Effect of parity and stage of gestation on growth and feed efficiency of gestating sows

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ABSTRACT: The effects of parity and stage of gestation on female growth criteria, and reproductive performance were evaluated on a commercial sow farm. A total of 712 females (Camborough, PIC, Hendersonville, TN) were group-housed and individually fed with electronic sow feeders. Gilts (parity 1) and sows were offered 2.0 and 2.26 kg of feed per day (4.7 and 5.3 Mcal NE per day), respectively. Females were moved from the breeding stall to pens on day 5 of gestation. A scale was located in the alleyway after sows left individual feeding stations. Feed intake and BW were recorded daily throughout gestation generating values for ADFI, ADG, and G:F for each sow. Data were divided into 3 parity groups: 1, 2, and 3+ and gestation was divided into 3 periods: day 5 to 39, 40 to 74, and 75 to 109. From day 5 to 39, ADFI was decreased ($P < 0.05$) for parity 3+ sows compared to the other periods of gestation. Parity 2 sows, although provided the same feed allowance, had greater ($P < 0.05$) ADFI during the first period of gestation than parity 3+ sows. Parity 1 and 2 sow ADG increased ($P < 0.05$) from day 39 to 74 of gestation, then decreased ($P < 0.05$) from day 74 to 109 of gestation. Parity 3+ sow ADG increased ($P < 0.05$) in each subsequent period of gestation. Parity 1 sows had the greatest ($P < 0.05$) ADG in comparison to parity 2 and 3+ sows in each period of gestation. Regardless of parity group, G:F was poorest ($P < 0.05$) from day 5 to 39 of gestation compared with sequential periods of gestation. Parity 1 sow G:F was greater ($P < 0.05$) than parity 2 and 3+ sows for all periods of gestation. Backfat gain indicated that parity 1 sows maintained backfat (approximately 18 mm) while parity 2 and 3+ sows gained ($P < 0.05$) approximately 1 mm backfat throughout gestation. Total born was greatest ($P < 0.05$) for parity 3+ sows with parity 1 sows marginally greater ($P < 0.10$) than parity 2 sows. Although there was statistical evidence ($P < 0.001$) for a positive correlation between BW gain and total born in parities 1 ($r = 0.23$; $P = < 0.001$), 2 ($r = 0.15$; $P = 0.035$), and 3+ ($r = 0.29$; $P < 0.001$), these correlations are very weak. Overall, this study indicates that parity 1 sows have the greatest G:F in gestation and that there is a lack of evidence for strong correlations between feed intake, growth, and reproductive performance.

Key words: electronic sow feeder, feed efficiency, gestation, sows

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INTRODUCTION

Our knowledge regarding the dietary energy requirements of the gestating sow currently enables us to manage feed supply during gestation on the basis of 3 main criteria: the sow's body condition

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(or BW), parity, and stage of gestation (Kim et al., 2013; Quiniou, 2014). The impact of these factors on gestating sow nutrient requirements has been heavily researched through the years (Noblet and Etienne, 1987; Dourmad et al., 2008; NRC, 2012). Several studies have observed feed intake and BW of rearing gilts (Rozeboom, 2015) and gestating sows housed in small University farms (Dourmad, 1991; Young et al., 2005; Kruse et al., 2010); however, research is limited in commercial production systems, specifically pertaining to the growth and feed efficiency of prolific (>14.5 pigs born alive) gestating sows.

With the transition from individual- to group-housed pregnant females, some systems with electronic sow feeders (**ESF**) can collect daily intake and BW data. Monitoring the daily intake and BW of pregnant females throughout gestation allows for a better understanding of sow intake patterns and growth performance, each of which are important when determining gestating sow nutrient requirements.

Therefore, the objectives of this study were to document feed intake in group-housed gestating sows fed via ESF from a commercial sow farm and determine the effect of parity and stage of gestation on growth and feed efficiency. In addition, backfat gain and reproductive performance measurements were obtained to determine if potential correlations existed between feed intake, growth, and reproductive performance.

MATERIALS AND METHODS

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The experiment was conducted at a commercial sow farm in central Nebraska. Females were individually housed in stalls (gilts 0.56 × 2.1 m and sows 0.61 × 2.3) from day 0 to 5 of gestation, then were group-housed from day 5 to 112 of gestation. Pens for sows provided 2.04 m^2 per sow and those for gilts provided 1.95 m^2 per gilt. Each pen was equipped with 6 electronic feeding stations (Nedap Velos, Gronelo, The Netherlands) allowing for up to 45 females per station and 28 nipple waterers to provide ad libitum access to water. Each feeding station was 2.0 m long × 0.56 m wide. Females were group-housed in dynamic groups (260 females per pen), meaning serviced sows were entering the group (approximately day 5 of gestation) as sows due to farrow were exiting (approximately day 112 of gestation). This occurred over a 3- to 4-wk period, thereafter, the pen remained static (no movement of newly bred sows into the pen) until the sows reached day 112 of gestation and the process repeated. Each pen was equipped with a scale (2.13 m long × 0.51 m wide, New Standard US Inc., Sioux Falls, SD) located in the alleyway following the feeding stations and prior to returning to the pen for individual sow weight collection every time the sow exited the feeding station.

Animals and Diets

From day 5 to 112 of gestation, females were fed a diet (Table 1) containing 0.63% standardized ileal

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

Ingredient	%
Corn	54.75
Soybean meal	11.85
DDGS, 8.5% oil[2]	30.00
Monocalcium phosphate	0.65
Limestone	1.65
Salt	0.50
Liquid lysine, 50%	0.15
Choline chloride, 60%	0.11
Vitamin and trace mineral premix[3]	0.38
Total	100
Calculated analysis	
Standardized ileal digestible (SID) AA, %	
Lys	0.63
Ile:Lys	93
Leu:Lys	258
Met:Lys	46
Met & Cys:Lys	88
Thr:Lys	82
Trp:Lys	23
Val:Lys	112
ME, kcal/kg	3,225
NE, kcal/kg	2,341
CP, %	18.5
Ca, %	0.83
P, %	0.59
Available P, %	0.47
Standardized total tract digestibility (STTD) P, %	0.35
Ca:P	1.42

[1]Diet was fed from day 5 to 112 of gestation.

[2]Distillers dried grains with solubles.

[3]Provided per kg of diet: 22,000 mg vitamin E, 1,650 mg folic acid, 2,200 mg pyridoxine, 198 mg chromium, 49,500 mg carnitine, 1,700 mg Ca from calcium carbonate, 110 mg Cu from copper sulfate, 198 mg I, 734 mg Fe from ferrous sulfate, 220 mg Mn from manganous oxide, 198 mg Se from sodium selenite, and 734 mg Zn from zinc sulfate.

digestible (**SID**) Lys according to parity and body condition (gilts and ideal sows, and skinny sows were offered 2.0, 2.3, and 3.0 kg/d, respectively) following standard practice at this commercial farm. This would have provided daily NE intakes of 4.7, 5.3, and 7.0 Mcal assuming a sow consumed all her daily feed allowance. A total of 861 females (Camborough, PIC, Hendersonville, TN; 296 gilts and 565 sows) were enrolled in the study on day 5 of gestation. On day 112 of gestation, at 1400 h, females were moved to the farrowing house and provided ad libitum access to a lactation diet containing 1.2% SID Lys. Both gestation and lactation diets were corn-soybean meal-based and presented in meal form.

Feed intake data were manually extracted daily through Nedap Velos software at approximately 1300 h to ensure all females had eaten their daily allocation before system reset at 1400 h. The Nedap Velos system reported 1 total intake value per day of gestation and it is assumed that the feed which was dispensed was consumed by the sow before leaving the feeding station. Sows had to walk across a scale as they moved from the feeding station back into the pen and as a result, sow BW was automatically recorded. Sows were also manually weighed at least twice during the course of the study. These weights were collected on all females near the beginning and end of gestation. These weights were then used to eliminate outlier weights in the data set based on the ADG generated from the 2 weights and predicted BWs based on the initial known weight and day of gestation.

The study was conducted over a 149-d period, from late May to mid-October. A total of 861 females were enrolled in the study, of which 712 completed. Of the initial 861 females, 40 were removed due to death or culling decisions made by the farm. Ninety-seven females were deleted from the study because they were removed from their pen for greater than 3 consecutive days due to illness or lameness. The remaining 12 females were removed due to unknown radio frequency identification ear tag.

Daily intake and weight values were recorded for each sow from day 5 to 112 of gestation. As a result, ADFI, BW, ADG, and G:F were generated daily for each sow. These data were then divided into 3 parity groups (1, 2, and 3+) and gestation was divided into 3, 5-wk intervals (day 5 to 39, 40 to 74, and 75 to 109). Days 110, 111, and 112 of gestation were not included in the analysis. When determining ADFI, BW, and ADG, for each period, the mean per period is reported and the median is reported for G:F. Scatterplots were created to visualize feed intake and BW data over the course of gestation and identify any variability that may exist.

Total gestation feed intake was determined by calculating the sum of all intake values for each individual sow. Body weight gain for each sow was determined by calculating the difference between initial and final BW. Body weight includes the weight of the conceptus. The number of ESF feeding visits was defined as any visits that were greater than 5 min apart. Feed intake software only generated a single feed intake value per day for each female, thus because sows entered the ESF multiple times per day, we were unable to determine if each of these visits were feeding events.

Backfat depth was measured at entry into pen gestation and on entering the farrowing house (approximately day 5 and 112 of gestation). Backfat depth was measured at the P2 position (last rib, 7 cm from the center line of the back) using a Lean-Meater (RENCO, Minneapolis, MN). Backfat gain during gestation was estimated by calculating the difference between values taken at day 5 and day 112 of gestation.

Reproductive performance criteria of sows were recorded using the PigCHAMP Knowledge Software (Ames, IA) and were extracted at the end of the trial. The following reproductive traits were collected in parity 1 to 5 sows: the total number of pigs born, total number of pigs born alive, number of stillborn pigs, number of mummified fetuses, number of weaned pigs, and gestation length.

Diet Sampling and Analysis

Diet samples were taken from each electronic feeding station every week during feeder calibration. Weekly samples of corn, soybean meal, and dried distillers grains with solubles for gestation feed were obtained from the feed mill prior to mixing. Samples were submitted (Ward Laboratories, Inc., Kearney, NE) for analysis of DM (method 935.29; AOAC Int., 2012), CP (method 900.03; AOAC Int., 2012), crude fiber (method 978.10; AOAC Int., 2012 for preparation and Ankom 2000 Fiber Analyzer [Ankom Technology, Fairport, NY]), ash (method 942.05; AOAC Int., 2012), ether extract (method 920.39 a; AOAC Int., 2012 for preparation and ANKOM XT20 Fat Analyzer [Ankom Technology, Fairport, NY]), Ca, and P (method 968.08 b; AOAC Int., 2012 for preparation using ICAP 6500 [ThermoElectron Corp., Waltham, MA]).

Statistical Analysis

Prior to data analysis, descriptive statistics in the form of means, histograms, and scatter-plots were generated using the PROC MEANS, PROC GPLOT, and PROC SGPLOT statements in SAS (version 9.4, SAS Institute Inc., Cary, NC). Correlations between selected variables were performed using the PROC CORR statement in SAS. Extreme observations were found for female ADG, using descriptive statistics, generated from the variability between daily BW collection. Observations were deemed as outliers based on a calculated critical t-score using a Bonferroni adjustment (0.05/number of observations). This indicated that observations ± 4.97 SDs from the mean were considered outliers and were removed from the data set.

Female ADFI, BW, ADG, and G:F were analyzed using generalized linear mixed models whereby the linear predictor included parity group, period of gestation and all interactions as fixed effects, as well as the random effects of period nested within individual sow. So specified, models recognized the individual female as the experimental unit for this study. Female ADFI, BW, ADG, and G:F were fitted assuming a normal distribution of the response variable. Backfat and reproductive performance were analyzed similarly whereby the linear predictor included parity group as the fixed effect and individual sow as the random effect. The final models used for inference were fitted using restricted maximum likelihood estimation. Degrees of freedom were estimated using the Kenward–Rogers approach.

Estimated means and corresponding standard errors (SEM) are reported for all cell means. Pairwise comparisons were conducted on such means using either Tukey or Bonferroni adjustment to prevent inflation of type I error due to multiple comparisons. Statistical models were fitted using the GLIMMIX procedure of SAS. Results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

RESULTS AND DISCUSSION

General

Chemical analysis of DM, CP, crude fiber, ether extract, Ca, P, and ash for each of the major feed ingredients and for the complete feed are presented in Table 2. The values reported for the complete feed reasonably met formulated values and the individual feed ingredients aligned similarly with values reported in the NRC (2012). Gilts, ideal sows, and skinny sows should have consumed 4.7, 5.3, and 7.0 Mcal NE per day based on their feed allowances which are similar to estimates from the NRC (2012) for parity 1, 2, and 3+ sows consuming a diet containing 2,518 kcal NE per kg with intakes ranging from 2.13 to 2.61 kg/d.

Table 2. Chemical analysis of major feed ingredients and complete feed (as-fed basis)[1]

	Corn	SBM	DDGS	Complete feed
Proximate analysis, %				
DM	87.93	89.40	90.53	89.33
CP	7.60	47.58	28.76	19.36
Crude fiber	1.88	3.27	8.24	3.81
Ca	0.03	0.45	0.03	0.90
P	0.27	0.68	0.87	0.63
Ether extract	3.28	0.91	8.59	4.35
Ash	1.21	6.31	5.42	5.18

DDGS = distillers dried grains with soluble; SBM = soybean meal.

[1]Diet samples (21 total samples) were taken from each electronic feeding station weekly and ingredients samples (16 total samples) were obtained from the feedmill as ingredients were added to the mixer.

Descriptive statistics for selected data are presented in Table 3. Average initial backfat depth was 16.1 mm ± 3.69 (mean ± SE) with a range of 8 to 26 mm. Average final backfat depth was 16.6 mm ± 3.18 with a range of 7 to 28 mm. Average BW gain was 56.8 kg ± 14.35. As changes in lean tissue growth rates in dam-line females have changed over the years, backfat and BW research have received considerable attention. Research has emphasized the importance of gestation feeding strategies that are based on female backfat and BW at breeding as opposed to previously evaluating body condition score in effort to obtain ideal body condition at farrowing (Young et al., 2004; Foxcroft et al., 2005). Although there is some disagreement on whether the ideal backfat depth at farrowing should be between 16 to 18 mm or 18 to 21 mm, most would agree that backfat depth under 15 mm and over 24 mm is problematic (Young et al., 1991; Hughes, 1993; Tantasuparuk et al., 2001). The average total born was 14.9 ± 3.13 and ranged from 1 to 25. In comparison, the average total born reported for 2015 in the industry productivity analysis (Stalder, 2015) was 13.5 ± 1.0 and the average total born reported for farms in the top 25% was 13.9 ± 0.8. The average number of pigs weaned was 13.3 ± 2.19 with a range of 0 to 17. The average number of pigs weaned reported for 2015 in the industry productivity analysis was 10.0 ± 1.2 and the average number of pigs weaned for farms in the top 25% was 11.0 ± 0.7.

Table 3. Descriptive statistics for data included in the study[1]

Item	Mean	SD	Minimum	Maximum
Initial backfat, mm	16.1	3.69	8	26
Final backfat, mm	16.6	3.18	7	28
Backfat gain, mm[2]	0.57	3.29	−9	11
Total intake, kg[3]	228.5	17.61	181	310
Initial BW, kg	165.0	22.99	107	234
Final BW, kg	221.8	21.01	163	294
BW gain, kg[4]	56.8	14.35	8	116
Parity	2.3	1.31	1	5
Total born	14.9	3.13	1	25
Born alive	14.2	3.06	1	23
Stillbirths	0.37	0.68	0	9
Mummies	0.30	0.59	0	4
Pigs weaned	13.3	2.19	0	17
Gestation length, d	115.3	0.99	112	117

[1]Values from a total of 712 females (Camborough, PIC, Hendersonville, TN) were used.

[2]Backfat gain = final backfat − initial backfat.

[3]Total intake = sum of daily intake values throughout the course of gestation for each individual sow.

[4]BW gain = final BW − initial BW.

Feed Intake

From day 5 to 39 of gestation, ADFI was decreased ($P < 0.05$) for parity 3+ sows compared to the other periods of gestation (Table 4). There was no evidence for differences ($P > 0.05$) in ADFI following day 39 of gestation for parity 3+ sows. There was no evidence for differences ($P > 0.05$) in ADFI for parity 1 or 2 sows from day 5 to 109 of gestation; however, numerically, ADFI was decreased from day 5 to 39 of gestation compared with later gestation. For parity 1 sows, ADFI is low within the first 10 d in the pen (Fig. 1). Feed intake for parity 2 and 3+ sows is also low within the first 10 d in the pen but intake returns to the assigned feed allowance much faster than parity 1 sows (Figs. 2 and 3). Parity 1 sow ADFI appears more variable throughout the course of gestation, with some sows consuming less than the provided 2.0 kg/d feed allowance (Fig. 1). Parity 2 and 3+ sows show improvements in ADFI with most sows consuming the 2.3 or 3.0 kg/d feed allowance throughout the course of gestation (Figs. 2 and 3). Parity 2 sows, although provided the same feed allowance, had greater ADFI during the first period ($P < 0.05$) than parity 3+ sows. Regardless of period, ADFI for parity 1 sows was lower ($P < 0.05$) compared to parity 2 and 3+ sows, which is attributed to the assigned feeding strategies.

Most producers would attribute this variation in ADFI by period, especially in parity 1 sows group-housed and fed via ESF, to the gilt training program of the farm. A gilt training program is designed to allow gilts to become familiar with the ESF system prior to breeding. In this production system, gilts receive 2 wk of training prior to breeding and being placed in gestation group housing as described by Vier et al. (2016) and Thomas et al. (2018a). The data indicate that even with extensive training, parity 1 sows were reluctant to consume the full feed allowance and remain at full feed for the course of gestation. Parity 2 and 3+ sows show better feed intake, but they appear to have similar struggles when they initially return to the ESF after weaning. On average, females visited the feeding stations 3 times per day.

There are many factors that may have attributed to the reduction in feed intake during the first 10 d of gestation and the occurrences of reduced feed intake seen throughout gestation. Recall, sows within this system entered into dynamic groups on day 5 of their respective gestation (260 females per pen, respectively) forming a pen over a 3- to 4-wk period. This group management strategy exposed the sows to continuous stresses of re-mixing (social harassment by pen mates). However, previous research indicates that managing sows in large groups, such as these, allows for pigs to alter their strategy of negotiations with social encounters as they fail to recognize all individuals in these large group sizes (Spoolder et al., 2009). As group size increases, pen size increases, thus space per female is greater. Females on this farm were provided 1.95 and 2.04 m^2 for gilts and sows, respectively. The minimum space requirements for group-housed sows remain undefined; however, Hemsworth et al. (2013) concluded that 1.4 m^2 per sow was not enough space and detrimental to animal welfare. However, it was not possible to give guidance on actual space allowance beyond this restriction. Based on previous research, housing management and space allowance in our study do not appear to be restricting but it is unknown what the impact of these, in addition to other group housing factors, may have on intake or subsequent performance.

Growth and Feed Efficiency

Regardless of parity, BW increased ($P < 0.05$) during each period of gestation (Table 4). Parity 3+ sows had the greatest BW ($P < 0.05$) compared to parity 1 or 2 sows, regardless of period. By the final period of gestation, parity 1 sows were 4 kg heavier ($P < 0.05$) than parity 2 sows. Body weight gain from day 5 to 112 of gestation was 68.6, 49.3, and 51.3 kg for parity 1, 2, and 3+ sows, respectively, with parity

Table 4. Growth and feed efficiency of gestating sows housed under commercial conditions as influenced by parity and gestation period[1,2]

	Day of gestation			
	5 to 39	40 to 74	75 to 109	Probability, P <
ADFI[3], kg				
Parity 1	$1.95^{x} \pm 0.006$	$1.96^{x} \pm 0.006$	$1.97^{x} \pm 0.006$	<0.001
Parity 2	$2.24^{z} \pm 0.006$	$2.25^{y} \pm 0.006$	$2.25^{y} \pm 0.006$	<0.001
Parity 3+	$2.22^{ay} \pm 0.005$	$2.27^{by} \pm 0.005$	$2.27^{by} \pm 0.005$	<0.001
BW[4], kg				
Parity 1	$155.2^{ax} \pm 0.95$	$177.7^{bx} \pm 0.95$	$202.4^{cx} \pm 0.95$	<0.001
Parity 2	$165.9^{ay} \pm 1.09$	$181.3^{by} \pm 1.09$	$198.7^{cy} \pm 1.09$	<0.001
Parity 3+	$190.4^{az} \pm 0.90$	$205.4^{bz} \pm 0.90$	$223.6^{cz} \pm 0.90$	<0.001
ADG[5], kg				
Parity 1	$0.53^{ay} \pm 0.011$	$0.75^{bx} \pm 0.011$	$0.65^{cx} \pm 0.011$	<0.001
Parity 2	$0.39^{ax} \pm 0.013$	$0.56^{by} \pm 0.013$	$0.40^{ay} \pm 0.013$	<0.001
Parity 3+	$0.30^{az} \pm 0.010$	$0.53^{by} \pm 0.010$	$0.61^{cx} \pm 0.010$	<0.001
G:F[6]				
Parity 1	$0.29^{ay} \pm 0.005$	$0.33^{bz} \pm 0.005$	$0.34^{by} \pm 0.005$	<0.001
Parity 2	$0.19^{ax} \pm 0.006$	$0.22^{bx} \pm 0.006$	$0.20^{ax} \pm 0.006$	<0.001
Parity 3+	$0.20^{ax} \pm 0.005$	$0.22^{bx} \pm 0.005$	$0.22^{bx} \pm 0.005$	<0.001

[1]A total of 712 females (PIC 1050) were used in a 108-d trial with 249, 188, and 275 females in parity groups 1, 2, and 3+.

[2]Values within response criteria with different superscripts within a row[abc] or column[xyz] differ, P < 0.05.

[3]Average daily feed intake is reported as the mean for each period.

[4]Female BW is reported as the mean for each period and includes the weight of the sow and products of conceptus.

[5]Female ADG is reported as the mean for each period.

[6]G:F is reported as the median for each period.

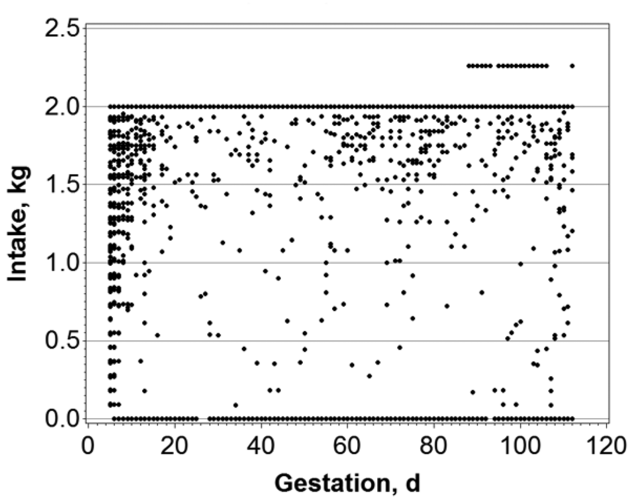

Figure 1. Daily feed intake from day 5 to 112 of gestation for parity 1 sows. Each dot represents an individual sow but dots may overlap. All gilts were offered 2.0 kg/d of feed with the exception of 7 gilts who were offered 2.3 kg/d at day 112 of gestation and 1 gilt who was offered 2.3 kg/d from day 88 to 106 of gestation.

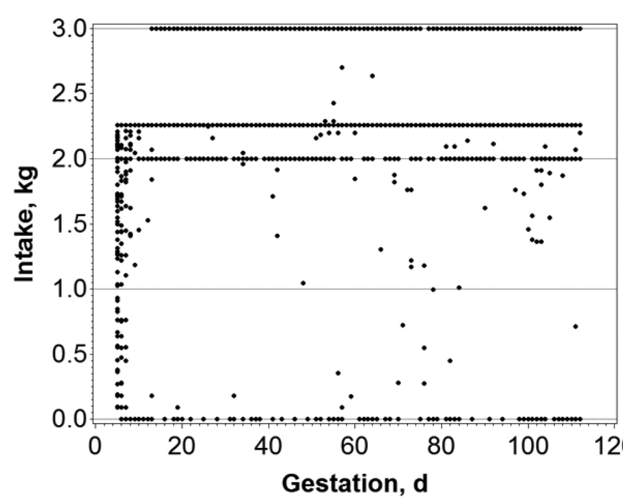

Figure 2. Daily feed intake from day 5 to 112 of gestation for parity 2 sows. Each dot represents an individual sow but dots may overlap. Parity 2 sows of ideal body condition were offered 2.3 kg/d of feed and those deemed skinny (3 sows) were offered 3.0 kg/d of feed. One sow was offered 2.0 kg/d of feed.

1 BW gain greater (P < 0.05) than parity 2 and 3+ sows (Table 5). Body weight gain in young females is expected to be greater than multiparous sows because they will not reach a mature weight until the fourth or fifth parity. Literature indicates average BW gain in gilts should approximate 55 kg (NRC, 1998; Ji et al., 2005) and 40 to 45 kg in sows (Verstegen et al., 1987; Noblet et al., 1990). Parity 1 sows from this herd gained 19.3 and 17.3 kg more than parity 2 and 3+ sows, exceeding previous recommendations.

Parity 1 and 2 sow ADG increased (P < 0.05) from day 39 to 74 of gestation, then decreased (P<

0.05) from day 74 to 109 of gestation (Table 4). Parity 3+ sow ADG increased ($P < 0.05$) during each period of gestation. Parity 1 and 3+ sow G:F increased ($P < 0.05$) following day 39 of gestation with no evidence for differences ($P > 0.05$) following day 74 of gestation. Parity 2 sow G:F increased ($P < 0.05$) from day 39 to 74 of gestation and decreased ($P < 0.05$) from day 74 to 109 of gestation. Fetus development is slow during the first third of pregnancy, and about 2/3 of fetal growth or energy deposition in the uterus occurs during the last 1/3 of pregnancy (Dourmad et al., 2008). Therefore, we would expect to see an increase in ADG and improvement in G:F attributed to the increase in fetal growth in the later stages of gestation. Parity 1 sows do not appear to show this increase in ADG or G:F. Parity 2 sows do not show an increase in ADG but G:F improves following day 74 of gestation. Parity 3+ sows show an increase in ADG but no changes in G:F following day 39 of gestation.

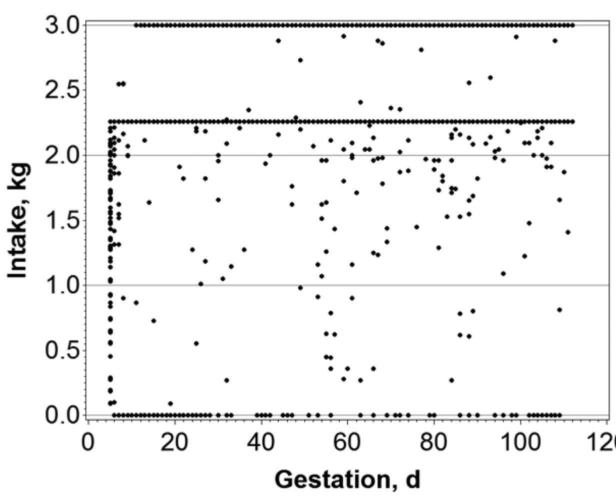

Figure 3. Daily feed intake from day 5 to 112 of gestation for parity 3+ sows. Each dot represents an individual sow but dots may overlap. Parity 3+ sows were offered 2.3 kg/d of feed and those deemed skinny (9 sows) were offered 3.0 kg/d of feed.

Parity 1 sow ADG and G:F was greater ($P < 0.05$) than parity 2 and 3+ in all periods of gestation (Table 4). Parity 2 sow ADG was greater ($P < 0.05$) than parity 3+ from day 5 to 39 of gestation; however, parity 3+ sow ADG was greater ($P < 0.05$) from day 75 to 109. Regardless of stage of gestation, there was no evidence for differences ($P > 0.05$) in G:F between parity 2 and 3+ sows. The differences in ADG and G:F among parities may be attributed to the differences in the composition (lean and fat) of gain. It also may be affected by the amount of feed required for maintenance and that available for growth. Perhaps the feeding regimen of providing gilts and sows 2.0 and 2.26 kg of feed per day (4.7 and 5.3 Mcal NE per day), respectively, resulted in greater energy over maintenance in gilts than in sows based on BW (Thomas et al., 2018b). This could be why gilts in this study gained more weight and were heavier at the end of gestation than their parity 2 counterparts. Dourmad et al. (1999) suggested that for a given energy supply, higher protein retention is generally observed in parity 1 sows than in older sows. This is partly explained by parity 1 sows having a lower energy requirement for maintenance because of their BW.

Table 5. Influence of parity group on backfat depth, weight, and reproductive performance[1,2]

	Parity group			
	1	2	3+	Probability, $P <$
Sow backfat, mm				
Initial	$18.2^{a} \pm 0.21$	$14.2^{c} \pm 0.24$	$15.4^{b} \pm 0.20$	<0.001
Final	$18.1^{a} \pm 0.19$	$15.6^{b} \pm 0.22$	$15.9^{b} \pm 0.18$	<0.001
Gain	$-0.03^{b} \pm 0.236$	$1.42^{ax} \pm 0.213$	$0.53^{aby} \pm 0.391$	<0.001
Sow weight, kg				
Initial	$146.4^{c} \pm 0.983$	$159.8^{b} \pm 1.132$	$185.3^{a} \pm 0.936$	<0.001
Final	$215.1^{b} \pm 1.096$	$209.2^{c} \pm 1.261$	$236.7^{a} \pm 1.043$	<0.001
Weight gain	$68.6^{a} \pm 0.725$	$49.3^{b} \pm 0.835$	$51.3^{b} \pm 0.690$	<0.001
Total born	$14.8^{bx} \pm 0.196$	$14.2^{by} \pm 0.226$	$15.5^{a} \pm 0.187$	<0.001
Born alive	$14.0^{b} \pm 0.192$	$13.6^{b} \pm 0.220$	$14.9^{a} \pm 0.182$	<0.001
Stillbirths	0.4 ± 0.044	0.3 ± 0.051	0.4 ± 0.042	0.451
Mummies	$0.4^{y} \pm 0.037$	$0.3^{x} \pm 0.042$	$0.3^{x} \pm 0.035$	0.047
Pigs weaned	13.4 ± 0.139	13.4 ± 0.160	13.2 ± 0.132	0.582

[1]A total of 712 females (PIC 1050) were used in a 108-d trial with 249, 188, and 275 females in parity groups 1, 2, and 3+, respectively.

[2]Values with different superscripts within a row[abc] $P < 0.05$ and values with different superscripts within a row[xyz] $P < 0.10$.

Backfat

Initial backfat depth was greatest ($P < 0.05$) for parity 1 sows, followed by parity 3+ and 2 sows (Table 5). There was no evidence for a difference in final backfat depth between parity 2 and 3+ sows; however, backfat depth of parity 1 sows was nearly 3 mm greater ($P < 0.05$). Backfat gain indicates that parity 1 sows maintained backfat during gestation while parity 2 and 3+ sows gained ($P < 0.05$) backfat.

Backfat thickness as an indicator of body condition, in addition to other criteria, has been used to support feeding recommendations in gestating sows (Quiniou, 2014). Backfat thickness guidelines indicate thin, ideal, and fat body condition for sows with less than 17, 19, and greater than 21 mm, respectively (Young et al., 2005; Houde et al., 2010; Quiniou, 2014). Differences in initial and final backfat between parity groups in this study (Table 5) may indicate that parity 1 sows were over conditioned. Based on the observations from this farm, parity 1 sows lose 4 mm of backfat during lactation. During the following gestation, the sows (now parity 2) gain 1.4 mm of backfat during gestation. During the next lactation period, the sows maintain backfat into the following gestation period (now parity 3 sow). These differences in backfat lead us to believe parity 1 sows from this herd were over conditioned.

Reproductive Performance

Total born was greatest ($P < 0.05$) for parity 3+ sows with parity 1 sows marginally greater ($P < 0.01$) than parity 2 sows (Table 5). Number of pigs born alive was greatest ($P < 0.05$) for parity 3+ sows, but there was no evidence for differences between parity 1 and 2 sows. There was no evidence for differences in stillborn pigs among the parity groups. The number of mummified fetuses was greater ($P < 0.10$) in parity 1 sows in comparison to parity 2 and 3+ sows. There was no evidence for differences in the number of pigs weaned among the parity groups.

Previous research is equivocal regarding the relationships that exist between female backfat thickness and subsequent reproductive performance (McKay 1993; Maes et al., 2004; Tummaruk et al., 2007). We observed no evidence for an association between: 1) backfat depth at the end of gestation and number of stillborn pigs, 2) backfat gain and number of weaned pigs, or 3) initial backfat and total number of pigs born. There was evidence for a negative correlation ($r = -0.15$; $P = 0.020$) between total feed intake and stillbirths in parity 1 sows (Table 6) and backfat gain was positively correlated ($r = 0.14$; $P = 0.026$) to the number of mummified fetuses. There was evidence for a negative correlation ($r = -0.17$; $P = 0.018$) between backfat gain and stillborn pigs in parity 2 sows. In parity 3+ sows, there was evidence for a negative correlation between total number of pigs born and backfat gain ($r = -0.26$; $P < 0.001$; Fig. 4). This is likely attributable to sows having a small litter and corresponding products of conceptus, having more energy that is available for backfat deposition. There was a positive correlation ($r = 0.13$; $P = 0.037$) between BW gain and the number of mummified fetuses in parity 3+ sows. There was evidence for a positive correlation in parity 1 ($r = 0.23$; $P < 0.001$), 2 ($r = 0.15$; $P = 0.035$), and 3+ ($r = 0.29$; $P < 0.001$) sows between BW gain and total born (Fig. 5). This is expected, as total number of pigs born increases, the weight associated with products of conceptus increases leading to increased BW gain. It is important to note that although these correlations are statistically significant, they are also very weak from a practical standpoint. Significant correlations were likely detected due to the large number of observations in this study. Additionally, sows prioritize daily requirements to meet the demands of the growing conceptus, sacrificing maternal reserves. This combined with the very low variation in feed intake and high variation in live weight could also attribute to the weak correlations.

When comparing total intake consumed throughout the course of gestation to backfat gain and BW gain, we observed a large range in backfat gain and BW gain among females fed the same amount of feed. We expect that as females consume more feed, backfat will increase as well as BW. There was evidence for a positive correlation ($r = 0.24$; $P < 0.001$) between backfat gain and total intake in parity 3+ sows. Recall, 12 sows from this study were deemed as skinny and received 3.0 kg per day and of these 12 sows, 9 were parity 3+ sows. This is likely influencing the observed correlation between backfat gain and total intake in parity 3+ sows. There was also evidence for a positive correlation between BW gain and total intake in parity 1 ($r = 0.37$; $P < 0.001$) and parity 3+ ($r = 0.15$; $P = 0.015$) sows (Fig. 6). Again, these correlations are significant but are very weak.

Table 6. Association between reproductive performance and total feed intake, backfat gain, and BW gain, grouped by parity[1]

		Total born	Born alive	Stillbirths	Mummies	Pigs weaned
Parity 1						
Total intake, kg[2]	*R*	0.04	0.04	−0.15	0.02	0.11
	Probability, *P* <	0.815	0.484	0.020	0.808	0.081
Backfat gain, mm[3]	*R*	−0.03	−0.07	0.02	0.14	0.01
	Probability, *P* <	0.640	0.291	0.709	0.026	0.917
BW gain, kg[4]	*R*	0.23	0.21	0.09	0.01	0.03
	Probability, *P* <	<0.001	0.001	0.151	0.830	0.621
Parity 2						
Total intake, kg[2]	*R*	−0.03	−0.03	0.00	0.03	0.07
	Probability, *P* <	0.700	0.650	0.980	0.679	0.351
Backfat gain, mm[3]	*R*	0.02	0.06	−0.17	−0.09	−0.04
	Probability, *P* <	0.830	0.400	0.018	0.2070	0.5558
BW gain, kg[4]	*R*	0.15	0.15	0.01	−0.01	0.06
	Probability, *P* <	0.035	0.038	0.900	0.874	0.438
Parity 3+						
Total intake, kg[2]	*R*	−0.11	−0.10	−0.04	−0.06	0.06
	Probability, *P* <	0.062	0.098	0.467	0.343	0.354
Backfat gain, mm[3]	*R*	−0.26	−0.25	−0.05	−0.05	0.03
	Probability, *P* <	<0.001	<0.001	0.419	0.397	0.599
BW gain, kg[4]	*R*	0.29	0.29	−0.03	0.13	−0.04
	Probability, *P* <	<0.001	<0.001	0.604	0.037	0.528

[1]A total of 712 females (PIC 1050) were used in a 108-d trial with 249, 188, and 275 females in parity groups 1, 2, and 3+, respectively.

[2]Total intake = sum of daily intake values throughout the course of gestation for each individual sow.

[3]Backfat gain = final backfat − initial backfat.

[4]BW gain = final BW − initial BW.

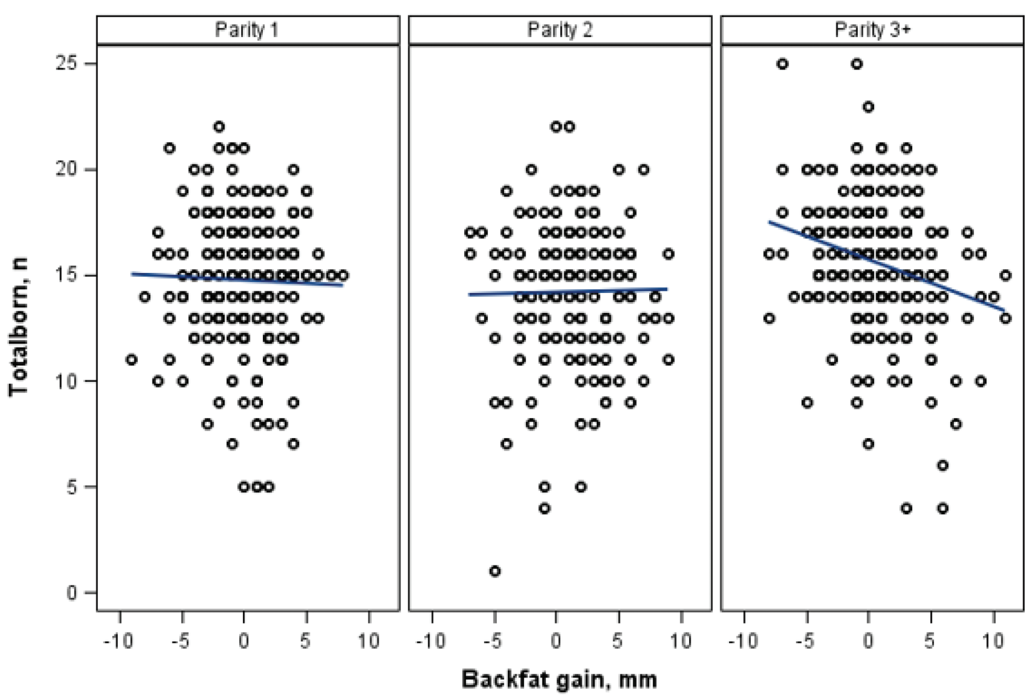

Figure 4. Comparison of total born and backfat gain by parity group. Backfat measurements were obtained upon entry into pen gestation (day 5) and again when loaded into the farrowing house (day 112 of gestation).

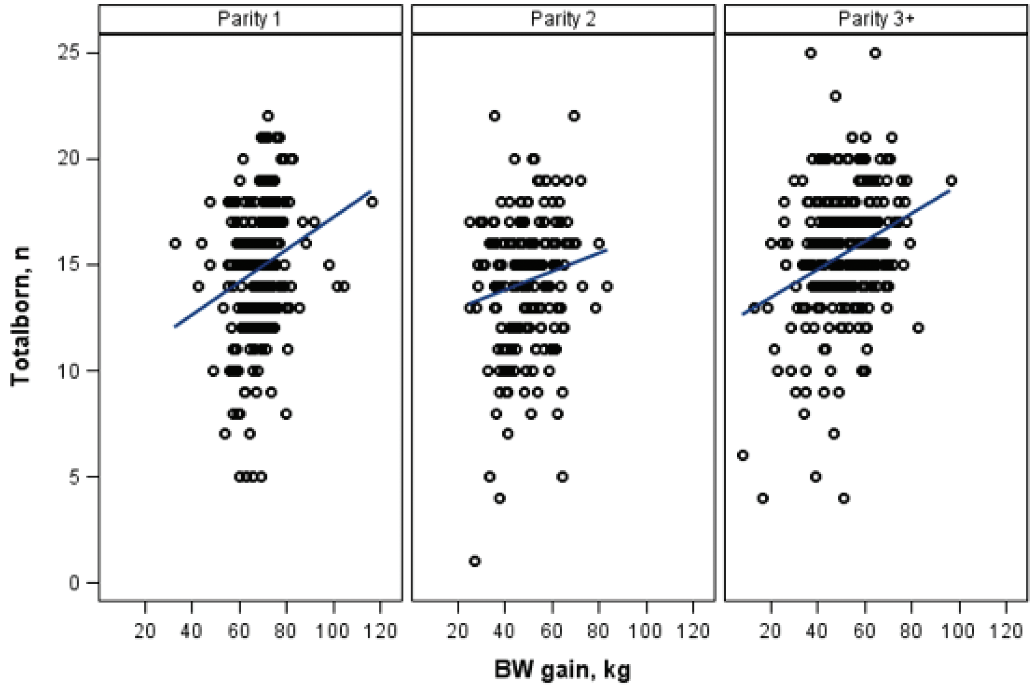

Figure 5. Comparison of total born and BW gain by parity group. Body weight measurements were obtained upon entry into pen gestation (day 5) and again when loaded into the farrowing house (day 112 of gestation).

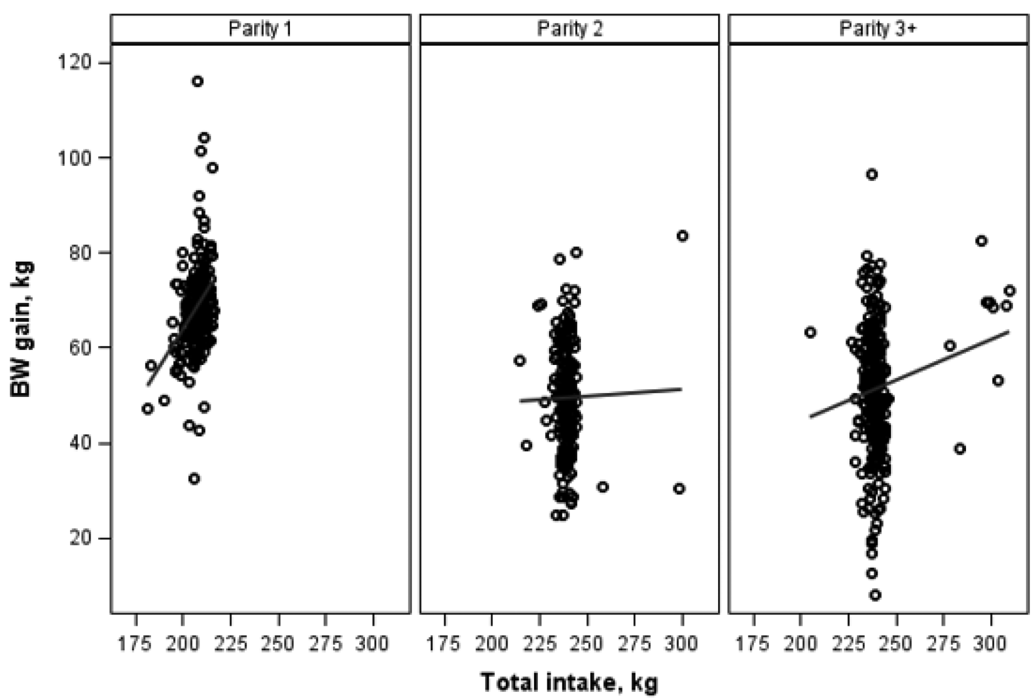

Figure 6. Comparison of BW gain and total intake by parity group. Initial and final BW obtained upon entry into pen gestation (day 5) and when loaded into the farrowing house (day 112 of gestation), respectively, were used to calculated BW gain.

CONCLUSION

From the existing data, is it apparent that even with a vigorous gilt training program, feed intake is decreased during the initial 10 d following the introduction of females to an ESF system, regardless of parity. Parity 1 sows have the greater G:F in gestation and as a result, based on the feed allowances used in the farm, also had the greatest weight gain during gestation compared with parity 2 and 3+ sows. Estimates of feed efficiency during gestation can be used to determine ideal weight gain during gestation. Although there were some significant correlations observed between feed intake, BW gain, and backfat depth with litter size, these correlations were very weak and likely of little practical significance. Overall, this study shows the changes in weight gain and feed efficiency based on differences in parity and period of gestation.

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LITERATURE CITED

AOAC. 2012. Official methods of analysis. 19th ed. AOAC Int., Washington, DC.

Dourmad, J. Y. 1991. Effect of feeding level in the gilt during pregnancy on voluntary feed intake during lactation and changes in body composition during gestation and lactation. Livest. Prod. Sci. 27:309–319. doi:10.1016/0301-6226(91)90126-B

Dourmad, J. Y., M. Etienne, A. Valancogne, S. Dubois, J. van Milgen, and J. Noblet. 2008. InraPorc: a model and decision support tool for the nutrition of sows. Anim. Feed Sci. Technol. 143:372–386. doi:10.1016/j.anifeedsci.2007.05.019

Dourmad, J. Y., J. Noblet, M. C. Pere, and M. Etienne. 1999. Mating, pregnancy and prenatal growth. In: I. Kyriazakis, editor, Quantitative biology of the pig. CABI Publishing, Wallingford, United Kingdom. p. 129–152.

Foxcroft, G, E. Beltranena, J. Patterson, N. Williams, and G. Pizzarro. 2005. Physiological limits to maximizing sow productivity. In: Proc. of 2005 London Swine Conf., Maximizing Sow Reproductive Efficiency, London, Ontario. p. 29–46.

Hemsworth, P. H., M. Rice, J. Nash, K. Giri, K. L. Butler, A. J. Tilbrook, and R. S. Morrison. 2013. Effects of group size and floor space allowance on grouped sows: aggression, stress, skin injuries, and reproductive performance. J. Anim. Sci. 91:4953–4964. doi:10.2527/jas.2012-5807

Houde, A., S. Méthot, B. Murphy, V. Bordignon, and M. Palin. 2010. Relationships between backfat thickness and reproductive efficiency of sows: a two-year trial involving two commercial herds fixing backfat thickness at breeding. Can. J. Anim. Sci. 90:429–435. doi:10.4141/CJAS09115

Hughes, P. E. 1993. The effects of food level during lactation and early gestation on the reproductive performance of mature sows. Anim. Prod. 57:437–445. doi:10.1017/S1357729800042776

Ji, F., G. Wu, J. R. Blanton, Jr, and S. W. Kim. 2005. Changes in weight and composition in various tissues of pregnant gilts and their nutritional implications. J. Anim. Sci. 83:366–375. doi:10.2527/2005.832366x

Kim, S. W., A. C. Weaver, Y. B. Shen, and Y. Zhao. 2013. Improving efficiency of sow productivity: nutrition and health. J. Anim. Sci. Biotechnol. 4:26. doi:10.1186/2049-1891-4-26

Kruse, S., E. Stamer, I. Traulsen, and J. Krieter. 2010. Relationship between feed, water intake, and body weight in gestating sows. Livest. Sci. 137:37–41. doi:10.1016/j.livsci.2010.09.025

Maes, D. G. D., G. P. J. Janssens, P. Delputte, A. Lammertyn, and A. de Kruif. 2004. Back fat measurements in sows from three commercial pig herds: relationship with reproductive efficiency and correlation with visual body condition scores. Livest. Prod. Sci. 91:57–67. doi:10.1016/j.livprodsci.2004.06.015

McKay, R. M. 1993. Preweaning losses of piglets as a result of index selection for reduced backfat thickness and increased growth rate. Can. J. Anim. Sci. 73:437–442. doi:10.4141/cjas93-046

Noblet, J., J. Y. Dourmad, and M. Etienne. 1990. Energy utilization in pregnant and lactating sows: modeling of energy requirements. J. Anim. Sci. 68:562–572. doi:10.2527/1990.682562x

Noblet, J., and M. Etienne. 1987. Metabolic utilization of energy and maintenance requirements in pregnant sows. Livest. Prod. Sci. 16:243–257. doi:10.1016/0301-6226(87)90042-x

NRC. 1998. Nutrient requirements of swine. 10th ed. Natl. Acad. Press, Washington, DC.

NRC. 2012. Nutrient requirements of swine. 11th ed. Natl. Acad. Press, Washington, DC.

Quiniou, N. 2014. Feeding the high potential sow: implementation of some key concepts. IFIP Institut du Porc, Le Rheu cedex, France. 1:57–68.

Rozeboom, D. W. 2015. Conditioning of the gilt for optimal reproductive performance. In: C. Farmer, editor, The gestating and lactating sow. Wageningen Academic Publishers, Wageningen, The Netherlands. p. 13–23.

Spoolder, H. A. M., M. J. Geudeke, C. M. C. Van der Peet-Schwering, and N. M. Soede. 2009. Group housing of sows in early pregnancy: a review of success and risk factors. Livest. Sci. 125:1–14. doi:10.1016/j.livsci.2009.03.009

Stalder, K. J. 2015. Pork industry productivity analysis. National Pork Board, Des Moines, IA.

Tantasuparuk, W., N. Lundeheim, A.-M. Dalin, A. Kunavongkrit, and S. Einarsson. 2001. Weaning-to-service interval in primiparous sows and its relationship with longevity and piglet production. Lives. Prod. Sci. 69:155–162. doi:10.1016/S0301-6226(00)00256-6

Thomas, L. L., M. A. Goncalves, C. M. Vier, R. D. Goodband, M. D. Tokach, S. S. Dritz, J. C. Woodworth, and J. M. DeRouchey. 2018a. Lessons learned from managing electronic sow feeders and collecting weights of gestating sows housed on a large commercial farm. J. Swine Health Prod. (in press).

Thomas, L. L., R. D. Goodband, M. D. Tokach, S. S. Dritz, J. C. Woodworth, and J. M. DeRouchey. 2018b. Partitioning components of maternal growth to determine efficiency of feed use in gestating sows. J. Anim. Sci. (in press). doi:10.1093/jas/sky219

Tummaruk, P., W. Tantasuparuk, M. Techakumphu, and A. Kunavongkrit. 2007. Age, body weight and backfat thickness at first observed oestrus in crossbred Landrace x Yorkshire gilts, seasonal variations and their influence on subsequence reproductive performance. Anim. Reprod. Sci. 99:167–181. doi:10.1016/j.anireprosci.2006.05.004

Verstegen, M. W. A., J. M. F. Verhagen, and L. A. den Hartog. 1987. Energy requirements of pigs during pregnancy: a review. Livest. Prod. Sci. 16:75–89. doi:10.1016/0301-6226(87)90028-5

Vier, C. M., M. A. D. Goncalves, L. L. Thomas, J. C. Woodworth, R. D. Goodband, S. S. Dritz, M. D. Tokach, and J. M. DeRouchey. 2016. Gilt training for electronic sow feeding systems in gestation. Kansas State University Swine Day 2016, Manhattan, KS.

Young, L. G., G. J. King, J. Shaw, M. Quinton, J. S. Walton, and I. McMillan. 1991. Interrelationships among age, body weight, backfat and lactation feed intake with reproductive performance and longevity of sows. Can. J. Anim. Sci. 71:567–575. doi:10.4141/cjas91-067

Young, M. G., M. D. Tokach, F. X. Aherne, R. G. Main, S. S. Dritz, R. D. Goodband, and J. L. Nelssen. 2004. Comparison of three methods of feeding sows in gestation and the subsequent effects on lactation performance. J. Anim. Sci. 82:3058–3070. doi:10.2527/2004.82103058x

Young, M. G., M. D. Tokach, F. X. Aherne, R. G. Main, S. S. Dritz, R. D. Goodband, and J. L. Nelssen. 2005. Effect of sow parity and weight at service on target maternal weight and energy for gain in gestation. J. Anim. Sci. 83:255–261. doi:10.2527/2005.831255x