and lactation
338 feed intake to be $-95 \text{ g} \cdot \text{d}^{-1} \cdot \text{mm}^{-1}$ during the first week of lactation and $-63 \text{ g} \cdot \text{d}^{-1} \cdot \text{mm}^{-1}$ during the
339 entire lactation period. Similarly, it was reported that the inverse relationship between average
340 daily feed intake and BF thickness at farrowing was remarkable for multiparous sows ($-129 \text{ g} \cdot \text{d}^{-1} \cdot \text{mm}^{-1}$),
341 while the inverse relationship was not evident in the primiparous sows ($-18 \text{ g} \cdot \text{d}^{-1} \cdot \text{mm}^{-1}$),
342 suggesting that the relationship between lactation feed intake and BF thickness at farrowing may
343 be dependent on the parity. Indeed, a recent publication from our lab confirmed this hypothesis
344 and revealed that with the increase of parity, the inverse relationship between average daily feed
345 intake and BF thickness at farrowing was $60\text{-}120 \text{ g} \cdot \text{d}^{-1} \cdot \text{mm}^{-1}$ (Kim et al., 2015). The mechanism
346 regarding the inverse relationship between lactation feed intake and BF thickness at farrowing is
347 not well understood. It was suggested by Weldon et al. (1994a) that reduction of lactation feed
348 intake may be attributed to the low plasma insulin concentration. Indeed, exogenous insulin
349 administration in lactation increased lactation feed intake during the infusion period, and this
350 effect was more pronounced for sows fed generously during gestation than sows fed restrictedly
351 (Weldon et al., 1994b). Another explanation for the lower lactation feed intake could be the
352 higher non-esterified fatty acid (NEFA) in the fat sows compared with thin sows (Weldon et al.,

1994a, 1994b). It was reported that plasma NEFA concentration at d 1 postpartum was negatively correlated with lactation feed intake at d 1 postpartum (Trottier and Easter, 1995). Increased insulin concentration in sows fed restrictedly in gestation may attenuate the release of NEFA from adipose tissue. It was known that insulin could decrease lipolysis and increase lipogenesis (Hadley, 1988), as well as reducing the activity of carnitine palmitoyltransferase I (Gamble and Cook, 1985), suggesting that oxidation of NEFA may be reduced. Therefore, insulin could increase lactation feed intake in two ways: the first way could be that higher circulating insulin may increase the peripheral glucose usage and thus more feed intake was required for maintaining blood glucose concentration; the other one could be the inhibition of mobilization of adipose tissue and oxidation of NEFA. In contrast with the aforementioned literature and the current study, Cromwell et al. (1989) reported that lactation feed intake was not affected by gestation feeding levels, even though the sows receiving more feed during gestation gained more BW during gestation and lost more BW during lactation in comparison with the sows receiving less feed during gestation. The inconsistent results may be ascribed to different feeding strategies. In the study conducted by Cromwell et al. (1989), additional feed was only provided during the last 23 d of gestation and the results showed that sows receiving extra feed had more live pigs at farrowing and the piglets were heavier at birth, indicating that the increase of BW during the last 23 d of gestation for sows receiving extra feed was mainly occurred in the fetal tissues (Elsley, 1968). Therefore, maternal body reserve, especially BF at farrowing, was not affected by additional feed during the last 23 d of gestation, possibly rendering the lactation feed intake not affected by gestation treatments.

4.1.3. Wean to estrus interval

In the present study, wean to estrus interval was not affected by feeding levels during 3 short periods of gestation. Yang et al. (1989) and Whittemore (1996) suggested that both the amount of body reserves at farrowing and weaning and their mobilization during lactation affected return to estrus. It was probable that the differences of BF thickness at farrowing and weaning among 4 feeding levels were not dramatic enough to trigger different activity of ovarian. Indeed, the existence of a critical amount of adipose and/or muscle tissue was necessary for the normal ovarian activity (Mullan and Williams, 1989; Dourmad et al., 1991). There was good evidence that, in the present study, predicted body protein mass of sows all increased during lactation, which may render similar wean to estrus intervals among the 4 feeding treatments. Additionally, it was likely that the degrees of BF mobilization during lactation among the 4 feeding treatments were not severe enough to differentiate its effect on return to estrus.

4.2. Effects of feeding levels on litter performance

4.2.1. Litter performance in the first reproductive cycle

The current experiment showed that the numbers of piglets born total, alive and at weaning were not different among different feeding levels during 3 short periods of gestation, which agreed with the reported literature (Lodge et al., 1966; Baker et al., 1969; Whittemore et al., 1988; Dourmad et al., 1991; Weldon et al., 1994a). However, some researchers have reported that increased gestation feeding levels (or energy intake) had adverse effects on the number of live born piglets at birth and/or weaning (Buitrago et al., 1974; Libal and Wahlstrom, 1977; Gonçalves et al., 2016). It could be speculated that higher energy intake or feeding levels during gestation may increase the clearance rate of progesterone and thus resulted in lower circulating

progesterone concentration (Prime and Symonds, 1993), which may be responsible for the reduction of embryo survival and eventually fewer liveborn piglets.

Being consistent with the results of Lodge et al. (1966), Baker et al. (1969), Elsley et al. (1969) and Cromwell et al. (1989), the current experiment demonstrated a linear increase of piglet birth weight in response to the rise of feeding levels during 3 short periods of gestation. Interestingly, gestation length was reduced in the lowest feeding level. One may wonder the reduced gestation length in the lowest feeding level may be responsible for the reduced piglet birth weight. When adjusted for the gestation length, however, birth weight of piglets from sows on the lowest feeding level still tended to be lower compared with the piglets from sows on the other three feeding levels, indicating that gestation feeding levels exerted its effects on fetal development. It was reported that malnutrition could elevate cortisol concentration in both maternal and fetal serum (Dwyer and Stickland, 1992). It was likely that sows on the lowest feeding level had higher maternal and fetal serum cortisol concentrations, which may stimulate the placenta to secrete relatively more estrogen and less progesterone, resulting in the decrease of gestation length (Wood and Keller-Wood, 1991). However, piglet weaning weight was not different among the 4 gestation feeding levels, indicating that milking capacity was not affected by gestation feeding levels.

In this present study, within-litter variations of piglets born alive at birth and weaning were similar among the 4 feeding levels. With the genetic selection progress in litter size of sows, the variation of piglet birth weight within litter has been increased (Merks, 2000). It was also reported that the increased percentage of low birth weight piglets, due to the increased heterogeneity of piglet weight within-litter, was responsible for the higher mortality rate of piglets (Lund et al., 2002). Therefore, nutritional strategies attempting to improve uniformity of

piglets within litter is promising in terms of enhanced economic return. The results of the current experiment suggested that different feeding levels during 3 short periods of gestation was not able to differentiate the fetal development, probably affected by placental vascularization and efficiency (Ford, 1997; Biensen et al., 1998).

4.2.2. Subsequent reproductive performance

There were no differences among the 4 previous gestation feeding levels in terms of subsequent reproductive performance. This suggests that there is no evidence for the long-term impact or carry-over effect of previous gestation feeding levels on the subsequent reproductive performance, as in the subsequent reproductive cycle, sows were managed under standard farm procedures.

To our best knowledge, this was the first study evaluating different feeding levels during 3 short periods of gestation on sow and litter performance and its impact on the subsequent reproductive performance. It was found, in the current experiment, that 1.20M, 0.66M and 0.65M feeding levels were needed to maintain a constant BW during these 3 short periods, respectively, suggesting that the current NRC (2012) maintenance energy requirement may be underestimated or overestimated depending on the gestation periods and the maintenance energy requirement may not be constant during gestation periods. This hypothesis was further supported by the fact that sows on 1.0M feeding level throughout gestation gained considerable amount of BW with limited increase of BF thickness.

5. Conclusions

Increasing feeding levels during 3 short periods of gestation increased BW and BF gains during gestation and caused less BW gain and more BF loss during lactation due to the reduction of

lactation feed intake in response to increasing gestation feeding levels. Increasing feeding levels during 3 short periods of gestation increased piglet birth weight, but did not affect piglet weaning weight. The feeding strategies in the current reproductive cycle did not impact subsequent reproductive performance. The data indicated that the current maintenance energy requirement of gestation sows may be underestimated or overestimated depending on gestation periods.

Conflict of interest

The authors declare that there is no conflict of interest that could affect the integrity of the currently reported results.

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563

Table 1

Composition and nutrient content of experimental diets in gestation and lactation (as-fed basis)

Item	Gestation	Lactation
Ingredient, g/kg		
Corn	652.3	611.6
Soybean meal	100.0	172.0
cDDGS ¹	200.0	150.0
Choice white grease	15.0	30.0
Limestone	10.0	8.8
Dicalcium phosphate	12.0	11.5
Lysine HCl (78%)	1.0	4.6
DL-Methionine	-	0.1
L-Threonine	-	1.3
L-Tryptophan	-	0.4
Salt	3.5	3.5
Premix ²	5.0	5.0
Tylan ³	1.3	1.3
Analyzed energy and nutrient composition, g/kg		
ME, MJ/kg ⁴	13.81	14.14
CP ⁵	157.0	180.1
Total Ca ⁵	7.5	8.0
STTD P ⁴	3.5	4.0
SID ⁶ Lys ⁴	5.7	10.0
SID Met + Cys ⁴	5.2	5.4
SID Thr ⁴	4.4	6.4
SID Trp ⁴	1.2	1.9

564 ¹cDDGS = corn distillers dried grains with solubles.

565 ²Supplied the following nutrients per kilogram of diets: vitamin A, 12,114 IU; vitamin D, 2,753
566 IU; vitamin E, 66 IU; vitamin K, 4.4 mg; thiamine, 1 mg; riboflavin, 10 mg; niacin, 55 mg;
567 pantothenic acid, 33 mg; pyridoxine, 2.2 mg; folic acid, 1.6 mg; vitamin B₁₂, 0.06 mg; I, 0.5 mg
568 from ethylenediamine dihydriodide; Se, 0.3 mg from sodium selenite; choline, 548 mg from
569 choline chloride; and metal polysaccharide complexes of zinc sulfate (125 mg of Zn), iron
570 sulfate (125 mg of Fe), manganese sulfate (40 mg of Mn), and copper sulfate (15 mg of Cu).

571 ³TylanTM 40 (Tylosin phosphate 40), Elanco Animal Health, Indianapolis, IN.

572 ⁴Calculated values according to NRC (2012).

573 ⁵Analyzed values.

574 ⁶SID = standardized ileal digestible.

Table 2
Effects of different feeding levels during three short periods of gestation on sow performance at different time points and during gestation and lactation

	Feeding levels ¹				SEM	<i>P</i> values ²			
	0.5M	1.0M	1.5M	2.0M		Treatment	Linear	Quadratic	Cubic
Number of sows	38	36	43	39					
Average parity	5.32	5.57	5.51	5.21					
Sow BW, kg									
d 27	220.88	221.29	222.32	222.31	4.35	0.80	0.40	0.81	0.88
d 55	224.54	226.94	228.16	229.90	4.02	0.05	<.01	0.74	0.75
d 83	229.85	234.55	236.71	240.32	4.06	<.01	<.01	0.82	0.51
d 109	236.94	245.93	252.72	258.35	4.18	<.01	<.01	0.42	0.82
Post-farrowing	227.13	237.09	241.28	248.10	4.33	<.01	<.01	0.57	0.34
Weaning	241.43	246.80	248.72	251.46	4.35	0.01	<.01	0.73	0.64
Sow BF, mm									
d 27	14.95	14.58	14.61	15.49	0.58	0.56	0.40	0.19	0.90
d 55	15.16	15.51	15.27	16.08	0.66	0.70	0.19	0.58	0.58
d 83	15.30	16.44	16.15	17.10	0.72	0.29	0.03	0.90	0.50
d 109	14.76	15.85	16.03	17.85	0.77	0.02	<.01	0.42	0.76
Post-farrowing	13.98	15.55	15.78	17.53	0.74	<.01	<.01	0.64	0.51
Weaning	13.14	14.32	14.84	15.95	0.60	<.01	<.01	0.94	0.80
Gestation BW change ³ , kg	16.12	24.74	30.62	36.71	2.30	<.01	<.01	0.34	0.62
Gestation BF change ⁴ , mm	-0.27	0.99	1.49	2.45	0.93	<.01	<.01	0.69	0.48
Lactation BW change, kg	14.31	9.84	7.09	3.50	1.84	<.01	<.01	0.77	0.70
Lactation BF change, mm	-0.79	-0.92	-1.12	-1.57	0.40	0.10	0.05	0.50	0.19
Lactation ADFI ⁵ , kg	7.05	7.00	6.91	6.52	0.22	0.10	0.09	0.20	0.25
Net BW change ⁶ , kg	21.16	25.36	26.17	29.66	1.86	<.01	<.01	0.82	0.39
Net BF change ⁷ , mm	-1.79	-0.31	0.27	0.56	0.50	<.01	<.01	0.03	0.62
Wean to estrus interval, d	4.98	4.96	4.96	4.85	0.12	0.78	0.38	0.63	0.76

575 ¹0.5M, 1.0M, 1.5M and 2.0M represented 0.5, 1.0, 1.5 and 2.0 × maintenance energy intake level
576 (100 × BW^{0.75} kcal ME·d⁻¹), respectively.

577 ²Probability of effect of feeding levels using analysis of variance and probability of linear,
578 quadratic and cubic effects of increasing feeding levels using orthogonal polynomial contrasts.

579 ³Weight change from d 27 to d 109 of gestation.

580 ⁴Backfat change from d 27 to d 109 of gestation.

581 ⁵Lactation length was used as a covariate in the statistical model.

582 ⁶Weight change from d 27 of gestation to weaning.

583 ⁷Backfat change from d 27 of gestation to weaning.

Table 3

Effects of different feeding levels during three short periods of gestation on sow performance during three periods of gestation

Item	Feeding levels ¹				SEM	<i>P</i> values ²			
	0.5M	1.0M	1.5M	2.0M		Treatment	Linear	Quadratic	Cubic
Number of sows	38	36	43	39					
Average parity	5.32	5.57	5.51	5.21					
Period 1 (d 27-34)									
BW change, kg ³	-6.29	-1.16	2.60	8.22	0.79	<.01	<.01	0.80	0.20
BF change, mm	-0.08	0.63	0.68	0.93	0.24	0.01	<.01	0.37	0.41
ADG, kg	-0.88	-0.16	0.36	1.15	0.10	<.01	<.01	0.74	0.20
Feed intake, kg	6.43	12.59	18.66	24.64	0.52	<.01	<.01	0.61	0.98
Gain to Feed, kg:kg	-0.99	-0.10	0.14	0.34	0.08	<.01	<.01	<.01	0.04
Period 2 (d 55-62)									
BW change, kg ⁴	-1.45	2.79	6.81	10.31	1.06	<.01	<.01	0.82	0.93
BF change, mm	-0.55	0.01	0.68	1.07	0.20	<.01	<.01	0.75	0.73
ADG, kg	-0.22	0.37	0.94	1.44	0.14	<.01	<.01	0.84	0.92
Feed intake, kg	6.52	12.83	19.02	25.27	0.52	<.01	<.01	0.98	0.77
Gain to Feed, kg:kg	-0.26	0.22	0.37	0.42	0.08	<.01	<.01	<.01	0.29
Period 3 (d 83-90)									
BW change, kg ⁵	-1.70	3.56	8.25	12.56	0.75	<.01	<.01	0.46	0.90
BF change, mm	-0.17	0.15	0.50	0.98	0.20	<.01	<.01	0.71	0.83
ADG, kg	-0.23	0.47	1.10	1.68	0.10	<.01	<.01	0.50	0.88
Feed intake, kg	7.18	13.72	20.04	26.61	0.56	<.01	<.01	0.60	0.55
Gain to Feed, kg:kg	-0.24	0.26	0.42	0.48	0.06	<.01	<.01	<.01	0.21

584 ¹0.5M, 1.0M, 1.5M and 2.0M represented 0.5, 1.0, 1.5 and 2.0 × maintenance energy intake level
 585 (100 × BW^{0.75} kcal ME·d⁻¹), respectively.

586 ²Probability of effect of feeding levels using analysis of variance and probability of linear,
 587 quadratic and cubic effects of increasing feeding levels using orthogonal polynomial contrasts.

588 ³BW change during period 1 = -10.97 + 4.71 × Feeding level (R² = 0.64, MSE = 15.78)

589 ⁴BW change during period 2 = -5.19 + 3.92 × Feeding level (R² = 0.37, MSE = 31.60)

590 ⁵BW change during period 3 = -6.15 + 4.73 × Feeding level (R² = 0.67, MSE = 13.57)

Table 4
Effects of different feeding levels during three short periods of gestation on litter performance

Item	Feeding levels ¹				SEM	P values ²			
	0.5M	1.0M	1.5M	2.0M		Treatment	Linear	Quadratic	Cubic
Number of litters	38	36	43	39					
Litter size									
Liveborn	13.25	12.86	12.94	12.66	0.56	0.86	0.44	0.92	0.71
Stillborn	0.92	1.26	0.97	1.06	0.30	0.58	0.82	0.52	0.22
Mummy	0.42	0.64	0.39	0.15	0.18	0.01	0.01	0.01	0.66
Total born	14.69	15.09	14.46	14.08	0.59	0.58	0.28	0.45	0.58
After cross-fostering	12.85	12.72	12.35	12.45	0.40	0.69	0.30	0.74	0.64
Death	2.26	2.23	1.95	1.71	0.35	0.49	0.13	0.69	0.84
Weaning	10.72	10.57	10.56	10.67	0.26	0.93	0.87	0.53	0.96
Litter wt, kg									
Liveborn	17.51	17.94	18.22	17.86	0.79	0.86	0.62	0.51	0.85
Weaning	67.54	67.32	67.35	68.59	1.86	0.92	0.64	0.63	0.89
Gain	48.46	50.43	49.67	51.10	1.88	0.70	0.32	0.87	0.49
Piglet wt, kg									
Average birth wt	1.32	1.42	1.42	1.44	0.04	0.05	0.02	0.29	0.42
Average birth wt, adjusted ³	1.33	1.41	1.42	1.44	0.04	0.08	0.02	0.36	0.49
Average wean wt	6.32	6.39	6.40	6.46	0.12	0.82	0.36	0.97	0.78
Piglet ADG, g	244.31	256.52	253.49	255.23	5.47	0.26	0.16	0.27	0.34
Piglet pre-weaning mortality	0.18	0.18	0.16	0.14	0.02	0.31	0.07	0.53	0.86
Gestation length, d	114.92	115.82	115.40	115.44	0.23	0.02	0.19	0.03	0.05
Lactation length, d	20.49	19.44	19.72	19.79	0.24	<0.01	0.04	0.01	0.08

591

¹0.5M, 1.0M, 1.5M and 2.0M represented 0.5, 1.0, 1.5 and 2.0 × maintenance energy intake level

592

(100 × BW^{0.75} kcal ME·d⁻¹), respectively.

593

²Probability of effect of feeding levels using analysis of variance and probability of linear,

594

quadratic and cubic effects of increasing feeding levels using orthogonal polynomial contrasts.

595

³Gestation length was used as a covariate in the statistical model.

Table 5

Effects of different feeding levels during three short periods of gestation on piglet weight variation within litter at birth and weaning

Item	Feeding levels				SEM	<i>P</i> values
	0.5M	1.0M	1.5M	2.0M		
Number of litters	6	6	6	6		
Coefficient of variation of piglet weights within litter, %						
Piglets born alive	23.68	21.48	22.87	23.30	2.99	0.96
Piglets at weaning	13.03	15.56	17.73	15.83	2.30	0.44
596	¹ 0.5M, 1.0M, 1.5M and 2.0M represented 0.5, 1.0, 1.5 and 2.0 × maintenance energy intake level					
597	(100 × BW ^{0.75} kcal ME·d ⁻¹), respectively.					
598	² Probability of effect of feeding levels using analysis of variance and probability of linear,					
599	quadratic and cubic effects of increasing feeding levels using orthogonal polynomial contrasts.					

Table 6

Effects of different feeding levels during three short periods of gestation on subsequent litter performance

Item	Feeding levels				SEM	<i>P</i> values			
	0.5M	1.0M	1.5M	2.0M		Treatment	Linear	Quadratic	Cubic
Number of litters	33	25	35	32					
Litter size									
Liveborn	12.40	12.82	13.19	12.46	0.58	0.63	0.81	0.25	0.65
Weaning	10.36	10.13	10.59	10.39	0.35	0.73	0.66	0.96	0.30
Litter wt, kg									
Liveborn	17.30	18.43	19.04	17.93	0.73	0.21	0.36	0.08	0.68
Weaning	64.35	65.16	66.20	66.24	2.62	0.21	0.48	0.86	0.90
Piglet wt, kg									
Liveborn	1.41	1.47	1.46	1.46	0.04	0.64	0.39	0.38	0.75
Weaning	6.21	6.41	6.20	6.33	0.16	0.62	0.80	0.81	0.20
Piglet ADG, g	248	259	245	253	7.41	0.43	0.99	0.79	0.10

600 ¹0.5M, 1.0M, 1.5M and 2.0M represented 0.5, 1.0, 1.5 and 2.0 × maintenance energy intake level
601 (100 × BW^{0.75} kcal ME·d⁻¹), respectively.

602 ²Probability of effect of feeding levels using analysis of variance and probability of linear,
603 quadratic and cubic effects of increasing feeding levels using orthogonal polynomial contrasts.

Table 7

Effects of different feeding levels during three short periods of gestation on predicted sow body compositions

	Feeding levels ¹				SEM	<i>P</i> values ²			
	0.5M	1.0M	1.5M	2.0M		Treatment	Linear	Quadratic	Cubic
Number of sows	38	36	43	39					
Average parity	5.32	5.57	5.51	5.21					
Estimated protein mass, kg ³									
d 27	35.01	35.36	35.23	35.01	0.58	0.54	0.88	0.15	0.66
d 109	37.95	39.48	40.04	40.59	0.68	<.01	<.01	0.13	0.50
Post-farrowing	36.29	37.77	38.03	38.80	0.66	<.01	<.01	0.22	0.20
Weaning	38.74	39.52	39.30	39.61	0.70	0.20	0.10	0.44	0.28
Change from d 27 to 109	2.94	4.05	4.93	5.63	0.31	<.01	<.01	0.39	0.96
Change during lactation	2.24	1.73	1.04	0.62	0.29	<.01	<.01	0.85	0.66
Estimated fat mass, kg ⁴									
d 27	40.98	40.36	40.61	41.88	1.49	0.64	0.46	0.28	0.97
d 109	44.36	46.99	49.70	53.27	2.39	<.01	<.01	0.68	0.88
Post-farrowing	41.27	44.77	46.81	51.04	2.22	<.01	<.01	0.73	0.47
Weaning	42.08	44.60	46.10	48.68	1.67	<.01	<.01	0.95	0.65
Change from d 27 to 109	3.12	6.65	8.75	11.23	1.66	<.01	<.01	0.42	0.54
Change during lactation	0.80	-0.18	-0.72	-2.36	0.86	<.01	<.01	0.52	0.69

604 ¹Feeding levels included 0.5, 1.0, 1.5 and 2.0 × maintenance energy intake level ($100 \times \text{BW}^{0.75}$
605 kcal ME·d⁻¹).

606 ²Probability of effect of feeding levels using analysis of variance and probability of linear,
607 quadratic and cubic effects of increasing feeding levels using orthogonal polynomial contrasts.

608 ³Protein mass was estimated using the equation from Dourmad et al. (1997): $2.3 + 0.178 \times \text{empty}$
609 BW (kg) — $0.33 \times \text{BF depth (mm)}$; empty BW = $0.905 \times (\text{BW})^{1.013}$.

610 ⁴Fat mass was estimated using the equation from Dourmad et al. (1997): $-26.40 + 0.221 \times \text{empty}$
611 BW (kg) + $1.33 \times \text{BF depth (mm)}$; empty BW = $0.905 \times (\text{BW})^{1.013}$.

Table 8
 Pearson correlation coefficients among sow performance parameters

	Gestation BW gain	Gestation BF change	Lactation BW change	Lactation BF loss	BF at farrowing	ADFI during lactation
Gestation BW gain	1.00					
Gestation BF change	0.48**	1.00				
Lactation BW change	-0.52**	-0.36**	1.00			
Lactation BF loss	-0.27*	-0.49**	0.54**	1.00		
BF at farrowing	0.46**	0.53**	-0.52**	-0.67**	1.00	
ADFI during lactation	-0.19*	-0.11	0.37**	0.31*	-0.35**	1.00

612 **represented probability of < 0.001, *represented probability of < 0.01.

Table 9
 Relationship between BW (kg) and BF (mm) changes during gestation and BW change and BF loss during lactation, and effect of BF at farrowing on lactation ADFI (kg)

Equation number	Equations	R ²	Root MSE
1	Lactation BW change = 22.36 - 0.51 × Gestation BW gain	0.26	9.57
2	Lactation BF loss = -0.76 - 0.27 × Gestation BF change	0.23	1.38
3	Lactation ADFI = 8.18 - 0.08 × BF at farrowing	0.12	1.02

Figure 1. Estimated survival curves for sows on 4 different feeding levels (0.5M, 1.0M, 1.5M and 2.0M) during 3 short periods of gestation. Multiple comparison among 4 feeding levels showed no significant differences ($P = 0.50$).

619 Figure 2. Relationship between gestation weight gain from d 27 to 109 of gestation and sow BW
620 gain during lactation ($r = -0.52$, $P < 0.001$). The blue line indicated the linear relationship and the
621 gray area represented the 95% confidence interval.

622
623

624 Figure 3. Relationship between gestation BF change from d 27 to 109 of gestation and sow BF
625 change during lactation ($r = -0.49$, $P < 0.001$). The blue line indicated the linear relationship and
626 the gray area represented the 95% confidence interval.

627
628

629 Figure 4. Relationship between sow BF thickness post-farrowing and average daily feed intake
630 during lactation ($r = -0.35$, $P < 0.001$). The blue line indicated the linear relationship and the gray
631 area represented the 95% confidence interval.

632