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EFFECT OF PROTEIN AND ENERGY INTAKE BY PRIMIPAROUS SOWS DURING LACTATION ON SOW AND LITTER PERFORMANCE AND SOW SERUM THYROXINE AND UREA CONCENTRATIONS[1,2]

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ABSTRACT

The effects of protein and energy intakes by primiparous sows during a 28-d lactation on thyroxine (T_4) and urea concentrations in blood serum of sows, and sow and litter performance were examined in two experiments. Dietary treatments were protein intakes of 380 (LP) and 760 (HP) g of crude protein•sow^{-1}•d^{-1} and energy intakes of 8 (LE) and 16 (HE) Mcal of metabolizable energy (ME)•sow^{-1}•d^{-1} in a 2 X 2 factorial arrangement. In Exp. 1 (34 sows), neither protein nor energy intake affected serum T_4 concentrations. In both experiments, serum urea concentrations during lactation were influenced by both protein (P<.001) and energy (P<.001) intakes. In Exp. 2 (221 sows), sows fed LP or LE lost more weight (P<.001) during lactation than sows fed either HP or HE. Backfat loss was greater (P<.001) in sows fed diets of LE than HE, whereas sows fed HP lost more backfat (P = .016) than sows fed LP. Pig weights on d 28 were influenced by both protein (P<.001) and energy (P = .038), with sows that were provided high intakes of either protein or energy having heavier pigs. Litter weight at weaning was heavier (P<.005) for sows consuming HP. Sows fed LP had larger litters at d 14 (P = .051) and 28 (P = .046) than sows fed HP. Sow energy intake had no effect on litter size or weight. Percentages of sows in estrus by 7, 14 and 35 d postweaning were higher (P<.004, P<.030 and P<.060, respectively) for sows fed HP than LP, whereas sow energy intakes had no effect on the interval from weaning to first estrus.

(Key Words: Sows, Lactation, Blood Serum, Thyroxine, Urea, Estrus.)

Introduction

The reproductive efficiency of first-litter sows is often relatively poor (King and Williams, 1984a). In particular, there is often a long period between weaning and the initiation of estrous cycles. Reese et al. (1982a,b) and Nelssen et al. (1985) have reported that low energy intakes during lactation prolong the interval from weaning to first estrus in primiparous sows. Others (O'Grady and Hanrahan, 1975; Walker et al., 1979) have reported that low protein intakes during lactation extend the interval from weaning to initiation of estrous cycles.

King and Williams (1984b) found that low intakes of both protein and energy increased the number of days from weaning to first estrus, and that sows fed a diet adequate in protein but restricted in energy were delayed in return to estrus.

Reese (1983) observed that sows that were fed diets restricted in energy during lactation and that failed to return to estrus appeared to be hyperactive. He suggested that the sows might be hyperthyroid and that this might have caused the delay in return to estrus after weaning. In contrast, Nelssen et al. (1984) reported that sows that were fed diets restricted in energy during lactation and that did not return to estrus had lower concentrations of serum thyroxine (T_4) and triiodothyronine postweaning than sows that were fed diets restricted in energy and that did return to estrus.

The objectives of the research reported herein were to determine the effects of different intakes of protein and energy during lactation on sow and litter performance, sow serum T_4 and urea concentrations, and the percentage of sows in estrus by d 7, 14 and 35 postweaning.

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Experimental Procedure

General. Crossbred primiparous sows (Landrace × Large White × Hampshire × Duroc) were fed 1.8 kg·sow^{-1}·d^{-1} of a diet containing 12% crude protein during gestation (table 1). At parturition, sows were randomly assigned within replication to four diets that were fed during a 28-d lactation. Dietary treatments consisted of two protein intakes 380 (LP) and 760 (HP) g of crude protein·sow^{-1}·d^{-1} and two energy intakes 8 (LE) and 16 (HE) Mcal of metabolizable energy (ME)·sow^{-1}·d^{-1} in a 2 × 2 factorial arrangement. Dietary treatments were designated as LE-LP, HE-LP, LE-HP and HE-HP, and are presented in table 1. All sows received equal daily quantities of vitamins and minerals, which met or exceeded National Research Council (NRC, 1979) recommendations. Sows were given their daily feed allowance in one feeding during the morning.

On d 110 of gestation, sows were weighed and backfat thickness (first rib, last rib and last lumbar vertebra) was determined ultrasonically. The sows were then moved into farrowing stalls.

Sows and pigs were weighed within 24 h after parturition. Litter size was standardized by transferring pigs within block (a block representing the four dietary treatments) and then between blocks (other groups of four sows) until d 3 postpartum. Creep feed was not provided and pig access to sow feed was considered minimal. On d 14 and 28 of lactation sows and pigs were weighed, and backfat thickness of the sows was determined.

After weaning, sows were moved into gestation stalls and fed 1.8 kg·sow^{-1}·d^{-1} of the gestation diet. Sows were checked for estrus once daily by moving the sow to a common pen with a boar. A sow was considered to be in estrus when she stood to be mounted by the boar. The experimental protocol was continued until the second day of standing estrus. If estrus was not detected by 35 d postweaning, blood samples that had been collected on a weekly basis were analyzed for progesterone.

TABLE 1. COMPOSITION OF GESTATION AND LACTATION DIETS[a]

Ingredient	Gestation diet[b] 5.8[d] 216[e]	Lactation diet[c] LE-LP 8 380	HE-LP 16 380	LE-HP 8 760	HE-HP 16 760
Tallow, bleachable fancy	54	215	430	215	430
Corn	1,452.2	1,080	1,080	182	182
Cornstarch			1,713		1,713
Soybean meal	204	415	415	1,450	1,450
Wheat bran		710	710	710	710
Limestone	8	54	54	62	62
Dicalcium phosphate	53	59	59	35	35
Salt	9	23	23	23	23
Trace mineral mix[f]	.9	5	5	5	5
Vitamin mix[g]	18	47	47	47	47
Selenium premix[h]	.9	3	3	3	3
Total feed, g/d	1,800	2,611	4,539	2,732	4,660

[a]Values represent amounts (g/d) of each ingredient.

[b]The diet was calculated to provide 16.2 g/d of Ca and 14.6 g/d of P.

[c]All diets were calculated to provide 35.5 g/d of Ca and 24.8 g/d of P.

[d]Energy, Mcal metabolizable energy/d.

[e]Protein, g/d.

[f]Composition (%): Zn, 20; Fe, 10; Mn, 5.5; Cu, 1.1; I, .15.

[g]Composition per kg of premix: vitamin A (stabilized), 551,146 IU; vitamin D_3 (stabilized), 55,115 IU; riboflavin, 551 mg; d-pantothenic acid, 1,984 mg; niacin, 3,307 mg; choline chloride, 55,115 mg; vitamin B_{12}, 1.65 mg; menadione sodium bisulfite, 220 mg; ethoxyquin, .44 g; vitamin E, 2,205 IU.

[h]Composition (%): Se, .02.

Sows that had not exhibited estrus by d 35 postweaning were slaughtered and their reproductive tracts were examined.

Progesterone was determined by the method of Anthony et al. (1981). The purpose of the progesterone analyses was to indicate whether a functional corpus luteum had developed on the ovaries of sows that had not been detected in estrus. The presence of luteal tissue on the ovary was indicated if the progesterone concentration was >5 ng/ml of serum. Therefore, it was assumed that sows with progesterone concentrations of >5 ng/ml had ovulated without expressing a detectable behavioral estrus.

Exp. 1. Thirty-four sows were used in this experiment. Sows were bled 3.5 h after feeding on d 100 and 107 of gestation, d 0, 7, 14, 21 and 28 of lactation, and weekly postweaning until the second day of standing estrus. Venous blood was obtained from the brachial region in an evacuated glass tube and allowed to clot (approximately 30 min). Blood samples were then placed in ice and stored in a refrigerator at 4 C until centrifugation (1,400 × g for 16 min, at 2 C) to separate serum. Serum was stored at −20 C until analyzed.

Serum samples were analyzed for T_4 concentrations by double antibody radioimmunoassay[6]. All determinations of serum T_4 were made within a single assay with an intra-assay coefficient of variation of 1.0%. Serum urea concentrations were determined by the automated procedure of Marsh et al. (1965).

Statistical analysis of serum T_4 and urea concentrations was by least-squares analysis of covariance (SAS, 1979; Steel and Torrie, 1980). Concentrations of serum T_4 on d 100 and 107 of gestation were used as covariates for serum T_4, and concentrations of serum urea on d 100 and 107 of gestation were used as covariates for serum urea.

Exp. 2. Two hundred twenty-one sows were used in this experiment. The sows farrowed in June, November and December of 1983 and January, June and November of 1984 (replications 1 through 6, respectively). The experimental regimen was the same as for Exp. 1, with the following exceptions: 1) sows were bled only on d 110 of gestation, and d 14 and 28 of lactation for serum urea; 2) sows were bled on d 15 postweaning and weekly thereafter for progesterone analyses if they had not been detected in estrus and 3) serum T_4 was not analyzed.

Protein and energy effects on sow weight and backfat changes were analyzed using least-squares analysis of covariance. Average backfat thickness on d 110 of gestation, postpartum sow weight and litter size on d 3 postpartum were used as covariates. Litter size 3 d postpartum was the only covariate used in the analysis of pig performance. Serum urea was tested by least-squares analysis of variance. Percentages of sows in estrus by d 7, 14 and 35 postweaning were tested using a chi-square contingency table (Conover, 1971), appropriate for categorical data.

[6] Antibodies Incorporated, P. O. Box 442, Davis, CA 95616.

Results and Discussion

Exp. 1. The effects of protein and energy intake by primiparous sows during lactation on serum concentrations of T_4 and urea are presented in figures 1 and 2, respectively. Concentrations of serum T_4 and urea on d 100 and 107 of gestation were used as covariates because of variations in these measurements among animals prior to initiation of treatments. Probability values for the covariates used in the analyses of serum T_4 and urea are presented in table 2. Although the probability values indicated significance at some points, the overall

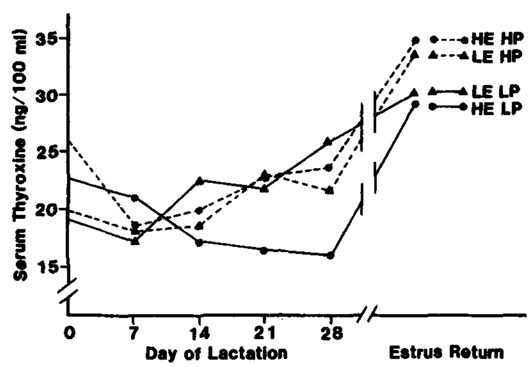

Figure 1. Serum thyroxine concentrations of primiparous sows at parturition, weekly intervals during lactation and estrus return (Exp. 1). Sows were fed diets containing LP or HP, 380 or 760 g of crude protein•sow^{-1}•d^{-1}, respectively, and LE or HE, 8 or 16 Mcal of ME•sow^{-1}•d^{-1}, respectively, in a 2 × 2 factorial arrangement. Protein × energy interaction at d 14 and 28 (P = .083).

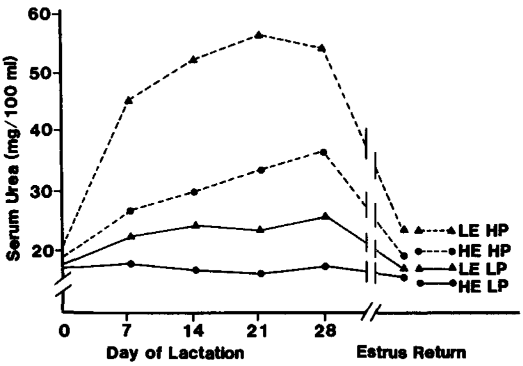

Figure 2. Serum urea concentrations of primiparous sows at parturition, weekly intervals during lactation and estrus return (Exp. 1). Dietary treatments were the same as those described for figure 1. Protein effect (P<.001); energy effect (P<.001); protein × energy interaction (P<.005).

effect of the covariates did not alter the general pattern that was observed for concentrations of serum T_4 and urea before adjustment.

Concentrations of serum T_4 were not influenced by either protein or energy intake during lactation. However, a protein × energy interaction (P = .083) was observed on d 14 and 28 of lactation, with sows fed the HE-LP diet having lower concentrations of serum T_4 than that of sows fed the other diets. This interaction occurred because of the response of protein level to increased energy. Concentrations of serum T_4 increased when energy was added to the HP diet, whereas the opposite effect occurred when energy was added to the LP diet. There was a similar response on d 21 of lactation but the interaction was not significant (P = .443).

Mean concentrations of serum T_4 were lower during lactation than during gestation or on the second day of standing estrus. These results are in agreement with those reported for other species. Vanjonack and Johnson (1975) and Heitzman and Mallinson (1972) reported negative correlations between lactational intensity (milk yield) and plasma thyroxine in dairy cows. Similar findings were reported by Lorscheider and Reineke (1971) for lactating rats, by Flamboe and Reineke (1959) for lactating goats and by Katovich et al. (1974) for lactating mares. Nelssen et al. (1984) reported lower T_4 concentrations on the day before weaning in sows fed 16 Mcal of ME$\cdot$sow$^{-1}\cdot$d^{-1} than in sows fed 8 Mcal of ME$\cdot$sow$^{-1}\cdot$d^{-1}. They also reported a rise in serum T_4 after weaning.

The increased concentration of serum T_4 observed at estrus return in our experiment is consistent with the data of Nelssen et al. (1984). The data indicate that sows restricted in energy intake during lactation do not become hyperthyroid, but may in fact become hypothyroid.

TABLE 2. PROBABILITY VALUES FOR THE COVARIATES USED IN THE ANALYSIS OF CONCENTRATIONS OF SERUM THYROXINE AND UREA IN SOWS

	Thyroxine		Urea	
Item	100[a]	107[b]	100[c]	107[d]
Day of lactation				
0	.317	.013	.556	.757
7	.009	.574	.168	.588
14	.051	.172	.704	.380
21	.220	.859	.346	.016
28	.013	.961	.944	.041
Day of estrus return	.229	.793	.226	.338

[a]The average serum thyroxine of sows on d 100 of gestation was 27.2, 22.1, 26.2 and 28.5 ng/100 ml for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

[b]The average serum thyroxine of sows on d 107 of gestation was 21.0, 19.2, 21.4 and 21.9 ng/100 ml for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

[c]The average serum urea of sows on d 100 of gestation was 17.3, 18.0, 16.6 and 17.8 mg/100 ml for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

[d]The average serum urea of sows on d 107 of gestation was 17.9, 18.0, 17.3 and 16.8 mg/100 ml for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

TABLE 3. EFFECT OF PROTEIN AND ENERGY INTAKE OF SOWS DURING LACTATION ON SOW PERFORMANCE

Item	Lactation diet					P values[d]			
	LE-LP 8[a] 380[b]	HE-LP 16 380	LE-HP 8 760	HE-HP 16 760	CV[c], %	P	E	P × E	Rep
No. of sows	62	50	61	48					
Lactation wt change, kg[e]									
0 to 14 d	−11.0	−8.2	−9.1	−1.8	63.7	.001	.001	.001	.001
14 to 28 d	−15.1	−10.7	−10.9	−1.9	59.0	.001	.001	.006	.002
0 to 28 d	−26.1	−18.9	−20.0	−3.7	45.6	.001	.001	.001	.001
Lactation backfat change, mm[e]									
0 to 14 d	−4.7	−2.9	−5.2	−2.9	49.9	.399	.001	.403	.001
14 to 28 d	−3.8	−1.4	−4.4	−2.0	66.0	.056	.001	.950	.841
0 to 28 d	−8.5	−4.3	−9.6	−4.8	32.8	.016	.001	.409	.001
Percentage in estrus									
⩽7 d	66.1	60.0	77.1	87.5		.004	>.250	>.250	
⩽14 d	77.4	74.0	85.3	89.6		.030	>.250	>.250	
⩽35 d	88.7	82.0	93.4	93.8		.060	>.250	>.250	
No. bled[f]	14	13	9	5					
No. with luteal activity before a detected estrus	1	0	0	0					

[a]Energy, Mcal metabolizable energy/d.

[b]Protein, g/d.

[c]Coefficient of variation.

[d]Probability values for the effects of protein (P), energy (E), protein × energy interaction (P × E) and replication (Rep).

[e]Least-squares means.

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

Protein (P<.001), energy (P<.001) and protein × energy interaction (P<.005) effects on serum urea are shown in figure 2. Serum urea increased as lactation progressed in all sows except those fed the HE-LP diet. Sows fed HP had higher (P<.001) concentrations of serum urea than sows fed LP at each bleeding during lactation. Furthermore, sows consuming LE had higher (P<.001) concentrations of serum urea than sows fed HE. An increase in energy intake from 8 to 16 Mcal $ME \cdot sow^{-1} \cdot d^{-1}$ resulted in a decrease in serum urea regardless of protein intake. The decrease in serum urea was greater in sows fed HE-HP than HE-LP, resulting in a protein × energy interaction (P<.005). Sows that were fed HP had higher (P = .037) concentrations of serum urea than sows fed LP at the time of return to estrus, but energy had no effect on urea concentration.

Reese et al. (1982a,b) and Nelssen et al. (1985) used serum urea as an index to determine the extent of amino acid catabolism, with the assumption that concentration of serum urea is positively correlated with amino acid catabolism. The data reported herein indicate that amino acid catabolism was greater in sows fed HP than LP, and also was greater in sows fed LE than HE. Apparently, amino acid catabolism increased as lactation progressed, except for the HE-LP diet. This presumably reflects a greater need for glucose and other energy substrates as the milk yield of the sows increased between d 7 and 28 of lactation.

Exp. 2. The effects of protein and energy intakes on sow performance are presented in table 3. Probability values for the covariates used in the analysis of sow performance are presented in table 4. Backfat on d 110 of gestation, post-farrowing sow weight and litter size on d 3 postpartum were used as covariates to remove the portion of the variation in lactation weight and backfat changes of sows that were associated with these factors.

Weight loss was greater in sows fed LP or LE (P<.001) than in sows fed either HP or HE during the first 14 and second 14 d of lactation. Thus, consumption of diets containing LP or LE increased (P<.001) sow weight loss during the entire 28-d lactation. A protein × energy interaction was observed for the first 14 d (P<.001), the second 14 d (P<.006) and the entire 28-d lactation (P<.001). Weight changes during each 14-d period and the entire 28-d lactation displayed the same protein × energy interaction in which sow weight loss decreased in response to energy to a greater extent when protein intake was high.

Sows fed LE lost more backfat than sows fed HE during the first 14 d (P<.001), the second 14 d (P<.001) and consequently during the entire 28-d lactation (P<.001). An effect opposite to that of energy was exhibited with protein. Backfat loss was not influenced by protein (P = .399) during the first 14 d, but sows fed diets with HP content lost more backfat during the second 14 d (P = .056) and,

TABLE 4. PROBABILITY VALUES FOR THE COVARIATES USED IN THE ANALYSIS OF SOW PERFORMANCE

Item	BF110D[a]	PFWT[b]	LS3D[c]
Lactation wt change, kg			
0 to 14 d	.203	.016	.001
14 to 28 d	.754	.577	.003
0 to 28 d	.585	.060	.001
Lactation backfat change, mm			
0 to 14 d	.001	.281	.224
14 to 28 d	.044	.261	.002
0 to 28 d	.001	.053	.001

[a]The average backfat thickness of sows on d 110 of gestation (BF110D) was 27.9, 28.0, 28.2 and 27.2 mm for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

[b]The average post-farrowing weight (PFWT) of sows was 156.5, 156.4, 156.0 and 153.7 kg for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

[c]The average litter size on d 3 (LS3D) was 9.5, 9.8, 9.5 and 9.8 for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

during the entire 28-d lactation (P = .016), than sows consuming diets containing LP. There were no significant protein × energy interactions for either of the 14-d periods or for the entire 28-d lactation.

The data of the present experiment agree with previously reported effects of energy restriction (Adam and Shearer, 1975; O'Grady et al., 1975; Reese et al., 1982a,b; Nelssen et al., 1985), and of protein restriction (Mahan and Mangan, 1975; Greenhalgh et al., 1977; NCR-42, 1978) during lactation on sow performance. King and Williams (1984b) found weight changes during lactation (average length 32 d) to be −35.8, −32.5, −29.8 and −3.9 kg for LE-LP, HE-LP, LE-HP and HE-HP treatments, respectively, whereas the corresponding sow weight changes in our experiment were −26.1, −18.0, −20.0 and −3.7 kg. Similar results were observed for backfat changes, with King and Williams (1984b) reporting changes of −5.4, −1.4, −2.2 and .3 mm for LE-LP, HE-LP, LE-HP and HE-HP, respectively; corresponding changes in our experiment were −11.3, −7.4, −12.1 and −6.5 mm. Stahly et al. (1979) have shown that even when sows are allowed feed ad libitum they catabolize body tissue in early lactation and lose weight. Results from our experiment and those of King and Williams (1984b) demonstrate that sows fed diets containing HE-LP and LE-HP had similar weight losses but large differences in backfat loss, indicating that the composition of the weight loss may be different.

Percentages of sows in estrus by d 7, 14 and 35 postweaning are also presented in table 3. A higher percentage of sows fed the HP diets returned to estrus by d 7 (P<.004), 14 (P<.030) and 35 (P<.060) postweaning compared with sows fed the LP diets. Energy intake did not influence return to estrus, but a slight improvement was observed when energy intake was increased in the HP diet. No protein × energy interactions were found at either 7, 14 or 35 d postweaning for return to estrus.

A total of 41 sows were bled for progesterone analysis. Only one sow that did not exhibit a behavioral estrus had an increase in progesterone indicative of a functional corpus luteum. A progesterone concentration >5 ng/ml indicated that this sow probably ovulated between d 10 and 17 postweaning. Furthermore, of the sows that were slaughtered and their reproductive tracts collected and examined, only one displayed an abnormal tract. This sow had two large (>30 mm diameter) cystic follicles on the ovaries.

Our finding that estrus was delayed when sows were fed diets containing LP is similar to that of O'Grady and Hanrahan (1975), and King and Williams (1984b). However, the effect of energy intake in our experiment was somewhat in contrast to the reports of Reese et al. (1982a,b) and Nelssen et al. (1985) in which they noted that sows fed 8 or 10 Mcal of $ME \cdot sow^{-1} \cdot d^{-1}$ exhibited longer intervals from weaning to estrus than sows consuming 12, 14 or 16 Mcal of $ME \cdot sow^{-1} \cdot d^{-1}$. Nevertheless, in our experiment a slight (nonsignificant) response was observed when energy intake was increased in the diet containing HP, with a higher percentage of sows in estrus by d 7, 14 and 35 postweaning when fed the diet containing HE-HP than when fed the LE-HP diet. However, the response to increased energy was opposite in the diets containing LP, with fewer sows in estrus by d 7, 14 and 35 postweaning when fed HE-LP than when fed LE-LP. Thus the effect of energy was negated. The combination of LP and HE possibly restricted the amount of protein available for metabolic functions even more than the LE-LP combination, because of an increased need for synthesis of milk proteins. As energy was increased in the LP diet there was a consequent increase in pig and litter weights.

The influences of protein and energy intakes by sows on pig performance are presented in table 5. Litter size on d 3 postpartum was used as a covariate to remove the portion of the variation in pig performance that was associated with differences in litter size on d 3 postpartum. Pig weight on d 14 was not affected by protein (P = .295) or energy intake (P = .395). However, both protein (P<.001) and energy (P = .038) influenced pig weight on d 28 of lactation, with sows fed HE or HP having heavier pigs. Energy intake did not influence litter weight or size on either d 14 or 28 of lactation. Litter weights on d 14 were similar for all treatments, but sows fed HP had heavier litters (P<.005) on d 28 than sows fed LP. Litter size was smaller for sows fed HP than sows fed LP on both d 14 (P = .051) and d 28 (P = .046) of lactation.

The data reported herein are in agreement with results of Reese et al. (1982a,b) and Nelssen et al. (1985), who found an increase in pig weight as dietary energy intake in lactation increased. Furthermore, Mahan and Mangan (1975), Greenhalgh et al. (1977) and NCR-42

TABLE 5. EFFECT OF PROTEIN AND ENERGY INTAKE OF SOWS DURING LACTATION ON PIG PERFORMANCE

	Lactation diet					P values[d]				
	LE-LP	HE-LP	LE-HP	HE-HP						
	8[a]	16	8	16						
Item	380[b]	380	760	760	CV[c], %	P	E	P × E	Rep	LS3D[e]
No. of litters	62	50	61	48						
Pig wt, kg[f]										
14 d	3.7	3.8	3.8	3.8	12.5	.295	.395	.424	.004	.003
28 d	6.0	6.2	6.5	6.8	10.9	.001	.038	.728	.003	.001
Litter wt, kg[f]										
14 d	34.4	35.3	35.2	34.3	15.0	.964	.991	.214	.001	.001
28 d	54.3	56.9	58.3	59.4	14.0	.005	.112	.533	.001	.001
Litter size[f]										
14 d	9.3	9.3	9.1	8.9	9.0	.051	.325	.422	.001	.001
28 d	9.1	9.2	8.9	8.8	10.9	.046	.945	.265	.001	.001

[a]Energy, Mcal metabolizable energy/d.

[b]Protein, g/d.

[c]Coefficient of variation.

[d]Probability values for the effects of protein (P), energy (E), protein × energy interaction (P × E) and replication (Rep) and for the covariate effect of litter size on d 3 (LS3D).

[e]The average litter size on d 3(LS3D) was 9.5, 9.8, 9.5 and 9.8 for diets LE-LP, HE-LP, LE-HP and HE-HP, respectively.

[f]Least-squares means.

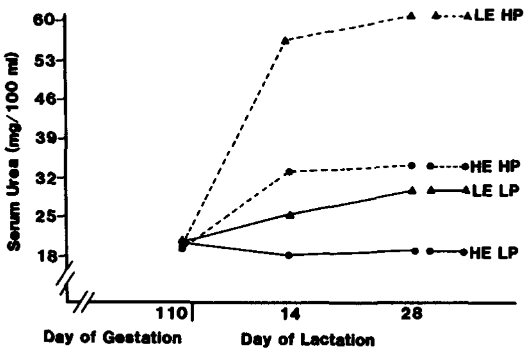

Figure 3. Serum urea concentrations of primiparous sows in late gestation and lactation (Exp. 2). Dietary treatments were the same as those described for figure 1. Protein effect (P<.001); energy effect (P<.001); protein × energy interaction (P<.001).

(1978) have shown an increase in pig weight when a diet high in protein was fed to sows during lactation.

Our finding that litter weight was not influenced by sow energy intake is in agreement with the findings of Elsley et al. (1968) and Adam and Shearer (1975). However, our data are in contrast to reported effects of energy restriction by Reese et al. (1982a,b) and Nelssen et al. (1985), who demonstrated that litter weight was reduced in sows fed 8 Mcal of $ME \cdot sow^{-1} \cdot d^{-1}$. Although there was a trend towards heavier litters in sows fed the HE diets in our experiment (P = .112), it was negated by the heavy litters of sows fed LE-HP. Apparently, the additional protein fed to sows consuming LE-HP compensated for the inadequate energy intake and therefore litter weight was not influenced by the LE intake of those sows. Sows fed diets containing HP also had heavier litters (P<.005) on d 28 of lactation than sows fed diets containing LP.

The data on litter size are in agreement with the findings of Mahan and Mangan (1975), Greenhalgh et al. (1977) and NCR-42 (1978), in which there was a decrease in litter size in sows fed HP diets when compared with sows fed diets containing LP. No explanation for this reduction in litter size was given by the previous authors. In the present research high circulating levels of serum urea were observed in sows fed HP diets. Mahan and Hiltner (1984) reported that sows fed urea during lactation had elevated serum urea, and that mammary tissue transfers a portion of the urea to the milk; thus increasing milk urea. However, they also found that serum urea in young pigs consuming milk from sows fed urea was not elevated. Thus, urea toxicity by transfer of urea from sows to pigs via the milk does not seem to be a likely explanation for the reduced litter size.

Protein (P<.001) and energy (P<.001) affected concentrations of serum urea (figure 3). A protein × energy interaction (P<.001) also was observed in which the concentration of serum urea increased in response to protein to a greater extent when energy content of the diet was low. The results of this experiment were similar to those reported for Exp. 1.

The findings of Exp. 2 demonstrate that sows fed diets restricted in protein and(or) energy during lactation lose a considerable amount of weight. However, backfat loss appears to be more energy-dependent than protein-dependent, thus the composition of the weight loss under various feeding regimens may be quite different.

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