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INFLUENCE OF ENERGY INTAKE DURING LACTATION ON THE INTERVAL FROM WEANING TO FIRST ESTRUS IN SOWS[1]

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Summary

A total of 191 crossbred sows were used to determine the effect of energy intake during one lactation on (1) sow and pig performance and (2) the percentage of sows in estrus by 7, 14, 21 and 70 d postweaning. Sows received 8 (Lo) or 16 (Hi) Mcal of metabolizable energy (ME)/d (Exp. 1 and 2) and 8 (Lo), 12 (Md) or 16 (Hi) Mcal of ME/d (Exp. 3) during a 28-d lactation period. All sows were fed an equal amount of crude protein, vitamins and minerals that met or exceeded the recommendations of the National Research Council. Each day after weaning, sows were fed 1.8 kg of a 14% crude protein diet and checked for estrus using boars. Serum samples were obtained weekly from sows not detected in estrus by 15 d postweaning for progesterone analysis. In Exp. 1 sows fed Lo lost more ($P<.01$) weight and backfat, and weaned lighter weight ($P<.01$) pigs than sows fed Hi. Fewer sows fed Lo exhibited estrus ($P\leqslant.1$) by 7, 14, 12 and 70 d postweaning than sows fed Hi. In Exp. 2, sows fed Lo lost more ($P<.01$) weight and backfat than sows fed Hi, but pig weaning weights did not differ. Fewer sows fed Lo expressed estrus by 7 d ($P<.01$) postweaning than those fed Hi. In Exp. 3 sow weight and backfat loss decreased ($P<.01$) linearly as energy intake increased. Pig weaning weights were not affected by energy intake. Fewer sows fed Lo expressed estrus ($P\leqslant.05$) by 7, 14, 21 and 70 d postweaning than those fed Md and Hi. There was no difference in the percentage of sows fed Md or Hi that exhibited estrus by these time periods. Blood samples collected on d 110 of gestation and d 14 and 26 of lactation, indicated that energy intake did not influence hematocrit values, total serum protein or albumin concentrations. A significant energy intake by time interaction was observed for serum blood urea N. Three of the 25 sows bled for progesterone analysis had luteal tissue activity suggesting ovulation had occurred even in the absence of a detected behavioral estrus.

(Key Words: Sows, Energy, Lactation, Postweaning Estrus.)

Introduction

In modern swine production systems it is important that sows return to estrus rapidly following weaning. Data from farms and experiment stations indicate a wide range in the percentage of sows that exhibit estrus within 7 d postweaning (Rasbech, 1969; Fahmy et al., 1979; Hurtgen et al., 1980; Karlberg, 1980; Pattison et al., 1980; Szarek et al., 1981). Factors that influence the weaning to estrus interval include type of feed and feed intake during gestation (O'Grady, 1967; Young and King, 1981, respectively), lysine intake during lactation (O'Grady and Hanrahan, 1975), protein intake during gestation and lactation (Svajgr et al., 1972), postweaning feed intake (Brooks and Cole, 1972), lactation length (Baker et al., 1953; Self and Grummer, 1958; Lynch, 1965) and altered suckling stimulus (Britt and Levis, 1980).

Elsley et al. (1968), O'Grady et al., (1973) and Adam and Shearer (1975) reported that energy intake during lactation had no effect on

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the number of days from weaning to first estrus in sows fed energy levels that met or exceeded the requirements of lactating sows according to the NRC (1979). However, MacLean (1968, 1969) observed that sows exhibiting prolonged weaning to estrus intervals were generally thin. Energy intake during lactation is inversely related to sow weight loss during lactation, (Elsley et al., 1968; O'Grady et al., 1975), thus low energy intake during lactation may contribute to delayed estrus following weaning.

The purpose of the experiments reported herein was to determine the effect of energy intake during lactation on (1) sow and pig performance and (2) the percentage of sows in estrus by 7, 14, 21 or 70 d postweaning.

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS (EXP. 1 THROUGH 3)[a]

	Diets[b]			
Ingredient	Gestation[c] (Gest)	Low[d] energy (Lo)	Medium[d] energy (Md)	High[d] energy (Hi)
	g			
Cornstarch (IFN 4-02-889)		85	960	1,807
Tallow, bleachable fancy[e] (IFN 4-07-880)		225	348	454
Corn (IFN 4-02-992)	1,087	341	341	341
Soybean meal (IFN 5-04-604)	280	1,187	1,187	1,187
Wheat bran (IFN 4-08-554)		566	566	566
Beet pulp (IFN 4-00-669)	360			
Limestone (IFN 6-02-632)	4	54	54	54
Dicalcium phosphate (IFN 6-01-080)	41	49	49	49
Salt (IFN 6-04-151)	9	23	23	23
Trace mineral mix[f]	1	5	5	5
Vitamin mix[g]	18	47	47	47
Selenium premix		3	3	3
Total feed/d	1,800	2,585	3,583	4,536

[a]Diets Gest, Lo, Hi were fed in Exp. 1, 2 and 3. Diet Md was added in Exp. 3.

[b]Fed to provide the following amount (g/d) of protein, Ca and P during gestation and lactation, respectively: 254, 14.5, 12.5 and 630, 35, 24.

[c]Fed to provide 5.4 Mcal$\cdot$sow$^{-1}\cdot$d^{-1} during gestation.

[d]Quantities of cornstarch and tallow were varied to provide 8, 12 and 16 Mcal of ME$\cdot$sow$^{-1}\cdot$d^{-1} during lactation.

[e]Provided approximately 21% of the daily energy intake for the Lo, Md and Hi diets.

[f]Percentage composition was Zn, 20; Fe, 10; Mn, 5.5; Cu, 1.1; I, .15.

[g]Composition was vitamin A (stabilized) 2,750,000 USP; vitamin D_3 (stabilized) 220,000 IU; riboflavin, 1,450 mg; D-pantothenic acid, 11,000 mg; niacin, 11,000 mg; choline chloride, 110,000 mg; vitamin B_{12}, 11 mg; menadione sodium bisulfite, 1,100 mg; ethoxyquin, 2.2 g; vitamin E, 11,000 IU/kg of premix.

Experimental Procedure

Exp. 1. Seventy-one crossbred (Large White × Duroc × Landrace) primiparous sows were randomly assigned at parturition to either a low (Lo) or high (Hi) energy diet (table 1). The diets were formulated and fed to provide energy intakes of 8 (Lo) or 16 (Hi) Mcal of metabolizable energy (ME)$\cdot$sow$^{-1}\cdot$d^{-1} during a 28-d lactation period. All sows received the same daily quantities of protein, vitamins and minerals, which met or exceeded the recommendations of the NRC (1979). Sows were fed 1.8 kg/d of a 14% crude protein gestation (Gest) diet (table 1) until d 108 of gestation, at which time they were moved into farrowing crates located in environmentally controlled rooms. Sows were fed 2.3 kg/d of the Hi diet until parturition. To minimize variation in litter size, pigs were transferred among sows irrespective of treatment until d 3 following parturition. Pigs did not receive creep feed and their access to sow feed was minimal.

Following parturition and weaning, sows were weighed and backfat measurements were obtained by ultrasonic determination[5]. Pig weaning weights and number of pigs weaned were recorded. After weaning, sows were moved into gestation crates located in an environmentally controlled room and fed 1.8 kg$\cdot$sow$^{-1}\cdot$d^{-1} of the Gest diet. Sows were moved to pens containing a boar to check for estrus on a daily basis. A sow was considered to be in estrus when she stood to be mounted by the boar on 2 consecutive days. On d 15 postweaning, sows were bled if they had not previously been detected in estrus. Weekly samples were obtained thereafter until estrus was detected or until termination of the experiment 70 d postweaning. Serum was analyzed for progesterone as described by Anthony et al. (1981) to identify sows that had luteal tissue activity (indicative that ovulation had occurred) in the absence of a detected behavioral estrus. A serum progesterone concentration of >5 ng/ml was considered to indicate the presence of luteal tissue activity.

Diet effects on sow weight and backfat change during lactation were tested using least-squares analysis of covariance (Helwig and Council, 1979; Steel and Torrie, 1980) with the following model:

$$Y_{ijk} = \mu + D_i + R_j + B_1 W_{ijk} + B_2 X_{ijk} + B_3 X_{ijk}^2 + e_{ijk},$$

where

Y_{ijk} is the response for diet i, replication j, sow k,

μ is the mean of that response,

D_i is the effect of the ith diet,

R_j is the effect of the jth replication,

W_{ijk} is postparturition sow weight or backfat used as a covariate,

X_{ijk} is the litter size at 3 d postparturition used as a covariate,

$B_{1,2,3}$ are the coefficients of regression of Y_{ijk} on W_{ijk}, X_{ijk} and X_{ijk}^2 and

e_{ijk} is the random error.

Effects on litter performance were tested with the same model except the W_{ijk} covariate was removed.

Diet effects on the cumulative percentage of sows in estrus by 7, 14, 21 and 70 d postweaning were tested using a linear model approach appropriate for catagorical data (Grizzle et al., 1969). This is distinct from the standard linear model approach for continuous variables, because the estrus/no estrus condition is a categorical rather than a continuous response variable. Day of weaning was designated as d 0 in calculating the number of days to first estrus.

Exp. 2. Fifty-one second parity Nebraska Gene pool sows (Zimmerman and Cunningham, 1975) were randomly assigned to either the Lo or Hi diets as described in Exp. 1. The experimental procedure and statistical analysis were the same as described for Exp. 1.

Exp. 3. Two replications of an experiment were conducted using 69 crossbred (Hampshire × Landrace × Yorkshire) primiparous sows randomly assigned to diets described in Exp. 1. In addition, a third diet (medium, Md) was included to provide 12 Mcal of ME$\cdot$sow$^{-1}\cdot$d^{-1} during lactation (table 1). Management and data collection procedures were the same as for Exp. 1. The 37 sows representing one of the two replications were bled on d 110 of gestation and d 14 and 26 of lactation to determine the effect of energy intake on hematocrit values, serum blood urea N (BUN), total serum protein and albumin concentrations. Two blood samples were obtained from the brachial region 3.5 h following the morning feeding, which consisted of one-half of the daily feed allowance. The duration of the sampling period did not exceed

[5] IthaCo Ultrasonic Scanoprobe, Ithaca, NY.

TABLE 2. EFFECTS OF ENERGY INTAKE DURING LACTATION ON SOW AND PIG PERFORMANCE (EXP. 1)

Item	Diets: Lo	Diets: Hi	SE
Sows			
No.	36	35	
Lactation wt change, kg[ab]	−20.8	−.6	1.6
Lactation backfat change, mm[ab]	−7.5	−1.6	.4
Percentage in estrus			
≤7 d[b]	50.0	94.3	
≤14 d[c]	63.9	94.3	
≤21 d[c]	63.9	97.1	
≤70 d[d]	86.1	100.0	
No. bled[e]	13	2	
No. with luteal activity before a detected estrus	2	0	
Pigs			
Avg litter size at weaning, no.[a]	8.3	8.5	.2
Avg pig weaning wt, kg[ab]	6.4	7.3	.2

[a]Least-squares means.

[b]$P<.01$.

[c]$P<.05$.

[d]$P = .1$.

[e]Sows bled for progesterone analysis if estrus had not been detected by 15 d postweaning.

30 min. One sample was collected in an evacuated glass tube[6], placed on ice, centrifuged and aliquots of serum were transferred to sterile plastic tubes and frozen (−20 C) until analysis. Analyses for BUN, total serum protein and albumin were performed using the automated procedures described by Marsh et al. (1965), Frankel et al. (1970) and Doumas et al. (1971), respectively. The other blood sample was collected in a tube containing sodium heparin. Hematocrits[7] were determined within 3 h of collection.

Linear and quadratic regression analyses were performed on sow weight and backfat changes, including pig performance using the same model outlined for Exp. 1. Blood constituents and hematocrit values were tested using splitplot analysis (Helwig and Council, 1979; Steel and Torrie, 1980) with the Lo, Md and Hi diets as the main plots and the bleeding times as the subplots.

[6]Vacutainer Tube, Becton-Dickinson, Rutherford, NJ.

[7]International Micro-Capillary reader, International Equipment Co., Needham Hts., MA.

Results

Exp. 1. The effects of energy intake during lactation on sow and pig performance are presented in table 2. As expected, sows consuming the Lo diet lost more ($P<.01$) weight and backfat during lactation than sows fed Hi. Sows fed Lo also weaned lighter weight ($P<.01$) pigs than sows fed Hi, although average litter size at weaning was not affected by energy level. The cumulative percentage of sows in estrus by 7, 14, 21 and 70 d postweaning was less ($P<.01$; $P<.05$; $P<.05$; $P = .10$), for each time period, respectively, for sows fed Lo than for those fed Hi. According to serum progesterone concentrations, two of the 15 sows not detected in estrus by 15 d postweaning had luteal tissue activity in the absence of a detected behavioral estrus. Both sows were fed Lo during lactation and expressed estrus, one on d 33 and the other on d 57 postweaning.

Exp. 2. The results of Exp. 2 are presented in table 3. As expected sows fed Lo lost more ($P<.01$) weight and backfat during lactation than sows fed Hi. There were no differences due to energy intake on average pig weight and litter size at weaning. The cumulative percentage

TABLE 3. EFFECTS OF ENERGY INTAKE DURING LACTATION ON SOW AND PIG PERFORMANCE (EXP. 2)

Item	Diets		SE
	Lo	Hi	
Sows			
No.	24	27	
Lactation wt. change, kg[ab]	−18.0	.6	1.4
Lactation backfat change, mm[ab]	−4.4	−.5	.5
Percentage in estrus			
≤7 d[c]	70.8	96.3	
≤14 d	87.5	100.0	
≤21 d	87.5	100.0	
≤70 d	100.0	100.0	
No. bled[d]	3	0	
No. with luteal activity before a detected estrus	0	0	
Pigs			
Avg litter size at weaning, no.[a]	7.5	7.8	.1
Avg pig weaning wt, kg[a]	6.7	6.7	.2

[a]Least-squares means.

[b]$P<.01$.

[c]$P<.05$.

[d]Sows bled for progesterone analysis if estrus had not been detected by 15 d postweaning.

TABLE 4. EFFECTS OF ENERGY INTAKE DURING LACTATION ON SOW AND PIG PERFORMANCE (EXP. 3)

Item	Diets			SE
	Lo	Md	Hi	
Sows				
No.	23	23	23	
Lactation wt change, kg[ab]	−25.7	−13.3	−3.3	1.7
Lactation backfat change, mm[ab]	−8.4	−4.6	−1.8	.6
Percentage in estrus[c]				
≤7 d	65.2	91.3	95.7	
≤14 d	73.9	95.7	100.0	
≤21 d	73.9	95.7	100.0	
≤70 d	82.6	95.7	100.0	
No. bled[d]	6	1	0	
No. with luteal activity before a detected estrus	1	0	0	
Pigs				
Avg litter size at weaning, no.[a]	8.9	8.9	8.6	.2
Avg pig weaning wt, kg[a]	6.6	6.7	7.0	.2

[a]Least-squares means.

[b]Linear effect of energy intake ($P<.01$).

[c]Lo vs Md and Hi ($P<.05$) at all time periods.

[d]Sows bled for progesterone analysis if estrus had not been detected by 15 d postweaning.

of sows fed Lo that exhibited estrus by 7 d postweaning was lower (P<.05) than for sows fed Hi. No statistical difference in the percentage of sows in estrus was found for any of the remaining time periods evaluated, although slightly fewer sows fed Lo exhibited estrus by 21 d postweaning as compared with those fed Hi. Three sows fed Lo were bled for progesterone analysis, none of which had luteal tissue activity before the first detected estrus.

Exp. 3. The effects of energy intake on sow and pig performance are presented in table 4. Sow weight and backfat loss during lactation decreased (P<.01) linearly as energy intake increased. Average litter size and pig weight at weaning were not significantly affected by energy intake. The cumulative percentage of sows in estrus by 7, 14, 21 and 70 d postweaning was lower (P<.05) for sows fed Lo than those fed Md and Hi. No difference in the percentage of sows in estrus was found between those fed Md or Hi at any time period. Seven sows were bled for progesterone analysis. One sow fed Lo had luteal tissue activity before d 70 postweaning, by which time estrus had not been detected.

A significant diet by time interaction was observed for serum BUN concentration (figure 1). During the period from d 110 of gestation to d 14 and 26 of lactation, BUN concentration increased (P<.01) to a higher level in sows fed Lo than in those fed Md and Hi. Sows fed Md also had a higher (P<.05) BUN concentration than those fed Hi during the same period. From d 14 to 26 of lactation, BUN concentration increased (P<.01) in sows fed Lo, but remained constant in sows fed Md and Hi. No interaction was observed with total serum protein or albumin concentrations or hematocrit, thus only the main effects are presented

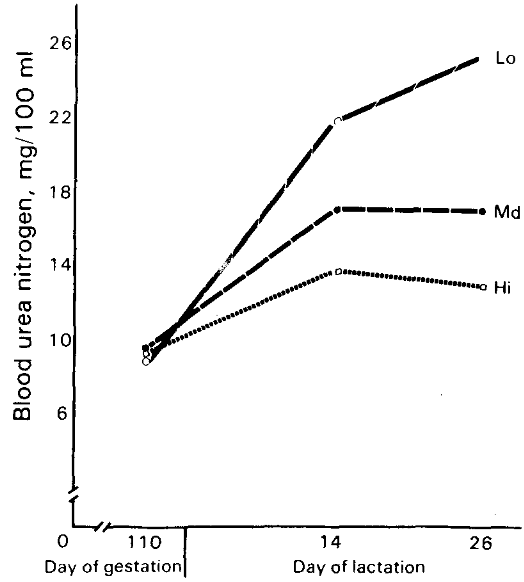

Figure 1. Changes in blood urea N (mg/100 ml) in response to energy intake during lactation, Exp. 3. Lo, Md and Hi = 8, 12 and 16 Mcal of ME$\cdot$sow$^{-1}\cdot$d^{-1}, respectively. Number of sows was 12, 12 and 13 for the Lo, Md and Hi diets, respectively.

TABLE 5. EFFECT ON ENERGY INTAKE AND TIME ON HEMATOCRIT VALUES, TOTAL SERUM PROTEIN AND ALBUMIN CONCENTRATIONS (EXP. 3)

Item	Diet[a] Lo	Md	Hi		Time Day 110 of gestation	Day 14 of lactation	Day 26 of lactation	SE
Hematocrit, %[bcd]	35.8	35.6	35.8	.5	34.0	36.0	37.2	.8
Total protein, g/100 ml[bc]	6.5	6.5	6.4	.1	6.2	6.6	6.7	.2
Albumin, g/100 ml[be]	3.9	4.0	3.8	.1	3.9	3.8	4.1	.1

[a]Number of sows/diet was 12, 12 and 13, respectively.

[b]Least-squares means.

[c]Day 110 of gestation vs d 14 and 26 of lactation (P<.01).

[d]Day 14 vs d 26 of lactation (P<.10).

[e]Day 14 vs d 26 of lactation (P<.01).

in table 5. Total serum protein concentration and hematocrit values increased ($P<.01$) from d 110 of gestation to d 14 and 26 of lactation. Albumin concentration and hematocrit values increased ($P<.01$ and $P<.10$, respectively) during the period from d 14 to 26 of lactation.

Discussion

Sows were able to lactate even when their dietary energy intake was severly restricted because catabolism of body tissues was occurring to meet the nutrient requirements of lactation. Thus, sows that were fed low amounts of energy lost more weight and backfat than sows given higher amounts of energy. The relationship of sow weight loss to energy intake during lactation agrees with reports of Elsley et al. (1968) and O'Grady et al. (1975). Others (Lodge, 1959; Lodge et al., 1961; Lidvall and Griffin, 1962; Parker and Clawson, 1967; Elsley et al., 1969; Vermedahl et al., 1969; Hardy and Lodge, 1969; Hitchcock et al., 1971; O'Grady and Hanrahan, 1975; Varley and Cole, 1976) have reported that feed intake during lactation directly affects sow weight change. Although the complete composition of the weight loss is unknown, the substantial loss of backfat by sows fed diet Lo indicates that adipose tissue probably accounted for a major proportion of the loss. The results of O'Grady et al. (1975) support this conclusion.

Sows fed Lo in Exp. 1 weaned lighter weight pigs than sows fed Hi, presumably because they were not able to fully compensate for their lower energy intake by tissue catabolism. In contrast, sows fed Lo in Exp. 2 and 3 weaned pigs whose weights were not significantly less than those weaned by sows fed the other diets. No explanation for the variation in weaning weight is apparent. In the studies of Elsley et al. (1968), O'Grady et al. (1973) and Adam and Shearer (1975) energy intake during lactation did not influence pig weaning weight or litter size at weaning. In all three of these studies, however, pigs were creep fed, which may have masked differences in pig weaning weight.

The mechanism by which energy intake during lactation influenced the interval from weaning to first estrus in the present study is uncertain. However, it is apparent that sows that had large weight and backfat losses during lactation experienced a higher incidence of delayed estrus following weaning than those that maintained their weight and backfat. Body reserves were probably depleted in some sows to such a severe extent that reproductive dysfunction resulted. Progesterone concentrations indicate that reproductive dysfunction existed for 70 d postweaning (termination of experiments). Previous reports (Elsley et al., 1968; O'Grady et al. 1973; Adam and Shearer, 1975) indicate that when quantities of energy exceeding 12 Mcal of digestible energy$\cdot$sow$^{-1}\cdot$d^{-1} were fed during lactation, no difference was observed in the number of days from weaning to first estrus. Their results agree with those obtained in Exp. 3 in which no difference was observed in the percentage of sows in estrus by 7, 14, 21 and 70 d postweaning between sows fed Md or Hi diets.

MacLean (1968, 1969) observed that, in general, sows with prolonged intervals from weaning to estrus were thin. Sows fed Lo may have been more comparable to those of MacLean (1968, 1969) than to those of Elsley et al. (1968), O'Grady et al. (1973) and Adam and Shearer (1975) in which return to estrus was not affected by energy intake.

The effect of low energy intake in reducing the percentage of sows in estrus by 7, 14, 21 and 70 d postweaning was less evident in Exp. 2 than in Exp. 1 and 3. These data suggest that second parity sows may differ from primiparous sows in their energy requirements for optimum return to estrus. Szarek et al. (1981) evaluated 3,119 records from a commercial swine unit and determined that the percentage of sows that expressed estrus by 7 d postweaning was higher for multiparous sows than for primiparous sows (75 vs 48%, respectively). Hurtgen et al. (1980) reported similar results.

When energy intake is inadequate, proteins can serve as an energy source (Ruiz et al., 1971). The authors of the present study hypothesized that the rate of protein catabolism would be greater, especially in sows fed Lo and would possibly be demonstrated by changes in BUN, total serum protein, albumin concentrations and hematocrit values. Ruiz et al., (1971) reported that BUN concentration was higher in swine fed low vs high energy diets, which was assumed to indicate an increase in the rate of protein catabolism. According to the BUN concentrations reported herein, the rate of protein catabolism was apparently higher in sows fed Lo than in those fed Md and Hi during d 14 and 26 of lactation vs d 110 of gestation. From d 14 to 26 of lactation, the rate of

protein catabolism apparently increased in sows fed Lo, but stabilized in sows fed Md and Hi.

Concentrations of total serum protein and albumin have previously been used as indicators of protein adequacy in swine. Total serum protein concentration decreased during protein-calorie malnutrition (Pal, 1976), protein deprivation in gestating swine (Rippel et al., 1965; Pond et al., 1969; Hesby et al., 1970) and during fasting in swine (Kornegay et al., 1964). Rippel et al. (1965) and Hesby et al. (1970) observed a decrease in albumin concentration when gestating swine were fed normal corn diets and low levels of protein, respectively. Thus, our results suggest that protein was catabolized to meet the energy requirements of lactation, but a portion of the protein was apparently available or channeled to maintain total serum protein and albumin concentrations.

Hematocrit values were not affected by energy intake. Kornegay et al. (1964) reported that hematocrit values increased in pigs fasted for 167 h, while Pal (1976) noted a decrease during protein-calorie malnutrition. The increase in hematocrit values reported herein over the sampling times probably indicates a decrease in blood volume. The increases observed in total protein and albumin with time may reflect changes in blood volume and not real increases in the concentrations of these proteins.

A base level of energy intake that repeatedly will affect the interval from weaning to first estrus was established. Although a daily energy intake of 8 Mcal of ME is 4 Mcal less than the minimum recommendation for lactating sows according to the NRC (1979), situations may exist in which energy restriction during lactation is this severe and consequently will affect return to estrus in sows. Restriction can result from limit feeding, low energy density of the lactation diet because of excessive addition of fibrous feeds and depressed feed intake when environmental temperatures are high.

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