RESEARCH REPORT
ANIMAL SCIENCE

Title: Optimal dietary energy and protein for the development of gilts - **NPB #12-209**

Investigator: Jeffrey Vallet[1]

Co-investigators: Dr. Julia Calderon[2], Dr. Kenneth Stalder[2]; Dr. Christina Phillips[3], Dr. Gary Bradley[3], Dr. Jeremy Miles[1], Dr. Lea Rempel[1], Dr. Clay Lents[1], Dr. Brad Freking[1], Dr. Gary Rohrer[1]; Dr. Dan Nonneman[1]; Dr. Bob Cushman[1]

Institution: [1]USDA, ARS, USMARC; [2]Iowa State University, Murphy Brown LLC[3]

Date Submitted: June 30, 2014

Industry Summary

Sow longevity is a key component for efficient and profitable pig farming and efforts to improve it should start with the adequate management of replacement gilts. A key factor in gilt management is to provide them with adequate feeding that supplies the right amount of amino acids and energy for their maintenance and growth to allow them to reach puberty at an early age and build up fat reserves to be later used during their first lactation. Therefore, six different diets, consisting of 2 levels (85% and 100%) of lysine (LYS) and 3 levels (85%, 100% and 115%) of metabolizable energy (ME) were used in this study to try to manipulate the lean to fat ratio in replacement gilts by creating a lysine and/or energy imbalance in the diet. The 100% LYS, 100% ME were based on an informal survey of the swine industry to obtain average levels that are currently fed to gilts. Gilts had free access to diets from 100 days of age until approximately 260 days of age, when they were slaughtered. Data on litter of origin of the gilts, growth, body composition, feed intake, feed efficiency, age at puberty, measurements of the reproductive tract at the time of slaughter and carcass composition were collected for this study. We found no difference in growth and minor differences in body composition traits among the six diets. However, gilts fed a low energy diet consumed almost 15 kg more feed than gilts fed a high energy diet, indicating that gilts adjusted their feed intake according to the energy in the diet. Thus, regardless of the diet, gilts used the same amount of Mcal to deposit 1 kg of body weight. Also, LYS consumption was higher (on average 26 g/day) than the

recommended lysine intake irrespective of the diets. Therefore, despite considerable differences in the ratios of ME and LYS in the diets, they had very little effect on measures of growth or body composition. We also did not observe a difference in the age at puberty or in the measurements taken of the reproductive tract between diets. Ovulation rate, uterus length and ovary length and width were a function of age, stage of the estrous cycle and the number estrous cycles rather than feed provided or body condition. Carcasses from gilts fed a high energy diet, were almost 3 kg heavier than carcasses from gilts fed a low energy diet, most likely due to a larger organ size and heavier organ weight of the gilts fed the low energy diets. More research is necessary in order to find an 'ideal' gilt development diet that would create an amino acid and/or energy imbalance and decrease lean deposition and increase fat reserves in replacement gilts with free access to feed.

Keywords: *body composition, carcass, feed efficiency, gilt development, lysine, metabolizable energy, puberty, reproductive tract*

Scientific abstract

The main objective of this study was to determine three diets for use in a NPB primary trial of dietary effects on gilt development and retention of sows in the breeding herd to fourth parity. A second objective was to examine the influence of litter of origin traits on gilt development. At birth, gilts were weighed, a blood sample was collected for immunocrit measurement, and litter details (born alive, stillborn, mummies) were recorded. Gilt weights were also recorded at weaning. One-thousand-two-hundred-and-twenty-one crossbred Large White × Landrace gilts housed in groups of 17 to 18 were randomly allotted to one of 6 corn-soybean diets formulated using a 2 × 3 factorial arrangement that provided 2 levels of standardized ileal digestible (SID) lysine [100% (high, HL) and 85%, (low, LL); the latter designed to restrict protein deposition] and 3 levels of metabolizable energy [ME; 85% (low, LME), 100% (medium, MME), 115% (high, HME)] at 100 d of age. Gilts were weighed and back fat thickness and loin area muscle were recorded every 28 d beginning when diets were applied. Fat free lean meat content was also calculated for every 28 d period. Feed intake was recorded as feed disappearance within the pen at 2 week intervals. Grams of lysine and Mcal consumed for every 2 week period and grams of lysine and Mcal consumed daily were calculated based on diet formulation on a pen basis. Average daily gain, feed, lysine and ME intake per kg of BW gain were also calculated. Starting at 160 d of age, gilts were exposed daily to vasectomized boars and observed for behavioral estrous. At approximately 260 d of age, gilts were slaughtered and their reproductive tract was collected. Whether the gilt was cycling, stage of cycle, ovulation rate, uterine length and ovary length and width were recorded. Warm and chilled carcass weight and carcass fat thickness were also recorded. Fat free lean meat content and dressing percentage were calculated. Data were tested for normality and analyzed using mixed model equation methods. The interaction between lysine level and

ME levels was not a significant source of variation for growth and body composition traits ($P > 0.05$). In addition, There were no main effects of lysine levels or ME levels for growth or body composition traits, except for back fat thickness which was slightly higher for gilts fed a HME diet, although this result is biologically questionable because the magnitude of the difference was small. Gilts fed the LL diet had a lower lysine intake compared with gilts fed the HL diet ($P < 0.05$). Gilts fed HME diets had a lower feed intake but a higher ME intake compared with gilts fed LME or MME diets ($P < 0.05$). Additionally, gilts fed the HME had lower feed and lysine intake per kg of BW compared with gilts fed LME or MME diets ($P < 0.05$). However, there was no difference in the Mcal consumed per kg of BW among treatments ($P > 0.05$). There were no differences among treatments in age at puberty or any of the reproductive tract measurements ($P > 0.05$). Carcasses from gilts fed the HME diet were 3.3 kg and 2.5 kg heavier than those from gilts fed the LME or MME diets ($P < 0.05$). Additionally, carcasses from gilts fed the HME diet had a higher dressing percentage than carcasses from gilts fed the LME or MME diets ($P < 0.05$). Despite significant differences in the ratio of lysine and energy in the diets, no changes in growth or reproductive traits occurred, likely due to compensatory feed intake in response to the energy content of the diet. Caloric efficiency (Mcal to deposit 1 kg of BW) was similar among treatments. The higher carcass weight and dressing percentage of gilts fed the HME diets is likely related to their lower feed intake and possible reduced organ weight compared with gilts fed LME or MME diets. Further research is required to identify the optimal lysine-to-energy ratio to manipulate growth and body composition in order to reduce age at puberty and improve lifetime reproductive performance and longevity in replacement gilts fed *ad libitum*

Introduction

Sow longevity is a key component of an efficient and profitable pig farming enterprise. Efforts to improve sow longevity should be aimed at replacement animals. They need to be managed, housed and fed appropriately during the developmental phase to ensure that they are at a high level of health on entry to the herd. Efficient performance includes not only growth and feed utilization, but reproductive performance as well. There is a common consensus among pig producers that if gilts reach puberty at an earlier age, sow longevity and/or reproductive performance will be improved. Chapman *et al*. (1978) found that selecting gilts that reached puberty and conceived earlier improved their reproductive performance and a younger age at first conception or at first farrowing was associated with superior expected longevity (Le Cozler *et al*., 1998; Saito *et al*., 2011). Nutrition is the most manageable environmental factor that influences the efficiency with which gilts enter the sow herd (Klindt *et al*., 2001). Adequate nutrition during growth is required for proper development of reproductive females (Klindt *et al*., 1999), as body composition is associated with puberty onset (Klindt *et al*., 2001).

Gilt development diets have often been formulated to contain excess amino acid levels to encourage maximal protein deposition (Rozeboom *et al*., 1999); however, according to Stalder *et al*. (2007) the key for success in gilt development is to slow down protein deposition and build fat reserves. Fat reserves could be manipulated by an imbalance in amino acid intake. Inadequate availability of amino acid intake restricts lean tissue growth and would redirect energy in the diet into fat deposition (Voermans *et al*., 1994, Kitt, 2010). Conversely, energy intake can affect the ratio between fat and protein deposition in the pig (De Greef, 1992). Baidoo (2001) stated that an appropriate gilt development diet should be either moderate in lysine (0.6%) with high energy (3.5 Mcal/ kg) or high in lysine (1.31 %) with moderate energy (3.2 Mcal/kg), but he also suggested that such diets should be limit fed, which is not a common practice in the pig industry. In fact, there are few studies comparing different gilt development diet compositions fed *ad libitum* with large numbers of observations or in a commercial setting; therefore, it is important to examine the effects of diet composition on gilt growth and reproductive development in environments that mimic common commercial practices for raising replacement gilts.

Secondary to the effects of diet on growth, estrous cyclicity and reproductive tract development, this experiment provides an opportunity to examine litter of origin effects on these same traits. In a recent report, Flowers *et al*. (2009) indicated that age at puberty was reduced in gilts raised in small litters (< 7 piglets) compared to large litters (> 10 piglets). Bartol *et al.* (2013) reported that colostrum availability influences early reproductive tract development and provided evidence that lack of colostrum (measured using the immunocrit; Vallet *et al*., 2013) was associated with reduced fertility. These results suggest that aspects of the preweaning environment can affect reproductive competence during adulthood. Thus, a secondary objective of this experiment was to collect litter of origin information, including immunocrit measures to assess colostrum availability to each gilt, and determine relationships with growth and reproductive traits.

Objectives: The objectives of this preliminary trial were:

1. To determine three diets for use in a NPB primary trial of dietary effects on gilt development and retention of sows in the breeding herd to fourth parity.
2. To determine effects of energy and amino acid levels on growth, cyclicity, reproductive tract and mammary gland development in gilts.
3. To determine the effects of litter of origin traits on subsequent gilt development
4. To retain tissues from all animals for genomic analyses, for both discovery of new potential markers for gilt traits and validation of previously discovered genetic markers for gilt traits.

Materials and Methods:

Animals and Management. One-thousand-two-hundred-and-twenty-one crossbred Large White × Landrace gilts were used in this study. Maternal line gilts for this experiment originated from Murphy Brown LLC facilities in Milford Utah from sows from parities 2 through 8, that had been mated using pooled semen. On day 1 of age, gilts were weighed, a blood sample was collected for immunocrit measurement (Vallet *et al*., 2013), and tails were collected and stored frozen for later genotyping. Genotyping efforts were funded separately and results are not included in this report. The total number born, born alive, and stillborn, and the number of mummies were recorded for each litter. Gilts were also weighed at weaning. Gilts were moved at weaning to group-housing (17 to 18 gilts per pen with a minimum 0.95 m^2 per gilt) in two naturally ventilated commercial grower-finisher barns at a Murphy Brown LLC facility in Goldfield, Iowa. Pens used in the study had approximately 80% of the area with solid concrete flooring in which a feed trough was centrally positioned with four feeding spaces. The remaining area of the pen had slatted concrete flooring. Gilts were placed on trial diets at approximately 100 d of age. Gilts were randomly allotted to 6 corn-soybean based diets in a 2 × 3 factorial arrangement that provided 2 levels of lysine [100% (high, HL) and 85%, (low, LL)] the latter designed to restrict protein deposition) and 3 levels of metabolizable energy [ME; 85% (low, LME), 100% (medium, MME), 115% (high, HME)]. The 100% ME, 100% lysine control diet was based on an average of results of an informal survey of gilt diets in the swine industry undertaken by the National Pork Board. The dietary levels were designed to restrict growth (85% lysine, 85% ME), provide a control level of growth (100% lysine, 100% ME), and to have diets for which growth and/or body composition of the developing gilts is altered (i.e. imbalance of lysine and ME, designed to manipulate the lean to fat ratio). Care was taken to distribute gilts evenly among dietary treatments that originated from different parity sows and placement of littermate gilts within the same pen and dietary treatment was avoided. Gilts were fed *ad libitum* in two phases. First, gilts received a grower diet (Table 1) from 100 d of age until they reached approximately 90 kg of BW. After that gilts were fed *ad libitum* a finisher diet (Table 2) until they were slaughter at approximately 260 d of age. Feed disappearance was recorded every two weeks for each pen. Gilts had *ad libitum* access to water via a nipple drinker on the pen.

On farm measurements

Body composition trait. Gilts were individually weighed and back fat thickness and loin eye area were measured at the 10^{th} rib using real time ultrasound (Biotronics Inc, IA, USA) at 100 d of age and then every four weeks until slaughter. Fat free lean meat content (FFL) was predicted using the following equation developed by the National Pork Board (2000) for live hogs using real–time ultrasound:

$$0.833 \times [\text{sex of the pig (barrow} = 1; \text{gilt} = 2)] - \left[16.498 \times 10^{\text{th}} \text{ rib fat depth (in)}\right]$$

$$+\left[5.425 \times 10^{\text{th}} \text{ rib loin muscle area } (\text{in}^2)\right] + [0.291 \times \text{live BW (lb)}] - 0.534$$

Table 3 shows the descriptive statistics for the measurements recorded at the beginning of the trial (i.e. 100 d of age).

Feed intake and feed efficiency traits. Feed intake (FI) was recorded as the feed disappearance per pen every 2 week. Grams of lysine and kcal of ME consumed every 2 weeks were calculated by multiplying the formulated content of lysine and ME in the diet by the kg of feed consumed. Additionally, average daily feed (ADFI), lysine (ADLI) and Mcal of ME (ADMEI) intake per pig were also calculated by dividing the total FI, lysine and ME intake by the number of pig days per pen. Average daily gain (ADG) was calculated for each 4 week interval. Feed, lysine and ME intake per kg of BW gain were also recorded.

Feet and leg soundness. At 160 d of age, gilts were visually scored for 5 feet and leg structural soundness traits. Foot position, pasterns and leg angulation were scored using 9-point scales, where 1 and 9 indicate the extreme phenotypes of the traits (Nikkila et al., 2013). Toe evenness and foot size were scored using 3-point scales. Locomotion was scored using a 6-point scale developed by Main *et al.* (2000) where zero is a pig with normal gait, posture, behavior and it needs no help to walk and 5 represents a pig incapable of movement and severely lame.

Reproductive traits and removal reasons. Starting at 160 d of age, gilts were exposed to vasectomized boars and estrous was checked daily following a gilt stimulation protocol on a scale from 0 to 3; where 0 = no signs of estrous (gilt shows no interest towards boar and there are no vulvar changes); 1 = gilt "soliciting" the boar or with a red vulva; 2 = gilt responding to head-to-flank stimulation or gilt with a large, soft and swollen vulva with vulva discharge; and 3 = standing estrous; gilt would not move when applying the back pressure test. Age at first estrous, days in heat, and estrous interval were recorded. Reasons for gilt removals (including sick animals that needed to be moved to a sick pen, culling and deaths) from the study were based on decisions taken by the stockperson in charge of the gilts and were retrospectively acquired from the farm records.

Measurements collected at slaughter

Reproductive tract. Gilts were slaughtered at approximately 260 d of age and the reproductive tract and one entire mammary gland for each gilt were collected. The reproductive tract was categorized into the following categories: 0) pre-pubertal, small uterus, small follicles, no *corpora albacantia*; 1) large follicles previous to ovulation, *corpora albacantia* present, uterus large and turgid (possibly in estrous); 2) presence of *corpora*

hemorrhagica, indicating shortly after ovulation; 3) robust c*orpora lutea* (CL) present indicating early in the luteal phase; and, 4) pale CL present but without large follicles, indicating late in the luteal phase. CL were counted for all animals that were category 2, 3 or 4. Width and length of each ovary were measured using a caliper. Average ovary width and length were calculated by the sum of the width and length of each ovary divided by 2, respectively. The length of each uterine horn was measured with a measuring tape and the total uterine length was calculated as the sum of the two uterine horns. Gilts in behavioral anestrous (i.e. gilts that did not receive a score of 3 during the daily detection of estrous but were found to be cycling at slaughter) was also recorded. Ovulation rate was calculated by the sum of the number of *Corporea luta* on each ovary.

Carcass information. Warm carcass weight and fat thickness were recorded. Fat thickness was measured using a 7 point scale in increments of 0.2 cm from 0.39 to 1.4 cm. To calculate FFL, the center value for each fat thickness category was used. Fat free lean meat content was calculated using the following equation developed by the National Pork Board (2000) for unribbed carcasses using last rib backfat thickness measured with a stainless steel ruler:

$$23.568 - [21.348 \times \text{last rib fat depth (in)}] + [0.503 \times \text{warm carcass weight(lb)}]$$

Chilled carcass weight was calculated by multiplying warm carcass weight × 0.985. Body weight at slaughter was estimated as follow:

$$BW\ at\ 250\ d\ +\ (ADG\ \ from\ 220d\ to\ 250d\ \times number\ of\ days\ from\ last\ weight\ in\ to\ slaughter\ )$$

Statistical analysis

Body composition, feed intake and feed efficiency traits. Pen was considered the experimental unit (12 pens per diet; 72 pens on trial). Predicted variables were tested for normality before analysis using the Shapiro-Wilk test and examination of the normal plot. Data were analyzed using mixed model equations methods in SAS v9.4 PROC MIXED (SAS Inst. Inc., Cary, NC). The model included lysine and ME content, days on trial and their interactions as fixed effects. For growth, and body composition and feed efficiency traits, BW at the beginning of the study (i.e. at 100 d of age) was used as a linear covariate in the model to account for the gilts starting the trial at a similar BW. For feed intake traits, pen average BW at each 28 d period was included as a linear covariate in the model. Pen within lysine × ME level within barn was included as a random effect. A Tukey–Kramer adjustment was used to account for multiple comparisons. Statistical differences were reported

when $P < 0.05$. Results are reported as least-square means ± standard error of the mean. Results for continuous variables are reported as the regression coefficient with the associated standard error.

Leg and feet soundness. Frequency of gilts within each score within each trait was calculated and no further analysis was performed. Frequencies are shown in Table 4.

Removal reasons. Removal reasons were analyzed using a chi-square test in SAS v9.4 PROC FREQ (SAS Inst. Inc., Cary, NC).

Reproductive traits. One-thousand-two-hundred-and-two gilts had records for daily estrous detection. Pen was considered the experimental unit. Age at puberty, ovulation rate, uterus length and ovary length and width were tested for normality before the analysis using the Shapiro-Wilk test and examination of the normal plot. Data were analyzed using mixed model equations methods in SAS v9.4 PROC MIXED (SAS Inst. Inc., Cary, NC). The model for age at puberty included lysine and ME content and their interactions as fixed effects. Body weight at 160 d of age (i.e. when boar exposure began) was included as a linear covariate. Pen within lysine × ME level within barn was included as a random effect. For the rest of the traits, the models included lysine and ME content and their interactions and puberty score as fixed effects and pen within lysine × ME level within barn was included as a random effect. Body weight at 160 d of age was included as a linear covariate. A Tukey–Kramer adjustment was used to account for multiple comparisons. Statistical differences were reported when $P < 0.05$. Results are reported as least-square means ± standard error of the mean. Results for continuous variables are reported as the regression coefficient with the associated standard error. Number of gilts that did not showed standing estrous and number of gilts in behavioral anestrous were analyzed using a chi-square test in SAS v9.4 PROC FREQ (SAS Inst. Inc., Cary, NC). For the number of gilts that did not show standing estrous, two analyses were performed. The first one included all the gilts that were on trial at 160 d of age. For the second analysis, gilts that were removed from the experiment before 220 d of age were excluded as some of them could have been removed before they reached the physiological maturity required to show standing estrous.

Carcass traits. Pen was considered the experimental unit. Warm and chilled carcass weight, FFL, fat thickness and dressing percentage were tested for normality before the analysis using the Shapiro-Wilk test and examination of the normal plot. Because we did not have the real BW at slaughter and to avoid an over estimation of dressing percentage, we used the data for gilts that were within ± 2 SD of the mean dressing percentage for the analysis. Data were analyzed using mixed model equations methods in SAS v9.4 PROC MIXED (SAS Inst. Inc., Cary, NC). The model included lysine and ME content and their interactions as fixed effect and BW at slaughter

was included as a linear covariate. Pen within lysine × ME level within barn was included as a random effect. A Tukey–Kramer adjustment was used to account for multiple comparisons. Statistical differences were reported when $P < 0.05$. Results are reported as least-square means ± standard error of the mean. Results for continuous variables are reported as the regression coefficient with the associated standard error.

Litter of origin effects. Collection of litter of origin traits allowed for an examination of the effects of these traits on growth, estrous cyclicity and reproductive tract development. Specifically, the effects of parity of the dam, piglet birth weight, day 1 immunocrit (a measure of colostrum access), litter size at weaning, and growth rate from birth to weaning were examined using mixed model equation methods in SAS PROC MIXED (SAS Inst. Inc., Cary, NC) after accounting for effects of the diets. All models included barn, ME, lysine, and the ME by lysine interaction as fixed effects. Pen within lysine × ME level within barn was included as a random effect. Subsequently, each litter of origin factor was included [as either a continuous variable (birth weight, immunocrit, number weaned, growth rate from birth to weaning) or as a class variable (parity)] along with its interaction with pen within lysine × ME level within barn as a random effect. Thus, the analysis adjusts for pen, and accounts for pen error in the analysis of litter traits. The effects of birth weight and preweaning growth rate was determined in the same analysis, so that the independent effect of each could be determined. Uterine length was clearly affected by day of the cycle, so day of the cycle at slaughter was calculated using estrous behavior observations collected until three days before the gilts were slaughtered. In this analysis, prepubertal gilts at slaughter were assigned -1 as the day of the estrous cycle, gilts that were cycling at slaughter but did not have an observed estrous within 23 days of slaughter were deleted from the analysis, because the stage of the cycle could not be determined. Analysis of the effects of litter of origin traits on uterine length was done after fitting the linear and quadratic effects of day of the cycle. Statistical differences were reported when $P < 0.05$. Results are reported as least-square means ± standard error of the mean. Results for continuous variables are reported as the regression coefficient with the associated standard error.

Growth trajectories and puberty failure. Mixed model equation methods were used to compare growth trajectories (over time) for body weight, loin eye area and back fat between gilts that reached puberty during the experiment and those that failed to reach puberty. For each growth trait, the model included effects of barn, ME, lysine and the pen within barn by ME by lysine interaction. Then, for the effect of puberty category (reached puberty or failed to reach puberty), the linear and quadratic effects of days on diet, and the interaction of puberty category with the linear and quadratic effects of diet were included. Finally, a random effect of the interaction of puberty status with pen within barn by ME by lysine in the diet was included. Components of the model were

dropped from the final model if they were not statistically significant. Results for continuous variables are reported as the regression coefficient with the associated standard error.

Results:

Growth and body composition traits. Descriptive statistics and LS means for growth and body composition traits are presented in Table 5 and 6, respectively. There was no difference ($P > 0.05$) in BW, loin eye area and FFL between lysine and ME content and their interaction. Backfat thickness did not differ ($P > 0.05$) between lysine content in the diet and there was no lysine by ME interaction ($P > 0.05$). There was a statistical difference ($P < 0.05$) in backfat thickness between ME level; however, the biological significance remains questionable because the difference between the low ME and high ME diets was only 0.22 cm. As expected, as time progressed, BW, backfat thickness, loin eye area and FFL increased across treatments (Table 7). Figures 1, 2, 3 and 4 show the least square means for the growth patterns of growth and body composition traits by lysine and ME content in the diet and their interaction. Gilts with heavier BW at 100 d of age, were also heavier later in the study ($P < 0.05$).

Feed intake traits. Descriptive statistics and LS means for feed intake traits are presented in Tables 8 and 9, respectively. There was no effect ($P > 0.05$) of lysine content in the diet for FI, ME intake, ADFI and ADMEI. Unsurprisingly, gilts fed a high lysine diet had a higher total lysine intake ($P < 0.05$) and a higher ADLI ($P < 0.05$) compared to gilts fed a low lysine diet. Gilts fed the LME diet ate 7.26 kg and 14.9 kg more feed and 0. 06 kg and 0.12 kg more lysine than gilts fed the MME and the HME diets, respectively ($P < 0.05$). However, in spite of the higher FI, gilts fed the LME diet consumed less Mcal of ME across the experiment and lower ADMEI than gilts fed the MME and HME diet ($P < 0.05$). Average daily feed intake and ADLI were also higher ($P < 0.05$) for gilts fed the LME diet compared with gilts fed the MME and HME diets. There was no difference in FI and ADFI among gilts fed diets with the same energy content in the diet irrespective of the lysine content in the diet ($P > 0.05$). Although not statistically significant, gilts feed the LL-LME and HL-LME diets had a higher FI than gilts fed any of the rest of the diets. Also, there was a numerical difference between lysine by ME interaction in the total lysine intake and ADLI, but it was not statistically significant. Overall, feed intake traits increased from 100 d to 190 d on trial and decreased by 250 d ($P < 0.05$, Table 7). Figures 5, 6, 7, 8, 9 and 10 show the least squares means for the growth patterns of the feed intake traits by lysine and ME content in the diet and their interaction. Feed intake traits increased with every increase in 1 kg of BW ($P < 0.05$).

Feed efficiency traits. Descriptive statistics and LS means for feed efficiency traits are presented in Tables 10 and 11, respectively. Lysine content in the diet made no difference in ADG, FI and ME intake per kg of BW gain ($P > 0.05$). Gilts fed a low lysine diet consumed 5 g of lysine less per kg of BW compared with gilts fed a high lysine diet (30.18 ± 0.34 and 35.84 ± 0.34 respectively, $P < 0.01$). ADG and ME intake per kg of BW gain did not differ ($P > 0.05$) among ME content in the diets. Gilts fed the low ME diet consumed 0.34 kg and 0.72 kg more feed per kg of BW gain than gilts on the medium ME and high ME diet, respectively ($P < 0.05$). Additionally, gilts fed the low ME diet consumed 2.67 g and 5.7 g more lysine per kg of BW gain than gilts fed the medium ME and high ME diet, respectively ($P < 0.05$). There was no lysine by ME content interaction ($P > 0.05$) for any of the feed efficiency traits recorded. ADG decreased as the trial progressed ($P < 0.05$) and feed, lysine and ME intake per kg of BW gain increased approximately 2.5 times from 100 d to 250 d across treatments ($P < 0.05$, Table 7). Figures 11, 12, 13 and 14 show the least squares means for the patterns of the feed efficiency traits over time by lysine and ME content in the diet and their interaction. Average daily gain decreased and FI, lysine and ME intake per kg of BW gain increased with every increase of 1 kg at 100d of age.

Removals. One-hundred-and-thirty-five gilts were removed from the experiment. Forty-three gilts died, and 92 gilts were removed. The most common cause of removal was leg problems (73.91%), 11.91% did not have a record for the reason of removal, and the other 14.13% of gilts were removed for several reasons such as prolapses, aggression injuries, and respiratory problems. However, there was no difference in the number of gilts removed for each removal reason among dietary treatments; though there was a tendency for more gilts fed a high lysine diet to be removed from the study ($P = 0.10$). Forty gilts were removed before 220 d of age. The number of gilts removed during the trial for the different lysine and ME contents in the diet and their interaction are shown in Table 12.

Reproductive traits. Descriptive statistics and LS means for age at puberty, ovulation rate, uterine length and ovary length and width are presented in Tables 13 and 14, respectively. Average age at puberty was 193 d of age with a range from 160 d to 265 d. Ninety-one-percent of gilts showed standing estrous when all the gilts on trial at 160 d of age were included. When gilts removed from the trial before 220 d of age were excluded from the analysis, 94.23% of gilts showed standing estrous. However, there was no difference in the number of gilts that showed standing estrous among dietary treatments in both analyses ($P > 0.05$). Additionally, there was no difference between dietary treatments in the age that gilts reached puberty ($P > 0.05$). There was no difference between dietary treatment for ovulation rate, uterus length and ovary length and width ($P > 0.05$). Forty-nine gilts were classified as pre-pubertal (i.e. puberty score = 0) at slaughter; and there were more pre-pubertal gilts in the low lysine treatment than in the high lysine treatment (33 vs. 16 gilts, respectively; $P < 0.05$). Gilts with puberty

score = 3 had a higher ovulation rate, longer uterus and longer and wider ovaries than gilts that received a different puberty score at slaughter ($P < 0.05$). Similarly, there was a significant linear and quadratic effect of day of the estrous cycle at slaughter in uterine length. Twenty-one gilts were in behavioral anestrous and there was no difference between dietary treatments ($P > 0.05$). Ovulation rate and ovary length and width increased with every 1 kg increase at 160d of age. Body weight at 160d did not influenced age at puberty or uterus length.

Carcass traits. Descriptive statistics and least squares means for warm and chilled carcass weight, dressing percentage, FFL and fat thickness are presented in Table 15 and 16, respectively. There was no difference between lysine levels for any of the carcass measurements ($P > 0.05$). Warm and chilled carcass weight and FFL were greater for gilts fed the high ME diet than for gilts fed the low or medium ME diet ($P < 0.05$). Also, dressing percentage was 1.1% and 0.9% higher for gilts fed the high ME diet than for gilts fed the low or medium ME diet respectively ($P < 0.05$). There was a statistical difference for fat thickness ($P < 0.05$) with gilts fed the high ME diet being fatter at slaughter than the gilts fed the low or medium ME diets, however, the biological significance remains questionable. There was a lysine by ME interaction effect on dressing percentage where gilts fed the high ME diets had a higher dressing percentage irrespective of the lysine level in the diet ($P < 0.05$). Warm and chilled carcass weight, FFL and fat thickness increased and dressing percentage decreased for every increase of 1 kg of BW at slaughter, respectively ($P < 0.05$).

Litter of origin traits.

a) Parity. Parity effects were found for piglet birth weights, piglet immunocrit and preweaning growth rates. Further analysis indicated that birth weights were maximal in parities 3 and 4. Immunocrits were maximal for parities 3 through 7, and were lower in parities 2 and 8. Preweaning growth rates were also maximal in parities 3 through 7. There were no effects of parity on age at puberty, ovulation rate, or reproductive tract parameters. There was a significant effect of parity ($P < 0.01$) on puberty failure. Upon closer examination this effect was confined to parity 8, and was due to the fact that all gilts from one of the three parity 8 sows in the experiment failed to reach puberty. Thus, puberty failure in this group was specific to the offspring of a single sow and is likely to be genetic in origin, or due to some other characteristic of that particular sow and her litter.

b) Birth weight and preweaning growth. A histogram surface plot of birth weights and preweaning growth rates for gilts in this experiment is illustrated in Figure 15. This plot indicates that most of the gilts ranged between 1 and 2 kg in birth weight and between 0.15 and 0.35 kg per day in preweaning growth rate. Analysis of age at puberty indicated significant effects of both birth weight and preweaning growth rate on age at puberty. A surface plot of the relationships (Figure 16) indicates that age at puberty is youngest for small piglets with rapid

preweaning growth. These results suggest that reducing age at puberty might be accomplished by avoiding large birth weight piglets and/or selecting gilts with the highest preweaning growth rates (Figure 17). Because the effects of birth weight and preweaning growth rate on age at puberty are in opposite directions, weaning weights cannot be used effectively for selection of animals with the potential for reduced age at puberty (Figure 18). Both birth weights and preweaning growth rates were also positively associated with gilt growth rates ($P < 0.01$). Figure 19 indicates a surface plot of predicted body weights at 200 days of age for piglets with different birth weights and preweaning growth rates. Day 200 would be predicted to be around the time gilts would normally be mated to enter the breeding herd, given an average age of puberty of 190 days. The surface plot demonstrates that large birth weight, high growth rate pigs would exceed 160 kg at the time of breeding, providing another reason to avoid high birth weight gilts for selection into the breeding herd. No effect of either birth weight or preweaning growth rate were found for reproductive tract measures or ovulation rate.

c) Immunocrit effects. There was no relationship between the immunocrit and age at puberty. However, there was a significant relationship between puberty failure and immunocrit (Figure 20), piglets with a low immunocrit had an increased rate of puberty failure. Analysis of gilt weights, loin eye area and back fat measured from day 100 to day 240 of age indicated that weights and back fat were significantly reduced in low immunocrit gilts, while loin eye area was not related to the immunocrit (Figures 21, 22). Turning to uterine tract measurements at slaughter, no relationships between the immunocrit and ovarian measures or ovulation rates were found. Figure 23 illustrates the effect of the day of the estrous cycle on uterine length, and after adjusting uterine length data for day of the estrous cycle, there was a significant positive relationship between the immunocrit and total uterine length. Uterine length increased by 30 cm over the range of immunocrit measures observed (Figure 24).

d) Number weaned. There was a trend ($P = 0.09$) for a negative relationship between the number weaned and age at puberty (data not shown). This possible relationship is no doubt due to the effect of preweaning growth rate on age at puberty. No relationships were found for the incidence of puberty failure, ovulation rate, or any of the reproductive tract measures.

Growth traits and puberty failure. Loin eye area growth trajectories over time did not differ between gilts that reached puberty and those that did not. By contrast, body weight growth trajectories differed between gilts that reached puberty and those that failed to reach puberty, but the slopes of weight changes over time were not different between puberty categories. Thus, gilts that reached puberty were 3 kg heavier ($P < 0.01$), but grew in parallel with those that failed to reach puberty. Turning to back fat, the quadratic slope of changes in back fat

over time differed ($P < 0.01$) between gilts that reached puberty and those that did not (Figure 25). Examination of the relationships suggested that back fat accretion was slower over time in gilts that experienced puberty failure compared to those that did not.

Discussion:

Growth, body composition and feed intake traits. In contrast to our hypothesis, the imbalance of lysine and ME in the diets did not alter growth and/or body composition of gilts in this study except for back fat thickness which was slightly greater for gilts fed a HME diet. Because the difference between the treatment groups is so small, the biological meaning is likely irrelevant. Studies reported that a deficiency in the level of essential amino acids in the diet, from an optimum level for growth, is associated with a decrease in growth rate and an increase in body fatness (Noblet and Henry, 1977; Russell *et al.*, 1983; Sørensen *et al.*, 1993; Main *et al.*, 2008; Cia *et al.*, 2010). However, in these studies the percentage of lysine in the diet was lower, animals were younger and/or BW was lower and animals did not have *ad libitum* access to feed in comparison to the present study. Furthermore, the lack of differences among dietary treatments for the different growth and body composition traits in this study can be explained by changes in gilt feed intake in response to the various diets. For instance, gilts fed the low ME diets had a greater feed intake. Energy concentration is the primary dietary factor affecting voluntary feed intake (Henry 1985). It has been reported that a decrease in energy content in the diet is associated with a compensatory increase in feed intake (Tokach *et al.* 2000), but that the level of energy intake is slightly lower to that of pigs fed with a higher energy diet (Henry and Rérat, 1972) which is in agreement with our results. Henry (1985) stated that the lower energy intake in spite of the higher feed intake in low energy diets may be explained by a limitation of gastrointestinal capacity before energy demand is met; a point at which diet bulkiness overrides compensation for energy content.

It has also been reported that the pig is able to modify its feed intake according to its specific requirement for amino acids (Henry, 1985); however our results indicate that lysine content in the diet did not influence feed intake. A similar result was reported by Loughmiller *et al.* (1998) that daily feed intake was not affected by lysine content in the diet. Although gilts fed the high lysine diet had a higher total lysine and average daily lysine intake, the latter was similar to results reported elsewhere for the optimal lysine intake irrespective of dietary treatments. Optimal daily lysine intake reported in the literature range from 11.8 to 26.5 g/d for pigs from 46 to 136 kg of BW (Campell *et al.*, 1984; Rao and McCracken, 1990;Kerr *et al.*, 1993; Sørensen *et al.*, 1993; Friesen *et al.*, 1995; Hahn *et al.*, 1995). In the present study, gilts consumed, on average 26.9 g/d, which is in the upper range of results reported in the literature. Therefore, lysine requirements were met or exceeded irrespective of the lysine content in the diet. Friesen *et al.* (1994a) suggested that total lysine intakes greater than 22 g/d do not improve

feed efficiency. Just (1984) also reported that an excess in amino acid intake does not negatively affect feed efficiency in grow-finisher pigs. Additionally, Friesen *et al.* (1994) indicated that in pigs over 100kg of BW, response to an increase in lysine intake is diminished. This could also explain the lack of lysine effect on growth and body composition as the gilts in this study reached such weight less than 60 days after the study started.

Feed efficiency traits. Although feed intake per kg of BW gain was greater in gilts fed low energy diets, it does not necessarily mean that those gilts were less efficient. Caloric efficiency was similar among dietary treatments. Same daily calories were consumed and the same amount of calories was used to deposit 1 kg of BW irrespective of dietary treatment. Indeed, there was no difference in ADG among treatments. On the contrary, there was a difference in lysine utilization among treatments. When lysine effect was examined, gilts fed the low lysine diet consumed less grams of lysine per kg of BW gain. This is likely related to feed intake per kg of BW, as the gilts eat the same amount of feed per kg of BW gain but the amount of lysine present in the feed was different. A similar result was observed when examining ME effect on lysine intake per kg of BW gain as gilts fed the low ME diet consumed more grams of lysine to deposit a kg of BW and also had a greater feed intake compared with the gilts feed the medium and high ME. Nonetheless, it is important to note that lysine intake per kg of BW gain in this study was considerably higher than the requirements reported by other studies of 20g/kg of BW gain (Srichana *et al.*, 2004; De la Llata, 2007; Shelton *et al.*, 2009). Further research is necessary regarding amino acid needs and amino acid efficiency in finisher gilts with the potential to reach heavy body weights as studies are limited regarding this topic.

Removals. There was no difference in the number of removed gilts or in the reason for removal between treatments. However, reasons for removal in this study agree with those reported by other studies for sows and gilts where leg problems was one of the main reasons for removal (D'Allaire *et al.*, 1987; Boyle *et al.*, 1998; Engblom *et al.*, 2007). Rapid growth and heavy weight are risk factors for developing leg problems in pigs (Nakano *et al.*, 1987).

Reproductive traits. There was no difference in age at puberty among dietary treatments. A number of factors such as age, BW, backfat thickness and boar exposure affect the onset of puberty in the gilt. Kirkwood and Aherne (1985) suggested that gilts need a minimum BW and a minimum level of backfat to attain puberty and the close proximity in backfat and BW between treatments could partly explain the lack of differences in age at puberty in this study.

Studies about the effect of different lysine and ME levels in the diet on age at puberty are scarce; in fact, most of the studies focus on different dietary regimes (i.e. *ad libitum* vs. restricted feeding) and their effects on reproductive performance and sow longevity. However, Friend (1973) reported that gilts fed a low lysine level in the diet reached puberty later than gilts fed high lysine diets which is contrary to our results. The different results are most likely due to the lower lysine content in the diet (0.49%) used in that study compared to this one (0.8 and 1%; Table 1). Our results are in agreement with those reported by Maricle *et al.* (2006) who fed gilts using a three-phase feeding regime with different levels of lysine per phase with either *ad libitum* or restricted feeding. The authors reported that feeding regime did not affect age at puberty. A similar result was reported by Klindt *et al.* (1999) when gilts were fed diets with different energy content with either *ad libitum* or restricted feeding. Patterson *et al.* (2002) did not find an effect of dietary regime on age at puberty when gilts were fed *ad libitum* with two different diets that either maximized lean growth potential or produced lower lean growth but similar fat growth to the first diet. On the contrary, Herrmann *et al.* (1979) and Klindt *et al.* (2001) reported that gilts that were severely feed restricted during the growing period and then fed *ad libitum* showed estrous earlier than gilts with higher energy intake. These previous reports suggest that in order to achieve differences in age at puberty, restricted feed intake during the growing period might be more successful.

Approximately 6% of gilts did not exhibit standing estrous, which agrees with the results of Ehnvall *et al.* (1981); but only 4% of gilts had not attained puberty when evaluated at slaughter. At slaughter, the absence of *corpora lutea* or *corpora albicantia* was used to confirm that gilts did not reach puberty. The remainder of gilts with no standing estrus was assumed to be behaviorally anestrous (cycling but no estrous behavior). The ability to distinguish between the two is an advantage of the experimental design used in this study, because the mechanisms for behavioral anestrous and puberty failure are likely to be different. Supporting this concept, sixty-seven percent of pre-pubertal gilts at slaughter were fed diets low in lysine, thus low protein in the diet was associated with puberty failure even though low protein did not affect the incidence of behavioral anestrous, and also did not affect growth rate or lean deposition. As previously mentioned, it has been reported that low lysine in the diet delays puberty onset but we also did not find a difference in age at puberty between lysine levels. The delay in puberty onset in this study was likely related to other factors.

There was no difference between dietary treatment for ovulation rate, uterus length and ovary length and width. Ovulation rate is a function of age and the number of estrous cycles rather than a direct function of body condition (Aherne *et al.*, 1991; Gaughan *et al.*, 1997; Rillo *et al.*, 2005). Nonetheless, it was reported that increasing energy intake for pre-pubertal gilts increases ovulation rate (den Hartog and van Kempen 1980; Kirkwood and Aherne, 1985; Beltranena *et al.*, 1991). In the present study, gilts had similar energy intake, and

similar number of estrous cycles (i.e. on average 3 estrous cycles at the time of slaughter; data not show) irrespective of dietary treatment which could explain the lack of differences.

Carcass traits. Warm and chilled carcass weight, FFL, dressing percentage and fat thickness were similar regardless of lysine level in the diet which is in agreement with results reported by Friesen *et al.* (1995) but contrary to the results reported by Ruusunen *et al.* (2007) where pigs fed low lysine diets had a lower carcass weight. Even though the diets used in this study were formulated to provide a control and a low lysine level, the fact that dietary lysine content did not affect growth or composition traits suggests that the low level was not low enough to compromise growth, and explains the different results between studies.

By contrast, energy level in the diet did have an effect on carcass traits; gilts fed the high energy diets had greater carcass weight, FFL and dressing percentage compared with gilts fed diets with a low or medium energy level. This was an unexpected result as body weight and FFL did not differ during the trial. Although organ weights were not recorded for this study, it is possible that the higher carcass weight and FFL for gilts fed the high energy diet are related to organ size and organ weight. In this study, gilts fed low energy diets also had a considerably higher feed intake and previous studies have found that animals with higher feed intake have larger and heavier organs compared with animals that consumed less feed (Burrin *et al.,* 1992; Thomke *et al.,* 1995; Fisher *et al.,* 2001; Ruusunen *et al*., 2007). This in turn would reduce carcass weight and dressing percentage.

Litter of origin traits. Collection of litter of origin traits provided an opportunity to examine relationships with growth and reproductive traits during later life. Significant effects were found for birth weight, preweaning growth rate and immunocrit, but not for parity or number of piglets weaned. Thus, there appears to be an opportunity to improve gilt reproductive development by manipulating these parameters during the preweaning period.

a) Parity Parity did not appear to have much effect on adult reproductive traits measured in this experiment. Neither age at puberty nor any of the reproductive tract measures were influenced by parity of the dam. Piglet birth weights, immunocrit and preweaning growth rates were affected by parity. Maximum birth weight occurred in third and fourth parity gilts, while immunocrit and preweaning growth rates were optimal in parities 3 through 7. The lack of effect of parity on age at puberty is consistent with our results indicating that birth weight and preweaning growth rate had opposite effects on age at puberty. Both birth weights and preweaning growth were maximal in parity 3 and 4, so their opposite effects on age at puberty likely cancelled each other out. Despite the results that uterine length is affected by the immunocrit, the differences among parities in the immunocrit were

likely to be insufficient to result in detectable changes in uterine length. Thus, there appears to be no reason to select gilts for the breeding herd based solely on the parity of the dam, for the range of parities examined in this experiment (parities 2 through 8).

b) *Birth weights and preweaning growth rate.* Large birth weights and poor preweaning growth were both associated with greater age at puberty. Birth weights are largely unaffected by the genetics of the piglet and are more influenced by the genetics and/or prenatal intrauterine environment of the dam (Cassady *et al*., 2002). Litter size is a major factor affecting birth weight as larger piglets at birth are associated with small litters. Litter size is also a key factor affecting preweaning growth rate, piglets in larger litters grow more slowly due to increased competition during lactation (Beaulieu *et al*., 2010; Douglas *et al*., 2013). Thus the effect of litter size on birth weight and preweaning growth would provide opposing influences on age at puberty, reducing the predictive utility of weaning weights. Interestingly, the negative association between preweaning growth rate and age at puberty is consistent with the results of Flowers (2009) who reported that gilts raised in small litters, which would likely grow faster, had reduced age at puberty. However, in the Flowers experiment, there was no assessment of the effects of either birth weights or preweaning growth rate, so these relationships cannot be directly compared between experiments. These results suggest a strategy for reducing age at puberty based on birth weights and preweaning growth rate. Results indicate that age at puberty would be reduced by avoiding gilts weighing greater than 2 kg at birth as replacement gilts for the breeding herd. In addition, management strategies that maximize preweaning growth rate of gilts would also result in a beneficial reduction in age at puberty. Strategies for gilts destined for the breeding herd might include fostering gilts to third through seventh parity gilts (optimal preweaning growth rates), and/or reducing the number of nursing piglets in litters by fostering off boars and any gilts greater than 2 kg at birth. In addition, any strategy that improves sow milk production would likely result in reduced age at puberty in the offspring.

c) *Immunocrit* Results indicated significant immunocrit effects on puberty failure, growth rate, back fat accretion, and uterine length. The immunocrit is a measure of serum immunoglobulin in piglet blood (Vallet *et al*., 2013). Because piglets are born with essentially no immunoglobulin, and receive immunoglobulin from colostrum within the first 24 h after birth, the immunocrit is an indirect measure of the amount of colostrum received by the piglet from the sow (Vallet *et al*., 2013). The effect of the immunocrit on uterine length is consistent with previous reports that colostrum is required for appropriate neonatal uterine development (Bartol *et al*., 2013). Uterine gland development in piglets that do not receive colostrum is delayed, and relaxin, a component of colostrum, partially restores aspects of development. Relaxin is known to be a uterine growth factor (Hall *et al*., 1990), thus our results are consistent with the concept that colostrum stimulates uterine growth during

the neonatal period, at least partially through relaxin or other bioactive compounds in colostrum. Uterine length has been proposed to effect uterine capacity (Chen and Dziuk, 1993). Previous reports indicate that each surviving conceptus at day 50 of gestation was associated with 36 cm of initial uterine length (Wu *et al*., 1989). Our results indicated that uterine length increases by about 30 cm over the range of immunocrits found in this experiment, suggesting that colostrum availability may affect litter size by as much as a piglet per litter through its effects on uterine length. This is consistent with previous results indicating that adult litter size is positively associated with day 1 immunocrit values (Bartol *et al*., 2013). Growth rates, back fat and puberty failure were also affected by the immunocrit, suggesting that colostrum may have a broad spectrum of effects on the piglet that carry over into adulthood. Colostrum is known to promote maturation of the lining of the gut (Thymann *et al*., 2006; Cabrera *et al*., 2013), which likely explains the relationships between the immunocrit and growth rate and back fat. It is possible that bioactive factors in colostrum may also influence maturation of brain regions necessary for puberty onset, explaining the effect of the immunocrit on puberty failure. Taken together, these results indicate that a focus on colostrum management for gilts destined for the breeding herd would provide improvements in a variety of factors that are likely to enhance sow lifetime productivity. In addition, the immunocrit is likely to be useful in assessing whether management strategies designed to improve colostrum intake by piglets are effective (Vallet, 2013).

d) *Number weaned.* There were few effects of the number of piglets weaned on adult reproductive traits, despite clear effects of preweaning growth rate on age at puberty, which is in contrast to the previous results of Flowers (2009). In this experiment crossfostering was used to minimize the variability in the number of piglets on a lactating sow, so it is possible that our failure to detect the effects of the number of piglets weaned was due to a reduction in the variability of this trait. Flowers (2009) saw differences between litters nursing litters of < 7 versus those nursing >10, essentially forcing variability in the number of piglets weaned. Because our experimental protocol was to crossfoster such that piglets per sows fell in the range of 10 to 13, the necessary variability in the number of piglets weaned to demonstrate the effects observed by Flowers were unlikely to be present. Nevertheless, results indicating that preweaning growth rate influenced age at puberty does suggest that manipulating the number of piglets per sow, or any other strategy that optimizes sow lactation and/or piglet growth rate during the preweaning period, will likely improve gilt reproductive competence in adulthood.

In summary, manipulation of the metabolizable energy or lysine level in the diet had very limited effects on gilt growth and development, because gilts adjusted their feed intake according to the metabolizable energy in the diets. The lack of effect of different levels of lysine on growth, back fat and loin eye area suggested that both dietary levels used in the experiment were above requirements. The only exception to this was that lower dietary

lysine treatment was associated with a greater incidence of puberty failure, however the incidence of puberty failure in gilts fed the low lysine diet was still relatively low. Turning to litter of origin effects, high birth weights and low preweaning growth rates were associated with a greater age at puberty, suggesting that these might be manipulated to result in an earlier age at puberty. Immunocrits were positively associated with growth rates and back fat accretion and negatively associated with the rate of puberty failure. These results suggest that efforts to improve the amount and quality of colostrum available to piglets would be beneficial to the reproductive competence of adult gilts.

References:

Aherne, F. X., Williams, I. H., and Head, R. H. 1991. Nutrition-reproduction interactions in swine. In: Farrell, D. J. (Ed.) Recent Advances in Animal Nutrition in Australia. University of New England, Armidale, NSW, Australia.

Baidoo, S. K. 2001. Sow nutrition for productivity and longevity: Any new ideas? In: Proceedings of the Allen D Leman Swine Conference. p. 223 – 226

Bartol F. F. , Wiley, A. A., Miller, D. J., Silva, A. J., Roberts, K. E., Davolt, M. L., Chen, J. C., Frankshun, A. L., Camp, M. E., Rahman, K. M., Vallet, J. L., and Bagnell, C. A. 2013. Lactation Biology Symposium: lactocrine signaling and developmental programming. *J Anim Sci.* 91:696-705.

Beaulieu, A. D., Aalhus, J. L., Williams, N. H., and Patience, J. F. 2010. Impact of piglet birth weight, birth order, and litter size on subsequent growth performance, carcass quality, muscle composition, and eating quality of pork. *J Anim Sci.* 88:2767-2778

Beltranena, E., Aherne, F. X., Foxcroft, G. R., and Kirkwood, R. N. 1991 Effects of pre- and postpubertal feeding on production traits at first and second estrous in gilts *J. Anim. Sci.* 69: 886-893

Boyle, L., Leonard, F.C., Lynch, B., and Brophy, P. 1998. Sow culling patterns on sow welfare. *Ir. Vet. J.* 51: 354-357

Burrin, D. G., Britton, R. A., Ferrell, C. L., and Bauer, M. L. 1992. Level of nutrition and visceral organ protein synthetic capacity and nucleic acid content in sheep. *J. Anim. Sci.* 70: 1137-1145

Cabrera, R., Lin, X., Ashwell, M., Moeser, A., and Odle, J. 2013. Early postnatal kinetics of colostral immunoglobulin G absorption in fed and fasted piglets and developmental expression of the intestinal immunoglobulin G receptor. *J Anim Sci.* 91:211-218

Campbell, R. G., Taverner, M. R., and Curic, D. M. 1988. The effects of sex and live weight on the growing pig's response to dietary protein. *Anim. Prod.* 46:123-130

Cassady, J.P., Young, L.D., and Leymaster, K.A. 2002. Heterosis and recombination effects on pig growth and carcass traits. *J Anim Sci.* 80:2286-2302

Chapman, J. D., Thompson, L. H., Gaskins, C. T., and Tribble, L. F. 1978. Relationship of age at first farrowing and size of first litter to subsequent reproductive performance in sows. *J. Anim. Sci.* 47: 780-787

Chen, Z. Y, and Dziuk, P. J. 1993. Influence of initial length of uterus per embryo and gestation stage on prenatal survival, development, and sex ratio in the pig. *J Anim Sci.* 71:1895-1901.

Cia, M. C., Edwards, S. A., Glasgow, V. L., Shanks, M., and Fraser, H. 2010. Modification of body composition by altering the dietary lysine to energy ratio during rearing and the effect on reproductive performance of gilts. *Anim. Sci.* 66: 457-463

D'Allaire, S., Stein, T.E., and Leman, A.D. 1987. Culling patterns in selected Minnesota swine breeding herds. *Can. J. Vet. Res.* 51: 506-512

De Greef, K. H. 1992. Prediction of production. Nutrition induced tissue partitioning in growing pigs. Ph.D. Thesis. Agricultural University, Wageningen, The Netherlands

De La Llata, M., Dritz, S. S., Tokach, M. D., Goodband, R. D., and Nelssen, J. L. 2007. Effects of increasing lysine:calorie ratio and added fat for growing-finishing pigs reared in a commercial environment: I. growth performance and carcass characteristics. *Prof. Anim. Sci.* 23: 417-428

den Hartog, L. A., and van Kempen, G.L.M. 1980. Relation between nutrition and fertility in pigs. *Neth. J. Agric. Sci*. 28: 211-227

Douglas, S. L., Edwards, S. A., Sutcliffe, E., Knap, P. W., and Kyriazakis, I. 2013. Identification of risk factors associated with poor lifetime growth performance in pigs. *J Anim Sci.* 91:4123-4132

Ehnvall, R., Blomquist, A., Einarsson, S., and Karlberg, K. 1981. Culling of gilts with special reference reproductive failure. *Nord. Med*. 33: 167-171

Engblom, L., Lundeheim, N., Dalin, A.M., and Andersson, K. 2007. Sow removal in Swedish commercial herds. *Livest. Sci.* 106: 76-86

Fischer, R., Miller, P. S, and Lewis, A. 2001.The Effect of Compensatory Growth on Organ Weights and Carcass Composition in Growing Gilts. Nebraska Swine Reports. Paper 97

Flowers, W.F. 2009. Effect of Neonatal Litter Size and Early Puberty Stimulation on Sow Longevity and Reproductive Performance. National Pork Board Research Report http://www.pork.org/FileLibrary/ResearchDocuments/05-082-FLOWERS-NCSU.pdf

Friend, D. W. 1973. Influence of dietary amino acids on the age at puberty of Yorkshire gilts. *J. Anim. Sci.* 37: 701-707

Friesen, K G, Nelssen, J L., Unruh, J A., Goodband, R D., and Tokach, M D. 1994. Effects of the interrelationship between genotype, sex, and dietary lysine on growth performance and carcass composition in finishing pigs fed to either 104 or 127 kilograms. *J. Anim. Sci*. 72: 946-54

Friesen, K. G., Nelssen, J. L., Goodband, R. D., Tokach, M. D., Unruh, J. A., Kropf, D. H., and Kerr, B. J. 1995. The effect of dietary lysine on growth, carcass composition, and lipid metabolism in high lean growth gilts fed from 72 to 136 kilograms. *J. Anim. Sci.* 73: 3392-3401.

Gaughan, J. B., Cameron, R. D., Dryden, G. M., and Young, B. A.1997. Effect of body composition at selection on reproductive development in large white gilts *J. Anim. Sci.* 75: 1764-1772

Hahn, J. D., Biehl, R. R., and Baker, D. H. 1995. Ideal digestible lysine level for early- and late-finishing swine. *J. Anim. Sci.* 73: 773-784

Hall, J. A, Cantley, T. C, Day, B. N, and Anthony, R. V. 1990. Uterotropic actions of relaxin in prepubertal gilts. *Biol Reprod*. 42:769-774

Henry, Y., and Rérat, A., 1972. La relation azote-energie dans l'alimentation de port en croissance. Ninth Cong. Int. Nutrition, Mexico

Henry, Y. 1985. Dietary factors involved in feed intake regulation in growing pigs: a review. *Livest. Prod. Sci.*12: 339-354

Herrmann, U., Richter, K., and Hoffmann, S. 1979. Untersuchungen zer futterung weiblicher jungschweine - einfu der energieversorgung und der wachstumsintensitat auf den pubertatseintritt und die spatere fruchtbarkeitsleistung. *Tierzucht* 33: 132-135

Just, A. 1984. Nutritional manipulation and interpretation of body compositional differences in growing swine. *J. Anim. Sci.* 58: 740-752

Kerr, B. J. 1993. Optimizing lean Tissue deposition in swine. BioKyowa Tech. Rev. Vol. 6. Nutri-Quest, Inc., Chesterfield, MO

Kirkwood, R.N., and Aherne, F.X. 1985. Energy intake, body composition and reproductive performance of the gilt. *J. anim. Sci*. 60: 1518-1529

Kitt, S. J. 2010. Feeding the high performing sow herd. In: Proceeding of the Allen D. Leman Swine Conference. 37: 141-144

Klindt, J., Yen, J T., and Christenson, R. K. 1999. Effect of prepubertal feeding regimen on reproductive development of gilts *J. Anim. Sci.* 77:1968-1976

Klindt, J., Yen, J T., and Christenson, R. K. 2001. Level of dietary energy during prepubertal growth and reproductive development of gilts. *J. Anim. Sci.* 79: 2513-2523

Le Cozler, Y., Dargon, J., Lindberg, J. E., Aumaître, A, and Dourmad, J. Y., 1998. Effect of age at first farrowing and herd management on long-term productivity of sows. *Livest. Prod. Sci.* 53: 135-142

Loughmiller, J. A., Nelssen, J. L., Goodband, R. D., Tokach, M. D., Titgemeyer, E. C. and Kim, I. H. 1998. Influence of dietary lysine on growth performance and carcass characteristics of late-finishing gilts. *J. Anim. Sci.* 76: 1075-1080

Main, D. C. J., Clegg, J., Spatz, A., Green, L.E. 2000. Repeatability of a lameness scoring system for finishing pigs. *Vet. Rec*. 147: 574-576

Main, R. G., Dritz, S. S., Tokach, M. D., Goodband, R. D., and Nelssen, J. L. 2008. Determining an optimum lysine:calorie ratio for barrows and gilts in a commercial finishing facility. *J. Anim. Sci.* 86: 2190-2207

Maricle, B., Anderson, M., Perkins, J., McClure, D., Albrecht, L., Moreno-Salgado, J. R., Miller, P. S, Johnson, R. K. 2006. Effects of nutrition during gilt development on lifetime productivity of sows of two prolific maternal lines: Growth and puberty characteristics of rep. 1 gilts. Nebraska Swine Reports. Paper 216

Nakano, T., Brennan, J.J., Aherne, F.X., 1987. Leg weakness and osteochondrosis in swine: A review. *Can. J. Anim. Sci.* 67: 883-901

National Pork Board. 2000. Pork composition and quality assessment procedures. 42 p.

Nikkila MT, Stalder KJ, Mote BE, Rothschild MF, Gunsett FC, Johnson AK, Karriker LA, Boggess MV, Serenius TV. 2013. Genetic parameters for growth, body composition and structural soundness traits in comercial gilts. J. Anim. Sci. 91:2013-2046.

Noblet, J. and Henry, Y. 1977. Consequences d'une reduction du taux de matieres azotees sur le niveau de consommation et les performances de croissance chez le porc selon l'equilibre en acides amines et la concentration en energie d regime. *Ann. Zootech*. 26:379-394

Patterson, J. L., Ball, R. O., Willis, H. J., Aherne, F. X., and Foxcroft, G. R. 2002 The effect of lean growth rate on puberty attainment in gilts. *J. Anim. Sci.* 80: 1299-1310

Porter, P., and Hill, I. R., 1970. Serological changes in immunoglobulins IgG, IgA, and IgM and Escherichia coli antibodies in the young pig. *Immunology* 18, 565–572.

Rao, D. S., and McCracken, K. J. 1992. Energy:protein interactions in growing boars of high genetic potential for lean growth. 1. Effects on growth, carcass characteristics and organ weights. *Anim. Prod.* 54: 75-82

Rillo, S. M., De Alba, C., Falceto, M.V., and Peralta y Bustamante, W. 2005. Efecto del aparato genital de la primeriza sobre la productividad de la cerda. Available online at http://albeitar.portalveterinaria.com/noticia/3511/ARTICULOS-PORCINO-ARCHIVO/Efecto-del-aparato-genital-de-la-primeriza-sobre-la-productividad-de-la-cerda.html. Acceded on 5 May 2014.

Rozeboom, D.W. 1999. Feeding programs for gilt development and longevity. In: Proceedings of the Minnesota Nutrition Conference 60: 151-170

Russell, L. E., Cromwell, G. L., and Stahly, T. S. 1983. Tryptophan, Threonine, Isoleucine and Methionine Supplementation of a 12% Protein, Lysine-Supplemented, Corn-Soybean Meal Diet for Growing Pigs. *J. Anim. Sci.* 56: 1115-1123

Ruusunen, M.; Partanen, K.; Pösö, R., and Puolanne, E. 2007. The effect of dietary protein supply on carcass composition, size of organs, muscle properties and meat quality of pigs *Livest. Sci.* 107: 170-181

Saito, H., Sasaki, Y., and Koketsu, Y., 2011. Associations between age of gilts at first mating and lifetime performance or culling risk in commercial herds. *J. Vet. Med. Sci.* 73: 555–559

Shelton, N. W., Tokach, M. D., Dritz, S. S., Goodband, R. D., Nelssen, J. L., and DeRouchey, J. M. 2009. Effects of increasing standard ileal digestible (SID) lysine to metabolizable energy ratios on performance of 55 to 80 kg gilts in a commercial finishing environment. *J. Anim. Sci.* 87 (e-suppl. 3): 86(Abstr.)

Sørensen, M. T., Jorgensen, B., and Danielsen, V. 1993. Different feeding intensity of young gilts: effect on growth, milk yield, reproduction, leg soundness, and longevity. Report No. 14/1993, National Institute of Animal Science, Denmark. 20 p.

Srichana, P., Gaines, A. M., Ratliff, B. W., Allee, G. L., and Usry, J. L. 2004. Evaluation of the true ileal digestible (TID) lysine requirement for early finishing gilts. *J. Anim. Sci.* 82 (Suppl. 2): 66 (Abstr.).

Stalder, K., Morrison, B., and Baas, T., 2007. Non-genetic factors influencing sow longevity. Available at http://www.pork.org/filelibrary/Factsheets/ PIGFactsheets/NEWfactSheets/08-04-02g.pdf. Accessed 6 May 2014

Thomke, S., Alaviuhkola, T., Madsen, A., Sundstel, F., Mortensen, H. P., Vangen, O. and Andersson, K. 1995. Dietary energy and protein for growing pigs 2. Protein and fat accretion and organ weights of animals slaughtered at 20, 50, 80 and 110 kg Live Weight. *Acta Agr. Scand. A-An.* 45: 54-63

Thymann, T., Burrin, D. G., Tappenden, K. A., Bjornvad, C. R., Jensen, S. K., and Sangild, P. T. 2006. Formula-feeding reduces lactose digestive capacity in neonatal pigs. *Br J Nutr.* 95:1075-1081

Tokach, M.,Webster, M., and James, B. 2000. The role of nutrition and the feeding program on gilt longevity. In: proceedings of the Allen D. Leman Swine Conference p 132-138

Vallet, J. L. 2013. Use of the immunocrit to monitor a split-suckle program in commercial production. *Reproduction Suppl.* 68:225-226.

Vallet, J. L., Miles, J. R., and Rempel, L. A. 2013. A simple novel measure of passive transfer of maternal immunoglobulin is predictive of preweaning mortality in piglets. *Vet J.* 195:91-97

Voermans, J. A. M., Verdoes, N. and den Hartog, L. A. 1994. Environmental impact of pig farming. *Pig News and Information* 15: 51N-54N

Wu, M. C., Chen, Z. Y., Jarrell, V. L., and Dziuk, P. J. Effect of initial length of uterus per embryo on fetal survival and development in the pig. *J Anim Sci.* 67:1767-1772.

Table 1. Composition of experimental grower diets (kg/ton) fed to maternal line[1] gilts to evaluate 2 lysine levels and 3 metabolizable energy (ME) levels and their effects on growth, body composition and puberty attainment. Percentages are based on levels of ME and lysine in diets from an informal survey of swine producers.

Item	**85% lysine × 85% ME**	**85% lysine × 100% ME**	**85% lysine × 115% ME**	**100%lysine × 85% ME**	**100%lysine × 100% ME**	**100% lysine × 115% ME**
Corn	354.3	513.4	550.6	344.2	512.1	543.8
Soy bean mean (47 % CP)	175.5	226.4	239.1	186.4	226.4	239.1
Wheat middlings	272.7	0.0	0.0	272.7	0.0	0.0
DDGS -(8% fat)	68.6	136.4	30.5	66.4	136.4	35.5
AV fat blend	4.6	6.8	61.4	4.6	6.4	61.4
Limestone	11.5	8.8	6.8	11.0	8.8	6.9
Dical (18.5% Knox)	12.3	9.2	12.2	13.1	9.2	12.1
L-Lysine (98%)	1.2	0.3	0.5	2.7	2.2	2.3
Salt	4.6	4.6	4.6	4.6	4.6	4.6
MHA 84% dry	0.8	0.5	0.8	0.7	0.5	0.8
L-Threonine	0.6	0.3	0.4	0.5	0.3	0.4
Sow Trace Mineral Premix	1.6	1.6	1.6	1.6	1.6	1.6
Sow Vitamin Premix	0.5	0.5	0.5	0.5	0.5	0.5
Stafac 20	0.2	0.2	0.2	0.2	0.2	0.2
Ronozyme P CT 10,000	0.2	0.2	0.2	0.2	0.2	0.2
			Chemical composition			
ME, Swine (Mcal of ME/kg)	2.9	3.2	3.6	2.9	3.2	3.6
Crude fat, %	3.9	4.3	9.5	3.8	4.3	9.5
Crude Protein, %	19.0	20.1	17.8	19.5	20.2	18.1
dLysine, %	0.8	0.8	0.8	1.0	1.0	1.0
dLys:ME ratio	1.3	1.2	1.1	1.6	1.4	1.3
Calcium, total (%)	1.0	0.8	0.8	1.0	0.8	0.8
Phosphorus, total (%)	0.7	0.6	0.6	0.7	0.6	0.6
Phosphorus, digestible (%)	0.5	0.4	0.4	0.5	0.4	0.4
Ca:P	1.4	1.4	1.4	1.4	1.4	1.4
Ca:aP	1.9	1.9	1.9	1.9	1.9	1.9

[1] Maternal line

Table 2. Composition of experimental finisher diets (kg/ton) fed to maternal line[1] gilts to evaluate 2 lysine levels and 3 metabolizable energy (ME) levels and their effects on growth, body composition and puberty attainment

Item	**85% lysine × 85% ME**	**85% lysine × 100% ME**	**85% lysine × 115% ME**	**100% lysine × 85% ME**	**100% lysine × 100% ME**	**100% lysine × 115% ME**
Corn	393.6	340.2	615.8	391.3	339.3	610.3
Soy bean mean (47 % CP)	121.8	129.1	187.7	121.8	129.1	187.7
Wheat middlings	272.7	232.3	0.0	272.7	232.3	0.0
DDGS -(8% fat)	82.7	136.4	16.4	83.2	136.4	20.5
AV fat blend	4.6	45.5	61.4	4.6	45.0	61.4
Limestone	10.8	11.6	6.6	9.9	11.6	6.6
Dical (18.5% Knox)	14.0	5.5	13.3	15.4	5.5	13.2
L-Lysine (98%)	1.3	1.1	0.6	2.7	2.5	2.0
Salt	4.6	4.6	4.6	4.6	4.6	4.6
MHA 84% dry	0.2	0.2	0.2	0.2	0.2	0.2
L-Threonine	0.3	0.3	0.2	0.3	0.3	0.2
Sow Trace Mineral Premix	1.6	1.6	1.6	1.6	1.6	1.6
Sow Vitamin Premix	0.5	0.5	0.5	0.5	0.5	0.5
Stafac 20	0.2	0.2	0.2	0.2	0.2	0.2
Ronozyme P CT 10,000	0.2	0.2	0.2	0.2	0.2	0.2
			Chemical composition			
ME, Swine (Mcal/kg)	2.9	3.3	3.6	2.9	3.3	3.6
Crude fat, %	4.1	8.7	9.6	4.1	8.6	9.6
Crude Protein, %	17.0	17.8	15.3	17.1	18.0	15.5
dLyisne, %	0.7	0.7	0.7	0.8	0.8	0.8
dLys:ME ratio	1.1	1.0	0.9	1.3	1.2	1.1
Calcium, total (%)	1.0	0.8	0.8	1.0	0.8	0.8
Phosphorus, total (%)	0.7	0.6	0.6	0.8	0.6	0.6
Phosphorus, digestible (%)	0.6	0.4	0.4	0.6	0.4	0.4
Ca:P	1.4	1.4	1.4	1.3	1.4	1.4
Ca:aP	1.8	2.0	1.9	1.8	2.0	1.9

[1] Maternal line = Large White × Landrace

Table 3. Descriptive statistics for body weight, backfat thickness, loin area and fat free lean meat content of maternal line[1] gilts feed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction at 100 d of age

	Body weight (kg)				**Backfat thickness (cm)**				**Loin area (cm^2)**				**Fat free lean meat (kg)**			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Lysine																
85% lysine	55.0	7.0	35.5	75.5	0.9	0.2	0.5	1.5	19.5	2.9	11.5	26.8	21.4	2.8	13.6	29.8
100% lysine	55.6	7.1	34.1	76.8	0.9	0.2	0.4	1.5	19.5	2.9	11.3	27.3	21.5	2.7	12.8	30.0
ME																
85% ME	55.1	7.3	34.1	76.8	0.8	0.2	0.5	1.3	19.3	2.9	11.3	26.9	21.2	2.8	12.8	30.0
100% ME	55.2	7.2	36.4	75.9	0.9	0.2	0.4	1.3	19.6	2.9	12.3	27.3	21.5	2.8	14.4	29.8
115% ME	55.7	6.7	35.5	72.3	0.9	0.2	0.5	1.5	19.7	2.7	11.5	26.2	21.6	2.6	13.6	27.6
***Lysine* × ME**																
85% lys × 85% ME	56.0	7.0	37.7	76.8	0.8	0.2	0.5	1.2	19.3	19.3	3.0	12.2	21.3	2.8	14.4	30.0
85% lys × 100% ME	55.2	7.3	39.1	75.9	0.9	0.2	0.5	1.3	19.5	19.5	3.0	12.3	21.4	2.8	15.5	28.8
85% lys × 115% ME	55.5	6.9	35.5	71.4	0.9	0.2	0.6	1.5	19.8	19.8	2.7	11.5	21.7	2.6	13.6	27.6
100% lys × 85% ME	54.2	7.4	34.1	71.8	0.9	0.2	0.5	1.3	19.4	19.4	2.9	11.3	21.2	2.8	12.8	27.6
100% lys × 100% ME	55.2	7.0	36.4	75.5	0.9	0.2	0.4	1.3	19.7	19.7	2.9	12.3	21.6	2.8	14.4	29.8
100% lys × 115% ME	55.8	6.6	40.0	72.3	0.9	0.2	0.5	1.5	19.6	19.6	2.8	11.8	21.6	2.7	14.7	27.3

[1] Maternal line

Table 4. Number of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction in each score category for six feet and leg soundness traits at a130 d of age.

	Score								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Pasterns									
Front pastern	23	208	234	170	162	226	95	6	4
Rear Pastern	2	94	241	136	230	194	179	40	12
Foot position									
Front foot	0	6	111	411	451	140	7	0	2
Rear foot	0	1	54	574	467	28	2	2	0
Leg angulation									
Front leg	5	39	178	228	256	206	155	53	8
Rear leg	0	16	122	139	281	241	186	131	12
Foot size									
Front foot	0	4	99	268	417	300	34	4	2
Rear foot	4	8	100	349	493	163	10	1	0
Toe evenness									
Front toes	885	237	6	0	0	0	0	0	0
Rear toes	639	483	6	0	0	0	0	0	0
Locomotion	1029	77	20	2	0	0	-	-	-

[1] Maternal line = Large White × Landrace

Table 5. Descriptive statistics for body weight, back fat thickness, loin area and fat free lean meat content of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Body weight (kg)				**Backfat thickness (cm)**				**Loin area (cm^2)**				**Fat free lean meat (kg)**			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Lysine																
85% lysine	134.5	35.6	56.8	227.3	2.1	0.9	0.6	5.4	40.9	9.1	18.3	70.3	49.2	11.6	22.2	83.3
100% lysine	134.0	35.2	51.8	217.3	2.0	0.9	0.5	6.3	40.9	8.7	15.9	62.8	49.1	11.3	12.8	76.3
ME																
85% ME	134.3	35.6	56.8	216.1	2.0	0.9	0.6	5.2	40.8	9.0	18.3	67.2	49.2	11.5	22.3	77.3
100% ME	133.4	35.1	51.8	227.3	2.0	0.9	0.5	6.3	41.1	9.0	15.9	70.3	49.2	11.5	12.8	83.3
115% ME	135.1	8.4	57.3	213.6	2.2	0.9	0.6	5.7	40.9	8.7	18.6	67.3	49.1	11.3	22.2	75.3
***Lysine* × ME**																
85% lysine × 85% ME	134.5	35.7	56.8	216.1	1.9	0.9	0.6	5.1	40.7	9.2	18.3	67.2	49.2	11.7	22.3	77.3
85% lysine × 100% ME	133.5	35.2	60.5	227.3	2.1	0.6	0.7	4.9	41.1	9.3	20.6	70.3	49.3	11.6	23.2	83.3
85% lysine × 115% ME	135.5	36.0	57.3	213.6	2.2	0.9	0.6	5.4	40.9	8.9	18.6	67.3	49.2	11.4	22.2	75.3
100% lysine × 85% ME	134.0	35.4	59.1	212.3	2.0	0.9	0.6	5.2	40.8	8.8	20.5	61.9	49.2	11.4	24.9	74.6
100% lysine × 100% ME	133.3	34.9	51.8	217.3	2.0	0.8	0.5	6.3	41.1	8.7	15.9	62.8	49.1	11.4	12.8	76.3
100% lysine × 115% ME	134.6	35.3	63.2	211.4	2.1	1.0	0.7	5.7	40.8	8.5	21.0	61.4	48.9	11.1	25.3	73.8

[1] Maternal line = Large White × Landrace

Table 6. Least square means ± SEM for growth and body composition traits of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Body weight (kg)		**Backfat thickness (cm)**		**Loin area (cm^2)**		**Fat free lean meat (kg)**	
	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM
Lysine								
85% lysine	138.6	1.1	2.0	0.03	40.7	0.3	48.9	0.4
100% lysine	141.0	1.1	2.0	0.03	41.0	0.3	49.3	0.4
ME								
85% ME	139.0	1.1	1.9[a]	0.03	40.7	0.4	49.1	0.5
100% ME	140.4	1.1	2.0[a]	0.04	41.3	0.4	49.5	0.5
115% ME	140.0	1.2	2.2[b]	0.04	40.5	0.4	48.7	0.5
***Lysine* × ME**								
85% lysine × 85% ME	137.9	1.9	1.9	0.05	40.4	0.5	48.7	0.7
85% lysine × 100% ME	139.1	1.9	2.0	0.05	40.0	0.5	49.1	0.7
85% lysine × 115% ME	139.0	1.9	2.2	0.05	40.6	0.5	48.9	0.6
100% lysine × 85% ME	140.2	1.9	2.0	0.05	40.9	0.5	49.5	0.6
100% lysine × 100% ME	141.7	1.9	2.0	0.05	41.6	0.5	49.8	0.6
100% lysine × 115% ME	141.1	1.9	2.1	0.06	40.5	0.6	48.6	0.7
Measurement at 100d of age[2]	1.18(0.27)		0.002(0.001)		0.01(0.01)		0.18(0.11)	

[a, b] Significant difference within main effects; $P < 0.05$

[1] Maternal line = Large White × Landrace

[2]Results presented as regression coefficient and their associated standard error

Table 7. Least square means ± SEM for body composition, feed intake and feed efficiency traits of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 130 to 250 d of age

	130 d		160 d		190 d		220 d		250 d	
	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM
Body composition traits										
Body weight (kg)	85.2^{a}	0.9	113.5^{b}	0.9	142.9^{c}	0.9	167.7^{d}	0.9	189.8^{e}	0.9
Backfat thickness (cm)	1.1^{a}	0	1.5^{b}	0.02	1.9^{c}	0	2.6^{d}	0	3.1^{e}	0.03
Loin area (cm^2)	29.1^{a}	0.3	36.1^{b}	0.3	42.1^{c}	0.3	46.6^{d}	0.3	50.3^{e}	0.3
Fat free lean meat (kg)	32.9^{a}	0.4	42.4^{b}	0.3	51.3^{c}	0.4	57.2^{d}	0.4	61.7^{e}	0.3
Feed intake traits										
Feed intake (kg)	85.8^{a}	2.4	92.9^{b}	1.3	98.1^{c}	0.7	95.9^{b,c}	1.4	79.2^{a}	2.2
Lysine intake (kg)	0.8^{a,b,c}	0	0.8^{b}	0.01	0.08^{c}	0	0.7^{c}	0	0.6^{d}	0.01
ME intake (Mcal)	277.3^{a}	7.9	300.9^{b}	4.3	317.7^{c}	2.2	311.3^{b,c}	4.4	257.9^{a}	7.3
ADFI[2] (kg)	3.1^{a}	0.1	3.4^{b}	0.1	3.6^{c}	0	3.37^{a,b}	0.1	2.80^{d}	0.08
ADLI[3] (g)	28.8^{a,b,c}	0.7	29.3^{b}	0.4	28.3^{c}	0.2	26.5^{d}	0.4	21.8^{e}	0.6
ADMEI[4] (Mcal)	10.1^{a}	0.3	11.0^{b}	0.1	11.6^{c}	0.1	10.9^{a,b}	0.2^{d}	9.1^{a}	0.3
Feed efficiency traits										
ADG[5] (kg)	1.0^{a}	0	0.9^{b}	0.01	1.01^{a}	0	0.8^{c}	0	0.6^{d}	0.01
Feed intake per kg body weight gain (kg)	2.4^{a}	0.1	3.2^{b}	0.1	3.6^{c}	0.1	4.7^{d}	0.1	6.2^{e}	0.1
Lysine intake per kg body weight gain (g)	22.7^{a}	0.6	27.6^{b}	0.6	28.4^{b}	0.6	37.5^{c}	0.6	48.8^{d}	0.6
ME intake per kg body weight gain (Mcal)	7.8^{a}	0.2	10.3^{b}	0.2	11.7^{c}	0.2	15.4^{d}	0.2	20.0^{e}	0.2

[1] Maternal line = Large White × Landrace

[2]ADFI = Average daily feed intake

[3] ADLI = Average daily lysine intake

[4]ADMEI = Average daily Metabolizable energy intake

[5] ADG = Average daily gain

[a,b,c,d,e] Significant difference between days; $P < 0.05$

Table 8. Descriptive statistics for feed, lysine and metabolizable energy (ME) intake, average daily feed, lysine and ME intake of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Feed intake (kg)				Lysine intake (kg)				ME intake (kcal)				ADFI[2] (kg)				ADLI[3] (g)				ADMEI[4] (Mcal)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Lysine																								
85% lysine	89.7	15.0	54.4	121.6	0.7	0.1	0.5	0.9	290.5	44.0	175.1	372.8	3.2	0.6	1.9	4.6	24.6	3.3	16.1	33.4	10.5	1.7	6.0	13.5
100% lysine	91.1	14.1	63.8	121.2	0.8	0.1	0.6	1.0	295.5	42.2	198.4	394.3	3.3	0.6	2.2	4.6	29.3	3.5	21.9	38.9	10.7	1.7	6.8	14.0
ME																								
85% ME	97.5	15.2	59.6	121.6	0.8	0.1	0.5	1.0	286.3	44.7	175.1	357.0	3.5	0.6	2.1	4.6	29.0	4.3	17.7	38.9	10.3	1.8	6.0	13.5
100% ME	90.6	13.3	63.1	118.1	0.6	0.1	0.5	1.0	295.4	43.6	205.0	385.3	3.3	0.5	2.2	4.1	27.0	3.6	18.7	34.8	10.7	1.7	7.1	13.5
115% ME	83.1	11.2	54.4	110.0	0.7	0.1	0.5	0.9	297.4	40.5	193.9	394.3	3.0	0.4	1.9	3.9	24.8	3.4	16.1	33.0	10.7	1.6	6.7	14.0
***Lysine* × ME**																								
85% lysine × 85% ME	96.8	15.7	59.6	121.6	0.7	0.1	0.5	0.9	284.4	46.0	175.1	357.0	3.5	0.6	2.1	4.6	26.5	3.4	17.7	33.4	10.3	1.8	6.0	13.4
85% lysine × 100% ME	90.5	14.0	63.1	114.3	0.7	0.1	0.5	0.8	295.0	46.0	205.0	372.8	3.3	0.5	2.2	4.1	24.8	2.9	18.7	30.2	10.6	1.8	7.1	13.5
85% lysine × 115% ME	81.6	11.0	54.4	99.0	0.6	0.1	0.5	0.7	292.2	39.8	193.9	355.1	2.9	0.4	1.9	3.6	22.4	2.1	16.1	26.3	10.5	1.6	6.7	12.9
100% lysine × 85% ME	98.2	14.9	67.6	121.2	0.9	0.1	0.7	1.0	288.3	43.8	198.4	355.9	3.5	0.6	2.3	4.6	31.5	3.6	23.7	38.9	10.4	1.7	6.8	13.5
100% lysine × 100% ME	90.7	12.6	65.6	118.1	0.8	0.1	0.7	1.0	295.7	41.3	213.3	385.3	3.3	0.5	2.3	4.1	29.2	2.9	23.1	34.8	10.7	1.6	7.4	13.3
100% lysine × 115% ME	84.5	11.3	63.8	110.0	0.8	0.1	0.6	0.9	302.6	40.9	227.3	394.3	3.1	0.5	2.2	3.9	27.2	2.7	21.9	33.0	10.9	1.7	7.8	14.0

[1] Maternal line = Large White × Landrace

[2]ADFI = Average daily feed intake

[3] ADLI = Average daily lysine intake

[4]ADMEI = Average daily Metabolizable energy intake

Table 9. Least square mean ± SEM for feed, lysine and metabolizable energy (ME) intake, average daily feed, lysine and ME intake of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction 100 to 250 d of age

	Feed intake (kg)		**Lysine intake (kg)**		**ME intake (Mcal)**		**ADFI[2] (kg)**		**ADLI[3] (g)**		**ADMEI[4] (Mcal)**	
	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM
Lysine												
85% lysine	89.9	0.4	0.7[a]	0.01	291.3	1.5	3.2	0.02	24.7[a]	0.1	10.5	0.1
100% lysine	90.9	0.4	0.8[b]	0.01	294.7	1.5	3.3	0.02	29.2[b]	0.1	10.6	0.1
ME												
85% ME	97.8[a]	0.5	0.8[a]	0.01	287.2[a]	1.8	3.5[a]	0.02	29.1[a]	0.2	10.4[a]	0.1
100% ME	90.5[b]	0.5	0.74[b]	0.01	295.0[b]	1.8	3.3[b]	0.02	26.9[b]	0.2	10.6[b]	0.1
115% ME	82.9[c]	0.5	0.68[c]	0.01	296.8[b]	1.8	2.9[c]	0.02	24.7[c]	0.2	10.7[b]	0.1
***Lysine* × ME**												
85% lysine × 85% ME	97.1	0.8	0.7	0.01	289.2	2.6	3.5	0.03	26.6	0.2	10.3	0.1
85% lysine × 100% ME	90.8	0.8	0.7	0.01	294.2	2.6	3.3	0.03	24.9	0.2	10.7	0.1
85% lysine × 115% ME	81.8	0.8	0.6	0.01	300.8	2.6	3.0	0.03	22.4	0.2	10.5	0.1
100% lysine × 85% ME	98.4	0.8	0.9	0.01	285.3	2.6	3.6	0.03	31.6	0.2	10.4	0.1
100% lysine × 100% ME	90.3	0.8	0.8	0.01	295.8	2.6	3.3	0.03	29.1	0.2	10.6	0.1
100% lysine × 115% ME	84.0	0.8	0.7	0.01	292.8	2.5	3.0	0.03	27.0	0.2	10.8	0.1
BW at 100d of age[5]	0.27(0.04)		1.05(0.001)		405.97(63.13)		0.01(0.001)		0.05(0.01)		18.63(2.28)	

[1] Maternal line = Large White × Landrace

[2]ADFI = Average daily feed intake

[3] ADLI = Average daily lysine intake

[4]ADMEI = Average daily Metabolizable energy intake

[5]Results presented as regression coefficient and their associated standard error

[a,b,c] Significant difference within main effects; $P < 0.05$

Table 10. Descriptive statistics for average daily gain and feed, lysine and metabolizable energy (ME) intake per kg of body weight gain of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction

	ADG[2] (kg)				Feed intake per kg body weight gain (kg)				Lysine intake per kg body weight gain (g)				ME intake per kg body weight gain (Mcal)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Lysine																
85% lysine	0.9	0.2	0.2	1.3	4.0	1.6	2.1	12.2	30.2	10.5	17.7	89.1	12.9	4.8	6.9	35.9
100% lysine	0.9	0.2	0.4	1.5	4.1	1.4	1.8	8.7	35.8	11.0	18.7	73.5	13.2	4.6	5.4	31.1
ME																
85% ME	0.9	0.2	0.2	1.5	4.4	1.7	1.8	12.2	35.8	12.2	18.7	89.1	12.9	4.9	5.4	35.9
100% ME	0.9	0.2	0.4	1.2	4.0	1.4	2.2	8.2	33.1	10.2	18.9	61.0	13.2	4.5	7.1	26.6
115% ME	0.9	0.2	0.4	1.3	3.7	1.3	2.1	8.7	30.1	10.2	17.7	73.5	13.1	4.8	7.4	31.1
lysine × ME																
85% lysine × 85% ME	0.9	0.2	0.2	1.2	4.4	1.9	2.3	12.2	33.3	12.8	20.1	89.1	13.0	5.5	6.9	35.9
85% lysine × 100% ME	0.9	0.2	0.4	1.2	4.0	1.4	2.2	8.2	30.3	9.5	18.9	59.4	13.1	4.6	7.1	26.6
85% lysine × 115% ME	0.9	0.2	0.4	1.3	3.6	1.2	2.1	7.0	26.9	8.0	17.7	51.1	12.7	4.3	7.4	25.1
100% lysine × 85% ME	0.9	0.2	0.4	1.5	4.3	1.5	1.8	7.8	38.3	11.2	18.7	66.6	12.7	4.3	5.4	23.0
100% lysine × 100% ME	0.9	0.2	0.4	1.1	4.1	1.4	2.2	7.2	35.9	10.3	22.2	61.0	13.3	4.5	7.1	23.4
100% lysine × 115% ME	0.9	0.2	0.4	1.2	3.8	1.4	2.2	8.7	33.3	11.1	22.2	73.5	13.5	5.1	7.8	31.1

[1] Maternal line = Large White × Landrace

[2]ADG = Average daily gain

Table 11. Least square mean ± SEM for average daily gain and feed, lysine and metabolizable energy (ME) intake per kg of body weight gain of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	ADG[2] (kg)		**Feed intake per kg body weight gain (kg)**		**Lysine intake per kg body weight gain (g)**		**ME intake per kg body weight gain (kcal)**	
	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM	Lsmean	SEM
Lysine								
85% lysine	0.9	0.01	4.0	0.1	30.2[a]	0.3	12.9	0.1
100% lysine	0.9	0.01	4.1	0.1	35.8[b]	0.3	13.2	0.1
ME								
85% ME	0.9	0.01	4.38[a]	0.1	35.8[a]	0.4	12.9	0.2
100% ME	0.9	0.01	4.04[b]	0.1	33.1[b]	0.4	13.2	0.2
115% ME	0.9	0.01	3.66[c]	0.1	30.1[c]	0.4	13.1	0.2
***Lysine* × ME**								
85% lysine × 85% ME	0.9	0.01	4.4	0.1	33.3	0.6	12.7	0.2
85% lysine × 100% ME	0.9	0.01	4.0	0.1	30.3	0.6	13.3	0.2
85% lysine × 115% ME	0.9	0.01	3.6	0.1	26.9	0.6	13.5	0.2
100% lysine × 85% ME	0.9	0.01	4.3	0.1	38.3	0.6	13.0	0.2
100% lysine × 100% ME	0.9	0.01	4.1	0.1	35.9	0.6	13.1	0.2
100% lysine × 115% ME	0.9	0.01	3.8	0.1	33.3	0.6	12.7	0.2
BW at 100 d of age[3]	-0.003(0.001)		0.02(0.004)		0.14(0.04)		57.00(15.7791	

[1] Maternal line = Large White × Landrace

[2]ADG = Average daily gain

[3]Results presented as regression coefficient and their associated standard error

[a,b,c d] Significant difference within main effects; $P < 0.05$

Table 12. Number of maternal line gilts[1] removed from a study comparing 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction for gilt development diets fed from 100 to 250 d of age

	Lysine		**ME**			**Lysine × ME**					
	85% lysine	100% lysine	85% ME	100% ME	115% ME	85% lysine × 85% ME	85% lysine × 100% ME	85% lysine × 115% ME	100% lysine × 85% ME	100% lysine × 100% ME	100% lysine × 115% ME
Agression injuries	0	1	0	0	1	0	0	0	0	0	1
Back problems	0	3	1	1	1	0	0	0	1	1	1
Sudden death	21	22	14	15	14	7	5	9	7	10	5
Euthanised	2	1	0	2	1	0	2	0	0	0	1
Leg problems	28	40	21	24	23	8	10	10	13	14	13
Prolapse	0	4	1	1	2	0	0	0	1	1	2
Rectal injury	1	0	1	0	0	1	0	0	0	0	0
Respiratory problems	1	0	0	1	0	0	1	0	0	0	0
Unknown	5	6	3	4	4	2	2	1	1	2	3

[1] Maternal line = Large White × Landrace

Table 13. Descriptive statistics for age at puberty, ovulation rate, uterus length, and ovary length and width of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Age at puberty (d)				Ovulation rate				Uterus length (cm)				Ovary length (mm)				Ovary width (mm)			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Lysine																				
85% lysine	193.9	19.5	160	264	18.4	3.2	7	30	294.1	87.5	74	555	26.7	5.3	7.9	45.0	17.8	3.4	4.3	35.6
100% lysine	192.8	18.9	160	265	18.1	3.4	0	38	294.5	84.9	79	587	26.7	5.3	9.2	46.0	17.8	3.5	4.1	26.8
ME																				
85% ME	193.6	19	160	265	18.4	3.3	0	28	288	91.5	74	587	27.1	5.2	9.2	46.0	17.9	3.4	4.3	25.9
100% ME	193.9	20.3	160	264	18.1	3.3	10	28	303.2	79.3	89.5	525	26.5	5.6	9.3	45.0	17.8	3.5	5.5	35.6
115% ME	192.7	18.3	161	256	18.3	3.4	7	38	291.8	87	99	555	26.5	5.1	7.9	39.8	17.7	3.5	4.1	26.3
Lysine× ME																				
85% lysine × 85% ME	193.8	19.3	160	264	18.5	3	9	28	278.9	92.1	74	507	27.0	5.3	12.3	38.3	17.6	3.5	4.3	25.1
85% lysine × 100% ME	194.1	21.8	161	264	18.3	3.3	10	28	314.1	73.8	118	525	26.7	5.4	10.5	45.0	17.9	3.6	5.5	35.6
85% lysine × 115% ME	193.9	17.2	163	245	18.4	3.5	7	30	289.4	92.2	99	555	26.4	5.3	7.9	38.6	18.0	3.2	8.7	24.4
100% lysine × 85% ME	193.4	18.7	166	265	18.3	3.6	0	28	297.3	90.2	79	587	27.3	5.1	9.2	46.0	18.1	3.3	4.5	28.9
100% lysine × 100% ME	193.6	18.8	160	250	17.9	3.2	10	26	291.7	83.3	89.5	494	26.2	5.7	9.3	42.5	17.7	3.4	8.5	26.8
100% lysine × 115% ME	191.5	19.3	161	256	18.3	3.3	12	38	294.4	81.3	108	456	26.6	4.9	13.6	39.80	17.5	3.8	4.1	26.3

[1] Maternal line = Large White × Landrace

Table 14. Least square mean ± SEM for age at puberty, ovulation rate, uterus length, and ovary length and width maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Age at Puberty (d)		Ovulation rate		Uterus length (cm)		Ovary length (mm)		Ovary width (mm)	
	Ls mean	SEM	Ls mean	SEM	Ls mean	SEM	Ls mean	SEM	Ls mean	SEM
Lysine										
85% lysine	193.9	0.8	18.2	0.2	257.9	3	26.0	0.2	17.78	0.17
100% lysine	192.9	0.8	18	0.2	253.7	3.2	25.9	0.3	17.81	0.18
ME										
85% ME	193.6	1	18.2	0.2	252.7	3.6	26.4	0.3	17.85	0.20
100% ME	193.9	1	17.9	0.2	256.4	3.7	25.7	0.3	17.80	0.21
115% ME	192.7	1	18.2	0.2	258.2	3.6	25.8	0.3	17.74	0.20
Lysine× ME										
85% lysine × 85% ME	193.7	1.5	18.3	0.3	250.8	4.7	26.3	0.4	18.13	0.28
85% lysine × 100% ME	194.1	1.4	18	0.3	261.3	4.9	25.6	0.4	17.80	0.28
85% lysine × 115% ME	193.9	1.4	18.2	0.3	261.5	4.8	25.9	0.4	17.52	0.28
100% lysine × 85% ME	193.4	1.4	18	0.3	254.6	5	26.5	0.4	17.58	0.26
100% lysine × 100% ME	193.6	1.4	17.8	0.3	251.5	5	25.8	0.4	17.81	0.28
100% lysine × 115% ME	191.5	1.4	18.1	0.3	254.9	5	25.8	0.4	17.96	0.27
Puberty score[2]										
0			-	-	135.5^{a}	8.9	24.1^{a}	0.7	$17.9^{a,b}$	0.5
1			-	-	228.7^{b}	4.5	27.0^{b}	0.4	17.9^{a}	0.3
2			17.3^{a}	0.3	242.4^{c}	5	23.9^{a}	0.4	17.1^{b}	0.3
3			18.6^{b}	0.2	346.9^{d}	3.2	27.9^{c}	0.3	18.1^{a}	0.2
4			18.3^{b}	0.2	325.3^{d}	3.6	27.0^{b}	0.3	18.1^{a}	0.2
BW at 160 d of age[3]	-0.3(0.004)		0.02(0.003)		0.09(0.06)		0.02(0.007)		0.009(0.004)	

[1] Maternal line = Large White × Landrace

[2]Puberty score: 0) prepubertal; 1) large follicles previous to ovulation, corpora albacantia present; 2) presence of corpora hemorrhagic; 3) robust *Corpora lutea* (CL) present indicating early in the luteal phase; and, 4) pale CLs present but without large follicles, indicating late in the luteal phase.

[3]Results presented as regression coefficient and their associated standard error

[a,b,c,d] Significant difference within main effects; $P < 0.05$

Table 15. Descriptive statistics for warm and chilled carcass weight, fat thickness, fat free lean meant and dressing percentage of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Warm weight (kg)				Fat thickness (cm)				Fat free lean meat (kg)				Chilled weight (kg)				Dressing percentage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Lysine																				
85% lysine	137.5	11.5	89.5	170.0	1.1	0.2	0.4	1.4	75.7	5.4	54.3	90.9	135.5	11.3	88.2	167.5	71.0	2.9	64.8	77.7
100% lysine	138.1	11.5	101.4	174.5	1.1	0.2	0.5	1.4	75.9	5.5	59.0	93.2	136.0	11.3	99.8	171.9	71.5	2.8	65.0	77.7
ME																				
85% ME	136.0	10.9	102.3	165.9	1.1	0.2	0.5	1.4	75.0	5.2	59.5	88.8	133.9	10.7	100.7	163.4	70.9	2.9	64.8	77.7
100% ME	136.9	11.7	101.4	174.5	1.1	0.2	0.5	1.4	75.4	5.5	59.0	93.2	134.9	11.5	99.8	171.9	71.1	2.9	64.8	77.7
115% ME	140.5	11.5	89.5	168.6	1.1	0.2	0.4	1.4	77.0	5.4	54.3	90.4	138.4	11.3	88.2	166.1	71.8	2.7	65.6	77.7
***Lysine* × ME**																				
85% lysine × 85% ME	135.8	11.2	102.3	165.9	1.1	0.2	0.5	1.4	74.9	5.4	59.5	88.8	133.8	11.0	100.7	163.4	71.0	2.8	64.8	77.7
85% lysine × 100% ME	136.9	11.3	114.1	170.0	1.1	0.2	0.5	1.4	75.4	5.4	63.9	90.9	134.8	11.2	112.4	167.5	70.5	3.0	64.8	77.1
85% lysine × 115% ME	139.8	11.6	89.5	168.6	1.1	0.2	0.4	1.4	76.7	5.5	54.3	90.2	137.7	11.5	88.2	166.1	71.5	2.8	65.6	77.7
100% lysine × 85% ME	136.1	10.6	107.3	156.8	1.1	0.2	0.5	1.4	75.0	5.1	61.3	86.9	134.1	10.4	105.7	154.5	70.8	3.0	65.0	77.6
100% lysine × 100% ME	136.9	12.0	101.4	174.5	1.1	0.2	0.5	1.4	75.4	5.7	59.0	93.2	134.9	11.8	99.8	171.9	71.7	2.8	65.0	77.7
100% lysine × 115% ME	141.2	11.3	110.5	166.8	1.2	0.2	0.5	1.4	77.3	5.3	62.9	90.4	139.1	11.1	108.8	164.3	72.1	2.5	66.5	77.4

[1] Maternal line = Large White × Landrace

Table 16. Least square mean ± SEM for warm and chilled carcass weight, fat thickness, fat free lean meant and dressing percentage of maternal line[1] gilts fed 2 lysine levels, 3 metabolizable energy (ME) levels and their interaction from 100 to 250 d of age

	Warm weight (kg)		**Fat thickness (cm)**		**Fat free lean meat (kg)**		**Chilled weight (kg)**		**Dressing percentage**	
	Ls mean	SEM	Ls mean	SEM	Ls mean	SEM	Ls mean	SEM	Ls mean	SEM
Lysine										
85% lysine	137.5	0.3	1.10	0.01	75.7	0.1	135.5	0.3	71.0	0.1
100% lysine	138.1	0.3	1.11	0.01	75.9	0.1	136.0	0.3	71.5	0.1
ME										
85% ME	136.4^{a}	0.4	1.0^{a}	0.01	75.2^{a}	0.2	134.4^{a}	0.4	70.8^{a}	0.1
100% ME	137.2^{a}	0.4	1.0^{a}	0.01	75.5^{a}	0.2	135.1^{a}	0.4	71.0^{a}	0.1
115% ME	139.7^{b}	0.4	1.1^{b}	0.01	76.6^{b}	0.2	137.6^{b}	0.4	71.9^{b}	0.1
***Lysine* × ME**										
85% lysine × 85% ME	136.6	0.5	1.08	0.01	75.3	0.3	134.6	0.5	70.9^{a,b}	0.2
85% lysine × 100% ME	136.8	0.5	1.09	0.01	75.4	0.3	134.8	0.5	70.6^{a}	0.2
85% lysine × 115% ME	139.2	0.5	1.13	0.01	76.4	0.3	137.1	0.5	71.7^{b,d}	0.2
100% lysine × 85% ME	136.3	0.5	1.09	0.01	75.1	0.3	134.3	0.5	70.8^{a,b,c}	0.2
100% lysine × 100% ME	137.6	0.5	1.10	0.01	75.7	0.3	135.6	0.5	71.5^{c,d}	0.2
100% lysine × 115% ME	140.2	0.5	1.15	0.01	76.9	0.3	138.1	0.5	72.2^{d}	0.2
BW at slaughte[2]	0.48 (0.01)		0.004(0.0003)		0.22(0.01)		0.47(0.01)		-0.06(0.005)	

[1] Maternal line = Large White × Landrace

[2]Results presented as regression coefficient and their associated standard error.

[a,b] Significant difference within main effects ; $P < 0.05$

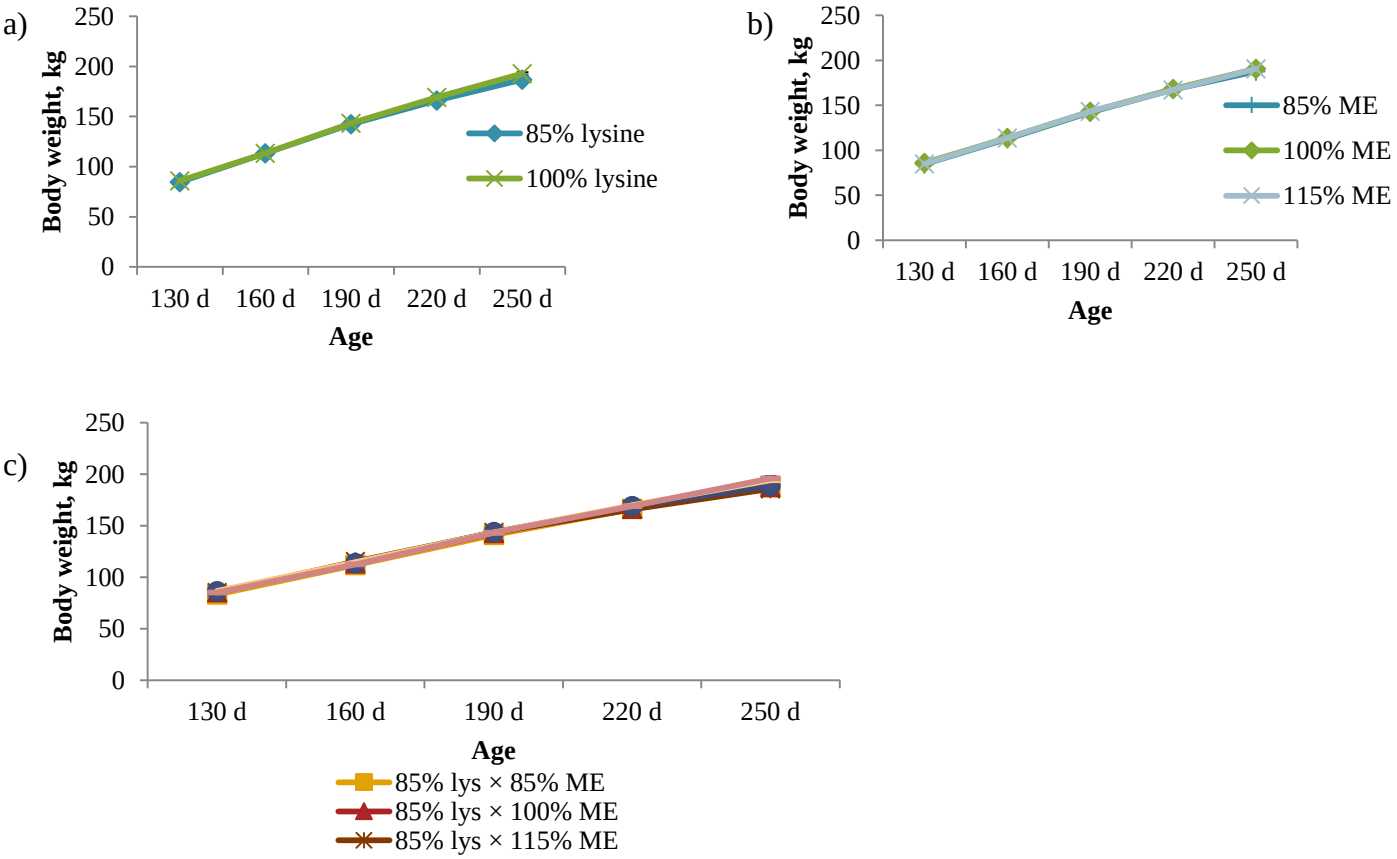


Figure 1. Growth patterns (least square means ± SEM) of body weight (kg) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

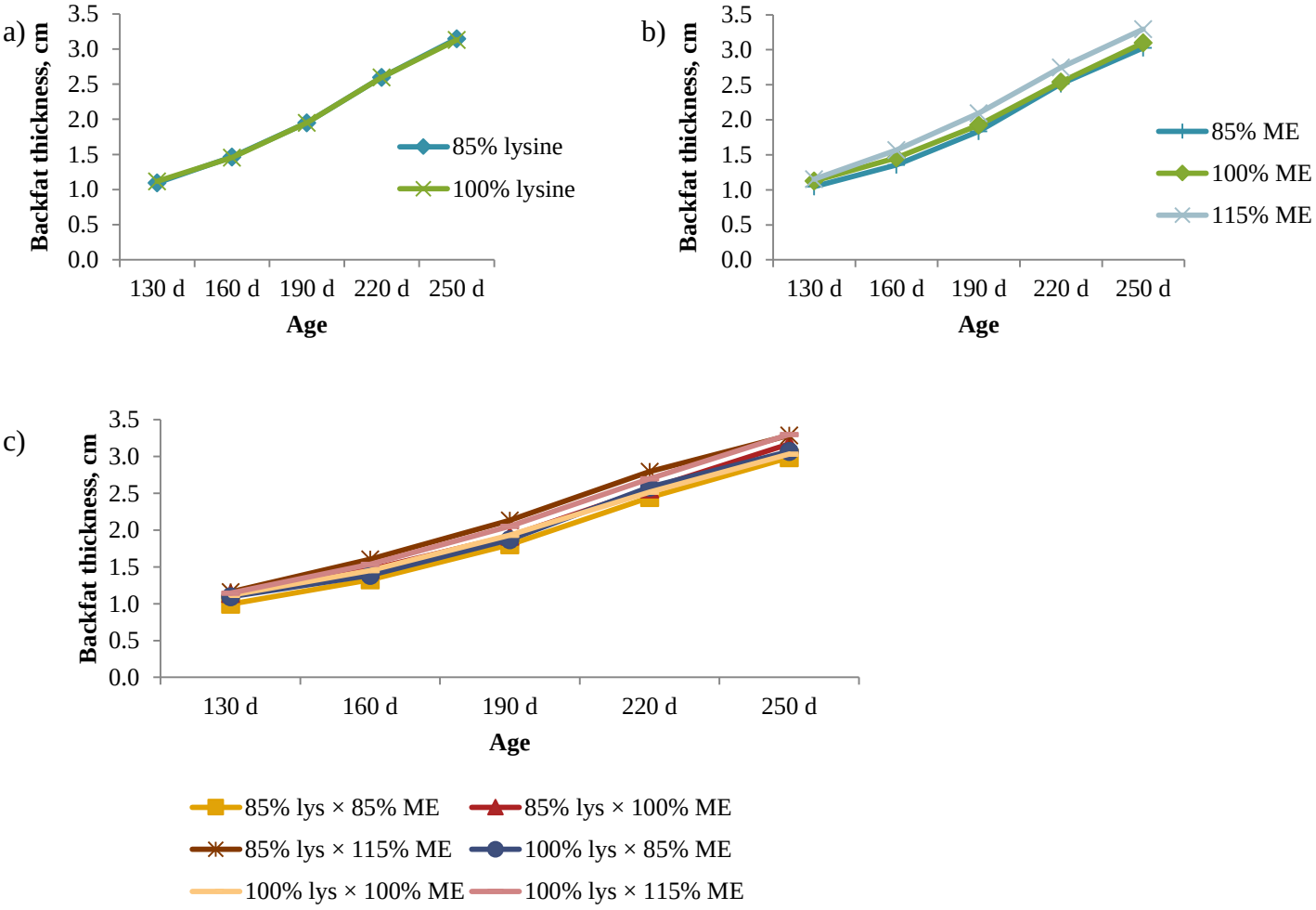
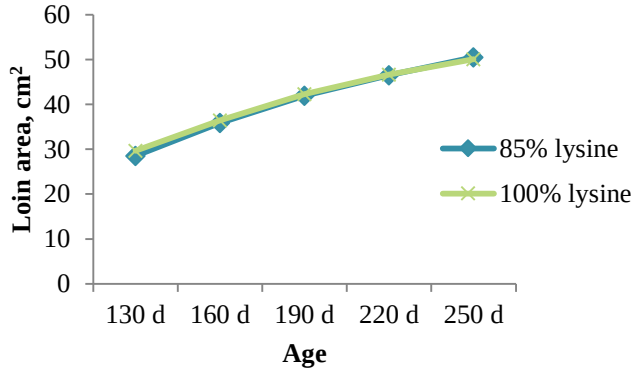


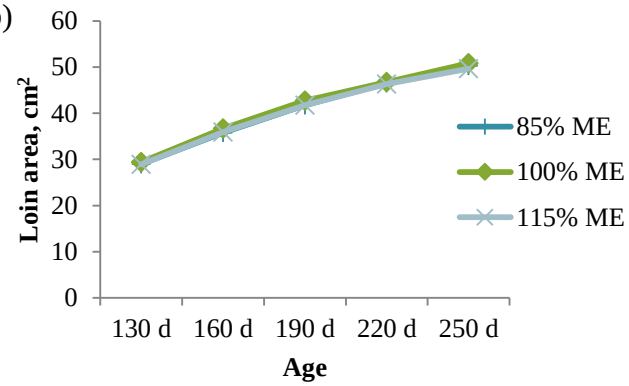
Figure 2. Growth patterns (least square means ± SEM) of backfat thickness (cm) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

a)



b)



c)

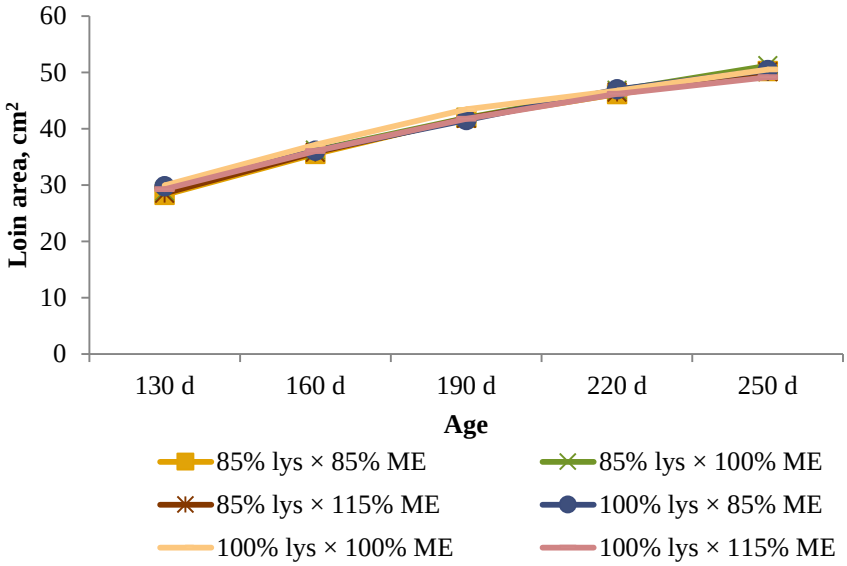


Figure 3. Growth patterns (least square means ± SEM) of loin aye area (cm^2) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

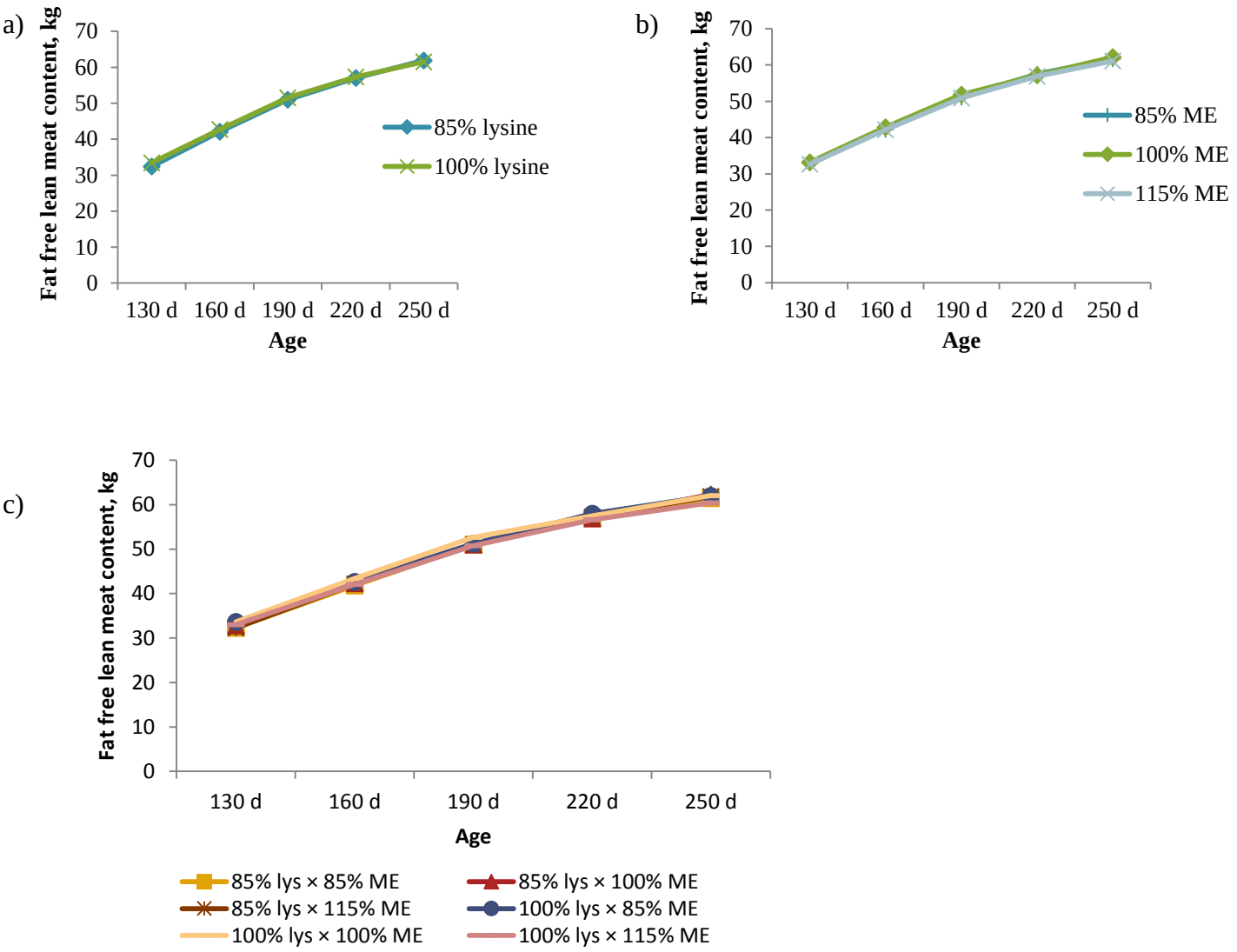


Figure 4. Growth patterns (least square means ± SEM) of fat free lean meat content (kg) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

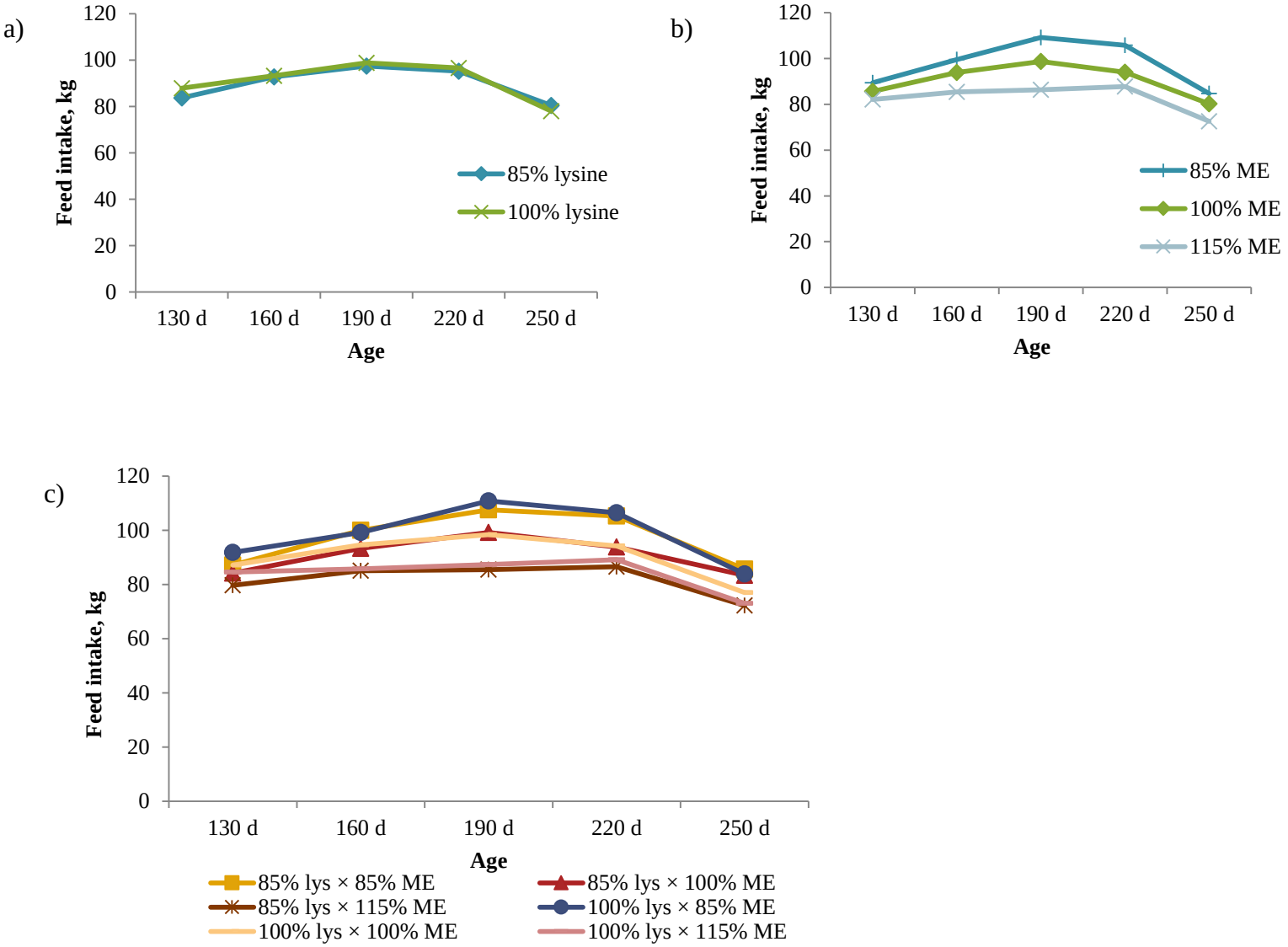


Figure 5. Feed intake (kg) pattern (least square means ± SEM) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

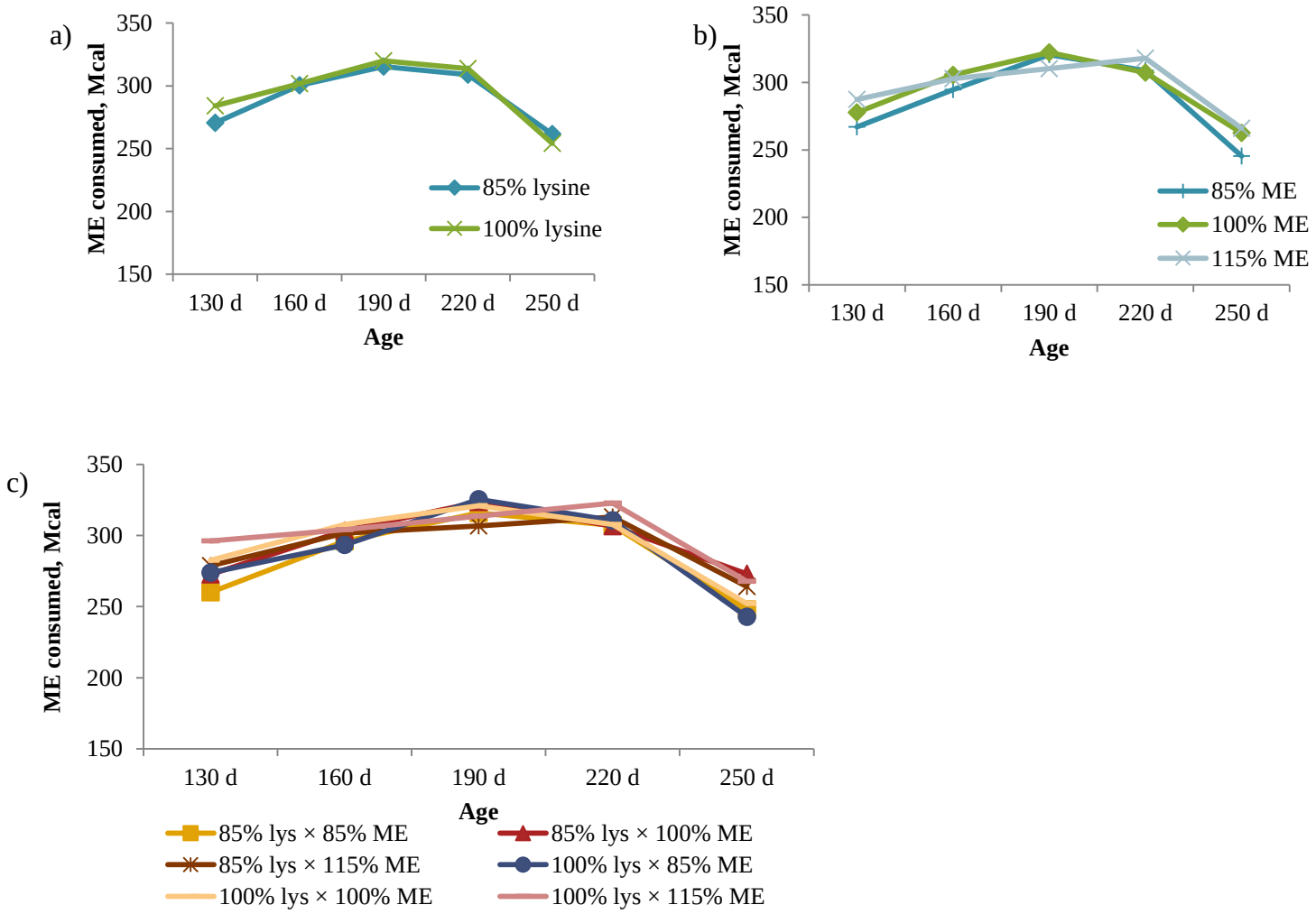


Figure 6. Metabolizable energy (ME, kcal) intake pattern (least square means ± SEM) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

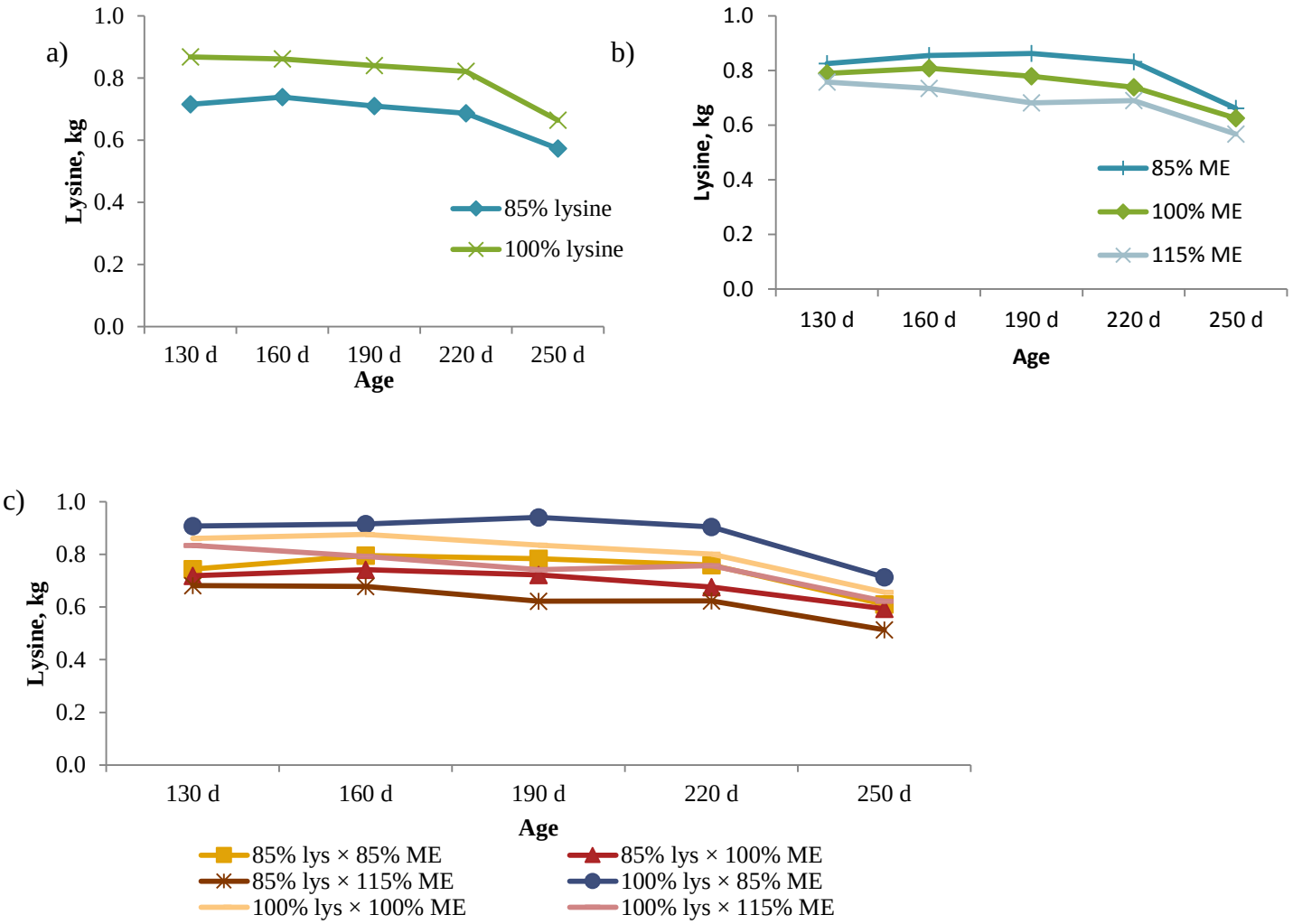


Figure 7. Lysine (g) intake pattern (least square means ± SEM) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

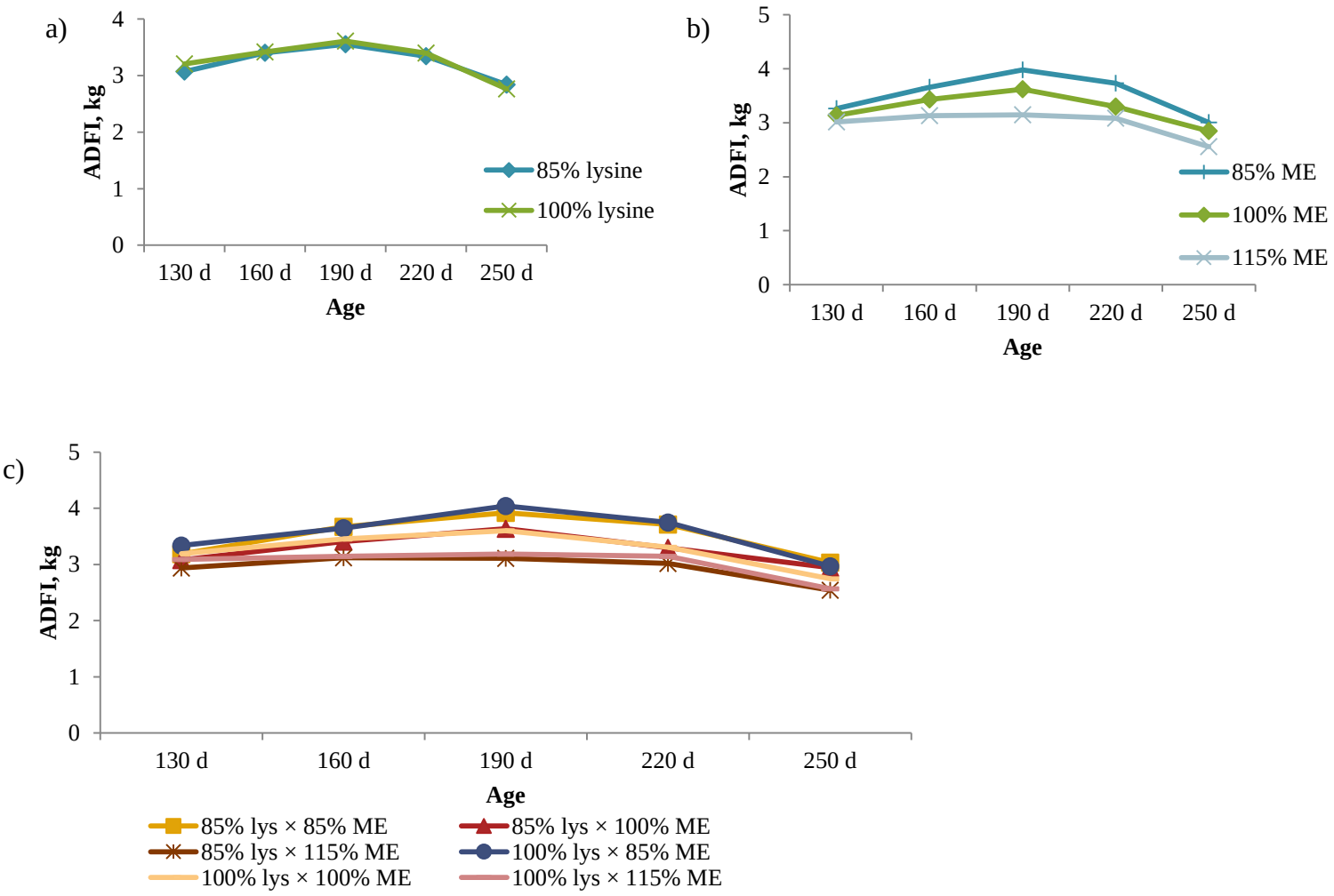


Figure 8. Average daily feed intake (ADFI, kg) pattern (least square means ± SEM) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

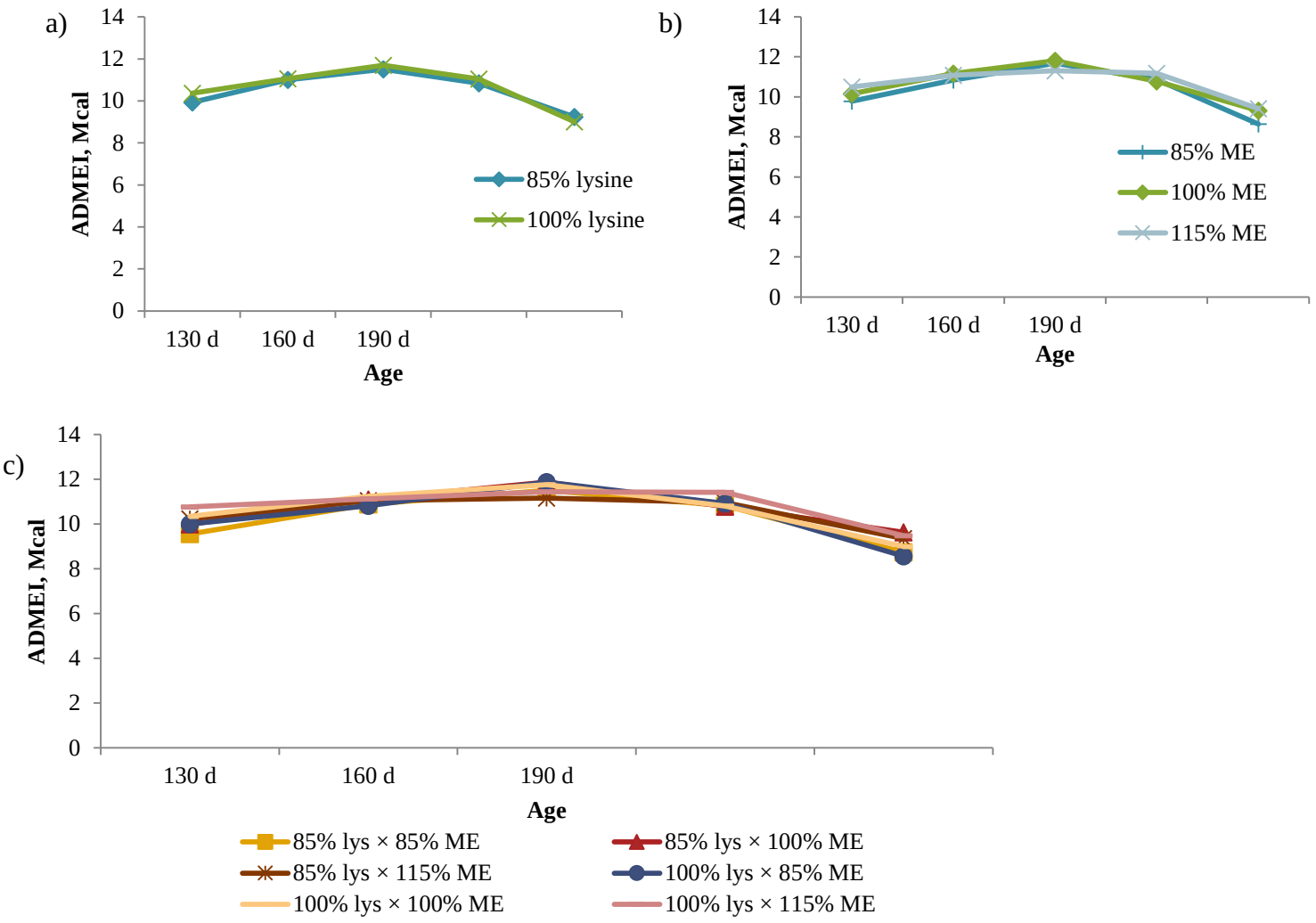


Figure 9. Average daily metabolizable energy intake (ADMEI, kcal) pattern (least square means ± SEM) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

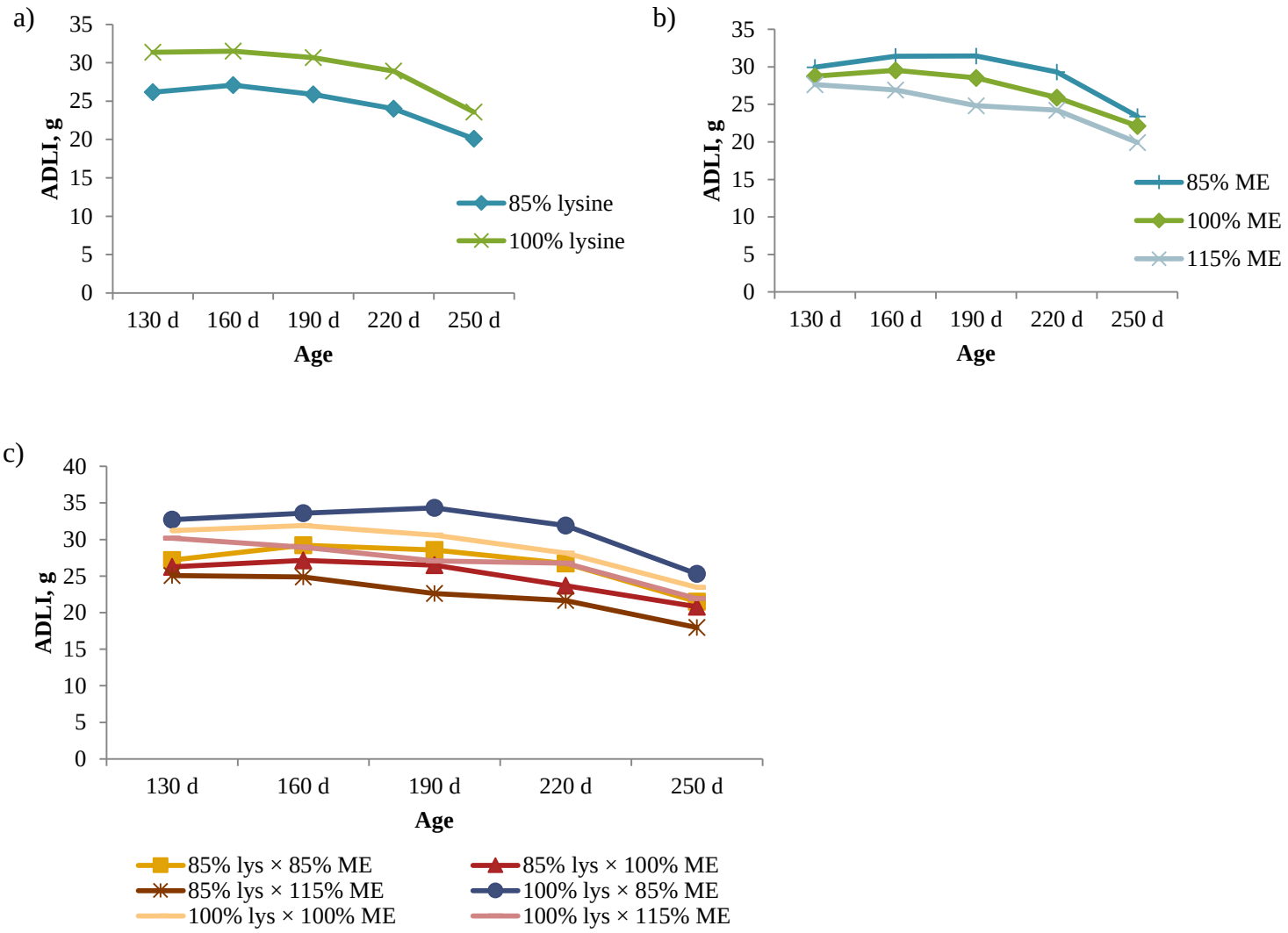


Figure 10. Average daily lysine intake (ADLI, g) pattern (least square means ± SEM) of gilts in a study comparing a) 2 lysine and b) 3 metabolizable energy (ME) levels and c) lysine by ME interaction in gilt development diets

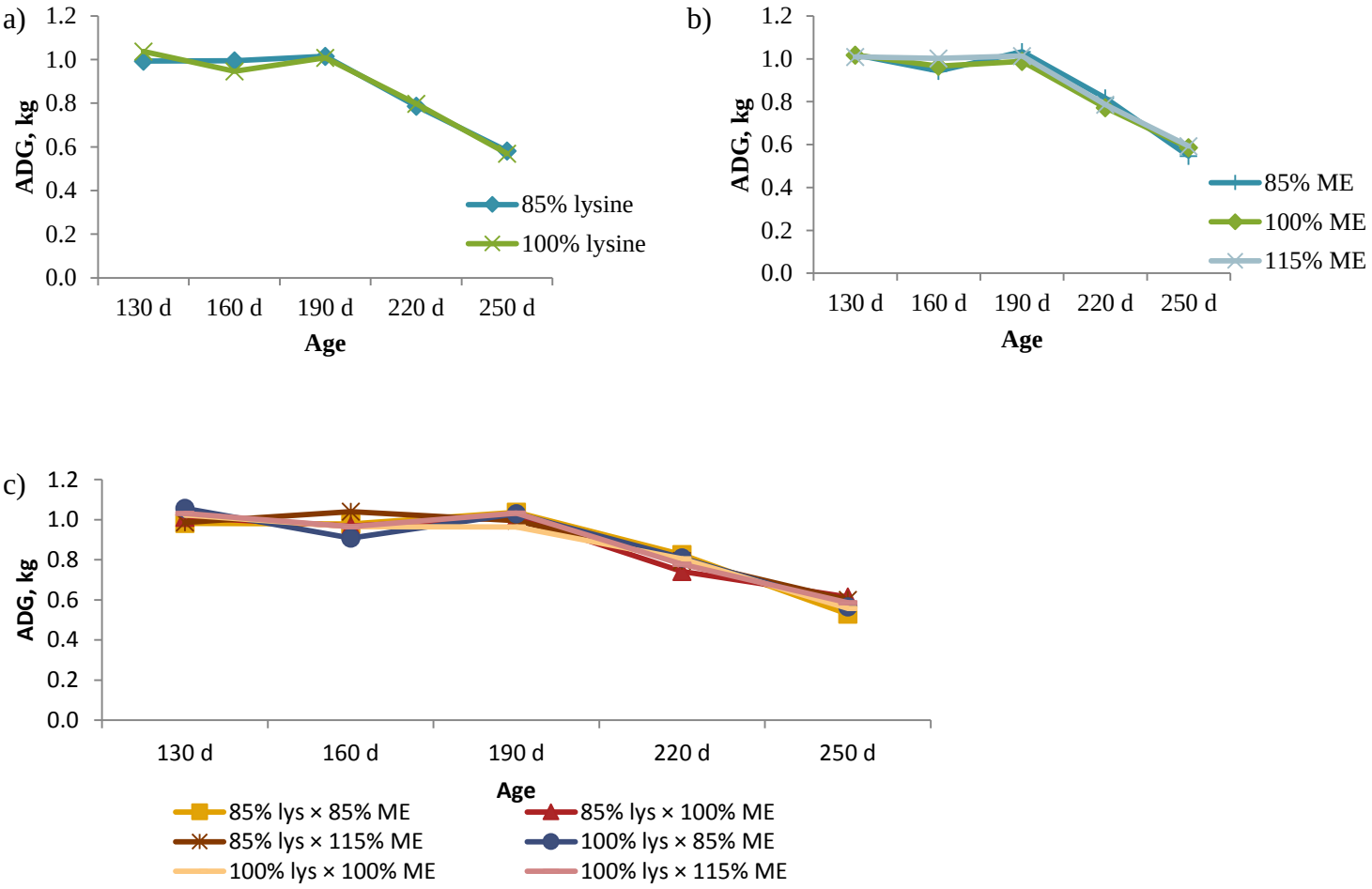


Figure 11. Average daily gain (ADG, kg) pattern (least square means ± SEM) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

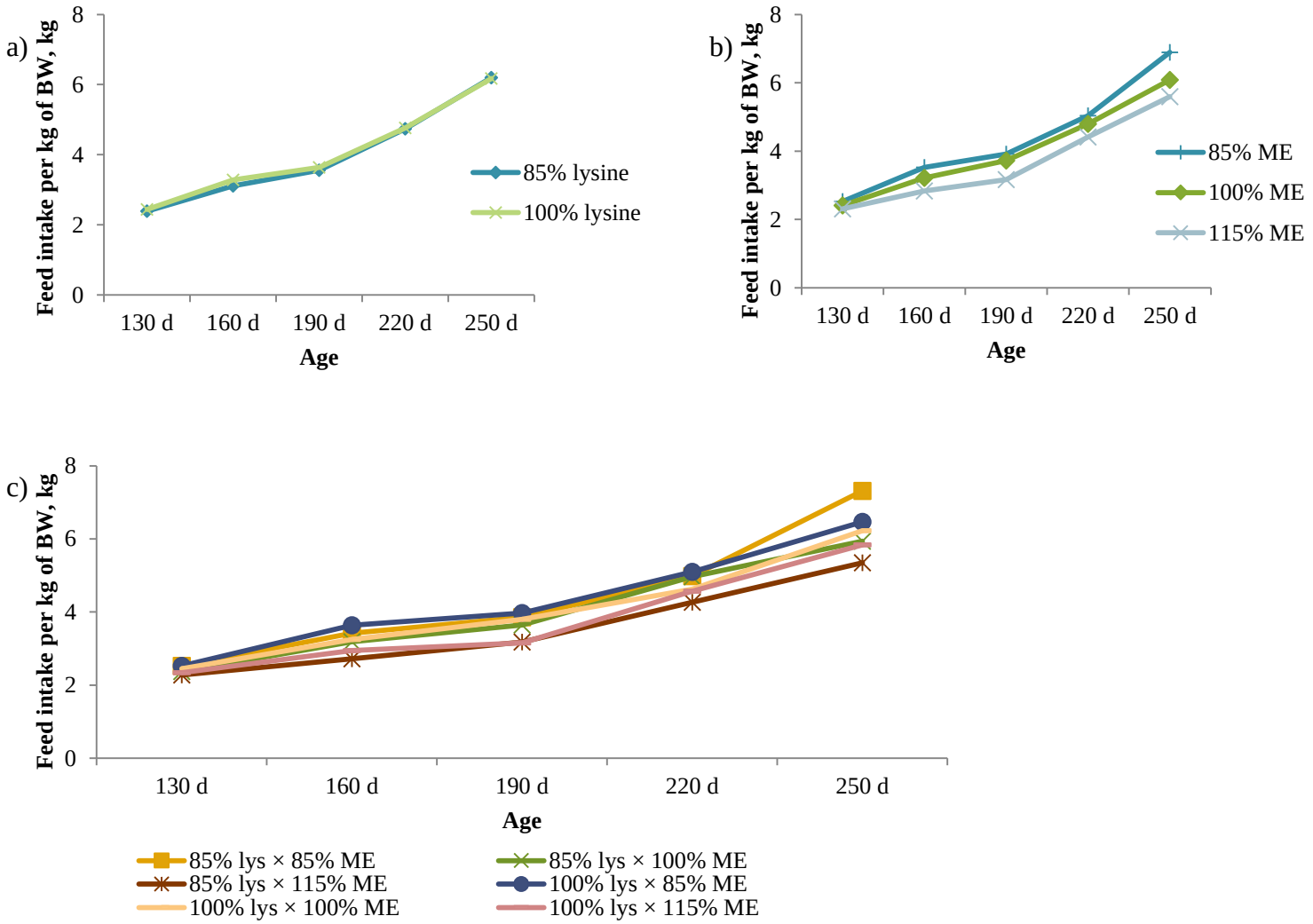


Figure 12. Feed intake (kg) pattern (least square means ± SEM) per kg of body weight (BW) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

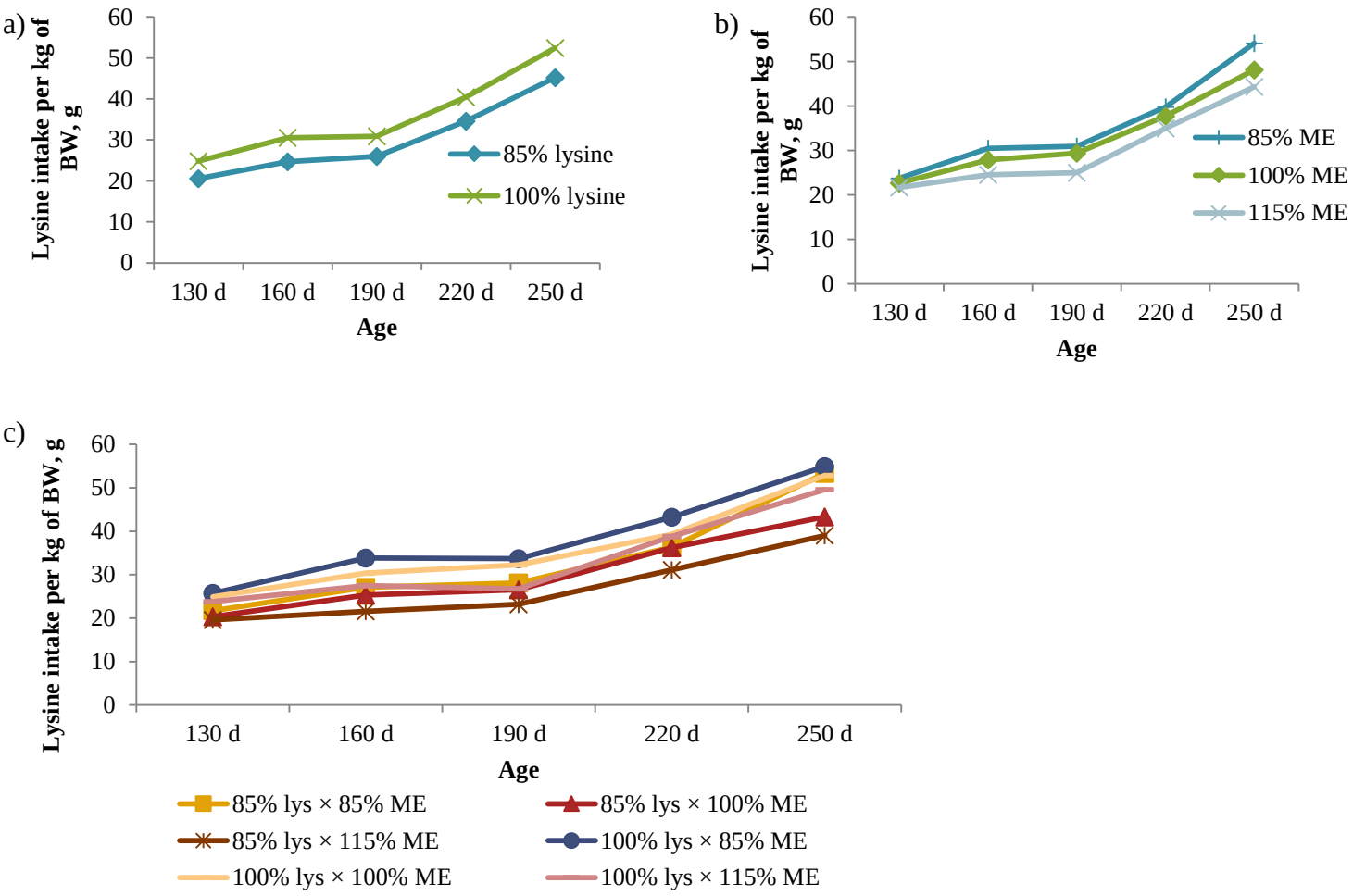


Figure 13. Lysine intake (g) pattern (least square means ± SEM) per kg of body weight (BW) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

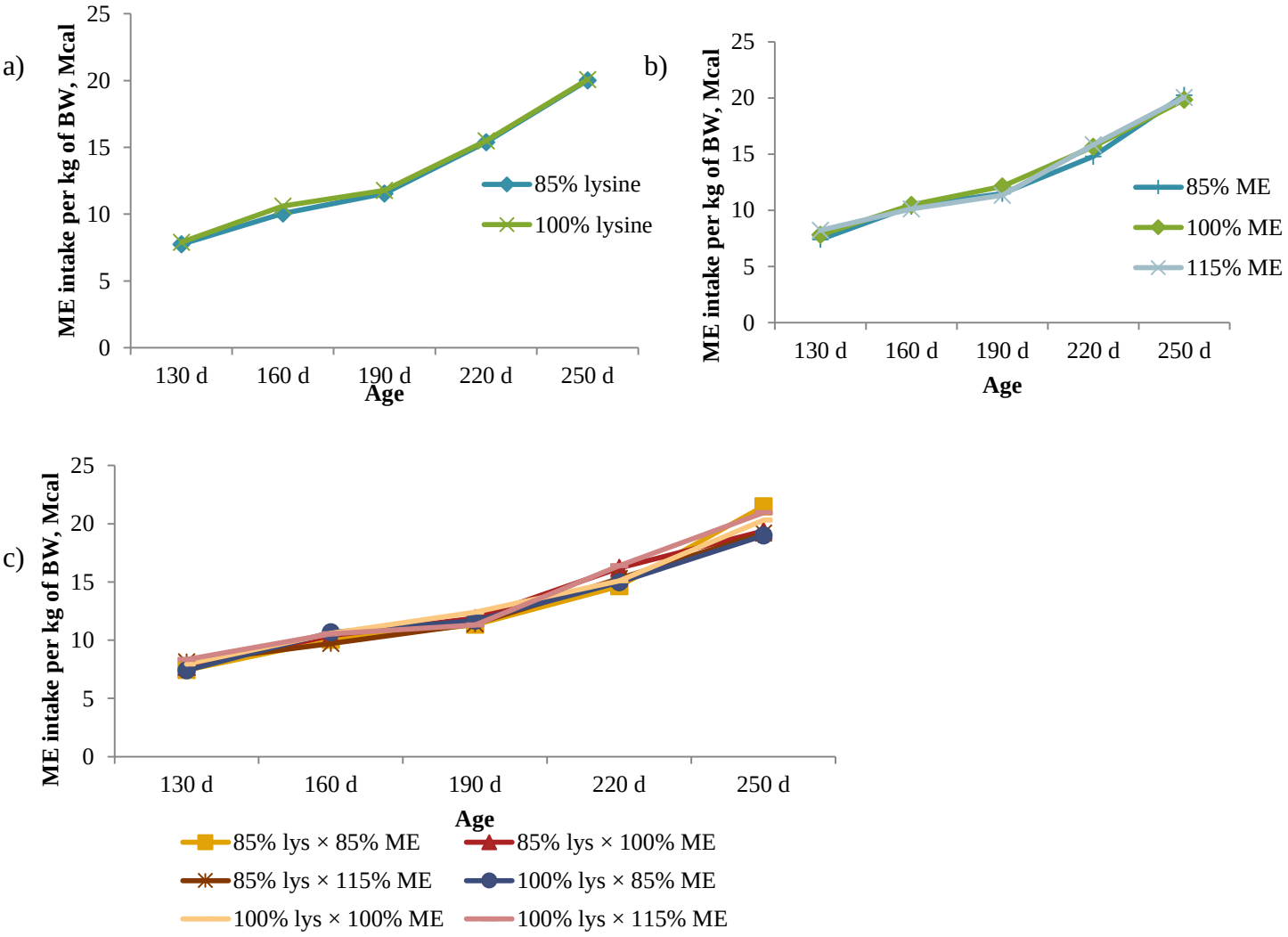


Figure 14. Metabolizable energy (ME) intake (kcal) pattern (least square means ± SEM) per kg of body weight (BW) of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age

[1]Maternal line = Large White × Landrace

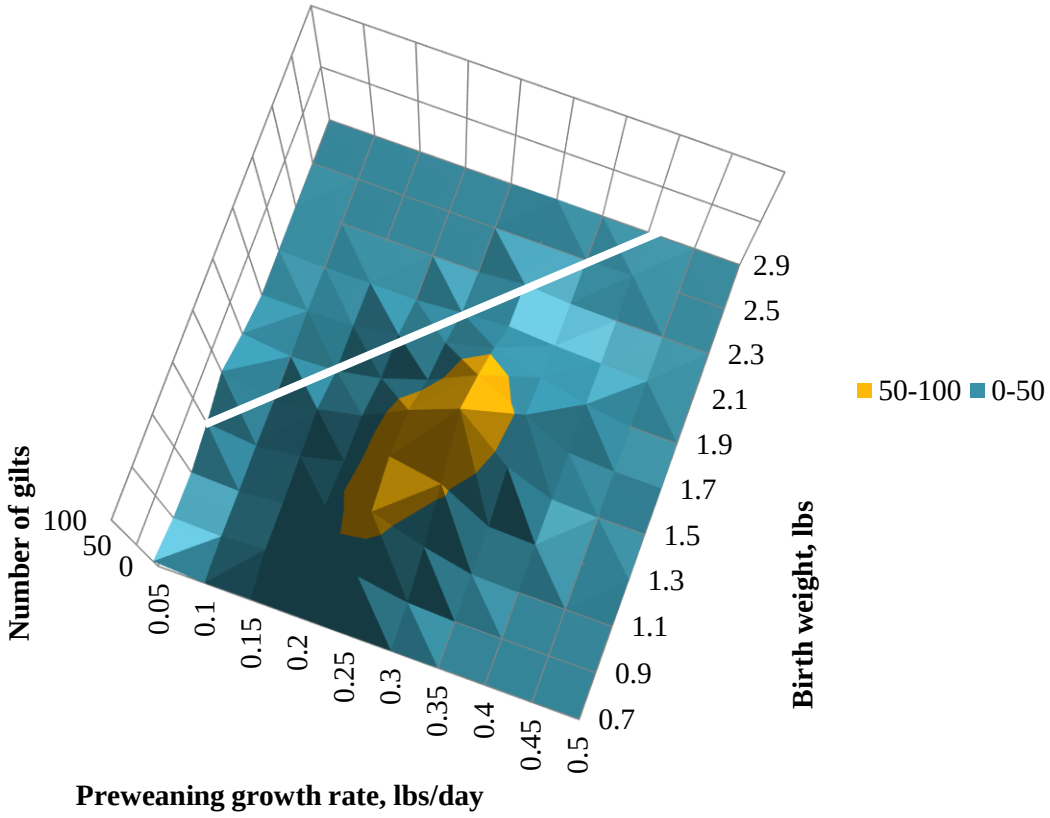


Figure 15. Histogram surface plot indicating the number of gilts at each birth weight and preweaning growth rate category. Most of the gilts fell within the range of 2 to 4.5 lbs in birth weight and within 0.35 to 0.75 lbs per day growth rate. The white line indicates the 200 day age at first estrous threshold from Fig. 16, and indicates that comparatively few gilts fall into this region.

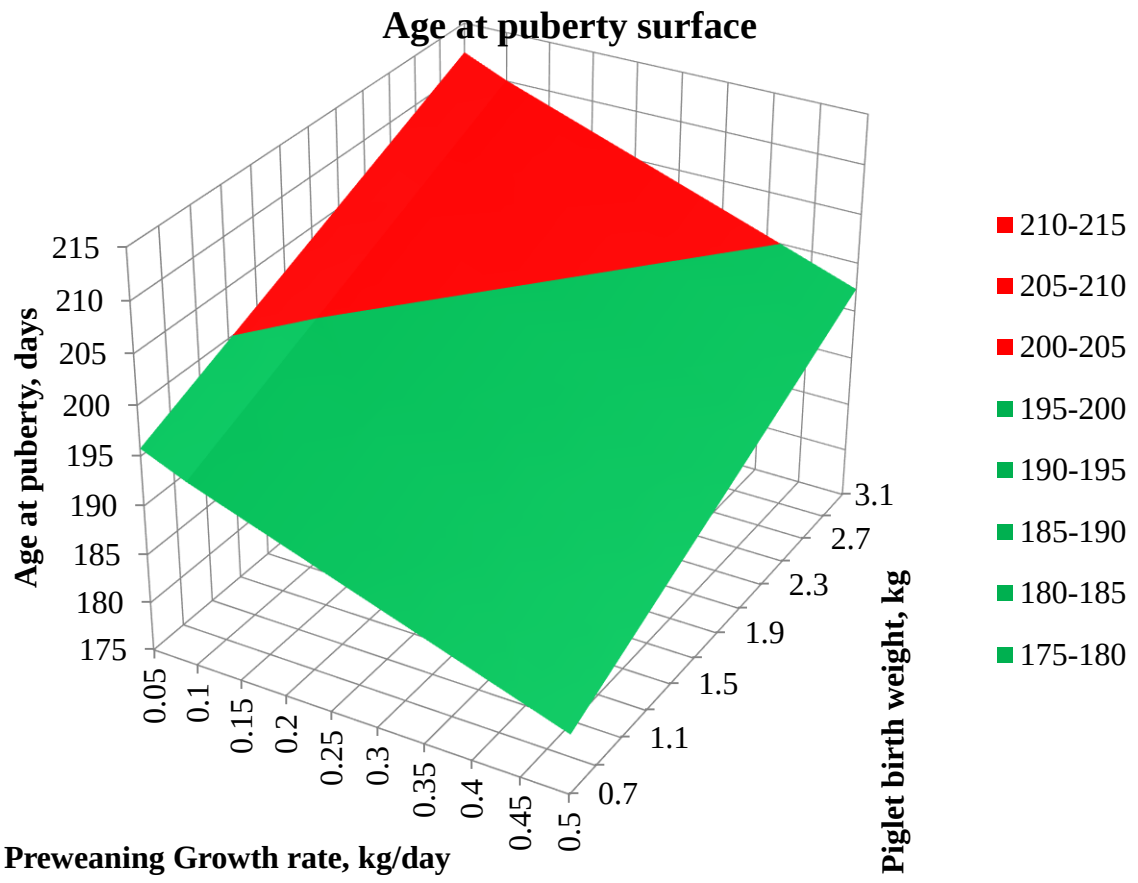


Figure 16. Surface plot of relationships between age at puberty, birth weights and preweaning growth rates of maternal line[1] gilts fed a) 2 lysine levels, b) 3 metabolizable energy (ME) levels and c) their interaction from 100 d to 250 d of age. Birth weight was positively ($P < 0.01$) and preweaning growth rate was negatively ($P < 0.01$) associated with age of first estrous. Red indicates the threshold for gilts reaching second estrous by 220 days of age.

[1]Maternal line = Large White × Landrace

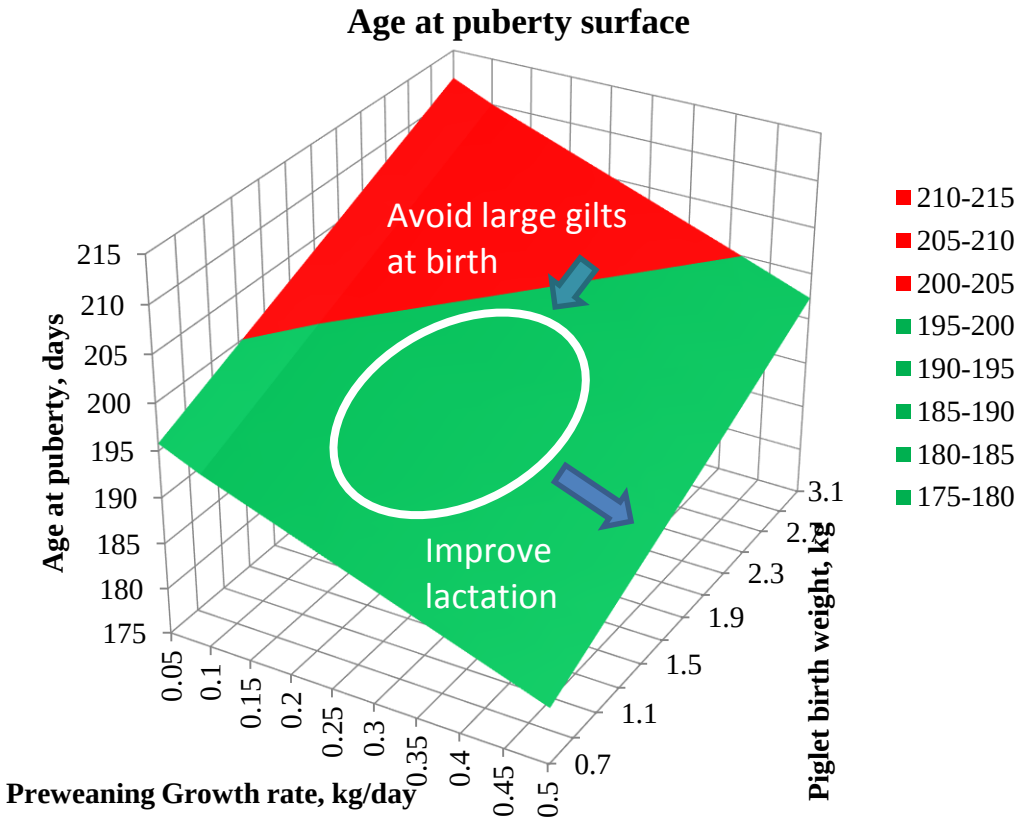


Figure 17. Response surface from Fig. 1 with an ellipse indicating the main population of gilts. Reduced age at first estrous would be expected to decrease if large birth weight gilts > 4.5lbs were excluded from the breeding herd and if preweaning growth rates were improved (e.g., using strategies to maximize lactation).

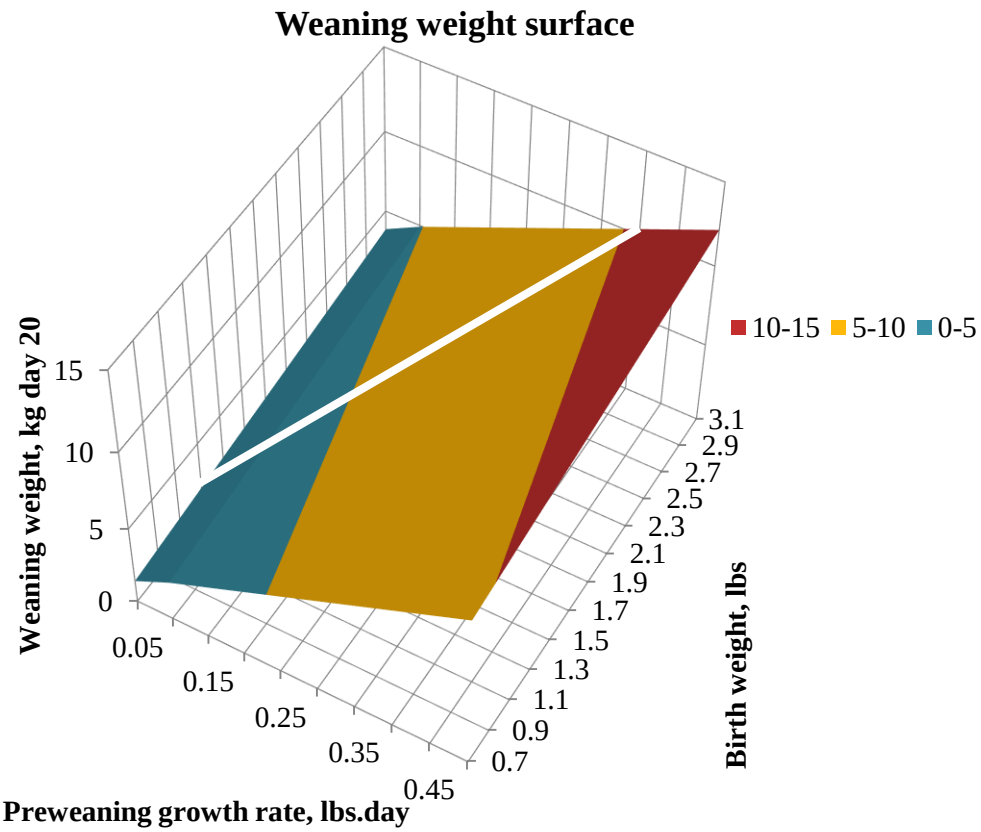


Figure 18. Weaning weight surface plot illustrating weaning weights that would result from birth weights combined with preweaning growth rates. White line indicates the region of 200 day first estrous threshold. Plot indicates that weaning weights cannot be used to find gilts predicted to have a first estrous after 200 days of age.

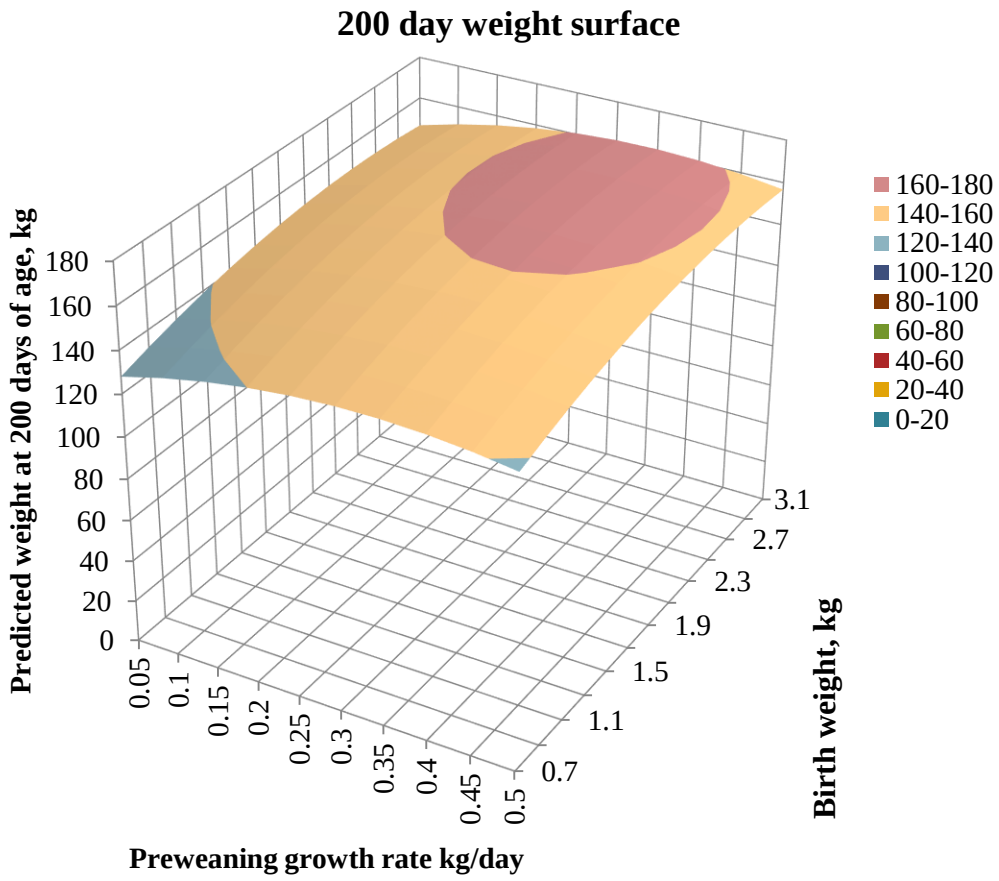


Figure 19. Surface plot indicating predicted weight at 200 days of age for gilts with varying birth weights and preweaning growth rates is illustrated. This plot demonstrates that gilts with large birth weights and high growth rates are predicted to be greater than 350 lbs at breeding, providing another reason to avoid gilts with high birth weights for the breeding herd.

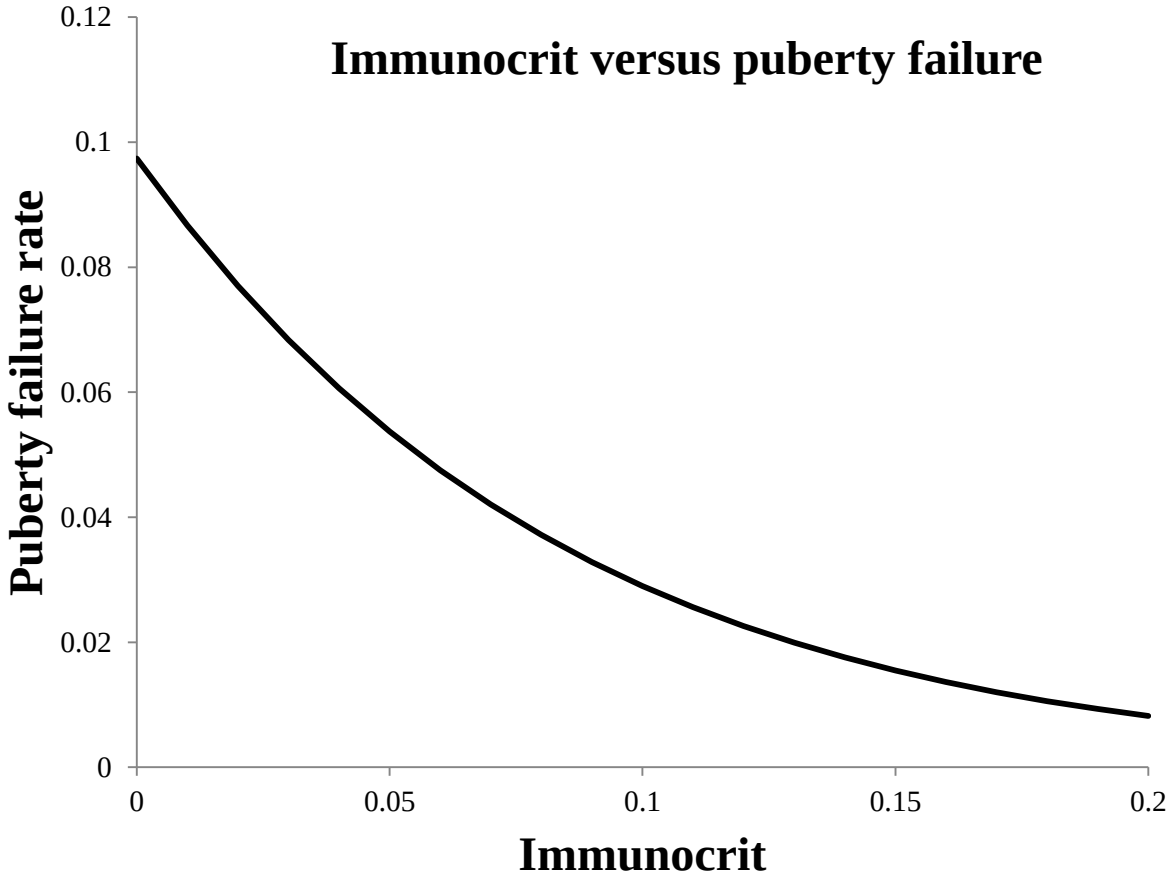


Figure 20. The relationship between the immunocrit on day 1 of age and the incidence of puberty failure ($P < 0.01$). Plot was generated using the regression curve obtained by statistical analsysis.

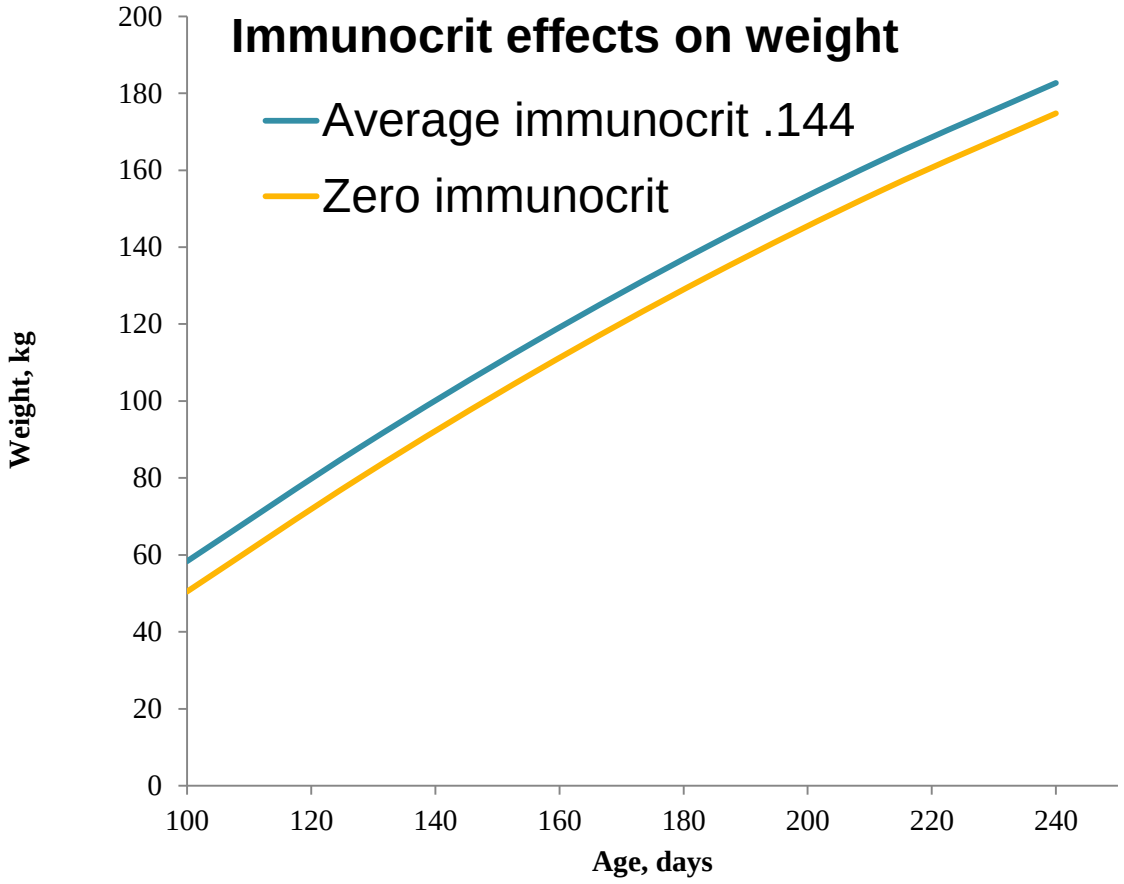


Figure 21. The effect of immunocrit ($P < 0.01$) on weight changes in gilts is illustrated. The two lines indicate predicted weight curves over time for gilts with an average immunocrit versus gilts with a zero immunocrit. Lines were generated using regression curves obtained after statistical analysis.

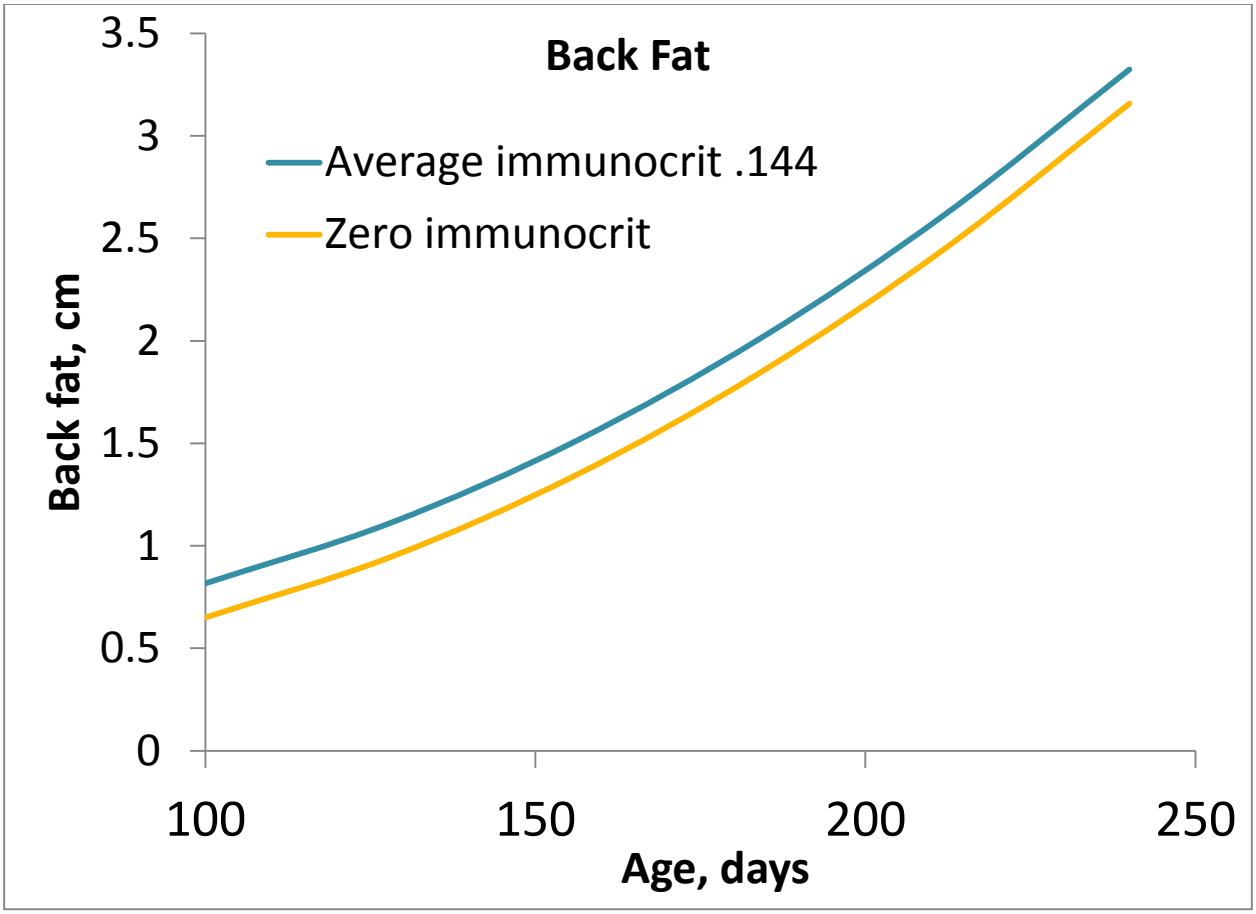


Figure 22. The effect of immunocrit on back fat ($P < 0.01$) is illustrated. The two lines indicate predicted back fat over time for gilts with average immunocrit versus gilts with zero immunocrit. Lines were generated using regression curves obtained after statistical analysis.

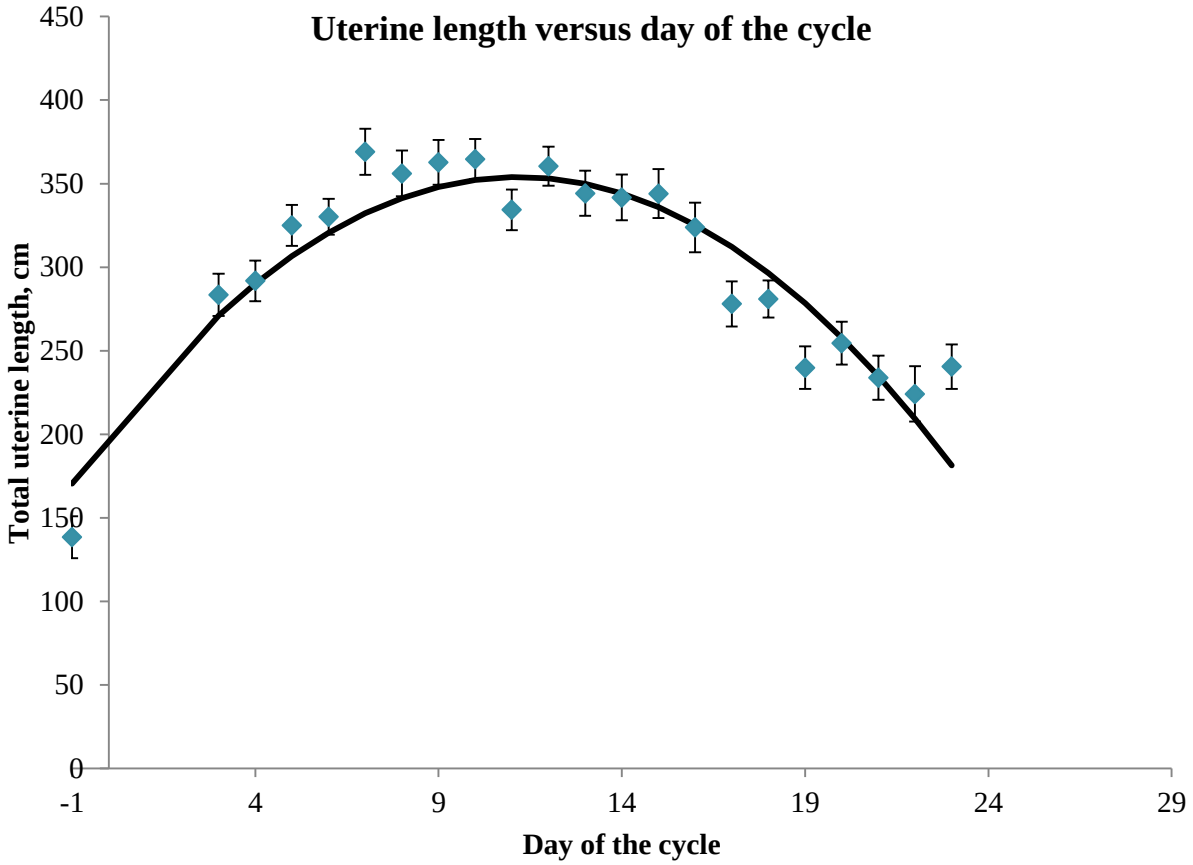


Figure 23. The relationship between the day of the cycle and total uterine length. Diamonds indicate least squares means for each day. Prepubertal pigs were assigned -1 for the day of the cycle, in order to include them in the analysis. Solid line indicates the quadratic prediction line fitting the data. Prediction line indicated that uterine length differs by at least 100 cm during the estrous cycle, and is maximum at approximately day 11 of the cycle.

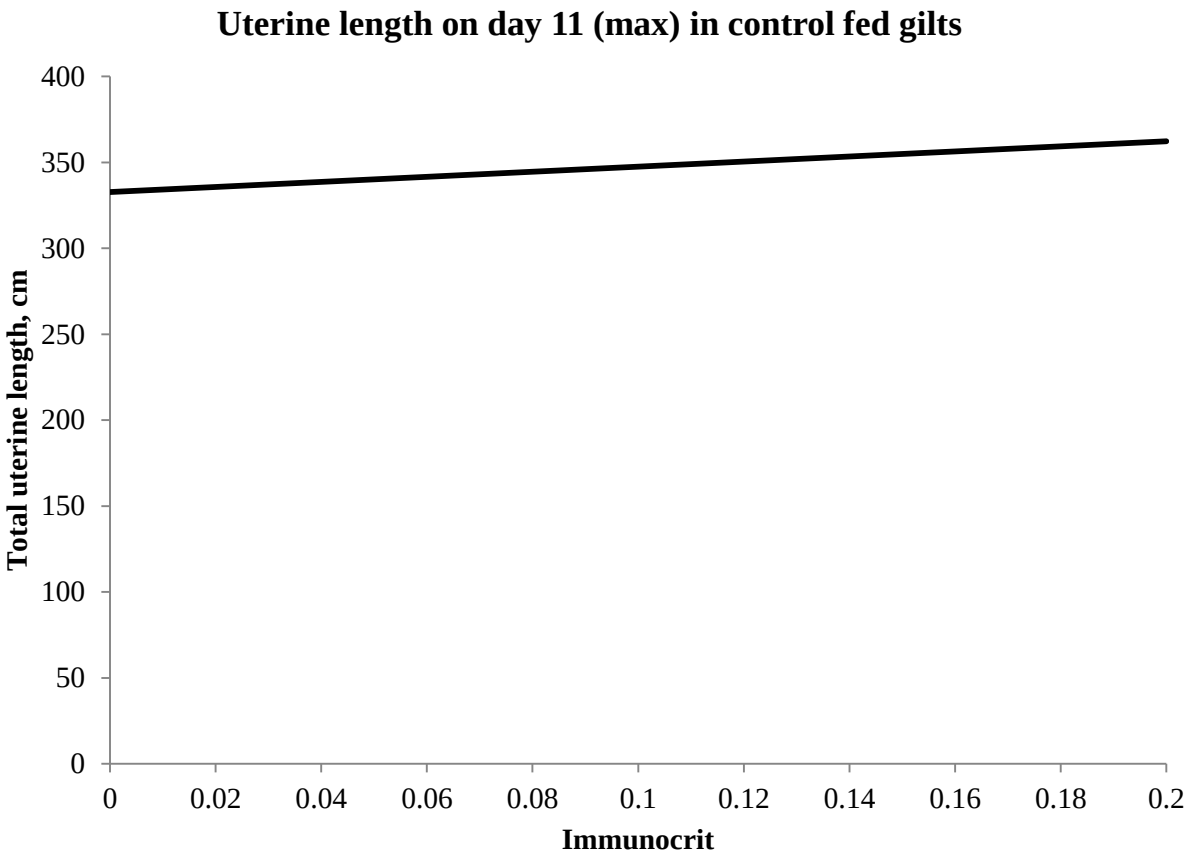


Figure 24. Graph indicates the relationship between the immunocrit on day 1 of age and subsequent uterine length as an adult ($P = 0.06$). The mean immunocrit was 0.144. The prediction equation indicates that total uterine length differed by ~30 cm over the range of immunocrit values observed.

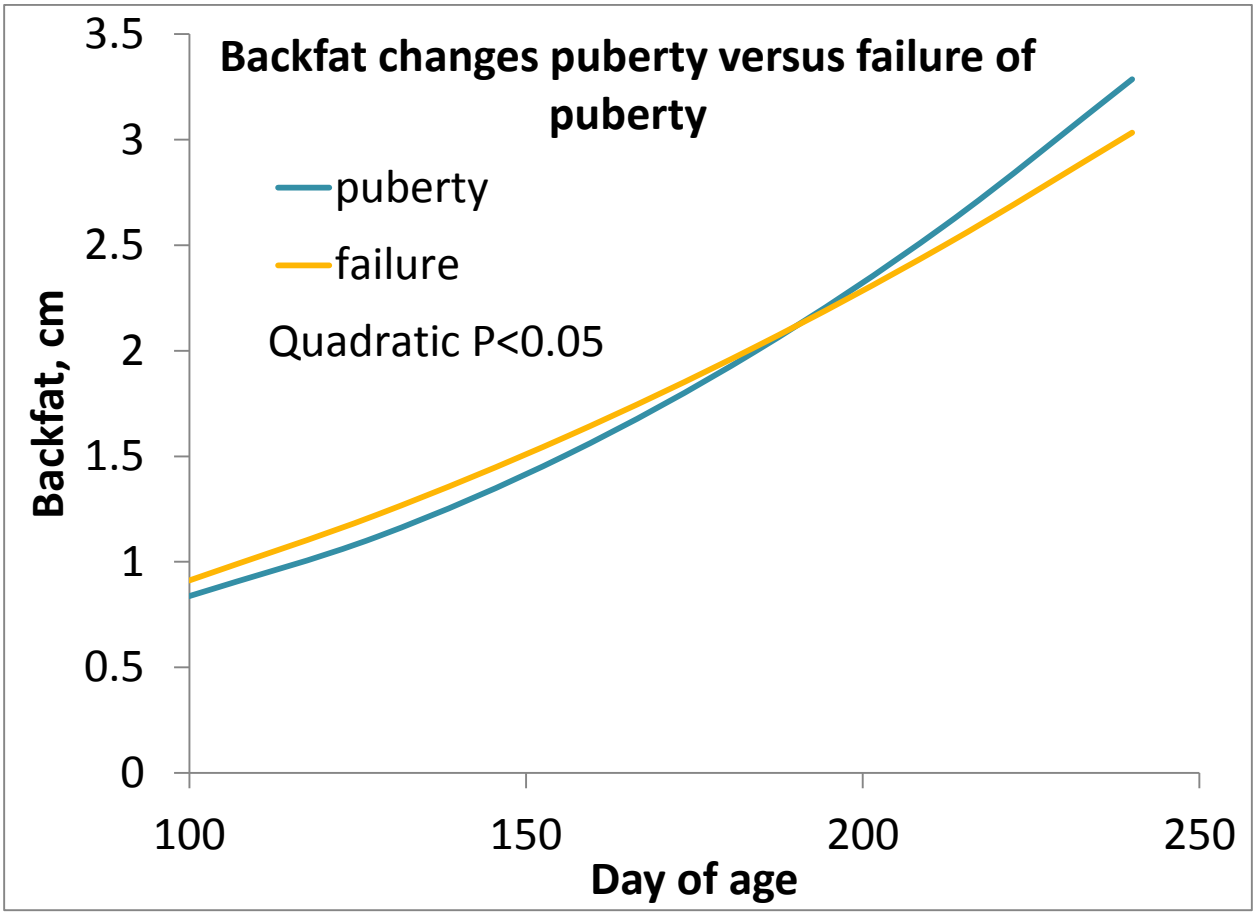


Figure 25. Graph indicates back fat changes with age for gilts that reached puberty during the experiment and those that did not. The quadratic portion of the prediction equations differed ($P < 0.05$) between the two groups. The difference between the two groups is subtle, suggesting that back fat is unlikely to be a useful predictor of puberty failure.