Kansas Agricultural Experiment Station Research Reports

Volume 3
Issue 7 *Swine Day*

Article 3

2017

Effect of Parity and Stage of Gestation on Maternal Growth and Feed Efficiency of Gestating Sows

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Recommended Citation

Thomas, L. L.; Goodband, R. D.; Tokach, M. D.; Dritz, S. S.; Woodworth, J. C.; and DeRouchey, J. M. (2017) "Effect of Parity and Stage of Gestation on Maternal Growth and Feed Efficiency of Gestating Sows," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 7. https://doi.org/10.4148/2378-5977.7456

Effect of Parity and Stage of Gestation on Maternal Growth and Feed Efficiency of Gestating Sows

Abstract

The objective of this study was to evaluate the effect of parity and stage of gestation on maternal weight gain and efficiency of feed use in group-housed gestating sows from a commercial sow farm. A total of 712 females (Camborough, PIC, Hendersonville, TN) were group-housed from d 5 to 112 of gestation and individually fed with electronic sow feeders (ESF). Feed intake and BW were recorded daily throughout gestation via the ESF and a scale located in an alleyway just after sows exited the feeding station. Gilts (parity 1) and sows received 6.5 and 7.3 Mcal ME per d. Maternal weight gain, not including products of conceptus, and feed efficiency were predicted using a series of equations to model nutrient utilization in gestation. Data were divided into 3 parity groups: 1, 2, and 3+, and gestation was divided into 3 periods: d 5 to 39, 40 to 74, and 75 to 109.

After dividing energy requirements into tissue pools for maintenance, growth (maternal protein and fat deposition) and products of conceptus, the greatest portion of the energy requirement was for maintenance and maternal growth. The predicted energy used for maternal protein and fat deposition decreased ($P < 0.05$) in each period of gestation, regardless of parity group. Parity 2 sows had the greatest ($P < 0.05$) energy use for maternal protein and fat deposition in all stages of gestation while parity 1 sows had a negative energy balance during the final stage of gestation. Parity 1 sow maternal BW increased ($P < 0.05$) in each period of gestation; however, parity 2 and 3+ sow maternal BW remained static after d 74 of gestation. Parity 3+ sows had the greatest ($P < 0.05$) maternal BW throughout the course of gestation in comparison to other parity groups. Regardless of parity, maternal ADG decreased ($P < 0.05$) from d 39 to 74 before increasing ($P < 0.05$) during the final stage of gestation. Parity 1 sows had the greatest ($P < 0.05$) ADG in all gestation periods. Parity 1 sow G:F decreased ($P < 0.05$) in each sequential period of gestation. Parity 2 and 3+ sow G:F decreased ($P < 0.05$) from d 39 to 74 but improved ($P < 0.05$) during the final period of gestation. Parity 1 sow G:F was greater than parity 2 and 3+ sows in most gestation periods. Overall, this study demonstrates how feed usage, stage of gestation, and parity affect sow maternal BW and tissue pool composition in highly prolific sows.

Keywords

maternal growth, gestation, sows

Cover Page Footnote

Appreciation is expressed to Thomas Livestock Company (Broken Bow, NE) for providing the animals and research facilities and to Tim Friedel, Steve Horton, and Jose Hernandez for technical assistance. Appreciation is expressed to New Standard US, Inc. (Sioux Falls, South Dakota) for providing the scale system and to Tim Kurbis for technical assistance.

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Effect of Parity and Stage of Gestation on Maternal Growth and Feed Efficiency of Gestating Sows[1,2]

L.L. Thomas, R.D. Goodband, M.D. Tokach, S.S. Dritz,[3] J.C. Woodworth, and J.M. DeRouchey

Summary

The objective of this study was to evaluate the effect of parity and stage of gestation on maternal weight gain and efficiency of feed use in group-housed gestating sows from a commercial sow farm. A total of 712 females (Camborough, PIC, Hendersonville, TN) were group-housed from d 5 to 112 of gestation and individually fed with electronic sow feeders (ESF). Feed intake and BW were recorded daily throughout gestation via the ESF and a scale located in an alleyway just after sows exited the feeding station. Gilts (parity 1) and sows received 6.5 and 7.3 Mcal ME per d. Maternal weight gain, not including products of conceptus, and feed efficiency were predicted using a series of equations to model nutrient utilization in gestation. Data were divided into 3 parity groups: 1, 2, and 3+, and gestation was divided into 3 periods: d 5 to 39, 40 to 74, and 75 to 109.

After dividing energy requirements into tissue pools for maintenance, growth (maternal protein and fat deposition) and products of conceptus, the greatest portion of the energy requirement was for maintenance and maternal growth. The predicted energy used for maternal protein and fat deposition decreased ($P < 0.05$) in each period of gestation, regardless of parity group. Parity 2 sows had the greatest ($P < 0.05$) energy use for maternal protein and fat deposition in all stages of gestation while parity 1 sows had a negative energy balance during the final stage of gestation. Parity 1 sow maternal BW increased ($P < 0.05$) in each period of gestation; however, parity 2 and 3+ sow maternal BW remained static after d 74 of gestation. Parity 3+ sows had the greatest ($P < 0.05$) maternal BW throughout the course of gestation in comparison to other parity groups. Regardless of parity, maternal ADG decreased ($P < 0.05$) from d 39 to 74 before increasing ($P < 0.05$) during the final stage of gestation. Parity 1 sows had the greatest ($P < 0.05$) ADG in all gestation periods. Parity 1 sow G:F decreased ($P < 0.05$) in each sequential period of gestation. Parity 2 and 3+ sow G:F decreased ($P < 0.05$) from d 39

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to 74 but improved ($P < 0.05$) during the final period of gestation. Parity 1 sow G:F was greater than parity 2 and 3+ sows in most gestation periods. Overall, this study demonstrates how feed usage, stage of gestation, and parity affect sow maternal BW and tissue pool composition in highly prolific sows.

Introduction

Previous research in regards to gestating sow nutrient requirements has been used to develop models based on the sow's body condition, parity, and stage of gestation.[4,5,6] The models predict energy requirements and utilization for individual sows where priority is given to satisfy energy requirements for body maintenance functions, growth of conceptus, and maternal body protein deposition with nutrients above these requirements available for maternal lipid deposition.[5,6] In cases when energy is insufficient, maternal body lipid is mobilized and used as an energy source. Dourmad et al.[7] indicated that the initial stage of gestation seems to be the sole period during which body reserves can be reestablished.

Previous literature has reported changes in nutrient utilization by different stages of gestation and parity through comparative slaughter techniques.[7,8,9] However, data are limited pertaining to the application of these models in today's commercial sow herds to determine maternal growth and efficiency of feed usage of modern sows. Knowing this information will allow for a better understanding of how females use energy provided during gestation and their metabolic state upon entry into the farrowing house. Therefore, the objective of this study was to investigate the effect of parity and stage of gestation on modeled maternal weight gain and efficiency of feed utilization in group-housed gestating sows from a commercial sow farm.

Methods

The data used to model maternal weight gain and efficiency of feed use were obtained from a study by Thomas et al.[10] This study was conducted on a commercial sow farm to examine the effects of parity and stage of gestation on whole body growth and feed efficiency of gestating sows. A total of 712 females (Camborough, PIC, Hendersonville, TN) were group-housed and individually fed with electronic sow feeders (Nedap Velos, Gronelo, Netherlands) with ad libitum access to water. Females were moved from the breeding stall to pens on d 5 of gestation to d 112 and fed a diet with 0.63% standard-

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[4] Noblet, J. and M. Etienne. 1987b. Metabolic utilization of energy and maintenance requirements in pregnant sows. Livest. Prod. Sci. 16:243-257. doi: https://doi.org/10.1016/0301-6226(87)90042-X.

[5] 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.

[6] NRC. 2012. Nutrient Requirements of Swine. 11th ed. Natl. Acad. Press, Washington, DC.

[7] Dourmad, J. Y., M. Etienne, and J. Noblet. 1996. Reconstitution of body reserves in multiparous sows during pregnancy: Effect of energy intake during pregnancy and mobilization during the previous lactation. J. Anim. Sci. 74:2211-2219. doi:10.2527/1996.7492211x.

[8] McPherson, R. L., F. Ji, G. Wu, J. R. Blanton, Jr, and S. W. Kim. 2004. Growth and compositional changes of fetal tissues in pigs. J. Anim. Sci. 82:2534-2540. doi:10.2527/2004.8292534x.

[9] Ji, F., G. Wu, J. Blanton, and S. 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.

[10] Thomas, L. L., R. D. Goodband, M. D. Tokach, J. C. Woodworth, J. M. DeRouchey and S.S. Dritz. 2016. Effect of parity and stage of gestation on growth and feed efficiency of gestating sows. Master's thesis. Kansas State University, Manhattan, KS. http://krex.k-state.edu/dspace/handle/2097/35461.

ized ileal digestible (SID) Lys. Feed allowance was based on parity and body condition with gilts (parity 1) and sows fed 6.5 and 7.3 Mcal ME per d, respectively, following standard practice at this commercial farm. The diet was formulated to contain 1,463 kcal per lb ME and all females had ad libitum access to water. A scale (2.13 m long × 0.51 m wide, New Standard US Inc., Sioux Falls, SD) was located in the alleyway after the feeding stations and leading to the pen. Daily feed intake and BW were recorded throughout gestation to determine ADFI, ADG, and feed efficiency for each sow. Body weight (lb) was reported as the sum of maternal BW and the weight of the conceptus.

Reproductive performance criteria of sows were recorded using the PigCHAMP Knowledge Software (Ames, IA) and were extracted at the end of the trial. 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 were recorded.

Maternal body predictions do not include the products of conceptus, which is defined as the fetus, placenta, and fluids. Maternal weight gain and feed efficiency were predicted for each female using a series of equations to model nutrient utilization by determining daily conceptus weight, daily maintenance requirement, daily energy retention of conceptus, and daily energy use for maternal protein and lipid deposition. Models presented by the NRC[6] and Dourmad et al. (2008) were used to predict the response of the sow to a given nutrient supply. Both models assume that in pregnant sows, energy is partitioned between maintenance, growth of conceptus, and maternal protein and lipid deposition as outlined by Dourmad et al.[11] Priority is given to maintenance requirements and the demands of the growing conceptus.[11] If nutrient allowances exceed these requirements, excess nutrients can contribute to the sow's body reserves. Conversely, body reserves will be mobilized when energy intake is below that for maintenance and products of conceptus. The NRC[6] prediction equation for energy-dependent maternal protein deposition requires an adjustment factor to account for unexplained changes in protein deposition that are not clearly defined. Consequently, the model proposed by Dourmad et al.[5] was used to predict maternal protein and lipid deposition. Variables were calculated on an ME basis, as presented in the sow gestation models.[5,6]

The NRC[6] predicts the weight of conceptus and energy content of conceptus using natural logarithmic values, and as a function of time and litter size at farrowing:

> Weight of conceptus (kg/d) = (exp (8.621 - 21.02 × exp (-0.053 × gestation, d) + 0.114 × total born, n))/1000;
>
> Energy content of conceptus (kJ/d) = (exp (11.72 – 8.62 × exp (-0.0138 × gestation, d) + 0.0932 × total born, n)).

The equations are from Dourmad et al.,[11] where the authors combined a set of regression equations, developed by Noblet et al.,[12] generating one equation for both weight and energy content of conceptus (fetus, placenta, and fluids). The equations allow for

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[11] 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, UK. p. 129-152.
[12] Noblet, J., W. H. Close, and R. P. Heavens. 1985. Studies on the energy metabolism of the pregnant sow. Br. J. Nutr. 53:251-265. doi: https://doi.org/10.1079/BJN19850034.

estimations of conceptus weight and energy content at any given day of gestation; however, these equations should be used with caution as they were developed more than 30 years ago from a population of 26 gilts (Large White breed) with a range in litter size of 9 to 14. Total born has increased significantly since those studies, now averaging over 14 pigs in some of the most prolific sow herds.[10] When applying these equations to sows with over 14 pigs born alive, the predictions are unrealistically high. The NRC[6] accounts for these changes in litter size by correcting for mean piglet birth weight, using the following ratio:

Ratio = (total born, n × average piglet birth weight, kg) / (1.12 × exp {[9.095 – 17.69 exp (-0.0305 × gestation length, d) + 0.0878 × total born, n]}/1000).

The numerator portion of the ratio is the actual litter birth weight and the denominator portion of the ratio, are derived from Dourmad et al.,[11] (except for the value 1.12), as the anticipated litter birth weight (fetus only, not including the weight of the placenta or fluids) based on anticipated gestation length (114 d) and litter size. It is unknown what the value 1.12 represents and details are not reported in the NRC[6] nor are they found in the previous literature discussing the use of these equations.[11,12,13] In the calculations generated in our study, weight of conceptus and energy content of conceptus on d 114 of gestation are corrected for mean piglet birth weight based on the above ratio, excluding the value 1.12:

Ratio = (total born, n × average piglet birth weight, kg) / (exp {[9.095 – 17.69 exp (-0.0305 × 114) + 0.0878 × total born, n]}/1000).

In our study, it was not possible to collect pig birth weight. As a result, pig birth weight was estimated from an experiment by Goncalves et al.[14] Goncalves et al.[14] determined the effects of amino acid and energy intake during late gestation on pig birth weight of high performing (14.5 total born) females (Camborough, PIC, Hendersonville, TN) housed under commercial conditions. Individual pig birth weights from a total of 1,102 females were used to develop a prediction equation with total born and parity group (1 or 2+) as predictor variables. The optimum equation to predict pig birth weight is described as:

Pig birth weight (kg) = b – 0.035 × total born, n.

Where the intercept (b) for parities 1 and 2+ were 1.78 and 1.90, respectively.

The ratio can then be applied to the predicted weight of conceptus and the predicted energy content of conceptus on d 114 of gestation, providing a final conceptus weight and final conceptus energy content, correcting for litter birth weight, yielding more realistic predictions. Recall, daily predictions are required for modeling purposes for each of these variables and the ratio can only be used to determine weight and energy

[13] 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.
[14] Goncalves, M. A. D., K. M. Gourley, S. S. Dritz, M. D. Tokach, N. M. Bello, J. M. DeRouchey, J. C. Woodworth, and R. D. Goodband. 2016. Effects of amino acids and energy intake during late gestation on high-performing gilts and sows on litter and reproductive performance under commercial conditions. J. Anim. Sci. 2016. 94:1993-2003. doi:10.527/jas2015-0087.

content of conceptus on d 114 of gestation because we only have known pig BW at farrowing. To determine weight and energy content of conceptus for each d of gestation, we reviewed the data from Noblet et al.[12] where the NRC[6] equation originated. We determined the regression equation was calculated for a litter size of 12. Next, we determined conceptus weight and energy content of conceptus from d 4 through 114 of gestation for a litter size of 12. We were then able to calculate the percent of final conceptus weight and percent of final energy content of conceptus for each d of gestation. Multiplying these percentages by final conceptus weight and final energy content of conceptus at d 114 of gestation generated a value for each d of gestation. Thus, the optimum equations used to predict weight and energy content of conceptus at each d of gestation are:

> Weight of conceptus (kg/d) = Final conceptus weight at d 114 (kg) × % of final conceptus weight;
>
> Energy content of conceptus on each day (kJ/d) = Final energy content of conceptus at d 14 (kJ) × % of final energy content of conceptus.

Where final conceptus weight and final energy content of conceptus are calculated using the NRC[6] equations, correcting for mean piglet birth weight, on d 114 of gestation.

Energy retention of the conceptus (ERc, kJ) was determined by calculating the difference in energy content of conceptus between each day of gestation.

Following the gestation sow model proposed by Dourmad et al.,[5] ME for maintenance (MEm) under thermoneutral conditions and with moderate physical activity ranges from 400 to 460 kJ per kg $BW^{0.75}$.[4,15] Our estimations assume that temperature conditions were thermoneutral throughout the duration of this study and that females spent no more than 4 hours per day standing; however, neither temperature measurements nor female physical activity were recorded during this study and therefore it is unknown if these factors impact our estimations for female maintenance requirement. The optimum equation used to predict female maintenance requirement per d of gestation is:

> MEm (kJ/d) = 440 × $BW^{0.75}$.

Nitrogen retention in the pregnant sow was estimated to determine maternal protein deposition. Nitrogen retention was calculated considering N retained in the conceptus (NR_c) and N retained in maternal tissues which depends on parity, stage of gestation, and the supply of ME above the maintenance requirement. Protein content of the conceptus was predicted using the following equation,[13,5] which can then be divided by 6.25, yielding N content of conceptus:

> Protein content of conceptus (g/d) = (exp (8.090 – 8.71 × exp (-0.0149 × gestation, d) + 0.0872 × total born, n));

[15] Everts, H. 1994. Nitrogen and energy metabolism of sows during several reproductive cycles in relation to nitrogen intake. Ph.D. thesis, Wageningen Agricultural University, The Netherlands.

Nitrogen content of conceptus (g/d) = Protein content of conceptus (g) / 6.25.

Nitrogen retained in the conceptus (NRc) was determined by calculating the difference in daily N content of conceptus. Whole body N retention was calculated using the following equation,[11,5] assuming protein and amino acid intake was not limiting:

$$NR\ (g/d) = 0.85 \times (NR_c - 0.04 + 45.9 \times (gestation,\ d/100) - 105.3 \times (gestation,\ d/100)^2 + 64.4 \times (gestation,\ d/100)^3 + a \times (ME - MEmm) / 1000).$$

Where NR_c = N retention in conceptus (g/joules), a = 0.571 in the first pregnancy and a = 0.366 for other parities, ME= kJ per day ME intake, and MEmm = maintenance requirement at d 5 of gestation.

The amount of energy available to be deposited as protein in maternal tissues (ERmp) was calculated from N retention:[5]

$$ERmp\ (kJ/d) = 23.8 \times 6.25 \times (NR - NR_c).$$

In this model, priority is given to satisfy energy requirements for body maintenance functions, growth of conceptus, and maternal body protein deposition, with the remaining nutrients available for lipid deposition (ERmf). If energy intake is insufficient to support maintenance requirements, growth of conceptus, and maternal body protein deposition, maternal body lipid is mobilized and used as a source of energy (Dourmad et al., 2008):

$$ERmf\ (kJ/d) = (Intake,\ kJ/d - (MEm + ERc / kc + ERmp / kp)) \times kf.$$

Where kc, kp, and kf are the efficiencies of ME for uterine growth, protein deposition and fat deposition. Efficiencies of 0.50, 0.60, and 0.80 were used for kc, kp, and kf in this study as reported by Dourmad et al. (2008). The efficiency of utilization of ME has been evaluated in previous research with estimates for maternal gain between 70 to 85%.[4,16,17] In the case of energy mobilization from body reserves (lipid mobilization) to provide energy, the efficiency is the same as fat, 0.80 (kr).[13]

The energy available for maternal tissue deposition was determined by combining the energy available for protein and lipid deposition. This was then converted from kJ to kcal to kg, assuming the kcal per kg ME provided in the diet was 3,225 kcal per kg, and later used to determine maternal feed efficiency:

$$\text{Energy available for maternal deposition (kg/d)} = ((ERmp + ERmf) / 4.184) / (kcal/kg\ ME).$$

[16] Close, W. H., J. Noblet, and R. P. Heavens. 1985. Studies on energy metabolism of the pregnant sow: The partition and utilization of metabolizable energy intake in pregnant and non-pregnant animals. Br. J. Nutr. 53:267-279. doi:https://doi.ird/10.1079.BJN19850034.

[17] Everts, H. and R. A. Dekker. 1994. Effect of nitrogen supply on the excretion of nitrogen and on energy metabolism of pregnant sows. Anim. Prod. 59:293-302. doi: https://doi.org/10.1017/S0003356100007972.

If the female did not eat or did not consume enough, and energy intake was insufficient to support maintenance requirements, growth of the conceptus, and maternal protein deposition, the energy available for maternal deposition will be negative. This indicates that the female is in a negative energy balance and is mobilizing maternal lipids to meet maintenance requirements, energy required by the conceptus, and maternal protein deposition.

Finally, protein and lipid deposition were determined in terms of female BW:[5]

Maternal protein deposition (g/d) = (ERmp / 23.8);

Maternal lipid deposition (g/d) = (ERmf / 39.7).

Total maternal protein and maternal lipid deposition were predicted by calculating the sum of each, for each individual sow.

Maternal BW gain per d of gestation was determined by subtracting the weight of conceptus (fetus, placenta, and fluids), correcting for mean piglet birth weight, from the average weight recorded per d of gestation. Maternal BW gain from d 5 to 112 of gestation, respectively, was determined using the following equation:

Maternal BW gain, kg = (final BW, kg – initial BW, kg) – final weight of conceptus, kg.

When calculating maternal BW gain, the d of gestation for the final BW and weight of conceptus were the same. Meaning, if a female was moved to farrowing on d 111 of gestation, the final BW would be from d 111 of gestation and the corresponding weight of conceptus would also be from d 111 of gestation.

Maternal ADG was defined as the difference in daily maternal BW. Maternal feed efficiency is reported as G:F and was determined using the following equation:

G:F = Maternal ADG, kg / energy available for maternal deposition, kg.

Where appropriate, units were converted from kg to lb and kJ to kcal using the conversion factors 2.2046 and 4.184. Data from this study were divided into 3 parity groups (1, 2, and 3+) and gestation was divided into 3 periods (indicating the average d within each period): d 5 to 39 (22), 40 to 74 (56), and 75 to 109 (92). Averages for each period were reported for all predictions with the exception of G:F, where the median for each period was reported.

Prior to data analysis, descriptive statistics in the form of means, histograms and scatterplots were generated using the PROC MEANS, PROC GPLOT, and PROC SGPLOT statements in SAS (Version 9.4, SAS Institute Inc., Cary, NC). 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 standard deviations from the mean were considered outliers and 937 observations were removed from the data set.

PROC MIXED in SAS was used to develop the pig birth weight. The statistical significance for inclusion of terms in the model was determined at $P < 0.05$. Further evaluation of models with significant terms was then conducted based on the Bayesian Information Criterion (BIC). A model comparison with a reduction in BIC of greater than 2 was considered improved. The fixed effects evaluated were total born and parity group (1 and 2+), and the random effect evaluated was wk. There was no total born by parity group interaction or quadratic response of total born, thus these terms were removed from the model. The final model for the piglet birth weight prediction equation contained parity and total born as input variables.

Weight of conceptus, female maintenance requirement, energy retention of conceptus, energy available for maternal protein deposition, protein deposition, energy available for maternal lipid deposition, lipid deposition, energy available for maternal deposition, maternal 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. Response variables were fitted assuming a normal distribution. 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

Descriptive statistics for predicted data is presented in Table 1. The average predicted pig birth weight was 2.9 lb ± 0.28 (mean ± SD) with a range of 2.2 to 4.1 lb. Our calculations are similar to Quiniou,[18] who reported an average pig birth weight of 3.04 lb for sows farrowing an average of 13.8 pigs per litter. Average final conceptus weight was predicted to be 66.0 lb ± 14.3 with a range from 4.3 to 111.3 lb. Average maternal BW gain was predicted to be 59.9 lb ± 34.2 with a range from -31.3 to 183.3 lb. Predicted total lipid deposition averaged 16.0 lb ± 9.8 and ranged from -7.9 to 68.6 lb. This indicates in some females, feeding level exceeded body maintenance requirements, the demands of the conceptus, and protein deposition in the maternal body with the remaining energy deposited as lipid. In some cases, the opposite occurred and energy intake was insufficient to support all requirements and as a result, maternal body lipid was mobilized and used as a source of energy. Total protein deposition averaged 8.9 lb ± 1.3 and ranged from 5.8 to 13.1 lb.

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

Regardless of parity, conceptus weight increased ($P < 0.05$) in each subsequent period of gestation (Table 2). Differences between conceptus weight among parities started between d 40 to 74 of gestation and continued into the final period of gestation with parity 3+ sows having the greatest ($P < 0.05$) conceptus weight and parity 1 sows having the lowest.

Regardless of parity, maintenance requirements increased ($P < 0.05$) in each sequential period of gestation (Table 2). Regardless of period of gestation, parity 3+ sows had the greatest ($P < 0.05$) maintenance requirement compared to parity 2 and 1 sows. The maintenance requirement for parity 2 sows was greater ($P < 0.05$) than parity 1 sows from d 5 to 74; however, from d 74 to 109 of gestation, parity 1 sows had a greater ($P < 0.05$) maintenance requirement.

Regardless of parity, energy retention of the conceptus increased ($P < 0.05$) in each sequential period of gestation (Table 2). There was no evidence for differences among parity groups until d 40 of gestation, at which time parity 3+ sows had the greatest ($P < 0.05$) energy retention of the conceptus. From d 74 to 109 of gestation, energy retention of the conceptus was greatest ($P < 0.05$) for parity 3+ sows, followed by parity 2 and 1 sows.

Regardless of parity group, the predicted energy used for maternal protein deposition decreased ($P < 0.05$) in each subsequent period of gestation (Table 2). Regardless of period of gestation, parity 1 sows had the greatest ($P < 0.05$) energy use for maternal protein deposition followed by parity 2 and 3+ sows. Due to the method of calculation, conclusions for predictions for maternal protein deposition into maternal tissue are the same as those reported for energy used for protein deposition (Table 2).

Regardless of parity, the amount of energy used for maternal lipid deposition decreased ($P < 0.05$) in each subsequent period of gestation (Table 2). Parity 2 sows had the greatest ($P < 0.05$) energy available for maternal lipid deposition in each period of gestation, followed by parity 3+ and 1 sows. Due to the method of calculation, conclusions for predictions for maternal lipid deposition into maternal tissue are the same as those reported for energy used for lipid deposition (Table 2).

After dividing energy requirements into tissue pools for maintenance, growth (maternal protein and fat deposition), and products of conceptus (fetal, placenta, and fluids), it is clear that the greatest portion of the energy requirement is for maintenance and maternal growth (Figures 1-3). Each tissue pool is affected by differences throughout gestation and parity group as described above.

Regardless of parity group, the energy used for maternal protein and lipid deposition decreased ($P < 0.05$) in each subsequent period of gestation (Table 3). This reduction in energy used for maternal protein and lipid deposition as the female progresses through gestation can be attributed to increasing maintenance requirements and demands of the conceptus. Parity 2 sows had the greatest ($P < 0.05$) energy available for maternal protein and lipid deposition, regardless of period, followed by parity 3+ and 1 sows which can be attributed to feed intake levels.

Maternal BW increased ($P < 0.05$) in each sequential period of gestation for parity 1 sows (Table 3). In parity 2 and 3+ sows, maternal BW increased ($P < 0.05$) from d 39 to 74 of gestation; however, there was no evidence ($P > 0.05$) for differences in maternal BW from d 75 to 109 of gestation. Maternal BW was greatest ($P < 0.05$) for parity 3+ sows. From d 5 to 39 of gestation, parity 2 sow maternal BW was greater ($P < 0.05$) than parity 1 sows, with no evidence for differences between the two parity groups from d 40 to 74 of gestation. From d 75 to 109 of gestation, parity 1 sow maternal BW was greater ($P < 0.05$) compared to parity 2 sows.

Regardless of parity group, maternal ADG decreased ($P < 0.05$) in the period from d 39 to 74 of gestation and increased ($P < 0.05$) from d 74 to 109 of gestation (Table 4). Maternal ADG was greater ($P < 0.05$) for parity 1 sows compared with parity 2 or 3+ sows in all gestation periods. Parity 2 sow maternal ADG was greater ($P < 0.05$) than parity 3+ sows from d 5 to 74 of gestation.

In early to mid-gestation, nutrients are used primarily to support maternal growth. Following d 70 of gestation the metabolic focus shifts to the growing demands of the conceptus.[8,9] Our findings are similar but maternal ADG starts to decrease before d 70 of gestation. For parity 1 sows, maternal ADG was highest in early gestation and decreased following d 39 of gestation. Regardless of parity, maternal ADG increases in late gestation, when we would expect the rates of maternal deposition to be the lowest as fetal growth is greatest during this time. We hypothesize that mammary gland development may have resulted in this increase in maternal ADG from d 74 to 109 of gestation. Maternal ADG in parity 1 sows was greater than parity 2 and 3+ sows in all phases of gestation, but ADG of parity 2 sows was only greater than parity 3+ sows from d 5 to 74 of gestation.

In parity 1 sows, maternal G:F is reduced ($P < 0.05$) in each subsequent period of gestation, resulting in a negative value from d 75 to 109 of gestation (Table 4). Parity 1 sow maternal G:F is greater ($P < 0.05$) than parity 2 and 3+ sows from d 5 to 74 of gestation but lowest ($P < 0.05$) from d 75 to 109 of gestation. Parity 2 and 3+ sows' maternal G:F is reduced ($P < 0.05$) from d 39 to 74 of gestation but improves ($P < 0.05$) from d 74 to 109. Parity 2 sow maternal G:F is greater ($P < 0.05$) than parity 3+ sows from d 75 to 109 of gestation. To our knowledge, G:F in sows in gestation has not been previously reported.

From the existing data, it is apparent that sow gestation nutrient requirements are affected largely by requirements of the sow for maintenance and maternal protein and lipid deposition, each of which is heavily influenced by parity and stage of gestation. Through the partitioning of each of these tissue pools, predictions indicate that even though parity 1 sows are in a negative energy balance late in pregnancy, maternal ADG and G:F are greater in most gestation periods compared with parity 2 and 3+ sows. Further research is needed to investigate these differences and if there is an impact on subsequent performance.

Table 1. Descriptive statistics for predicted data[1]

Item	Mean	SD	Minimum	Maximum
Piglet birth weight, lb[2]	2.9	0.28	2.2	4.1
Litter birth weight, lb[3]	43.0	6.6	4.1	56.5
Final weight of conceptus, lb[4]	66.0	14.3	4.3	111.3
Maternal weight gain, lb[5]	59.9	34.2	-31.3	183.3
Total lipid deposition, lb[6]	16.0	9.8	-7.9	68.6
Total protein deposition, lb[7]	8.9	1.3	5.8	13.1

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

[2] Piglet birth weight (lb) = (b – 0.035 × total born, n, where b for parities 1 and 2+ were 1.78 and 1.90)*2.2046.

[3] Litter birth weight (lb) = (piglet birth weight kg × total born, n)*2.2046.

[4] Final weight of conceptus (d 114), lb = ((((exp (8.621 - 21.02 × exp (-0.053 × gestation, d) + 0.114 × total born, n))/1,000) × (total born, n × average piglet birth weight, kg) / (exp {[9.095 – 17.69 exp (-0.0305 × 114) + 0.0878 × total born, n]}/1000)))*2.2046.

[5] Maternal weight gain, lb = ((final gestation BW, kg – initial gestation BW, kg) – final weight of conceptus, kg)*2.2046.

[6] Total lipid deposition, lb = (Sum of lipid deposition for each sow given by, (ERmf/ 39.7)/1000)*2.2046.

[7] Total protein deposition, lb = (Sum of protein deposition for each sow given by, (ERmp/23.8)/1000)*2.2046.

Table 2. Predicted model parameters based on parity and stage of gestation[1,2,3]

	Day of gestation, d			
	5 to 39	40 to 74	75 to 109	Probability, $P <$
Weight of conceptus, lb[4]				
Parity 1	0.79[a] ± 0.48	23.25[bx] ± 0.48	53.63[cx] ± 0.48	< 0.001
Parity 2	0.86[a] ± 0.55	24.79[bx] ± 0.55	57.10[cy] ± 0.55	< 0.001
Parity 3+	0.93[a] ± 0.46	27.04[by] ± 0.46	62.40[cz] ± 0.46	< 0.001
Maintenance requirement, kcal[5]				
Parity 1	4,620[ax] ± 20.0	5,114[bx] ± 20.0	5,640[cx] ± 20.0	< 0.001
Parity 2	4,859[ay] ± 23.0	5,194[by] ± 23.0	5,563[cy] ± 23.0	< 0.001
Parity 3+	5,387[az] ± 19.0	5,702[bz] ± 19.0	6,076[cz] ± 19.0	< 0.001
Energy retention of conceptus, kcal[6]				
Parity 1	21[a] ± 2.2	123[x] ± 2.2	328[cx] ±2.2	< 0.001
Parity 2	22[a] ± 2.5	132[by] ± 2.5	353[cy] ± 2.5	< 0.001
Parity 3+	24[a] ± 2.1	140[bz] ± 2.1	377[cz] ± 2.1	< 0.001
Energy used for maternal protein deposition, kcal[7]				
Parity 1	275[ax] ± 1.64	229[bx] ± 1.64	210[cx] ±1.64	< 0.001
Parity 2	258[ay] ± 1.89	211[by] ± 1.89	190[cy] ± 1.89	< 0.001
Parity 3+	228[az] ± 1.56	186[bz] ± 1.56	163[cz] ± 1.56	< 0.001
Maternal protein deposition, g[8]				
Parity 1	48[ax] ± 0.29	40[bx] ± 0.29	37[cx] ± 0.29	< 0.001
Parity 2	45[ay] ± 0.33	37[by] ± 0.33	33[cy] ± 0.33	< 0.001
Parity 3+	40[az] ± 0.27	33[bz] ± 0.27	29[cz] ± 0.27	< 0.001
Energy used for maternal lipid deposition, kcal[9]				
Parity 1	928[ax] ± 20.2	463[bx] ± 20.2	-244[cx] ± 20.2	< 0.001
Parity 2	1,510[ay] ± 23.2	1,170[by] ± 23.2	531[cy] ± 23.2	< 0.001
Parity 3+	1,070[az] ± 19.2	830[bz] ± 19.2	171[cz] ± 19.2	< 0.001
Maternal lipid deposition, g[10]				
Parity 1	98[ay] ± 2.13	49[bx] ± 2.13	-26[cx] ± 2.13	< 0.001
Parity 2	159[ax] ± 2.45	123[by] ± 2.45	56[ay] ± 2.45	< 0.001
Parity 3+	113[az] ± 2.02	87[by] ± 2.02	18[cx] ± 2.02	< 0.001

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

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

[3] The mean, per period of gestation, for each variable is reported.

Table 3. Maternal growth and feed efficiency of gestating sows as influenced by parity and stage of gestation[1,2]

	Day of gestation, d			
	5 to 39	40 to 74	75 to 109	Probability, *P* <
Energy available for maternal protein and lipid deposition, kcal[3]				
Parity 1	1,203^{ax} ± 21.7	692^{bx} ± 21.7	-35^{cx} ± 21.7	< 0.001
Parity 2	1,767^{ay} ± 24.9	1,380^{by} ± 24.9	721^{cy} ± 24.9	< 0.001
Parity 3+	1,298^{az} ± 20.6	1,016^{bz} ± 20.6	334^{cz} ± 20.6	< 0.001
BW, lb[3]				
Parity 1	341.3^{ax} ± 2.09	368.5^{bx} ± 2.09	392.6^{cx} ± 2.09	< 0.001
Parity 2	365.0^{ay} ± 2.40	375.0^{bx} ± 2.40	381.0^{by} ± 2.40	< 0.001
Parity 3+	418.9^{az} ± 1.99	425.9^{bz} ± 1.99	430.5^{bz} ± 1.99	< 0.001
ADG, lb[3]				
Parity 1	1.03^{ax} ± 0.025	0.59^{bx} ± 0.025	0.91^{cx} ±0.025	< 0.001
Parity 2	0.71^{ay} ± 0.028	0.09^{by} ± 0.028	0.33^{cy} ± 0.028	< 0.001
Parity 3+	0.50^{az} ± 0.023	-0.09^{bz} ± 0.023	0.75^{cz} ± 0.023	< 0.001
G:F[4]				
Parity 1	1.29^{ax} ± 0.110	0.67^{bx} ± 0.110	-1.24^{cx} ± 0.110	< 0.001
Parity 2	0.67^{ay} ± 0.127	-0.04^{by} ± 0.127	1.13^{cy} ± 0.127	< 0.001
Parity 3+	0.88^{ay} ± 0.105	-0.34^{by} ± 0.105	0.17^{cz} ± 0.105	< 0.001

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

[2] Values with different superscripts within a row^{abc} or column^{xyz} differ, $P < 0.05$.

[3] Values represent the mean per period of gestation.

[4] Values represent the median per period of gestation.

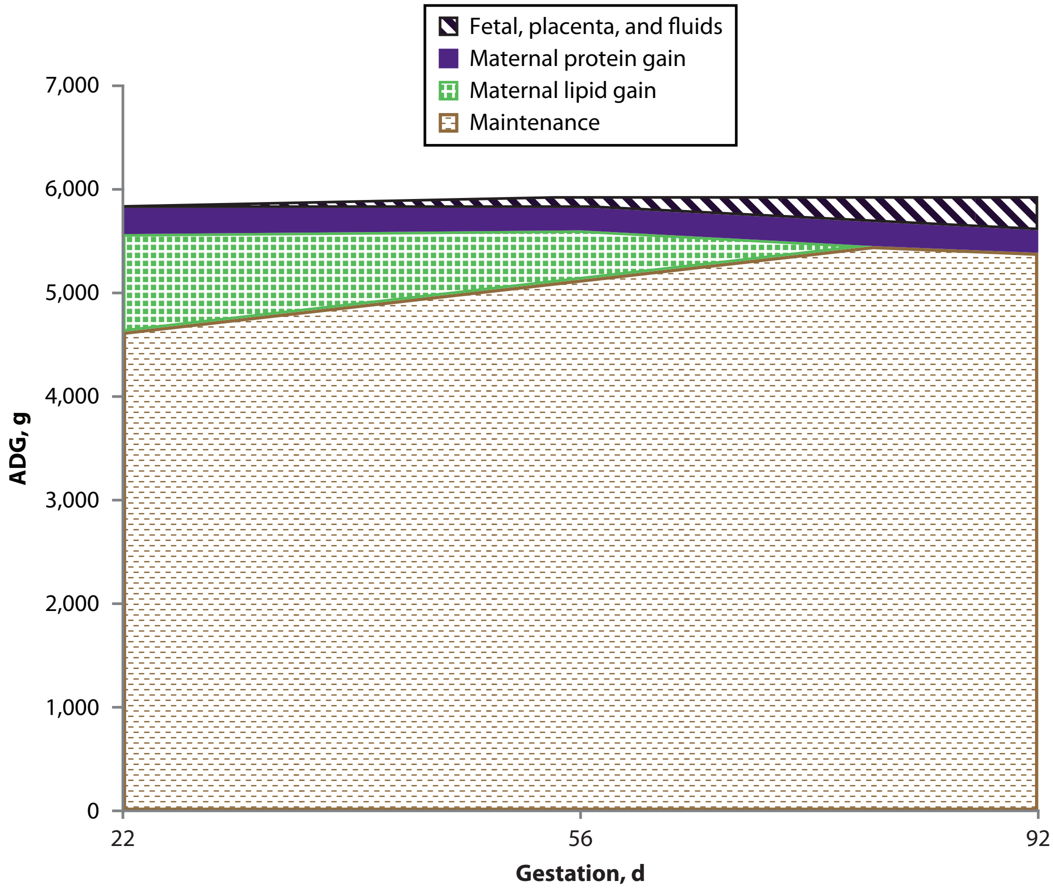

Figure 1. Predicted energy needs of parity 1 sows (kcal/d) during gestation based on different body tissues.

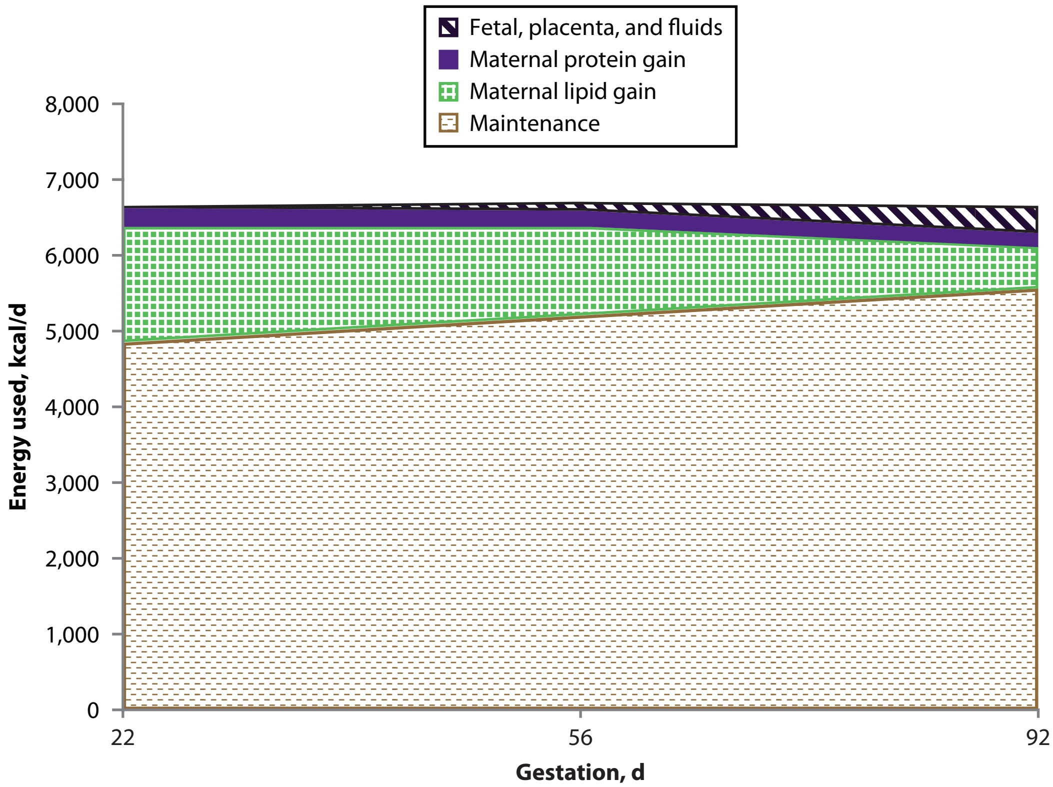

Figure 2. Predicted energy needs of parity 2 sows (kcal/d) during gestation based on different body tissues.

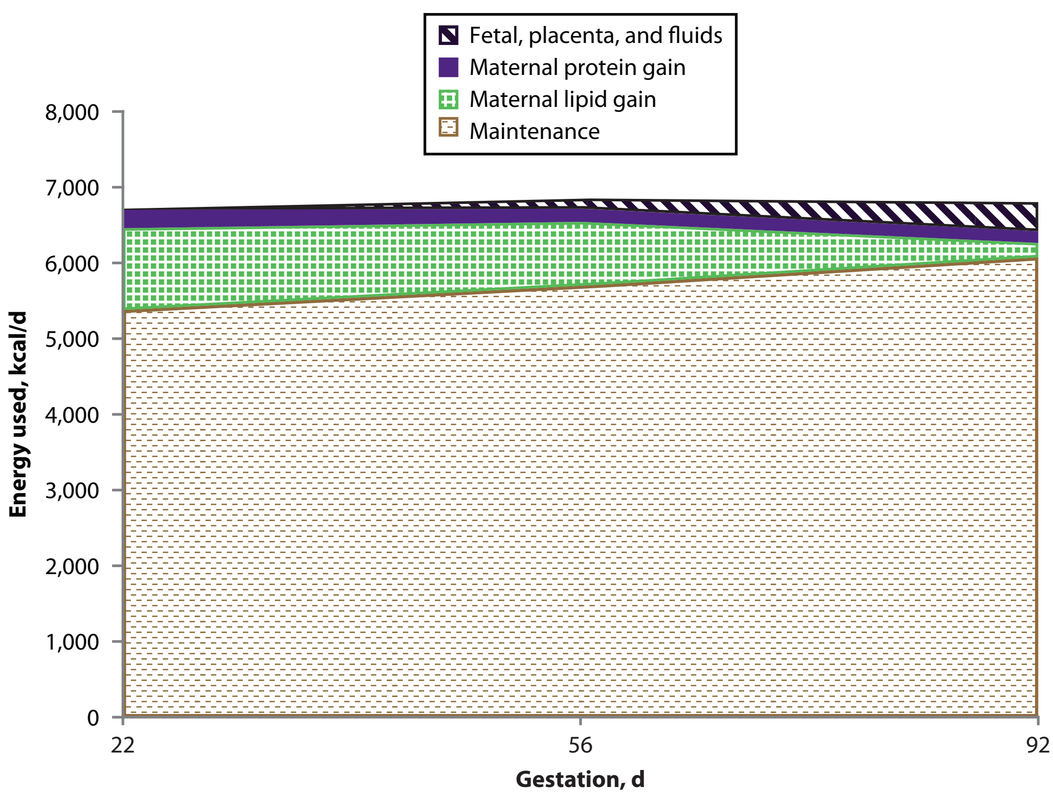

Figure 3. Predicted energy needs of parity 3+ sows (kcal/d) during gestation based on different body tissue.