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Effect of Dietary Energy Levels of Gestating Sows on Physiological Parameters and Reproductive Performance*

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ABSTRACT : This experiment was conducted to investigate the effects of dietary energy levels of gestating gilts on physiological parameters and reproductive performance for primiparous sows. A total of 40 F1 gilts (Large White×Landrace) were allocated to 4 treatments using a completely randomized design (CRD). Four different experimental diets contained 3,165, 3,265 3,365 and 3,465 kcal of ME/kg and each diet was provided to gilts at 2.0 kg/d during gestation. Consequently, energy intake of each treatment of gestating gilts was 6,330, 6,530, 6,730 and 6,930 kcal ME/kg, respectively. During the whole gestation period, body weight, fat mass gain and backfat thickness of gilts were increased in proportion to dietary energy levels (p<0.01). However, estimated protein mass gain of gilts was not affected by dietary energy level (p>0.10). At farrowing, the total number of pigs born per litter did not show any significant difference among treatments. However, the number of pigs born alive per litter in treatment 6,730 kcal ME/d was significantly higher than that of other treatments (p<0.05). Moreover, litter weight at birth was improved as dietary energy level was increased (p<0.05). Feed intake of sows during lactation tended to decrease as dietary energy level of gestation was increased, but litter weight gain was not affected by dietary treatment during the gestation period. Fat content in colostrum was higher as dietary energy level was increased during gestation. The concentration of blood estradiol-17β was increased and was higher at the first trimester of gestation in 6,730 kcal ME/d treatment compared to other treatments. These results suggested that increased dietary energy level during gestation resulted in higher body weight and backfat thickness of sows. In addition, reproductive performance of the sow, such as litter weight at farrowing and the number of pigs born alive, was improved when 6,730 kcal of ME/d treatment diet was provided. Consequently, the NRC (1998) recommendation of energy for gestating gilts (6,015 to 6,150 kcal of ME/d) should be reevaluated to maximize reproductive performance because recent high-producing sows require much more energy to produce a large litter size and heavier piglets from the first parity. (**Key Words :** Energy Level, Body Weight, Backfat Thickness, Progesterone, Primiparous Sow)

INTRODUCTION

Sow productivity has advanced at an incredible rate during the past decades. Miller (1992) demonstrated that the top one-third of participating Canadian farms weaned 22.25 pigs per sow per year (PSY) in 1991, a performance achieved by only a few elite herds a decade earlier. Further improvement is a certainty, as the threshold of 30 PSY becomes a realistic goal for commercial swine farms. Because of increased piglets born per litter production, the committee on animal nutrition of the NRC (1998) has listed the energy requirement of the bred gilt and sow between 6,015 and 6,395 kcal of ME/d. Estimated energy requirements during gestation have increased 55 kcal of ME/d for sows since earlier estimations (NRC, 1973). Also low energy intake during gestation period may increase the risk of being culled due to pregnancy failure (Kongsted et al., 2004). In high-producing modern sows, the energy supply during gestation should be around or above 8,500 kcal of DE/d to ensure adequate restoration of body reserves (Dourmad et al., 1996). However, several studies have demonstrated that increasing feed amount during gestation and the associated large increases in sow body weight depressed feed intake of lactating sows (Dourmad et al., 1991; Revell et al., 1994; Weldon et al., 1994) due to low plasma concentration of insulin during early lactation. Low feed intake during lactating period may have detrimental effects on sow such as poor reproductive performance and decreasing longevity.

Excessive energy intake in late gestation (after day 75) caused a detrimental effect on subsequent milk production. Weldon et al. (1991) suggested that energy intake of 10,500

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kcal of ME/d during late gestation reduced the amount of milk secreting tissue in the mammary gland compared with gilts fed 5,750 kcal of ME/d. Head et al. (1991) observed that fatten gilts had fewer milk secreting cells in their mammary glands than that of lean gilts.

Aherne and Kirkwood (1985) demonstrated that sows should be fed and managed so that they should be gained 25 kg of maternal BW throughout gestation per parity for at least the first three or four parities. The weight of the placenta and other products of conception would be approximately 20 kg, for a total of 45 kg of gestational weight gain by the sow (Verstegen et al., 1987). Young et al. (2004) observed that sows did not necessarily achieve the desired backfat gains with full precision. This was especially true for thin sows that needed to gain 6 to 9 mm of backfat to reach the targeted 19 mm goal. Previous research has shown that animals in an anabolic state, such as gilts fed high energy diet to increase ovulation rate, had decreased embryonic survival if the high energy intake continued after mating (Jindal et al., 1996; 1997).

A few researches have been conducted to establish energy requirement for high producing modern sows inherently productive and managed under conditions of an accelerated farrowing system. Consequently this experiment was conducted to evaluate the influence of dietary energy levels during gestation on reproductivity of high producing primiparous sows and their progeny.

MATERIALS AND METHODS

Selection and management of prepubertal gilts

A total of 40 gilts (Large White×Landrace) with an average 180 d of age and approximately 105 kg of body weight were selected and housed in environmentally controlled pen (2 gilts/pen) and each pen (2.5×3.5 m^2/pen) was equipped with a water cup nipple and a semiautomatic feeder allowed *ad libitum* access to feed and water. At 220 d of age, gilts were allotted to an individual gestation stall (2.4×0.64 m^2/pen) and fed diets individually in a twice daily to meet their metabolic requirements and to achieve an average weight of 140 kg. To synchronize estrus in gilts within a littermate group, the oral progestagen altrenogest (Regu-Mate, Hoechst-Roussel Vet., Canada) was provided. Semen (Darby AI center, Korea), collected from four boars (Duroc) in the same batch, was provided for artificial insemination (AI) of gilts.

Experimental design and animals managements

A total of 40 crossbred F1 sows (Large White× Landrace), averaging 236 days of age with body weight of 140.64±2.53 kg, were allotted to 4 dietary treatments by body weight and backfat thickness in a completely random design (CRD) with 10 replicates. The experimental diets for gestating gilts were formulated to contain 12.0% crude protein, 0.73% lysine, 0.90% calcium and 0.70% phosphorus but energy content was: i) 3,165 kcal of ME/kg ii) 3,265 kcal of ME/kg, iii) 3,365 kcal of ME/kg and iv) 3,465 kcal of ME/kg, respectively. Feed intake (FI) of gestating gilts was 2.0 kg/d regardless of treatments but energy intake of gilts was varied by dietary energy treatments and it was 6,330, 6,530, 6,730 and 6,930 kcal of ME/d, respectively. Lactating diet contained 3,265 kcal of ME/kg, 17.80% crude protein, 1.05% lysine, 0.90% calcium and 0.70% phosphorus, respectively (Table 1). All other nutrients were formulated to meet or exceed NRC requirement (1998).

Gilts were housed in temperature-controlled rooms with automatic fans used to regulate air flow and placed in an individual create (2.4×0.65 m^2) which was installed on concrete floor. After d 110 of gestation, pregnant gilts were washed and placed into farrowing crates.

After farrowing, lactation diet was restricted and its amount was increased gradually from 1.0 kg/d until 5 d postpartum whereupon diet was provided *ad libitum* during lactation period. Within 24 h of farrowing, Fe-dextran (150 ppm) was injected and treatments such as ear-notched, clipped needle teeth and tails were conducted. Weaning was done at approximately 24±2 d then sows were transferred to gestating crate.

Measurements and analysis

Gestation and lactation period, body weight and backfat thickness of sows were measured at P_2 position and blood samples were collected at breeding, 15, 35, 70, 90, 110 days of gestation and within 24 h post farrowing, 7, 14, 21 days of lactation. Number of piglets born alive, still born, mummified fetuses and total born and body weight were recorded weekly. Lactating sows were bled weekly from the anterior vena cava and four pigs from each litter were also bled via cardiac puncture. Blood samples were collected into heparinized tubes, centrifuged at 1,500×g for 15 min, and plasma was harvested from all blood samples and stored at -20°C until further analysis. After injection of oxytocin, colostrum and milk samples were collected into falcon tube and stored at -20°C until further analysis.

Insulin in serum was assayed using Coat-A-Count® insulin kits (DPC, Los Angeles, CA). The concentration of progesterone in the peripheral blood plasma was determined using a solid-phase radioimmunoassay kit (Coat-A-Count® Progesterone, Diagnostic Products Corporation, Los Angeles, CA, USA). The concentration of oestrone in peripheral blood plasma was determined using the DSL-8700 (Diagnostic Systems Laboratories Inc.,Webster, USA) oestrone radioimmunoassay kit. The concentration of LH in

Table 1. Chemical composition of gestating and lactating diets (%)

Items	Gestating diets				Lactating diet
	6,330	6,530	6,730	6,930	
Corn	67.87	66.93	67.33	67.95	66.05
SBM-44	11.97	12.58	13.36	14.20	26.98
Wheat bran	14.87	13.45	10.80	7.90	-
Fish meal	-	-	-	-	0.91
Mixed animal fat	-	-	-	-	1.25
Sugar molasses	-	-	-	-	0.80
Soy oil	1.36	3.04	4.46	5.85	-
L-lysine·HCl	0.21	0.20	0.20	0.19	0.17
Monocalcium phosphate	1.96	2.03	2.14	2.27	2.20
Limestone	1.16	1.12	1.06	0.99	0.87
Trace vitamins[a]	0.20	0.20	0.20	0.20	0.20
Trace minerals[b]	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.42
Antibiotics[c]	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00
Chemical compositions (analyzed values, %)					
CP	12.65	11.99	12.38	12.48	17.80
Calcium	0.89	0.90	0.90	0.89	0.90
Total P	0.70	0.70	0.69	0.69	0.70
Calculated energy, kcal of ME/kg	3,165	3,265	3,365	3,465	3,265
Lysine	0.73	0.73	0.73	0.73	1.05
Methionine	0.23	0.23	0.23	0.23	0.29

[a] Supplied per kg diet: vitamin A, 10,000 IU; vitamin D_3, 1,500 IU; vitamin E, 35 IU; vitamin K_3, 3 mg; pantothenic acid, 10 mg; niacin, 20 mg; biotin, 50 μg; vitamin B_{12}, 15 μg; folic acid, 500 μg; vitamin B_2, 4 mg; vitamin B_6, 3 mg.
[b] Supplied per kg diet: Cu, 55 mg; Fe, 75 mg; I, 250 mg; Mn, 20 mg; Se, 100 μg; Zn, 30 mg; Co, 250 mg.
[c] Neomycin was supplemented 20 mg/kg.

serum was analyzed using a previously established double-antibody RIA (Xue et al., 1994).

Statistical analysis

Statistical analysis was carried out comparing means according to LSD (least significance difference) multiple test, using general linear model (GLM) procedure of SAS (2000) package program. Each sow was an experimental unit for analysis of performance data.

RESULTS

Sow and litter performance

Table 2 showed that the changes of body weight and body weight gain during gestation was increased when gilts were fed higher energy diets (6,730 or 6,930 kcal of ME/d) compared to that of low energy diets ($p<0.01$). And body weight of lactating sows was decreased linearly as high energy diets were provided to sows ($p<0.05$). Consequently, overall body weight change of gilts from breeding to 3 weeks of lactation was not affected by dietary treatments and its increment was between 31 and 35 kg.

Estimated protein and fat masses of gilts were calculated based upon body weight and backfat thickness (Dourmad et al., 1997). Protein mass was not affected by dietary energy level of gestation (Table 3). Fat mass, however, was increased during gestation and was higher as energy level increased ($p<0.05$) and fat mass of lactating sows tended to decrease clearly when high energy diets were provided to gilts during gestation (Table 3).

The feed intake (FI) during lactation was increased as lactation progressed and was greater when sows were fed low energy diets during gestation (Table 2). Increased dietary energy level during gestation influenced on body weight and backfat thickness of gilts ($p<0.05$) but the loss of body weight and backfat thickness during lactation were increased due to the fact that FI of lactating sows was reduced when high energy diets were provided during gestation.

From the breeding, backfat thickness of gilts at P_2 position was maintained approximately 18 mm and was increased in proportional to dietary energy levels during gestation ($p<0.01$). However, during 3 weeks of lactation, backfat thickness of sows tended to decrease and was greater when sows were fed high energy treatment diets. And backfat thickness of sows was increased approximately 2 mm from breeding to 3 weeks of lactation regardless of dietary energy treatments.

Chemical compositions of sow milk were shown in Table 4. The percentage of fat in colostrum tended to increase as gilts were fed higher energy diets during gestation but it was declined as lactation progressed.

Table 2. Effects of dietary energy level in gestating sows on body weight, back-fat and feed intake of primiparous sows

Items	Treatment, kcal of ME/d				SEM[2]	p-value	
	6,330[1]	6,530	6,730	6,930		Linear	Quadratic
No. gilts	9	10	9	9	-	-	-
Body weight on gestation (kg)							
Breeding[3]	142.22	142.35	138.89	138.28	2.270	0.140	0.870
110 day	197.50	197.25	202.06	205.94	2.622	0.015	0.430
Breeding-110 day (gain)	55.28[B]	54.90[B]	63.70[A]	67.67[A]	2.542	0.001	0.338
Body weight on lactation (kg)							
0 d[4]	180.50	180.50	181.67	180.83	2.590	0.812	0.964
21 d postpartum	177.67	174.28	169.78	172.28	3.861	0.228	0.482
0-21 d postpartum (gain)	-2.83	-5.15	-11.89	-8.56	3.151	0.098	0.370
Breeding-21 d postpartum (gain)	35.44	32.40	30.89	34.00	3.153	0.680	0.330
Back-fat on gestation (mm)							
Breeding	18.39	19.05	17.28	17.28	0.738	0.150	0.780
110 day	22.33	23.36	23.11	25.39	0.990	0.054	0.557
Breeding-110 day (gain)	3.94[C]	4.31[BC]	5.83[B]	8.11[A]	0.638	0.001	0.221
Back-fat on lactation (mm)							
0 d	22.61	22.14	21.78	23.33	0.930	0.721	0.357
21 d postpartum	20.78	20.59	19.33	19.72	1.091	0.309	0.988
0-21 d postpartum (gain)	-1.83	-1.55	-2.45	-3.61	0.195	0.076	0.276
Breeding-21 d postpartum (gain)	2.39	1.54	2.06	2.44	1.032	0.969	0.853
Average daily feed intake on lactation (kg)							
0-7 d postpartum	4.27	3.95	3.72	3.49	0.302	0.024	0.655
7-14 d postpartum	4.79	4.68	4.48	4.64	0.359	0.560	0.609
14-21 d postpartum	5.81	5.87	6.00	5.66	0.358	0.841	0.909
0- 21 postpartum	4.96	4.84	4.73	4.57	0.217	0.087	0.799
Energy utilization on sows (kcal)							
Gestation[5]	678,125[C]	701,625[B]	716,401[AB]	742,353[A]	2,478.6	0.001	0.616
Lactation[6]	101,770	55,866	30,819	44,695	11,070.1	0.052	0.171

[1] Energy intake ME kcal/kg (2.0 kg provided to sow daily). [2] Standard error of mean. [3] Breeding day. [4] 24 hours postfarrowing.
[5] Gestation energy intake - uterus energy used. [6] Lactation energy intake - piglet energy used.
[A,B,C] Means with different superscripts significant difference (p<0.01).

However, the percentage of protein, lactose and solid-not-fat (SNF) was not affected by dietary energy treatments during gestation. Moreover, lactose was increased as lactation progressed regardless of dietary treatments.

The number of pigs born live and litter birth weight were increased as dietary energy intake increased during gestation (Table 5, p<0.05). The number of pig (total born and stillborn) was numerically higher when gilts were fed 6,730 kcal of ME/d diet during gestation although it was not significant difference. Individual pig birth weight tended to increase as dietary energy level increased during gestation but it was highest in 6,730 kcal of ME/d treatment diet at 21 d postpartum and lowest litter weight was observed in 6,330 kcal of ME/d diet treatment. Heavy litter weight at birth was also observed when 6,730 kcal of ME/d diet was provided to gilts during gestation (p<0.05) and higher litter weight at 21 d postpartum was observed when gilts were fed 6,730 kcal of ME/d diet but the response was not significant.

The estradiol-17β concentration in blood was increased and was higher in 6,730 kcal ME/d diet at 90 d postcoitum and at 7 d postpartum (Figure 1, p<0.05). But highest level of estradiol-17β was observed in 6,930 kcal of ME/d diet at 110 postcoitum. Moreover, higher estradiol-17β level was observed in 6,730 kcal of ME/d diet at first trimester of gestation (15 d and 35 d) which could result in high litter size in 6,730 kcal of ME/d treatment. Blood insulin concentration was somewhat maintained a certain ranges of value but was higher at 0 d postpartum regardless of dietary energy treatment during gestation (Table 6). Blood progesterone concentration, however, was maintained until 110 d postcoitum but it was declined at 0 d postpartum in all treatments (Table 6).

DISCUSSION

Increased body weight of gilts during gestation was observed as dietary energy level increased but more body weight loss during lactation was occurred when gestating gilts were fed high energy diets. Averette Gatlin et al.

Table 3. Effects of dietary energy level of gestating sows on estimated protein, fat mass and its gain of primiparous sows

Items	Treatment, kcal of ME/d				SEM[2]	p-value	
	6,330[1]	6,530	6,730	6,930		Linear	Quadratic
Estimated protein mass[c] on gestation (kg)							
Breeding	21.48	21.51	21.26	21.12	0.352	0.443	0.925
110 day	30.00	29.71	30.53	30.49	0.528	0.331	0.786
Breeding-110 day (gain)	8.52	8.20	9.27	9.37	0.482	0.115	0.747
Estimated protein mass on lactation (mm)							
0 d	26.90	27.05	27.37	26.70	0.395	0.741	0.165
7 d postpartum	27.66	27.40	27.39	27.12	0.464	0.413	0.896
14 d postpartum	27.03	26.55	26.32	26.32	0.492	0.290	0.631
21 d postpartum	26.98	26.44	26.08	26.38	0.508	0.367	0.371
0-21 d postpartum (gain)	0.08	-0.61	-1.29	-0.32	0.465	0.439	0.035
Breeding-21 d postpartum (gain)	5.50	4.93	4.82	5.26	0.687	0.617	0.277
Estimated fat mass[d] on gestation (mm)							
Breeding	29.50	30.70	27.29	27.16	1.254	0.073	0.620
110 day	46.98[b]	48.42[b]	49.01[ab]	52.90[a]	1.544	0.014	0.527
Breeding-110 day (gain)	17.48[C]	17.72[C]	21.72[B]	25.74[A]	1.037	0.001	0.130
Estimated fat mass on lactation (mm)							
0 d	43.59	42.95	42.74	44.61	1.653	0.733	0.513
7 d postpartum	44.77	42.39	41.69	43.49	1.698	0.510	0.290
14 d postpartum	42.63	41.72	38.04	39.97	1.803	0.148	0.482
21 d postpartum	40.52	40.19	36.86	37.92	2.151	0.245	0.794
0-21 d postpartum (gain)	-3.07	-2.76	-5.88	-6.69	1.537	0.051	0.732
Breeding-21 d postpartum (gain)	11.02	9.49	9.57	10.76	1.906	0.907	0.536

[1] Energy intake ME kcal/ kg (2.0 kg provided to sow daily). [2] Standard error of mean. [3] Breeding day.
[a, b] Means with different superscripts significant difference (p<0.05). [A,B,C] Means with different superscripts significant difference (p<0.01).
[c] Prediction equation from Dourmad et al. (1997): 2.28+0.178×(live weight, kg)+0.333×(backfat, mm).
[d] Prediction equation from Dourmad et al. (1997): 26.400.221×(live weight, kg)+1.331×(backfat, mm).

Table 4. Effects of dietary energy level of gestating sows on chemical compositions on colostrum and milk of sow

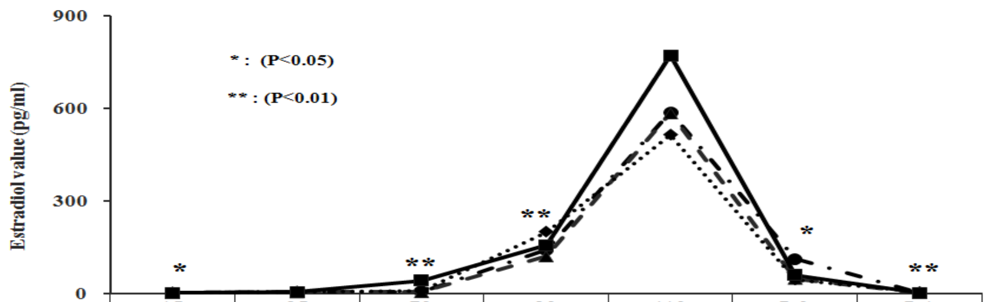
Items	Treatment, kcal of ME/d				SEM[2]	p-value	
	6,330[1]	6,530	6,730	6,930		Linear	Quadratic
Chemical composition at colostrum (%)							
Fat	8.18	10.51	10.43	11.18	0.724	0.018	0.301
Protein	6.47	5.93	6.46	7.27	1.042	0.541	0.528
Lactose	4.52	3.81	4.28	3.65	0.365	0.215	0.920
Solids-not-fat	11.48	10.47	10.85	11.66	0.855	0.811	0.306
Chemical composition at 21d postpartum (%)							
Fat	7.56	6.53	7.21	6.65	0.413	0.616	0.796
Protein	4.50	4.18	3.99	4.33	0.134	0.570	0.235
Lactose	5.60	5.55	5.55	5.27	0.126	0.398	0.657
Solids-not-fat	10.80	10.43	10.06	10.30	0.133	0.117	0.240

[1] Energy intake kcal of ME/kg (2.0 kg provided to sow daily). [2] Standard error of mean.

Table 5. Effects of dietary energy level of gestating sows on reproductive performance and growth of its progeny

Items	Treatment, kcal of ME/d				SEM[2]	p-value	
	6,330[1]	6,530	6,730	6,930		Linear	Quadratic
Reproduction performance							
No. born/litter[3]	11.67	11.89	14.33	12.33	0.810	0.252	0.139
No. born alive/litter	10.78[b]	11.00[b]	13.56[a]	11.33[b]	0.738	0.217	0.088
No. stillbirths/litter	0.44	0.11	0.67	0.56	0.667	0.488	0.895
No. initial pigs/litter[4]	10.78	11.00	12.11	11.11	0.447	0.368	0.148
No. at weaning/litter	10.78	10.78	11.11	11.11	0.436	0.624	0.860
Average litter weight on lactation (kg)							
Litter birth weight	16.19[ab]	15.13[b]	19.20[a]	17.73[ab]	1.079	0.102	0.616
Initial litter weight[4]	15.53	15.11	15.26	16.53	0.788	0.416	0.356
7 d postpartum	24.64	25.33	26.92	28.34	1.567	0.085	0.902
14 d postpartum	37.63	39.62	42.98	43.31	0.255	0.056	0.565
21 d postpartum	50.63	55.04	58.50	55.38	2.894	0.105	0.235
Average piglets weight on lactation (kg)							
Piglet birth weight	1.36	1.28	1.36	1.47	0.075	0.309	0.231
Initial piglet weight[4]	1.42	1.36	1.39	1.50	0.067	0.382	0.229
7 d postpartum	2.31	2.38	2.39	2.58	0.426	0.123	0.694
14 d postpartum	3.48	3.66	3.83	3.96	0.277	0.056	0.714
21 d postpartum	4.71	5.12	5.29	5.06	0.234	0.133	0.218
Energy for uterus gain and piglet gain (kcal)							
Breeding to fallowing[5]	37,164	36,265	44,088	40,737	2,478	0.102	0.616
Birth to 21 d postpartum[6]	238,203	274,950	293,761	274,180	8,475	0.099	0.095

[1] Energy intake ME kcal/ kg (2.0 kg provided to sow daily). [2] Standard error of mean. [3] Registered litter size. [4] After cross-fostering day at d 1 postpartum.
[5] Prediction equation from Noblet et al. (1985): 4.8×fetus BW gain, kg/0.5×1,000/4.18.
[6] Prediction equation from NRC (1998): (6.83×ADG×pigs)-(125×pigs).
[a,b] Means with different superscripts significant difference (p<0.05).



	15	35	70	90	110	L0	L1
3165	1.76	4.43	5.74	141.87	586.83	110.94	2.27
3265	1.49	4.05	4.54	120.63	584.31	47.77	2.61
3365	2.80	5.70	7.16	199.43	513.43	44.38	4.02
3465	1.63	4.75	42.03	156.09	771.34	59.33	2.14

Day of gastation and week of lactation

Figure 1. Concentration of plasma Estradiol-17β of primiparous sows during gestation and lactation.

Table 6. Concentrations of plasma insulin and progesterone of primiparous sows during gestation and lactation

Items	Time, d									
	0	15	35	70	90	110	L0	L7	L14	L21
Insulin (μl U/ml)										
6,330[1]	7.02	7.46	14.06	7.63	10.91	6.45	10.07	8.16	11.73	9.75
6,530	7.02	12.01	7.73	9.97	8.04	6.00	12.79	5.59	13.39	6.76
6,730	7.02	7.93	9.04	6.64	11.47	8.00	14.58	6.40	14.41	14.33
6,930	7.02	7.11	5.10	7.10	9.02	7.25	13.22	3.33	8.29	11.32
SEM	-	0.591	1.012	0.634	0.730	0.531	1.065	0.706	0.944	1.054
p (linear)	-	0.196	0.003	0.397	0.737	0.419	0.277	0.023	0.230	0.131
p (quadratic)	-	0.008	0.403	0.475	0.886	0.898	0.373	0.835	0.039	0.995
Progesterone (ml U/ml)										
6,330[1]	0.17	31.62	17.32 [B]	14.50	13.60 [b]	11.45[b]	0.99 [B]	0.18	-	-
6,530	0.17	32.41	12.65[C]	14.25	15.26[ab]	12.27[ab]	0.90[B]	0.29	-	-
6,730	0.17	30.35	17.72[B]	14.48	14.74[b]	14.30[a]	0.39[C]	0.26	-	-
6,930	0.17	32.01	23.23[A]	16.68	16.66[a]	14.03[a]	1.81[A]	0.21	-	-
SEM	-	1.030	1.058	0.578	0.378	0.423	0.149	0.033	-	-
p (linear)	-	0.932	0.001	0.216	0.006	0.008	0.019	0.835	-	-
p (quadratic)	-	0.856	0.001	0.313	0.826	0.438	0.001	0.285	-	-

[1] Energy intake ME kcal/kg (2.0 kg provided to sow daily). [2] Standard error of mean.
[a, b] Means with different superscripts significant difference ($p<0.05$).
[A,B,C] Means with different superscripts significant difference ($p<0.01$).

(2002) also demonstrated that body weight and backfat thickness were increased when sows were consumed high dietary energy during gestation. Dourmad (1991) suggested a positive relationship between maternal weight gain during gestation and weight loss during lactation but predicted muscle weight loss was affected by feed intake of gilts during gestation. Kusina et al. (1999) demonstrated that high producing sows are able to manipulate the composition of maternal gain during gestation particularly in early parities and much of maternal gain would be lean tissue if dietary amino acids were provided adequately. Pettigrew (1993) suggested pregnant sow should be fed 11 to 14 g of lysine/d to gain target amounts of lean tissue and prepare subsequent lactation. In the present study, maternal protein and fat mass were calculated based upon the equation of Dourmad et al. (1997). However, maternal gain during gestation was increased as the form of fat tissue rather than protein tissue although pregnant gilts were fed 14.6 g of lysine/d regardless of dietary energy treatments. The present study demonstrated that fat tissue increased approximately two folds in sows compared to that of protein tissue both in gestation and lactation consequently dietary energy supply would be important to maintain adequate body weight and backfat thickness for successful following parities of sows.

Backfat thickness during gestation tended to be higher as high energy diets were provided and high backfat loss during lactation was observed in high energy diets, while backfat changes from breeding to weaning remained constant with a range of 17 to 21 mm regardless of dietary energy treatments. Although the body weight and backfat thickness of gilts were increased in proportional to dietary energy levels during gestation, those values were decreased during lactation by low feed consumption in high energy treatment groups. Feed intake during lactation was significantly affected by dietary energy treatment during gestation particularly during the first week postpartum, consequently body weight and backfat thickness of sows became similar values after weaning in all treatments. Previous researches have explained a negative relationship between high backfat thickness at farrowing and lactation feed intake (Dourmad et al., 1991; Revell et al., 1998).

Three decades ago, Frobish et al. (1973) demonstrated that litter size was maximized when daily energy intake was approximately 6,000 kcal of ME/d. However, in this experiment, litter size was highest when gilts were fed 6,730 kcal of ME/d treatment diet. This result demonstrated that recent high producing modern sows required much more energy during gestation for maximizing both maternal and fetal growth compared to conventional sows of previous decades. In 1998, NRC recommended dietary energy for gestating sows between 150 and 175 kg BW from 6,015 to 6,150 kcal of ME/d. In this experiment, gestating gilts were fed 2.0 kg of feed daily but dietary energy level was differed by treatment groups consequently daily energy intake was varied at 6,330, 6,530, 6,730 and 6,930 kcal of ME/d, respectively. Low reproductive performance was observed in low energy treatment (6,330 kcal of ME/d) although it was exceeded NRC requirement (1998). Consequently energy requirement for recent high producing gestating sows should be increased more than 6,530 kcal of ME/d to maximize reproductive performance and their litter growth. Jindal et al. (1996) demonstrated that higher energy intake during the first trimester of gestation induced a detrimental effect on embryonic survival in gilts. In this experiment, dietary energy was provided to pregnant gilts from 6,330 to 6,930 kcal of ME/d however, there was no decrease of the total number of piglets and the number of pigs tended to increase when sows fed higher energy treatment diets.

Individual pig weight and litter weight were affected by dietary energy level of gestating sows but litter growth was highest when sows were fed 6,730 kcal of ME/d treatment diet compared to other treatments. This energy level was approximately 10% higher than NRC requirement of pregnant sows (1998), but 6,330 kcal of ME/d treatment showed the lowest reproductive performance of sows as well as growth performance of their progeny. This result demonstrated that more than 10% of additional energy should be provided to recent high producing pregnant sow compared to NRC requirement of energy (1998).

The energy retention both in maternal and fetal can be calculated based upon the equation of Noblet et al. (1985) and Dourmad et al. (1996). The maternal energy retention was increased as dietary energy level and the highest retention was observed in 6,930 kcal of ME/d and this result was able to be explained by the increment of backfat thickness during gestation.

The difference of energy retention between 6,330 and 6,930 kcal of ME/d treatment during gestation was approximately 6,000 kcal of ME/d and it was reflected on fetal growth subsequently energy retention for litter growth during gestation between 6,330 and 6,930 kcal of ME/d treatment was approximately 8.77%. This result demonstrated that dietary energy of gestating sow influenced directly on fetal growth rather than maternal retention when sows were fed at 6,730 kcal of ME/d energy level. However, when gestating sows were fed much higher energy diet (6,930 kcal of ME/d) than 6,730 kcal of ME/d, excessive dietary energy would be accumulated in maternal body, resulting in detrimental effect on feed intake of sows during lactation.

Ginther (1986) demonstrated that there was highly positive correlation between the follicular growth pattern and plasma estradiol-17β, which could be an indicator for estimation of litter size of gestation sows. In the present experiment, Estradiol-17β concentration at 15 d of gestation was clearly higher in 6,730 kcal of ME/d treatment ($p<0.05$) and its concentration at 35 d of gestation also showed different values although it was not significant difference. We speculate that the higher Estradiol-17β concentrations are derived from the larger follicle size of sows when higher energy diet was provided during gestation consequently litter size in 6,730 kcal of ME/d treatment was higher than other treatments. Prunier et al. (1993) demonstrated that plasma Estradiol-17β concentration before the LH surge was affected by feeding level of sows. Tucker (1988) reported that lactogenesis is accomplished by the increment of Estradiol-17β consequently higher concentration of Estradiol-17β alleviated the embryonic mortality and induced the development of mammary glands which resulted in the increase of litter size in 6,730 kcal of ME/d treatment. Practically, however, diagnosis of pregnancy is generally monitored at approximately 35 d rather than 15 d of gestation in most of swine farm therefore Estradiol-17β concentration at 35 d of gestation can be utilized efficiently for the estimation of litter size of gestating sows. However, the concentrations of FSH, LH, insulin and progesterone did not show any significant differences by dietary energy treatment of gestation sows.

CONCLUSIONS

Dietary energy requirements for gestating gilts were recommended from 6,015 to 6,150 kcal of ME/d by NRC (1998), but energy requirement for recent high producing sows are needed to reestablish. When gilts were fed 6,730 kcal of ME/d (3,365 kcal of ME/kg) during gestation, higher reproductive performance of gilts, such as the total number of piglet alive, piglet alive born, and piglet weaned was observed. Consequently, the adequate energy requirement of gestating gilts should be more than 6,530 kcal of ME/d (3,265 kcal of ME/kg) and less than 6,730 kcal of ME/d (3,365 kcal of ME/kg) when lysine was provided 14.6 g daily.

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