Analyses of Feed and Energy Intakes During Lactation for Three Breeds of Sows

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Daily feed intakes from 993 lactation records from 3 breeds of sows (42 Duroc, 405 Landrace, and 358 Yorkshire sows) were evaluated over a 19-mo period. Mixed models were evaluated for the Bridges, negative exponential, and generalized Michaelis-Menten functions. The generalized Michaelis-Menten function with 2 random effects provided the best fit to both daily feed intake (residual SD = 0.93 kg/d) and ME intake (residual SD = 3.04 Mcal/d). Duroc sows had lower (P < 0.001) feed and ME intakes than Landrace and Yorkshire sows. Feed and ME intakes were less for the summer season (June 15 to September 15) than for the other 3 seasons. Predicted mean ME intake (d 1 to 19) had significant (P < 0.001) relationships with number weaned (NW; ME intake, Mcal/d =16.84 + 1.445 NW − 0.0692 NW2) and 21-d litter weight [ME intake, Mcal/d = 21.42 + 0.0454 (21-d litter weight,kg)]. Sows with greater than average 21-d litter weights consumed only 12 to 14% of the additional ME required for the additional milk production. A transient reduction in feed intake was defined as when daily feed intake was 1.6 residual SD less than the predicted daily feed intake for 2 or more days. The incidence of transient reductions in feed intake was not affected (P > 0.10) by stage of lactation (68 early, 77 mid-, and 82 late lactation). The incidence of transient reductions in feed intake was affected (P < 0.05) by season, with incidence rates of 18.8, 16.3, 22.2, and 16.3% for summer, fall, winter, and spring, respectively.

Key words: sow, lactation , feed intake , weaning weight

INTRODUCTION

Genetic selection for increased sow productivity, including number born alive, litter weaning weight, and number weaned, results in increased demand for milk production (Shurson and Irvin, 1992; Bergsma et al., 2008). Both actual selection experiments and predicted responses indicate that selection for increased sow productivity will result in increased sow BW loss during lactation (Shurson and Irvin, 1992; Bergsma et al., 2008). This is primarily because the sow feed intake during lactation does not increase in proportion with the increased demand for milk production (Kim and Easter, 2001; Trottier and Johnston, 2001). Increasing the sow feed intake during lactation could reduce BW losses and allow for maintenance of body condition (Auldist and King, 1995; Revell et al., 1998; Kim and Easter, 2001). Selection for increased feed intake during lactation is a possible solution to improving sow performance and body condition and reducing days from weaning to estrus (Payne et al., 2004; Bergsma et al., 2008).

Sows experience transient reductions in feed intake, which result in different patterns of feed intake during lactation (Koketsu et al., 1996a,b). Sows with large, transient reductions in feed intake have a greater number of days in the interval from weaning to conception

(Koketsu et al., 1996b). The objectives of this research were 1) to quantify and model daily feed intakes (**DFI**) during lactation of 3 breeds of sows (2 maternal breeds of Yorkshire and Landrace selected for increased sow productivity and a Duroc breed selected for postweaning performance), 2) evaluate the incidence of transient reductions in feed intake, and 3) evaluate the relationship of feed intake to measures of sow productivity.

MATERIALS AND METHODS

Daily feed intake records were collected by Tempel Genetics Inc. (Gentryville, IN) from January 2007 through August 2008. A total of 19,321 DFI records were collected for 993 farrowings (Table 1). Data were obtained for 44 Duroc, 499 Landrace, and 450 Yorkshire lactation records. The data had been assigned to 21 contemporary groups, defined as farrowing groups within 28- to 30-d periods. The average contemporary group size was 47.3 (SD = 4.3). Over the 19-mo period, 5 different cornand soybean meal-based lactation diets were fed. The diets ranged from 3.19 to 3.33 Mcal ME/kg. Daily ME intakes were calculated as the DFI (kg/d) times the calculated ME concentration (Mcal/kg) of the specific diets. The DFI and ME intake data were assigned to 4 seasons: summer, June 15 to September 14; fall, September 15 to December 14; winter, December 15 to March 14; and spring, March 15 to June 14. The lactation records also included the number of pigs after cross-fostering, the number weaned, and litter weaning weight. Litter weight was adjusted to 21 d (National Swine Improvement Federation, 1987). The weaning-to-first estrus interval (**WTEI**) was obtained for all sows (n = 773) when a culling decision was not made before subsequent service. Sows were fed 1.36 kg of feed within 8 to 12 h after farrowing. Sows were fed twice the day after they farrowed (at least two 1.81-kg scoops). When sows achieved 5.44 kg/d, they were fed 3 times daily; at 7.26 kg/d, they were fed 4 times daily; and upon achieving 9.07 kg/d, they were fed 5 times daily.

Table 1. Number of sows and lactation records by breed, parity, and season[1]

Item	Duroc	Landrace	Yorkshire
No. of sows	42	405	358
No. of lactation records, overall	44	499	450
No. of lactation records by parity			
Parity 1	6	100	75
Parity 2	10	80	70
Parity 3	6	72	61
Parity 4	7	53	52
Parity 5	15	194	192
No. of lactation records by season			
Fall	9	69	67
Winter	11	126	105
Spring	9	160	162
Summer	15	144	116

[1]Spring: March 16 to June 15; summer: June 16 to September 15; fall: September 16 to December 15; winter: December 16 to March 15.

A preliminary analysis was conducted to evaluate the overall trend in DFI relative to days of lactation. The model included the random effect of lactation record and fixed effects including days of lactation, breed line, season, parity, and interactions of the genetic line, season, and parity with days of lactation. The daily sow feed and ME intake data were fitted to 3 alterative mixed nonlinear models using the nonlinear mixed (NLMIXED) procedure of SAS (SAS Institute Inc., Cary, NC; Schinckel and Craig, 2002). The exponential function has the form $DFI_{i,t} = DFIA[1 - \exp(Bt)] + DFI0$, where $DFI_{i,t}$ is the DFI of the ith lactation record on day t of lactation, DFIA is the asymptotic DFI (kg/d) or ME intake (Mcal/d), t is days of lactation, and DFI0 is an intercept. In this function, DFIA and B can be considered random effects.

The Bridges function has the general form $DFI_{i,t} = DFIA[1 - \exp(-\exp M')t^A] + DFI0 + e_{i,t}$, where DFIA is an estimate of asymptotic DFI, M′ is a transformed parameter (M), which is an exponential decay constant, t is days of lactation, A is the kinetic order constant (Bridges et al., 1986; Schinckel and Craig, 2002), and DFI0 is the predicted intercept (DFI at t = 0). The parameters DFIA, M′, and A can be considered random and have specific values for each group of observations. The random effect of one parameter (A or M′) can be predicted as being a linear function of the random effect for DFIA (dfii; Schinckel et al., 2006).

The third function fitted to the sow feed intake data was the generalized Michaelis-Menten function (**GMM**; Lopez et al., 2000; Schinckel et al., 2009). The GMM function has the form $DFI_{i,t}$ (kg/d) = $DFI0 + [(DFIA - DFI0)(t/K)^C]/[1 + (t/K)^C]$, where DFI0 is the predicted DFI at day = 0, DFIA is the asymptotic DFI, K is a parameter equal to the day of lactation at which one-half of the increase from DFI0 to DFIA is achieved {$DFI_{i,k} = [(DFIA + DFI0)/2][(DFIA + DFI0)/2]$}, and C is a unitless parameter related to changes in the rate at which DFI increases with days of lactation (Lopez et al., 2000). This function has an inflection point (**IP**, d) = $K[(C - 1)/(C + 1)]^{(1/C)}$ and the DFI at the IP = {[(1 + (1/C)]DFI0]} + {[1 – (1/C)]DFIA}. In this function, the parameters DFIA, K, and C can be considered random effects.

The inclusion of a single random effect for DFIA (dfii) in any of the 3 functions produces a series of growth curves in which each sow lactation record has an approximate constant percentage (dfii/DFIA) greater or lesser DFI than the mean DFI at each day of lactation. The inclusion of a second random effect into any of the 3 functions accounts for different patterns of DFI between sow lactations (Schinckel and Craig, 2002). The addition of a second random effect for C or K allows increased flexibility in fitting the between-sow variance in the shape of the lactation curves.

Alternative mixed models of each function were evaluated based on residual SD (**RSD**) and Akaike's information criterion (**AIC**) values. The R^2 values were calculated as squared correlations between the predicted and actual observations. The RSD was calculated with the equation

$$RSD = \left[\sum_{t=1}^{T}\sum_{i=1}^{I}\left(e_{i,t}\right)^2 \Big/ \left(n - p\right)\right]^{1/2},$$

where $e_{i,t}$ is the residual value of the ith pig at day t, n is the number of observations, and p is the number of parameters in the model. The NLMIXED procedure provided predicted values for the random effect of each lactation record, variance estimates for each random effect, covariance estimates for each pair of random effects, and the residual variance. Approximate SE of the function parameters, variance estimates, and covariance estimates are based on the second derivative matrix of the likelihood function. These approximate SE are based on large sample inferences (Lindsey, 1996; Neter et al., 1996). Transient reductions in DFI and ME intake were identified as 2 or more serial daily observations that had actual values of 1.6 or greater RSD less than their predicted values. Early transient records were identified as when the first initial low observation occurred on d 7 of lactation or earlier. Midlactation transient reductions had their first low observation on d 8 to 15. Late-lactation transient reductions in feed intake occurred on d 16 to 22. The duration (d) of the transient reduction in feed intake and sum of the residual values (actual minus predicted value) of DFI or ME intakes were calculated for each transient reduction. The other measure of variation evaluated was the RSD for each lactation. Sows with low DFI throughout the entire lactation period were also indentified when predicted asymptotic DFI was less than 4.5 kg, similar to the criteria of Koketsu et al. (1996a,b). The effects of breed line, parity, and season on the incidence of transient reductions in ME intake were evaluated by chi-squared tests using the FREQ procedure of SAS. The individual lactation record data including the values for each nonlinear function parameter, IP variables, and other predicted or actual values were fitted to a mixed model using the MIXED procedure of SAS. The model included the fixed effects of season, breed line, parity, and their interactions. To provide the appropriate significance tests based on expected means squares, the model also included the random effects of contemporary group nested within season as well as the interaction of this random term with each main effect. The relationships of daily ME intake with number after transfer, number weaned, and litter weaning weight (adjusted to 21 d) were evaluated. The linear and quadratic effects of each individual variable and all 3 variables were added to the fixed (parity, season, breed) and random effects (contemporary group within season) model. Nonsignificant ($P < 0.05$) variables were eliminated in a stepwise procedure. The R2 and residual variance of the models with and without the additional variables were calculated. Similar regression analyses were conducted with the C + ci values to evaluate the relationship of the shape of sow lactation ME intakes to the sow productivity variables.

Regression analyses were conducted to evaluate the relationship of the WTEI with measures of sow productivity and energy intake during lactation. Linear and quadratic effects of number weaned and weaning weight were added to a model including significant ($P < 0.05$) fixed effects (season, breed, parity) and random effects (contemporary group within season). Additional variables were added to the model, including the predicted mean daily ME from d 1 to 19, number of transient reductions in ME intake, sum of the residual values for the transient reductions in ME intake, and the RSD for the specific lactation record. Variables were added ($P < 0.05$) in a stepwise fashion. The impact of transient reductions of ME intake on the incidence of delayed estrous post weaning was evaluated via chi-squared analyses (FREQ procedure of SAS). Delayed return to estrous post weaning was defined as a WTEI of 8 d or greater (Revell et al., 1998).

RESULTS AND DISCUSSION

The means and SD for lactation length, DFI, and daily ME intake are presented in Table 2. The average lactation lengths were 19.9, 19.3, and 19.6 d for Duroc, Landrace, and Yorkshire sows, respectively, with SD ranging from 1.5 to 1.8 d. Daily feed intakes averaged 6.14, 6.61, and 6.86 kg/d for Duroc, Landrace, and Yorkshire sows, respectively, with SD ranging from 2.0 to 2.3 kg/d.

The WTEI were 5.21, 5.55, and 5.38 d for Duroc, Landrace, and Yorkshire sows. The SD in the WTEI was less ($P < 0.05$) for Duroc sows (0.52 d) than for Landrace and Yorkshire sows (1.71 and 1.63 d). The ranges in WTEI were 5 to 7 d for Duroc sows (n = 39 records) versus 3 to 17 d for both Landrace and Yorkshire sows (n = 394 and 340, respectively). The least squares means for the sow productivity traits are presented in Table 3. The number of pigs after transfer was less ($P < 0.001$) for Duroc than for Yorkshire and Landrace sows. Duroc sows weaned fewer pigs ($P < 0.001$; 8.11 vs. 9.72 and 9.89) and had lower ($P < 0.001$) litter weaning weights adjusted to 21 d (56.1 vs. 66.7 and 68.1 kg) than Landrace and Yorkshire sows. The number weaned was smaller ($P = 0.002$) for the winter season (8.60 pigs/litter) than for the other 3 seasons (9.21, 9.52, and 9.21 pigs/litter for spring, summer, and fall, respectively). The smaller number weaned for the winter season was caused by a combination of the slightly smaller number after transfer ($P = 0.08$) and percentage of survival ($P = 0.09$). Number weaned ($P = 0.001$) and litter weight were affected ($P = 0.009$) by parity. The number weaned (8.70 pigs/litter) was smaller and the 21-d litter weight (59.6 kg) was less for sows of parity 5 and greater than for sows of parity 4 and less (9.38 pigs and 64.7 kg/litter).

The least squares means for each breed-lactation day combination are shown in Figures 1 and 2. Feed intake increased rapidly from d 1 to 4, and the rate of increase decreased from d 4 to 10 and then tended to increase very slowly after d 10.

Table 2. Breed means for lactation length, daily feed intake, and daily ME intake

	Duroc		Landrace		Yorkshire	
Item	Mean	SD	Mean	SD	Mean	SD
Lactation length, d	19.9	1.5	19.3	1.7	19.6	1.8
Daily feed intake, kg/d	6.14	2.0	6.61	2.2	6.86	2.3
ME intake, Mcal/d	20.0	6.6	21.6	7.3	22.4	7.5
Weaning-to-estrous-interval,[1] d	5.21	0.52	5.55	1.71	5.38	1.63

[1]n = 39, 394, and 340 records for Duroc, Landrace, and Yorkshire sows.

The analyses indicated that the GMM function provided the best fit to the DFI data to days of lactation. The parameter estimates of the GMM functions for DFI are presented in Table 4. The DFIA parameter was the first random effect added to the nonlinear function based on AIC and RSD values. The second parameter to enter the nonlinear regression as a random effect was ci. This random effect indicates that the DFI at which DFI increased most rapidly (the IP) occurred at different percentages of asymptotic DFI. Although statistically significant based on AIC values, the addition of the random effect ci had relatively little impact on the RSD (0.9611 vs. 0.9326 kg) and R2 values (0.820 to 0.831). The value of

K, the day of lactation in which onehalf of the increase from DFI0 to DFIA was achieved, was 4.89 d for the function including 2 random effects.

The parameters for the GMM function for daily ME intake (MEI; Mcal/d) are presented in Table 5. The R2 values were only slightly (0.002 and 0.0013) greater for the fit of daily ME than the fit of feed intake to days of lactation. The value of K for the model with 2 random effects indicated that one-half the increase in ME intake from MEI0 to MEIA was achieved at 4.90 d of lactation.

The least squares means for the parameters of the GMM function (DFIA and C), day of lactation at the IP, and DFI at the IP are presented in Table 6. The predicted DFI at each day of lactation for each season and breed are presented in Figures 3 and 4. The DFIA was affected by season, breed, and the interaction of parity × breed. The mean DFIA for summer was less (8.20 kg/d) than for the other 3 seasons (9.56, 9.61, and 9.40 kg/d for fall, winter, and spring, respectively). The value for DFIA was less for Duroc (8.86 kg/d) than for Landrace and Yorkshire sows (9.26 vs. 9.45 kg/d, respectively). The parity × breed interaction was produced by the fact that parity 1 Duroc sows had greater DFIA values than Duroc sows of all other parities. In contrast, the DFIA values for Yorkshire and Landrace sows increased from parity 1 to 3 and did not increase in subsequent parities.

Table 3. Least squares means for number after transfer, number weaned, survival, and 21-d adjusted weaning weight

	No. after transfer			No. weaned			Percent survival			21-d weaning weight		
Item	Mean	SE	*P*-value	Mean	SE	*P*-value	Mean	SE	*P*-value	Mean	SE	*P*-value
Season	—	—	0.08	—	—	0.002	—	—	0.09	—	—	0.08
Fall	10.89	0.29	—	9.21	0.20	—	83.2	2.9	—	65.3	1.7	—
Winter	10.17	0.24	—	8.60	0.18	—	82.9	2.5	—	60.4	1.5	—
Spring	10.73	0.24	—	9.21	0.20	—	89.4	2.6	—	66.0	1.6	—
Summer	11.01	0.24	—	9.52	0.17	—	85.5	2.9	—	62.9	1.5	—
Breed	—	—	0.001	—	—	0.001	—	—	0.67	—	—	0.001
Duroc	9.25	0.29	—	8.11	0.24	—	86.2	3.3	—	56.1	2.0	—
Landrace	11.34	0.12	—	9.72	0.10	—	84.3	1.1	—	66.7	0.74	—
Yorkshire	11.51	0.12	—	9.89	0.10	—	85.0	1.2	—	68.1	0.78	—
Parity	—	—	0.09	—	—	0.001	—	—	0.18	—	—	0.009
1	10.90	0.26	—	9.78	0.21	—	89.3	3.0	—	64.3	1.7	—
2	10.47	0.24	—	9.10	0.19	—	85.6	2.7	—	64.3	1.6	—
3	10.64	0.27	—	9.09	0.22	—	84.1	3.1	—	63.8	1.7	—
4	11.15	0.26	—	9.53	0.21	—	84.4	3.0	—	66.3	1.8	—
≥5	10.34	0.18	—	8.70	0.14	—	82.9	2.0	—	59.6	1.2	—
Variance												
Contemporary group (season)	0.124	—	—	0.001	—	—	0.0004	0.0002	—	0.997	—	—
Residual	2.80	—	—	1.99	—	—	0.0020	0.0001	—	84.1	—	—

The values for C and days at the IP were affected ($P < 0.001$) by season and breed. The predicted days at the IP for season were different ($P < 0.001$) and ranged from 1.32 d for summer versus 1.72 to 2.01 d for the other 3 seasons. The days of lactation at the IP ranged from 1.36 d for Duroc sows to 1.88 and 1.95 d for Landrace and Yorkshire sows. The predicted DFI at the IP was less ($P < 0.001$) for summer (2.37 kg/d) than for the other seasons (range: 2.90 to 3.72 kg/d). The predicted DFI at the IP was less for Duroc sows (2.56 kg/d) than for Landrace and Yorkshire sows (2.96 and 3.01 kg/d).

The least squares means for parameters of the GMM for daily ME intake are presented in Table 7. The predicted daily ME intakes at each day of lactation for each season and breed are presented in Figures 5 and 6. The parameters of the GMM function for daily ME intake were affected by breed and season in a pattern approximately identical to that of DFI.

Table 4. Parameters for daily feed intake (Mcal/d) data fitted to the generalized Michaelis-Menten function[1]

Item	Estimate	SE	R^2 value	RSD[2]	AIC[3]
Fixed-effects model					
DFI_A	8.820	0.052	0.6629	1.310	66,388
DFI_0	1.788	0.075	—	—	—
C	1.821	0.051	—	—	—
K, d	4.592	0.062	—	—	—
Var (e)	1.818	0.018	—	—	—
Model with DFI_A as a random effect					
DFI_A	8.873	0.055	0.8200	0.9611	57,140
DFI_0	1.895	0.049	—	—	—
C	1.777	0.035	—	—	—
K, d	4.771	0.043	—	—	—
Var (dfi_i)	1.568	0.076	—	—	—
Var (e)	0.9708	0.010	—	—	—
Model with DFI_A and C as random effects					
DFI_A	9.267	0.071	0.8310	0.9326	56,989
DFI_0	1.624	0.062	—	—	—
C	1.612	0.041	—	—	—
K, d	4.890	0.049	—	—	—
Var (dfi_i)	1.513	0.082	—	—	—
Var (c_i)	0.140	0.014	—	—	—
Cov (dfi_i, c_i)	0.0183	0.025	—	—	—
Var (e)	0.9369	0.010	—	—	—

[1]Function has the form $DFI_{i,t} = [DFI_0 + (DFI_A - DFI_0)(t/k)^C]/[1 + (t/k)^C]$, where $DFI_{i,t}$ is daily feed intake (kg/d) of the ith lactation at t days of lactation, DFI_0 is daily feed intake at d 0, DFI_A is asymptotic daily feed intake (kg/d), t is days of lactation, k is a parameter related to days of lactation at which one-half of the increase from DFI_0 to DFI_A is achieved, C is a unitless parameter, dfi_i is a random effect for DFI_A, and c_i is a random effect for C.

[2]RSD = residual SD.

[3]AIC = Akaike's information criterion.

The values for MEIA were less ($P < 0.001$) for summer (26.7 Mcal/d) than for the other 3 seasons (30.5 to 31.6 Mcal/d). Durocs had lower ($P < 0.001$) values for MEIA (Mcal/d) intake than did Landrace and Yorkshires. The predicted days at the IP for ME intake were similar to those for DFI. The predicted day at the IP was affected by season ($P < 0.001$), and had a mean of 1.34 d for summer and ranged from 1.72 to 2.00 d for the other 3 seasons.

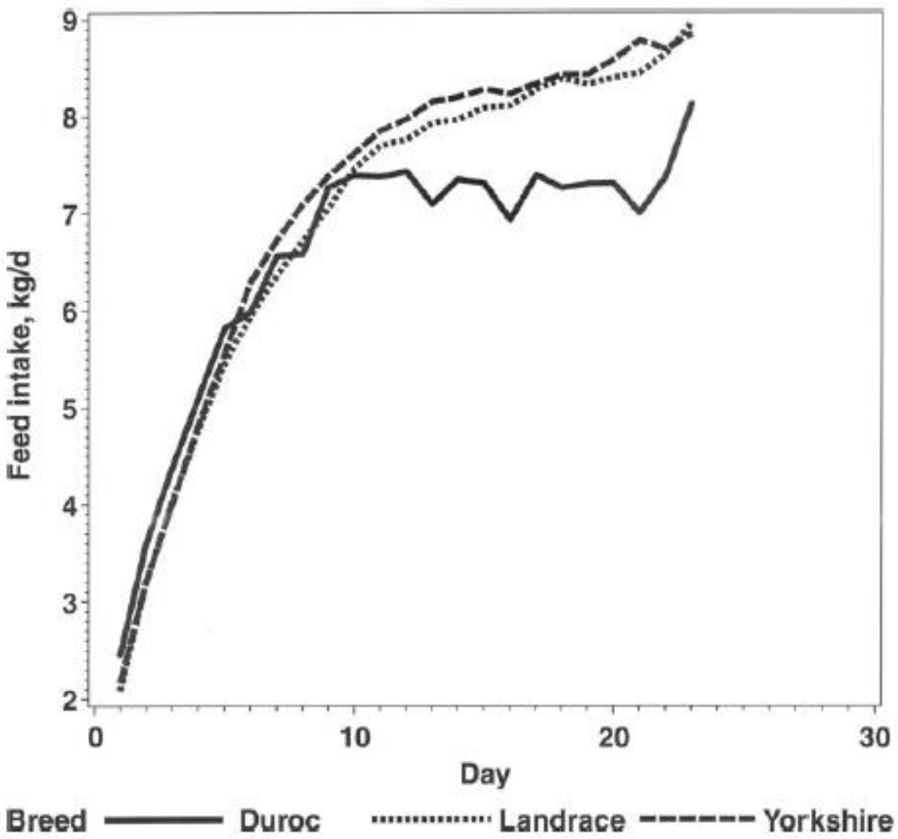

Figure 1. Least squares means for daily feed intake for each day of lactation for Duroc, Landrace, and Yorkshire sows.

The predicted ME intake at the IP was less ($P < 0.001$) for summer (7.80 Mcal/d) than for the other 3 seasons (range: 9.46 to 10.22 Mcal/d). The predicted DFI and ME intake from d 1 to 19 and the predicted feed intake on d 18 are presented in Tables 8 and 9. Both variables were affected by season ($P < 0.001$), breed ($P < 0.001$), parity ($P < 0.03$), and the breed × parity interaction ($P < 0.009$). Both mean DFI and ME intake from d 1 to 19 were less for summer than for the other 3 seasons. Duroc sows had less predicted mean DFI (6.30 kg/d) and ME intake (20.6 Mcal/d) than Landrace (6.66 kg/d and 21.8 Mcal/d) and Yorkshire sows (6.80 kg/d and 22.2 Mcal/d). The breed × parity interaction was produced by the fact that parity 1 Duroc sows had greater predicted mean DFI and ME intake from d 1 to 19 than Duroc sows at parity 2 and greater. In contrast, the mean predicted DFI and ME intake of Landrace and Yorkshire sows increased from parity 1 to 3 and remained constant in subsequent parities.

The predicted d-18 DFI and ME intake followed patterns similar to the overall mean d-1 to d-19 values. Predicted d-18 DFI and ME intake were less for summer (7.23 kg/d and 22.4 Mcal/d) than for the other 3 seasons (8.43 to 8.69 Mcal/d and 26.7 to 28.7 Mcal/d). Duroc sows had lesser predicted d-18 feed intakes (7.81 kg/d and 24.6 Mcal/d) than Landrace (8.36 kg/d and 27.3 Mcal ME/d) and Yorkshire sows (8.54 kg/d and 27.5 Mcal/d). Predicted d-18 DFI and ME intake were affected by the breed × parity interaction, with the same pattern as the mean predicted DFI and ME intake.

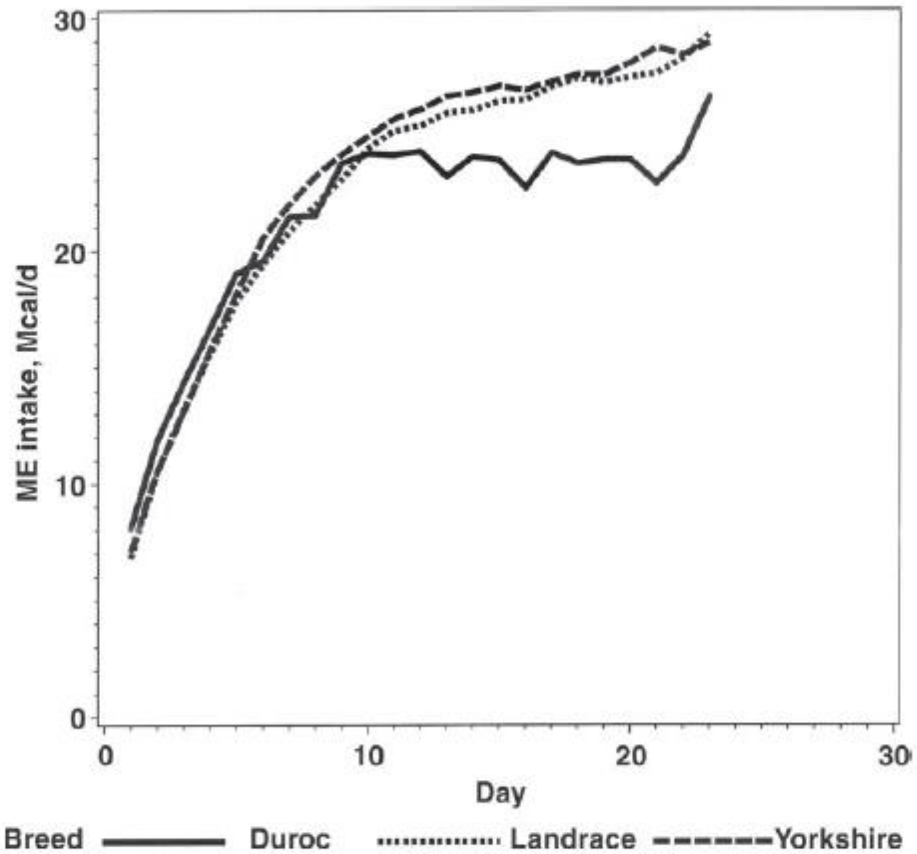

Figure 2. Least squares means for daily ME intake for each day of lactation for Duroc, Landrace, and Yorkshire sows.

Analysis of Transient Reductions in Feed Intake

A transient reduction in feed intake was defined as when DFI was 1.6 RSD less than the predicted DFI for 2 or more sequential days. A total of 153 transient reductions in feed intake occurred over the 993 litter lactation records. Eleven lactation records had 2 transient reductions in feed intake.

The incidence of transient reductions in feed intake was not affected ($P \geq 0.10$) by stage of lactation, with 68 early-, 77 mid-, and 82 late-lactation transient reductions in feed intake. The incidence of transient reductions in feed intake was affected ($P < 0.05$) by season, with incidence rates of 18.8, 16.3, 22.2, and 16.3% for summer, fall, winter, and spring, respectively. The incidence of early transient reduction in feed intakes was greater ($P < 0.05$) for Landrace sows (6.71%) than for Yorkshire (2.64%) and Duroc sows (0.0%). The incidence of early transient reductions in feed intake was greater ($P < 0.05$) for winter (9.27%) than fall, spring, or summer (4.76, 3.00, and 2.17%, respectively). Parity 1 sows had a greater ($P < 0.05$) incidence of early- and mid-lactation transient reductions in feed intake (8.02 and 8.02%) than did sows of the other parities (5.3 and 5.2%). The incidence of late transient reductions in feed intake was greater ($P < 0.05$, 8.7%) for the summer than for the fall, winter, or spring (4.8, 5.2, and 5.7%, respectively). The length of the transient reductions in feed intake was not affected by breed ($P = 0.69$), season ($P = 0.34$), or parity ($P = 0.19$).

Table 5. Parameters for ME intake (Mcal/d) data fitted to the generalized Michaelis-Menten function[1]

Item	Estimate	SE	R^2 value	RSD[2]	AIC[3]
Fixed-effects model					
MEI_A	28.81	0.17	0.6616	4.34	112,325
MEI_0	5.84	0.25	—	—	—
C	1.821	0.05	—	—	—
K, d	4.595	0.062	—	—	—
Var (e)	19.60	0.199	—	—	—
Model with MEI_A as a random effect parameter					
MEI_A	28.98	0.18	0.8220	3.13	102,818
MEI_0	6.207	0.15	—	—	—
C	1.848	0.35	—	—	—
K, d	4.783	0.043	—	—	—
Var (mei_i)	17.24	0.83	—	—	—
Var (e)	10.31	0.107	—	—	—
Model with MEI_A and C as random effects					
MEI_A	30.27	0.23	0.8323	3.04	102,671
MEI_0	5.32	0.20	—	—	—
C	1.612	0.041	—	—	—
K, d	4.898	0.049	—	—	—
Var (mei_i)	16.54	0.90	—	—	—
Var (c_i)	0.1377	0.014	—	—	—
Cov (mei_i, c_i)	0.090	0.085	—	—	—
Var (e)	9.95	0.107	—	—	—

[1]Function has the form ME_t (Mcal/d) = MEI_0 + $(MEI_A - MEI_0)(t/K)^C/[1 + (t/K)^C]$, where MEI_0 is ME intake at d 0, MEI_A is asymptotic ME intake (Mcal/d), t is days of lactation, K is a parameter related to days of lactation needed to achieve one-half of the increase from MEI_0 to MEI_A, C is a unitless parameter, mei_i is a random effect for MEI_A, and c_i is a random effect for C.

The length of the transient reductions was not different for stage of lactation.The overall mean for duration of the transient reduction in feed intake was 2.38 d, with a SD of 0.72 d and a range of 2 to 6 d. The predicted reductions in asymptotic feed intake associated with each transient reduction in feed intake had a mean of 6.14 kg, a SD of 2.95 kg, and a range of 3.16 to 18.25 kg.

The sum of the residual values for ME intake for the designated transient reduction in feed intake was not affected by breed (P = 0.15), season (P = 0.55), parity (P = 0.90), or stage of lactation (P = 0.31). The overall mean for the total predicted reduction in ME intake associated with each transient reduction in feed intake was 20.0 Mcal, with a SD of 9.60 Mcal and a range of 10.3 to 59.4 Mcal.

The RSD for each lactation record was also analyzed as a measure of overall variability in the difference between the actual and predicted DFI. The RSD for DFI had an overall mean of 0.974 kg/d and a range of 0.367 to 2.94 kg/d. The RSD for ME intake (Mcal/d) had a mean of 3.177, a SD of 1.25, and a range of 1.13 to 9.63 Mcal/d. The RSD for daily feed and ME intake were not affected by breed (P = 0.12), season (P = 0.44), or parity (P = 0.90). Sows that had a transient reduction in feed intake had RSD for DFI (1.47 kg/d) and ME intake (4.79 Mcal/d) that were approximately 65% greater than those for sows that did not have a transient reduction in feed intake (mean RSD = 0.89 kg/d and 2.90 Mcal/d).

Relationships of Metabolizable Energy Intake to Sow Productivity

Regression analyses were conducted to evaluate the relationships among measures of ME intake and sow productivity. Predicted mean daily ME intake from d 1 to 19 had a significant (P < 0.05) linear-quadratic relationship with number weaned (Table 10 and Figure 7) and a linear relationship to 21-d litter weight (Figure 8). Actual and predicted d-18 ME intakes and DFIA values had significant (P < 0.05) linear-quadratic relationships with number weaned. Actual and predicted d-18 ME intake and DFAA values had significant (*P* < 0.05) linear relationships with number weaned. The addition of number weaned increased the R2 of the equations (range in the R2 increase was 0.87 to 1.51%) for the ME intake variables. The addition of number weaned increased the R2 of the regression equations from 2.49 to 3.39%.

Table 6. Least squares means for parameters for daily feed intake (kg/d) fitted to the generalized Michaelis-Menten function[1]

	DFI_A			C			Days at IP[2]			Feed intake at IP		
Item	Mean	SE	*P*-value	Mean	SE	*P*-value	Mean	SE	*P*-value	Mean	SE	*P*-value
Season	—	—	0.001	—	—	0.001	—	—	0.001	—	—	0.001
Fall	9.56	0.21	—	1.57	0.04	—	1.87	0.10	—	2.99	0.11	—
Winter	9.61	0.16	—	1.64	0.03	—	2.01	0.08	—	3.12	0.09	—
Spring	9.40	0.17	—	1.53	0.03	—	1.72	0.09	—	2.90	0.09	—
Summer	8.20	0.17	—	1.37	0.03	—	1.32	0.09	—	2.37	0.09	—
Breed	—	—	0.002	—	—	0.001	—	—	0.001	—	—	0.003
Duroc	8.86	0.17	—	1.40	0.041	—	1.36	0.10	—	2.56	0.12	—
Landrace	9.26	0.09	—	1.59	0.016	—	1.88	0.04	—	2.96	0.04	—
Yorkshire	9.45	0.09	—	1.60	0.017	—	1.95	0.04	—	3.01	0.04	—
Parity	—	—	0.002	—	—	0.72	—	—	0.74	—	—	0.66
Breed × parity	—	—	0.0012	—	—	0.41	—	—	0.37	—	—	0.05
Duroc												
Parity 1	9.41	0.38	—	—	—	—	—	—	—	2.95	0.29	—
Parity 2	8.55	0.32	—	—	—	—	—	—	—	2.67	0.24	—
Parity 3	8.66	0.39	—	—	—	—	—	—	—	2.45	0.29	—
Parity 4	8.83	0.37	—	—	—	—	—	—	—	2.53	0.28	—
Parity ≥5	8.86	0.26	—	—	—	—	—	—	—	2.17	0.19	—
Landrace												
Parity 1	8.85	0.12	—	—	—	—	—	—	—	2.80	0.08	—
Parity 2	9.24	0.12	—	—	—	—	—	—	—	2.95	0.09	—
Parity 3	9.47	0.13	—	—	—	—	—	—	—	2.98	0.09	—
Parity 4	9.54	0.13	—	—	—	—	—	—	—	3.10	0.10	—
Parity > 5	9.50	0.10	—	—	—	—	—	—	—	3.00	0.06	—
Yorkshire												
Parity 1	8.84	0.13	—	—	—	—	—	—	—	2.73	0.09	—
Parity 2	9.26	0.13	—	—	—	—	—	—	—	2.87	0.09	—
Parity 3	9.81	0.14	—	—	—	—	—	—	—	3.10	0.10	—
Parity 4	9.86	0.14	—	—	—	—	—	—	—	3.25	0.10	—
Parity > 5	9.85	0.10	—	—	—	—	—	—	—	3.12	0.06	—
Variance												
Contemporary group (season)	—	—	0.1108	—	—	0.0020	—	—	0.0120	—	—	0.01016
Residual	—	—	0.8019	—	—	0.0597	—	—	0.347	—	—	0.4865

[1]Function has the form $DFI_{i,t} = DFI_0 + [(DFI_A - DFI_0)(t/k)^C]/[1 + (t/k)^C]$, where $DFI_{i,t}$ is daily feed intake (kg/d) of the ith lactation at t days of lactation, DFI_0 is daily feed intake at day = 0, DFI_A is asymptotic daily feed intake (kg/d), t is days of lactation, k is a parameter related to days of lactation at which one-half of the increase from DFI_0 to DFI_A is achieved, and C is a unitless parameter.

[2]IP = inflection point.

Regression analyses were conducted to evaluate the relationship of the C + ci values to measures of sow productivity. The C + ci values are associated with changes in the shape of the ME intake curves relative to days of lactation. The C + ci values had significant (*P* < 0.01) linear relationships with number after transfer and 21-d litter weight. These covariates were added to a model including significant (*P* < 0.05) effects of season, breed, parity, parity × breed, and contemporary group within season.

The addition of the number after transfer and number weaned in this model increased the R2 of the equations from 0.1640 to only 0.1687 and 0.1704, respectively. Although statistically significant, the number weaned and the 21-d weight accounted for little of the variation in the ci values related to the shape of the lactation ME intake curves. The regression analyses of the WTEI on measures of sow productivity and energy intake are presented in Table 11. The WTEI were not affected by season (*P* = 0.64), breed (*P* = 0.31), parity (0.67), or any interactions among the fixed effects (*P* > 0.80). The variance estimate for the random effect of contemporary group within season was 0.1103 d2. The regression models included only the fixed effect of season and the random effects of contemporary group within season to account for variation between contemporary groups for WTEI.

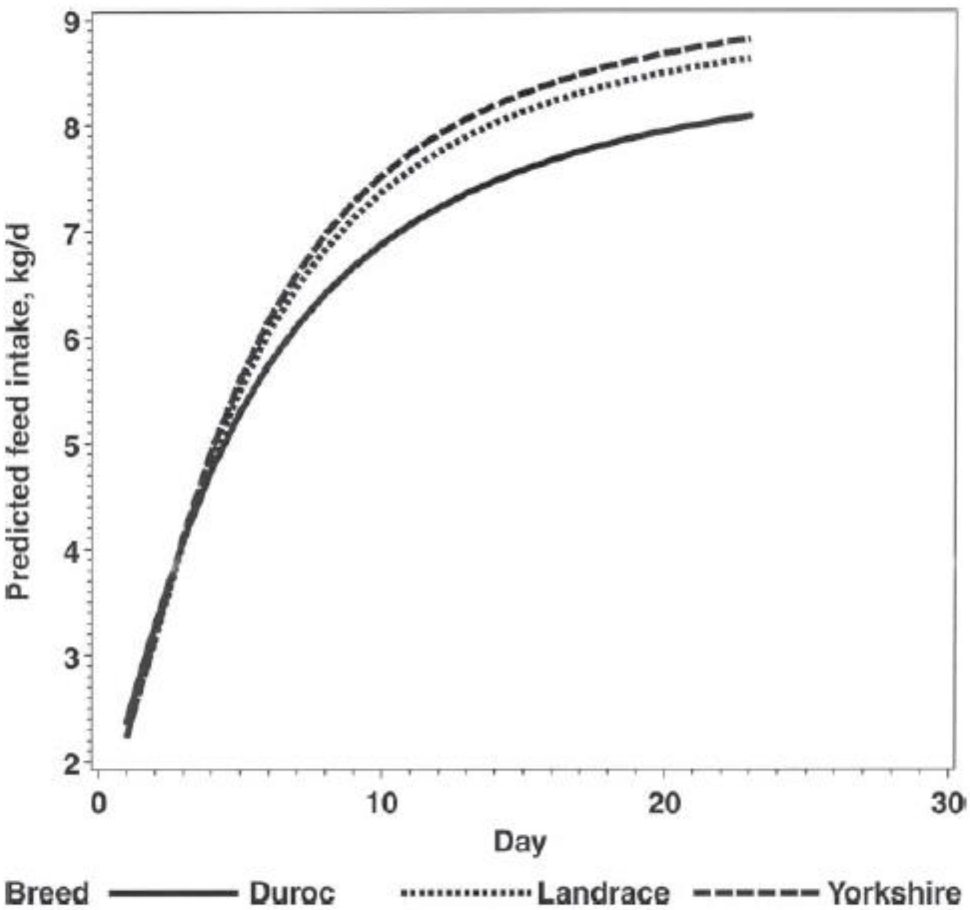

Figure 3. Predicted relationship of feed intake to day of lactation for Duroc, Landrace, and Yorkshire sows.

For the analysis of WTEI, quadratic effects of predicted d 1 to 19 energy intake quadratic (*P* = 0.008) and 21-d litter weight quadratic (*P* = 0.010) were found to be significant sources of variation. Although statistically significant, these 2 variables increased the R2 by only 1.4 (R2 = 0.028 with contemporary group and by 0.0419 with the 2 additional covariates). Sows with a combination of greater than average 21-d litter weight and less than average daily energy intakes were predicted to have greater than average WTEI. For example, at the approximate mean ME intake (22 Mcal ME/d) and 21-d weaning weight (67 kg) of Yorkshire and Landrace sows, the predicted WTEI was 5.46 d. With a SD of approximately 1 for greater than average 21-d weaning weight (76.2 kg) and a SD of 1 for less than average ME intake (20 Mcal/d), the predicted WTEI was 5.74 d. With a 2-SD increase in 21-d weaning weight (85.4 kg) and a 2-SD decrease in ME intake (18 Mcal ME), the predicted WTEI was 6.03 d.

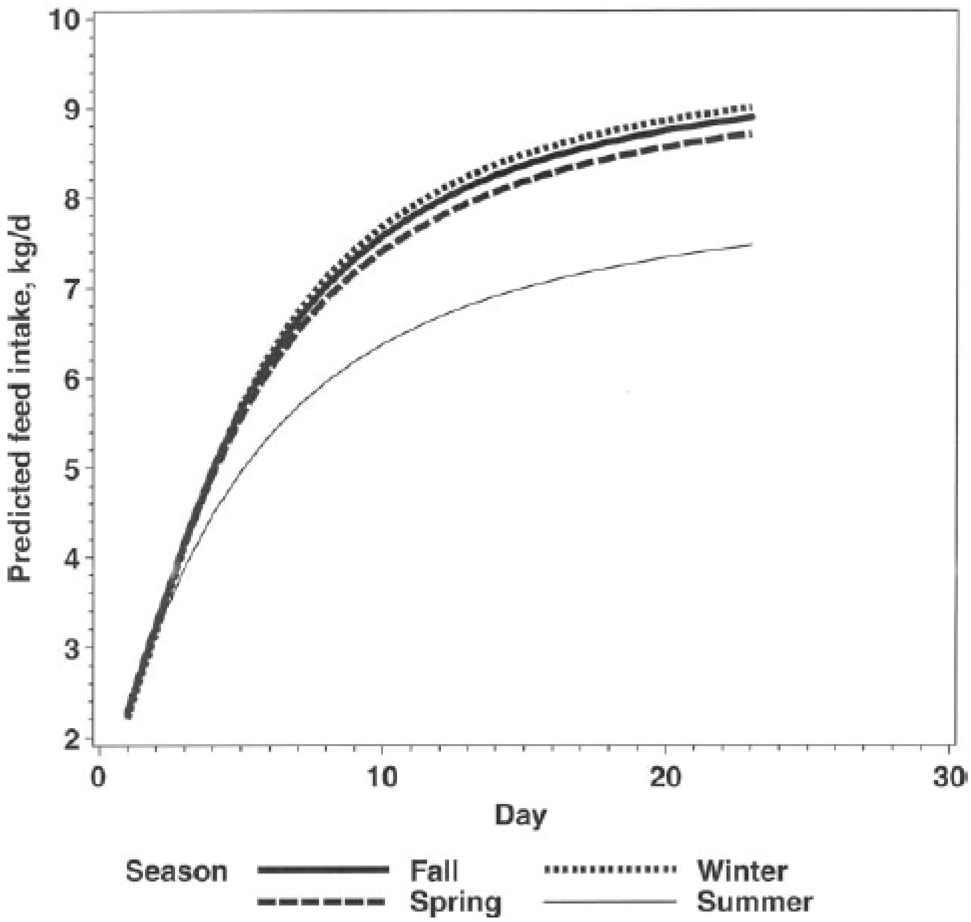

Figure 4. Predicted relationship of feed intake to day of lactation for each season.

The incidence of WTEI of 8 d or greater was 7.09% for Yorkshire and Landrace sows with 1 or 2 transient reductions in ME intake and was 3.65% for sows with no transient reductions in ME intake (*P* = 0.17). With the relatively low incidence of WTEI greater than 8 d and transient reductions in energy intake, the chi-squared analyses were not able to detect the incidence rates as being statistically different. For sows that were identified to be culled (approximately 22%), WTEI data were not collected. Sows were culled for several reasons, including their EPD for sow productivity and maternal line index (Stewart et al., 1991). A stronger relationship between feed intake during lactation and WTEI may have been found if the WTEI records had been collected on culled sows.

The DFI and ME intake of sows increased rapidly from d 1 to 4 of lactation and then increased at a decreasing rate to achieve essentially a plateau from 18 to 23 d of lactation. The ME intakes are greater and are substantially different from those of NRC [1986, 1998; DE intake (Mcal/d) = 13 + (0.596 × days) – [0.0172 (days)2; Figure 5]. The ME values were estimated as 0.96 × DE. The NRC equation predicts that maximal energy intakes are achieved at d 17 of lactation (18.16 Mcal DE/d, approximately 17.43 Mcal ME/d) and these decrease to 17.93 Mcal DE/d (17.2 Mcal/d ME) at d 21 of lactation.

Past research has found weekly feed intake to increase from wk 1 to 3. Shurson et al.

(1986) found DFI during wk 1, 2, and 3 of 3.83, 4.57, and 5.21 kg/d, respectively, for sows fed low-fat control diets and intakes of 3.86, 4.71, and 5.13 kg/d during wk 1, 2, and 3 for sows fed diets with added fat. Shurson and Irvin (1992) found DFI of 2.23, 3.41, 3.72, and 3.92 kg/d for Duroc sows and of 3.37, 4.83, 5.09, and 4.67 kg/d for Landrace sows from wk 1 to 4, respectively. Mosnier et al. (2009) sorted sows into 3 groups (reactive, intermediate, and nonreactive) based on their behavior recorded during a 5-min open field test performed on d 58 of gestation, and found greater DFI of 7.0, 8.8, and 8.9 kg/d for nonreactive sows compared to 5.8, 8.0, and 8.0 kg/d for reactive sows for wk 1, 2, and 3, respectively.

Duroc sows within the current study had overall lesser daily feed and ME intake than

Table 7. Least squares means for parameters for daily ME intake (Mcal/d) fitted to the generalized Michaelis-Menten function[1]

	MEI_A			C			Age at IP[2]			ME intake at IP		
Item	Mean	SE	*P*-value	Mean	SE	*P*-value	Mean	SE	*P*-value	Mean	SE	*P*-value
Season	—	—	0.001	—	—	0.001	—	—	0.001	—	—	0.001
Fall	31.6	0.69	—	1.57	0.04	—	1.87	0.08	—	9.86	0.34	—
Winter	31.4	0.54	—	1.64	0.03	—	2.00	0.07	—	10.22	0.30	—
Spring	30.5	0.56	—	1.53	0.03	—	1.72	0.07	—	9.46	0.30	—
Summer	26.7	0.57	—	1.38	0.03	—	1.34	0.07	—	7.80	0.30	—
Breed	—	—	0.002	—	—	0.001	—	—	0.001	—	—	0.003
Duroc	29.0	0.56	—	1.41	0.04	—	1.36	0.10	—	8.40	—	—
Landrace	30.3	0.29	—	1.59	0.02	—	1.88	0.03	—	9.72	—	—
Yorkshire	30.9	0.30	—	1.60	0.02	—	1.96	0.03	—	9.88	—	—
Parity	—	—	0.001	—	—	0.73	—	—	0.60	—	—	0.70
Breed × parity	—	—	0.001	—	—	0.38	—	—	0.36	—	—	0.065
Duroc												
Parity 1	30.8	1.12	—	—	—	—	—	—	—	9.66	0.94	—
Parity 2	28.0	1.1	—	—	—	—	—	—	—	8.67	0.79	—
Parity 3	28.3	1.3	—	—	—	—	—	—	—	8.04	0.94	—
Parity 4	28.9	1.2	—	—	—	—	—	—	—	8.40	0.90	—
Parity ≥5	29.0	1.0	—	—	—	—	—	—	—	7.27	0.63	—
Landrace												
Parity 1	28.0	0.40	—	—	—	—	—	—	—	9.18	0.25	—
Parity 2	30.2	0.43	—	—	—	—	—	—	—	9.65	0.28	—
Parity 3	31.0	0.43	—	—	—	—	—	—	—	9.77	0.28	—
Parity 4	31.2	0.48	—	—	—	—	—	—	—	10.16	0.33	—
Parity ≥5	31.8	0.38	—	—	—	—	—	—	—	9.82	0.18	—
Yorkshire												
Parity 1	27.8	0.43	—	—	—	—	—	—	—	8.95	0.29	—
Parity 2	30.3	0.48	—	—	—	—	—	—	—	9.39	0.28	—
Parity 3	32.1	0.48	—	—	—	—	—	—	—	10.20	0.33	—
Parity 4	32.3	0.48	—	—	—	—	—	—	—	10.63	0.32	—
Parity ≥5	32.2	0.33	—	—	—	—	—	—	—	10.23	0.19	—
Variance												
Contemporary group (season)	—	—	1.23	—	—	0.0020	—	—	0.0111	—	—	0.1156
Residual	—	—	8.51	—	—	0.0584	—	—	0.3533	—	—	5.075

[1]Function has the form ME_I (Mcal/d) = $MEI_0 + (MEI_A - MEI_0)(t/K)^C/[1 + (t/K)^C]$, where MEI_0 is ME intake at d 0, MEI_A is asymptotic ME intake (Mcal/d), t is days of lactation, K is a parameter related to days of lactation needed to achieve one-half of the increase from MEI_0 to MEI_A, and C is a unitless parameter.

[2]IP = inflection point.

Yorkshire and Landrace sows. Shurson and Irvin (1992) reported similar findings that Duroc sows had mean DFI from d 1 to 21 of 3.20 kg/d vs. 4.17 kg/d for Landrace sows.

The Yorkshire and Landrace lines of this herd have been intensely selected for increased number born alive, number weaned, and 21-d litter weight based on the STAGES genetic evaluation system (Stewart et al., 1991). Selection for increased 21-d litter weight is predicted to result in correlated responses for increased feed intake (Bergsma et al., 2008). The Duroc line has been selected for postweaning performance (terminal sire index). It should be recognized that the Duroc data with 42 sows included a very limited number of sires. The differences observed between the breeds observed in this trial are due to true breed differences, differences in genetic selection, and sampling error.

A significant ($P < 0.05$) breed × parity interaction was found, with parity 1 Duroc sows having greater DFI than higher parity Duroc sows. The DFI of Landrace and Yorkshire sows increased as parity increased to parity 3 and was constant from parity 3 to 7. Crenshaw et al. (2007) found DFI of 4.77, 5.49, and 5.89 kg/d (18.5 d lactation length) for parity 1, parity 2, and mature commercial crossbred sows, respectively. Daily feed and energy intakes were 14 to 15% less for the summer season (June 15 to September 15) when compared with the other 3 seasons. The seasonal effect found in the current study is likely due to differences in ambient temperatures among seasons. The thermoneutral zone of lactating sows ranges from approximately 15 to 20°C (Black et al., 1993). Ambient temperatures above 22°C result in reduced feed intakes during lactation (Messias de Bragan ca et al., 1998; Quiniou and Noblet, 1999). The effects of season, month, or shorter weekly or biweekly periods on feed intake during lactation are expected to be the result of the effective ambient temperatures (Black et al., 1993; Messias de Bragan ca et al., 1998). Management practices that decrease ambient temperatures and encourage greater feed intakes during the summer months will likely increase 21-d litter weights and reduce WTEI (Prunier et al., 1996, 1997).

It was expected that the RSD for daily feed and ME intake would be greater for the summer months. Additionally, it was expected that day to day fluctuations in environmental temperatures at and above the upper thermoneutral zone would result in increased daily fluctuations in feed and ME intake. However, the RSD for feed intake were not affected by season ($P = 0.444$) because estimated least squares means for summer, fall, winter, and spring were 1.07, 0.95, 1.01, and 0.94 kg/d, respectively. The RSD for ME intake were also not affected by season ($P = 0.438$) because estimated least squares means for summer, fall, winter, and spring were 3.48, 3.16, 3.30, and 3.04 Mcal ME/d, respectively. In this study, the impact of season had a greater effect on reducing overall feed and energy intake than on increasing day-to-day variation.

The DFI and lactation records were evaluated to determine overall low feed intakes to identify the number and magnitude of transient reductions in DFI, similar to the criteria used by Koketsu et al. (1996a,b). Koketsu et al. (1996a,b) defined a major decrease as when DFI decreased by 1.8 kg/d or more compared with the previous peak feeding level for 2 d or more. Our criteria were slightly different, defining a major decrease as when the sow DFI was 1.6 RSD (1.49 kg/d) less than the DFI predicted from fitting the feed intake records during lactation to the random-effects GMM function. Koketsu et al., (1996a) found that 38.3% of the lactation records had major declines in feed intake compared with 15.4% in this study. Sows with predicted asymptotic feed intakes of 4.5 kg/d or less were identified as overall low feed intake lactation records. Koketsu et al., (1996b) reported 1.2% of the sows had overall low feed intakes that did not exceed 4.5 kg/d. Four of the 993 lactation records (0.4%) were identified as having overall low feed intakes in this study.

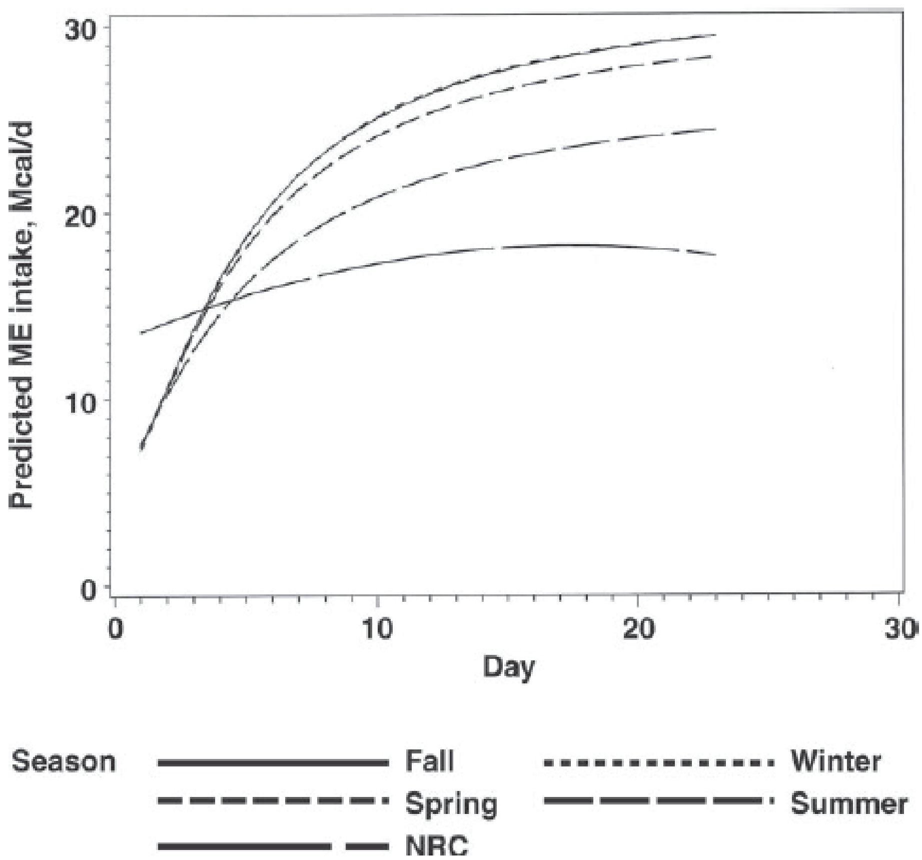

Figure 6. Predicted relationship of ME intake to day of lactation for each season and NRC (1998) values.

In this study, DFI and energy intakes had a linear-quadratic relationship with number weaned. The predicted ME intake (d 1 to 19) increased with increasing number weaned to 10.43 pigs/litter. Eissen et al. (2003) evaluated the relationship of average DFI from 10 to 28 d of lactation with litter size at weaning in 3 genetic populations of sows (genotype 1 =

purebred Landrace, genotype 2 and 3 = commercial crossbreds). Eissen et al. (2003) found that the linear and quadratic effects of litter size on DFI tended to be significant ($P < 0.07$). However, a significant quadratic relationship between DFI and litter size was detected only in genotype 2 sows with a maximal feed intake of 10.8 pigs/litter. Feed intakes of genotype 1 and 3 sows were not affected by litter size (Eissen et al., 2003). Koketsu et al. (1996a) found that feed intake did not significantly increase as litter size increased above 11 pigs/litter. In contrast, O'Grady et al. (1985) estimated that maximal feed intakes were achieved at 13 to 14 pigs/litter.

The predicted and actual ME intakes had a linear relationship with 21-d litter weight. Overall feed and ME intakes had stronger relationships to 21-d litter weight than number weaned. The regression coefficients indicated that sows with a 1-kg greater 21-d litter weight had a 0.0454 Mcal/d increase in ME intake. The predicted daily ME required for each kilogram of 21-d litter weight gain is predicted to range from 0.325 Mcal (NRC, 1986, 1998) to 0.365 Mcal (F. Aherne, University of Alberta, personal communication). Within the current study, sows with greater than average 21-d litter weights consumed only 12 to 14% of the additional energy required to produce each additional kilogram of 21-d litter weaning weight. Thus, sows with greater 21-d litter weights are predicted to have greater than average BW loss during lactation, similar to the findings of Eissen et al. (2003).

Genetic selection for increased 21-d litter weight is expected to result in increased DFI and lactation BW loss (Shurson and Irvin, 1992; Bergsma et al., 2008). The actual achieved (Shurson and Irvin, 1992) or predicted (Bergsma et al., 2008) increases in DFI produced as a result of genetic selection for 21-d weaning weight are not great enough to meet the energy demands of the sow for the increased milk production. Selection for sows with increased DFI and reduced lactation BW losses should be considered to improve overall sow reproduction performance (Eissen et al., 2003; Bergsma et al., 2008). Another possibility is to genetically increase lactation efficiency, defined as the milk output for a given feed intake and mobilization of body tissue (Bergsma et al., 2008). The rate of genetic progress for sow productivity traits was substantially increased with the implementation of BLUP genetic evaluation systems (Stewart et al., 1991; Knap et al., 1993). Maternal lines of pigs have also been intensely selected for increased lean growth rates (Stewart et al., 1991; Ball et al., 2008). Sows from different genetic populations with different body composition at farrowing may mobilize drastically different relative amounts of body tissues and protein versus lipid (Dourmad, 1991; Sauber et al., 1998).

Table 8. Least squares means for mean predicted daily feed intake (DFI, kg/d) from d 1 to 19 and at d 18

	Mean predicted DFI, d 1 to 19			Predicted d-18 DFI		
Item	Mean	SE	*P*-value	Mean	SE	*P*-value
Season	—	—	0.001	—	—	0.001
Fall	6.85	0.14	—	8.60	0.19	—
Winter	6.91	0.11	—	8.69	0.16	—
Spring	6.72	0.12	—	8.43	0.16	—
Summer	5.86	0.12	—	7.23	0.16	—
Breed	—	—	0.001	—	—	0.001
Duroc	6.30	0.12	—	7.81	0.17	—
Landrace	6.66	0.06	—	8.36	0.08	—
Yorkshire	6.80	0.06	—	8.54	0.09	—
Parity	—	—	0.003	—	—	0.009
Breed × parity	—	—	0.001	—	—	0.001
Duroc						
Parity 1	6.72	0.27	—	8.44	0.37	—
Parity 2	6.13	0.23	—	7.61	0.32	—
Parity 3	6.13	0.27	—	7.57	0.38	—
Parity 4	6.28	0.26	—	7.81	0.36	—
Parity ≥5	6.25	0.18	—	7.64	0.27	—
Landrace						
Parity 1	6.17	0.08	—	7.69	0.12	—
Parity 2	6.64	0.09	—	8.35	0.13	—
Parity 3	6.79	0.09	—	8.52	0.13	—
Parity 4	6.86	0.10	—	8.64	0.14	—
Parity ≥5	6.83	0.07	—	8.59	0.10	—
Yorkshire						
Parity 1	6.11	0.09	—	7.56	0.13	—
Parity 2	6.65	0.09	—	8.36	0.13	—
Parity 3	7.04	0.10	—	8.89	0.14	—
Parity 4	7.11	0.10	—	8.99	0.14	—
Parity ≥5	7.07	0.07	—	8.91	0.10	—
Variance						
Contemporary group (season)	—	—	0.0465	—	—	0.08318
Residual	—	—	0.3828	—	—	0.7445

Continued intense selection for litter size and litter weight may result in sows with greater mobilization of lean body tissue and protein during lactation (Sauber et al., 1998; Eissen et al., 2003; Bergsma et al., 2008).Several alternatives exist including

1) the measurement and selection for increased DFI during lactation,

2) measurement and selection of sows with decreased lactation BW loss or predicted body protein loss, and

3) selection of sows that cope better with the numerous stressors of farrowing (Mosnier et al., 2009).

Table 9. Least squares means for mean predicted ME intake (Mcal/d) from d 1 to 19 and at d 18

	Mean predicted ME intake, d 1 to 19			Predicted d-18 ME intake		
Item	Mean	SE	*P*-value	Mean	SE	*P*-value
Season	—	—	0.001	—	—	0.001
Fall	22.6	0.47	—	28.1	0.87	—
Winter	22.6	0.39	—	28.7	0.70	—
Spring	21.8	0.40	—	26.7	0.71	—
Summer	19.1	0.40	—	22.4	0.72	—
Breed	—	—	0.001	—	—	0.002
Duroc	20.6	0.39	—	24.6	0.71	—
Landrace	21.8	0.20	—	27.3	0.37	—
Yorkshire	22.2	0.20	—	27.5	0.37	—
Parity	—	—	0.003	—	—	0.004
Breed × parity	—	—	0.001	—	—	0.001
Duroc						
Parity 1	22.0	0.87	—	28.1	1.6	—
Parity 2	20.0	0.74	—	24.0	1.4	—
Parity 3	20.0	0.87	—	24.8	1.6	—
Parity 4	20.6	0.84	—	23.1	1.5	—
Parity ≥5	20.4	0.60	—	23.2	1.1	—
Landrace						
Parity 1	20.2	0.28	—	25.3	0.52	—
Parity 2	21.7	0.29	—	27.2	0.55	—
Parity 3	22.2	0.30	—	27.6	0.55	—
Parity 4	22.4	0.33	—	28.7	0.62	—
Parity ≥5	22.3	0.30	—	27.8	0.42	—
Yorkshire						
Parity 1	20.0	0.28	—	24.8	0.57	—
Parity 2	21.7	0.30	—	26.2	0.57	—
Parity 3	22.2	0.33	—	28.9	0.62	—
Parity 4	22.4	0.23	—	28.8	0.61	—
Parity ≥5	22.3	0.30	—	28.7	0.42	—
Variance						
Contemporary group (season)	—	—	0.545	—	—	1.035
Residual	—	—	4.072	—	—	7.936

IMPLICATIONS

Selection for increased sow productivity has resulted in increased feed intake during lactation. The feed intakes of the Yorkshire and Landrace sows are substantially above those reported previously (NRC, 1998). Sows with greater than average 21-d litter weights consumed only 12 to 14% of the additional energy required to produce the additional litter weight and were subsequently predicted to have greater than average BW loss during lactation. Continued selection for increased litter size and 21-d litter weight may require the measurement and selection for increased feed intake during lactation. Management to increase feed intake during lactation in the summer months is needed to reduce BW loss during lactation.

Table 10. Relationship of measures of daily ME intake to number weaned and 21-d litter weight[1]

Dependent variable	Independent variable	b_0	b_1 Estimate	b_1 SE	b_1 *P*-value	b_2 Estimate	b_2 SE	b_2 *P*-value	R^2 value	Var (e)
Predicted mean daily ME intake, d 1 to d 19, Mcal/d		—	—	—	—	—	—	—	0.4448	4.068
	Number weaned	16.84	1.445	0.38	0.001	−0.0692	0.020	0.001	0.4597	3.959
	21-d litter weight	21.42	0.045	0.005	0.001	—	—	—	0.4787	3.820
Actual d-18 ME intake, Mcal/d		—	—	—	—	—	—	—	0.3859	13.62
	Number weaned	19.8	2.22	0.71	0.001	−0.107	0.04	0.005	0.3946	13.43
	21-d litter weight	26.6	0.071	0.010	0.001	—	—	—	0.4108	13.08
Predicted d-18 MEI[2]		—	—	—	—	—	—	—	0.4431	8.045
	Number weaned	21.2	1.91	0.54	0.001	−0.092	0.03	0.002	0.4582	7.827
	21-d litter weight	27.1	0.063	0.008	0.001	—	—	—	0.4768	7.558
WF + wf_i,[3] Mcal/d		—	—	—	—	—	—	—	0.4268	8.493
	Number weaned	25.3	1.70	0.54	0.002	−0.085	0.029	0.004	0.4411	8.281
	21-d litter weight	29.7	0.65	0.008	0.001	—	—	—	0.4593	8.012
C + c_i[3]		—	—	—	—	—	—	—	0.1640	0.05812
	Number after transfer	1.58	0.0121	0.004	0.008	—	—	—	0.1687	0.05780
	21-d litter weight	1.60	0.0019	0.0007	0.005	—	—	—	0.1704	0.0577

[1]Model included the significant effects of season, breed, parity, and parity × breed and the random effect of contemporary group within season. The R^2 and Var (e) values are for the models not including and including the specific independent variables.

[2]MEI = ME intake, predicted from the random-effects generalized Michaelis-Menten function.

[3]Parameters of the generalized Michaelis-Menten function.

Table 11. Relationship of weaning to estrous interval (d) on predicted mean daily ME intake and 21-d litter weight[1]

Independent variable	b_0	b Estimate	b SE	b *P*-value	R^2 value	Var (e)
(Predicted mean d-1 to d-19 ME intake)^2	5.87	−0.00181	0.0005	0.0008	0.0280	2.606
(21-d litter weight)^2	—	0.000103	0.00004	0.010	0.0419	2.568

[1]The R^2 and residual Var (e) values are for models including random effect of contemporary group and contemporary group plus the 2 independent variables.

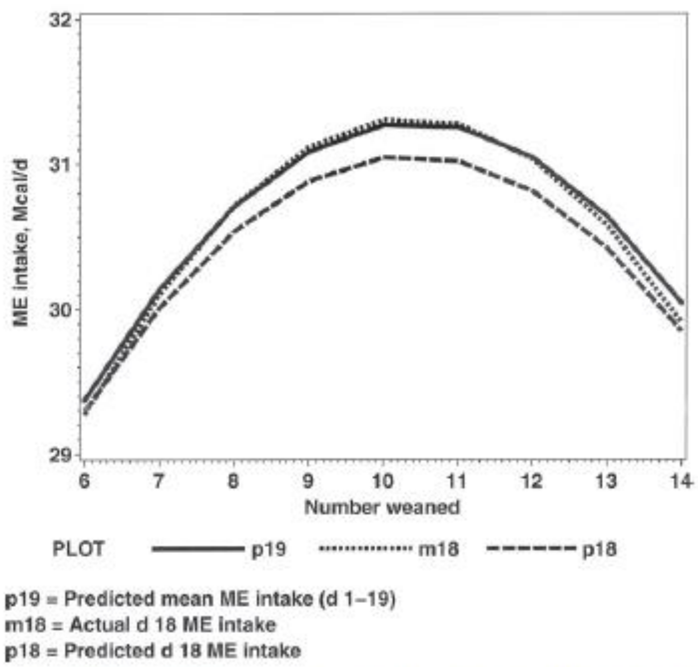

Figure 7. Relationship of predicted mean daily ME intake (d 1 to 19) and actual and predicted d-18 ME intake on number of pigs weaned.

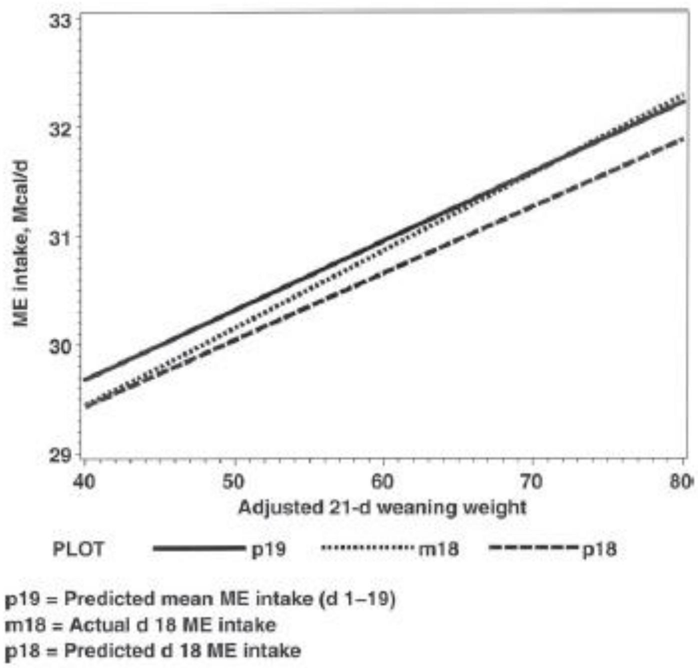

Figure 8. Relationship of predicted mean daily ME intake (d 1 to 19) and actual and predicted d-18 ME intake on 21-d litter weaning weight.

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