EFFECTS OF SEVERE ENERGY VERSUS PROTEIN DEPRIVATION DURING GESTATION OF REPRODUCTIVE PERFORMANCE AND BLOOD METABOLITES OF GILTS

By

F.O.I. ANUGWA¹, and W.G. POND²
Department of Animal Science, Cornell University
Ithaca, New York 14853

SUMMARY

Diets designated as high energy, high protein (HEHP), low energy, high protein (LEHP), high energy, low protein (HELP) and low energy, low protein (LELP) were fed to gilts from breeding through farrowing. Feeding rates were 1.82 (HEHP, HELP) or 0.68 kg (LEHP, LELP) of diet per gilt per day. Diets were calculated to provide 6.6 (HEHP, HELP) or 2.2 Mcal (LEHP, LELP) of digestible energy and 272 (HEHP, LEHP) or 60 g (HELP, LELP) of protein per gilt per day. Protein contents of the HEHP, LEHP, HELP and LELP diets were 15, 40, 3.3 and 9%. All sows and their progeny were treated similarly after farrowing. Gilts on the high energy diets (HEHP, HELP) gained significantly more weight during gestation than the gilts on the low energy diets (LEHP, LELP). Farrowing percentages were 100, 100, 80 and 40% for the HEHP, HELP, LEHP and LELP gilts respectively. Average litter size, birth weight, number of pigs weaned per litter or weaning weights were not significantly different among treatments. At the same stages of gestation, there were no significant differences among treatments in plasma glucose levels but plasma glucose significantly increased ($P < 0.05$) in all treatments with advancing pregnancy. Serum albumin concentrations were significantly lower ($P < 0.05$) in the HELP group than in the other groups by the end of gestation. The data indicate that lowering protein intake during gestation may be one way of reducing feed costs without impairing reproductive performance.

INTRODUCTION

The ultimate objective of swine production is to produce high quality pork at minimum cost. Feed normally represents 55 to 85% of the total cost of commercial swine production. The exact lower and upper limits of energy and protein required for optimum reproductive performance in gravid swine are not well defin-

ed. However, there is some evidence that levels below those recommended (NRC, 1973) may support normal reproduction (Dean and Tribble, 1961; Pickett and Beeson, 1962; Lodge *et al.*, 1966). A relatively high level of energy intake increases ovulation rate in gilts but decreases litter size at birth (Robertson *et al.*, 1951; Self *et al.*, 1955; Haines *et al.*, 1959). Libal and Wahlstrom (1977) reported a significant decrease in the number of live pigs born as daily energy intake increased from 4000 to 7000 kcal of metabolizable energy. Diets supplying as little as 90 g of protein daily (5% protein in the diet) resulted in normal reproduction performance over 3 reproductive cycles (Rippel *et al.*, 1965). However, essentially protein-free diets (9 g protein/day) fed during pregnancy reduced not only birth weights but also weight gains of the offspring from birth to slaughter (Pond *et al.*, 1969). Vermedahl *et al.*, (1969) and Baker *et al.*, (1969) reported depressed birth weight and 21 day weight of pigs from low energy dams while feed intake during gestation had no effect on daily gain of the pigs after 21 days. If energy and/or protein intake can be severely restricted during pregnancy without seriously affecting reproductive performance, the postnatal rate of weight gain or feed efficiency, savings in feed cost could be achieved.

The objectives of this experiment were to determine the effect of severe energy

¹Present address:

Department of Animal Science, University of Nigeria, Nsukka

²Present address:

Roman L. Hruska U.S.
Meat Animal Res. Centre, Clay Centre,
Nebraska, NE 68933.

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versus severe protein restriction throughout gestation on the reproductive performance of gilts and their plasma glucose, serum protein and serum albumin concentrations.

MATERIALS AND METHODS

Twenty Yorkshire gilts weighing an average of 122 kg (range 99–143 kg) were divided into 4 treatment groups. They

were assigned to the diets in Table 1 in rotation as they were bred. After breeding, the gilts were placed in individual pens and the experimental diets fed.

Diets were formulated and fed in amounts which allowed the gilts to receive equal amounts of minerals (85 g/day) and vitamins (20 g/day) but varied in the amount of digestible energy (DE) and

TABLE 1
Composition of gestation diets 1, 2, 3, 4

Ingredients	HEHP	LEHP	HELP	LELP
	(‰ of diet)			
Soybean meal	20.64	55.49	4.62	12.58
Alfalfa meal	5.16	13.87	1.15	3.14
Isolated soy protein	3.93	10.57	0.88	2.40
Corn oil ^a	3.32	4.46	3.34	4.55
Cerelose ^b	61.15	—	84.18	61.42
Mineral mix ^c	12.64	—	12.64	12.88
Vitamin mix ^d	1.10	2.97	1.10	3.03
	100.00	100.00	100.00	100.00
¹ Amount per animal per day (kg)	1.82	0.68	1.82	0.68
² Intake of DE/animal/day, Mcal	6.6	2.2	6.6	2.2
³ Protein contents (%)	15	40	3.3	9
⁴ Intake of protein/animal/day, g	272	272	60	60

^aMazola Corn Products Co., New York.

^bCerelose dextrose 200k, CPC International, Inc. Englewood Cliff, NJ

^cComposition of mineral mix in g per kg of diet was: cyphos 21 (mixture of CaHPO_4 and $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$ containing 21% P and 15–18% Ca) 23.81, CaCO_3 9.71, NaCl 5, $\text{FeSO}_4 \cdot \text{H}_2\text{O}$ 185, $\text{ZnCO}_3 \cdot \text{H}_2\text{O}$ 0.66, MgO 0.82, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ 0.011, KI 0.004, $\text{Na}_2\text{SE O}_3$ 0.0005, CuSO_4 0.01, KH_2PO_4 1.50.

^dAmount of vitamin mix per kg of diet was: vitamin A 5750 IU, vitamin D₃ 660 IU, thiamin 4 mg, riboflavin 9.9 mg, niacin 66 mg, calcium pantothenate 39.6 mg, choline chloride (70%) 2528.6 mg, vitamin B₁₂ 66 mcg, alpha tocopheryl acetate 100 IU, inositol 220 mg, folic acid 2.2 mg, menadione 4.4 mg, pyridoxine 3.3 mg, biotin 0.33 mg, Glucose monohydrate was added at 6778.6 mg per kg of diet to provide 10 g of vitamin mix per kg of diet.

protein provided. Two high energy diets were fed at the rate of 1.82 kg per day which were calculated to provide 6,600 kcal of -DE per gilt. One high energy group also received high protein (HEHP) while the other high energy group received a low protein (HELP) diet. The two low energy diets were fed at the rate of 0.68 kg per gilt per day and were formulated to provide 2,200 kcal of DE per day. Again, a combination of low energy, high protein (LEHP) and low energy, low protein (LELP) was used. The high protein (HEHP, LEHP) diets provided 272 g of protein per day while the low protein (HELP, LELP) diets provided 60 g of protein. Protein contents of the HEHP, LEHP, HELP and LELP diets were 15, 40, 3.3 and 9%. (The crude protein percentages had to vary because feed intake was restricted to different levels. For example, for the HEHP and LEHP diets which were fed at the level of 1.82 and 0.68 kg/animal/day, respectively, to give the same quantity (272 grams) of protein per day, their crude protein percentages must be different). Gilts were fed once a day and water was available through automatic waterers. Gilts were weighed every 2 weeks after breeding.

Sows and litters were maintained under similar feeding and management regimes. Thus, any effects on lactation were assumed to be carryover effects from the dietary treatments during gestation. The sows were fed a 13% protein, corn-soybean meal type lactation diet *ad libitum*.

All pigs were allowed access to a 20% protein creep feed from 2 weeks of age until weaning at 5 weeks of age. Male pigs were castrated at 3 weeks of age.

On days 38, 76 and 112 (corresponding to the end of the 1st, 2nd and 3rd trimesters) of pregnancy and on days 3 and 35 (corresponding to the beginning and end) of lactation, all the gilts were bled from the anterior vena cava approximately 5 hrs after feeding. Two piglets from each litter were also bled on days 3

and 35 of age from each of the HEHP, HELP and LEHP groups (giving 10, 10 and 8 piglets per treatment, respectively) and three piglets per litter from the LELP group. Blood samples were placed in both plain tubes for collecting serum or tubes containing sodium fluoride for preparation of plasma. Samples were stored at -20°C until being thawed for analysis.

Serum protein was determined using the biuret procedure (Gornall *et al.*, 1949) and serum albumin by absorption of bromocresol green (Batholomew and Delaney, 1966) using bovine serum albumin as standards. Plasma glucose was determined using a kit (General Diagnostics Glucostrate Kit, Warner-Lambert, Co., Morris Plains, New Jersey). This is a colorimetric procedure which uses the Hexokinase-Glucose-6-phosphate Dehydrogenase reaction scheme coupled with the concomitant reduction of a tetrazolium salt (2-p-iodophenyl-3-p-nitrophenyl-5-phenyl tetrazolium chloride, INT) to produce a chromagen which is measured with a spectrophotometer at a wavelength of 420 — 450 nm. Glucose was used as a standard.

Statistical analysis was performed using analysis of variance and correlation techniques (Snedecor and Cochran, 1974).

RESULTS AND DISCUSSION

A summary of the performance of gilts from breeding through lactation is given in Table 2. Survival rate of gilts in all four groups was 100%. Figure 1 contains the weight changes of the gilts during gestation. Gilts which were fed the HEHP and HELP diets gained weight at an average rate of 0.3 and 0.23 kg per day, respectively ($P > 0.05$) while gilts which were fed the LEHP and LELP diets lost weight during gestation at an average rate of 0.09 and 0.08 kg per day, respectively ($P > 0.05$). Thus the HEHP and HELP groups gained significantly ($P < 0.01$) more weight than either the LEHP or LELP groups, indicating that gestation body weight changes were more closely

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TABLE 2
Reproductive Performance of gilts

	Dietary Treatments							
		HEHP	LEHP ¹			HELP	LELP ¹	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Gestation:								
Initial weight, kg	120.8	6.2	124.0	3.3 (122.0)	124.8	8.1	119.5	4.5 (118.0±12.5)
Final weight, kg	154.0 ^a	6.6	114.5 ^b	4.8 (101.0)	150.3	11.0	110.5 ^b	8.5 (94.6±8.8)
Weight gained, kg	33.2 ^a	2.8	-9.5 ^b	0.7 (-21.0)	25.5 ^a	3.1	-9.10 ^b	4.0 (-23.3±5.2)
Weight gained, % initial weight	27.8 ^a	2.9	-7.7 ^b	0.8 (-17.21)	20.4 ^a	1.4	-7.5 ^b	3.6 (-19.5±3.1)
ADG, kg	0.30 ^a	0.03	-0.09 ^b	0.05 (-0.28)	0.23 ^a	0.05	-0.08 ^b	0.04 (-0.25±0.08)
Farrowing Percentage	100.0		80.0		100.0		40.0	
Percentage abortions	—		20.0		—		60.0	
Average number days before abortion	—		70		—		91.6	
At birth:								
Number live pigs born	8.2	0.73	7.5	1.2	9.25	1.6	10.0	0.7 (n.s.)
Average birth weight, kg	1.03	0.06	0.88	0.07	1.14	0.11	0.76	0.08 (n.s.)
Litter weight, kg	8.64	2.30	6.38	0.08	10.87	2.8	7.63	1.5 (n.s.)
At Weaning (5weeks):								
Average number of pigs weaned/litter*	6.60	0.68	6.25	1.31	7.0	1.2	5.5	4.5 (n.s.)
Average number of pigs weaned/litter. % litter size								
at birth	80.57	4.11	82.01	4.17	77.23	10.30	51.01	39.9 (n.s.)
Average weaning weight, kg	7.80	0.59	7.30	0.47	7.1	0.38	6.0	0.4 (n.s.)
Litter weaning weight, kg	50.7	5.16	44.2	6.96	49.19	7.30	31.20	24.8 (n.s.)

¹Values in diets 2 and 4, LEHP and LLEP, are for those gilts that carried fetuses to term; while values in parentheses are the average of gilts that aborted.

a—b Means in the same row with different superscripts are significantly different ($P < 0.01$)

Fig. 1. CHANGES IN THE WEIGHTS OF PREGNANT GILTS

related to energy intake than to protein intake.

Farrowing percentage differed significantly among treatments. For the HEHP and HELP groups, 100% of the gilts farrowed while the values for the LEHP and LELP groups were 80 and 40%, respectively. Only gilts on the low energy (LEHP and LELP) diets aborted. Veterinary examination did not reveal any pathological cause for the abortions. All abortions occurred at the end of the second trimester of gestation or later. This suggests that the increased gestation requirement for energy could not be met by the 2.2 Mcal of DE per day which the LEHP and LELP gilts received. The sharp weight loss at about the 10th week of gestation in the gilts that aborted lends support to this concept (Figure 1).

The LEHP and LELP gilts which carried fetuses to term lost about 7.5% of their initial body weight during gestation while the gilts which aborted lost an average of 19.5% of their initial body weight. There was a significant correlation ($r = 0.8647$, $P < .01$) between percentage weight gain during pregnancy and the ability to carry fetuses to term.

There were no significant differences ($P > 0.05$) in litter size among treatments although the LEHP group appeared to have the fewest number of pigs per litter. Dietary treatments did not significantly affect either birth weight of pigs or litter weight. Self *et al.*, (1960), Stothers (1962) and Frobish *et al.*, (1966) did not find any significant effect of energy level in feed during gestation on birth weight of pigs. Other workers (Hanson *et al.*, 1953; Lodge *et al.*, 1966; Vermedahl *et al.*, 1969; Adam and Shearer, 1971) reported that restricting energy intake during gestation reduced birth weight of individual pigs. Pond *et al.*, (1968, 1969) demonstrated that severe protein restriction in pregnancy may result in reduced birth weight and permanent stunting of pigs.

Average number of pigs weaned per litter in either absolute terms or as a percent-

tage or pigs born did not differ significantly ($P > 0.05$) among treatments. However, the variation within treatments was extremely high. One sow weaned 10 out of 11 pigs in the LELP group while another sow in this group only weaned 1 out of 9 pigs. Weaning weights averaged 7.8, 7.3, 7.1 and 6.0 kg for the HEHP, LEHP, HELP and LELP groups, respectively. These differences were not statistically significant. Total weight of all pigs per litter was 50.7, 49.2, 44.2 and 31.2 kg for the HEHP, HELP, LEHP and LELP treatments.

Concentrations of plasma glucose, serum albumin and serum protein in the gilts during pregnancy and lactation are shown in Table 3. At the same stage of gestation, there were no significant differences among treatments in plasma glucose levels. However, by the end of the 3rd trimester of pregnancy all groups had significant ($P < .05$) increases in plasma glucose levels compared with their 1st trimester values. Atinmo *et al.*, (1974a) also reported a significant rise in plasma glucose during the 10th week of gestation in gilts fed diets with 18, 3 or 0.5% protein throughout gestation. The exact cause of this rise in plasma glucose is not clear. Although insulin secretion in late pregnancy is significantly elevated in the basal state (Spellacy and Goetz, 1963; Spellacy *et al.*, 1965a, 1965b), there is evidence of decreased insulin sensitivity in late pregnancy (Hurt, 1956; Hytten and Leitch, 1971).

No significant differences were found among treatments at the same stage of gestation in serum protein concentrations. However, serum albumin concentrations were significantly lower in the HELP group than the other groups at the end of the 3rd trimester of gestation ($P < 0.05$). Atinmo *et al.*, (1974) also reported significantly lower serum protein and albumin concentrations from the 10th week of gestation to parturition in gilts fed a 3 or 0.5% protein diet compared with gilts receiving an 18% protein diet throughout gestation.

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TABLE 4:
Blood metabolites of the Neonatal pigs¹

	HEHP		LEHP		HELP		LELP	
	X	SE	X	SE	X	SE	X	SE
Plasma glucose, mg/100ml								
3rd day	98.0	4.8	95.5	3.5	99.0	2.9	97.4	5.0
35th day	101.0	5.0	100.6	4.0	102.2	3.0	102.6	4.5
Serum protein, g/100ml								
3rd day	7.5 ^a	0.4	7.5 ^a	0.8	6.3 ^{a,b}	0.8	4.9 ^b	0.5
Serum albumin, g/100ml								
35th day	5.1	0.2	5.7	0.1	4.8	0.1	5.0	0.1
3rd day	2.2	0.2	2.6	0.4	2.3	0.6	1.9	0.2
35th day	3.8	0.1	3.7	0.1	3.2	0.1	3.7	0.1

a,b,b Means with different superscripts in the same row are significantly different ($P < .05$).

¹Values represent the mean of 10 piglets for the HEHP and HELP groups, 8 piglets for the LEHP group and 6 piglets for the LELP group. The unequal numbers arose from unequal farrowing percentages.

deprivation occurs. The last trimester was most critical in the present study. Additional work is needed to evaluate the long term effects of severe energy and protein deficiency on reproductive performance over a number of reproductive cycles as well as their effects on body composition and meat qualities.

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