Energy Requirement for Pregnant Rats

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The goal of this study is to determine the minimum requirements of energy and protein in pregnant swine. Although there has been an increase in the amount of research undertaken with sows in recent years, there is still a serious shortage of experimental evidence on the nutritional needs of pregnant animals.

Firstly, there is the difficulty that many of the important measures of reproductive efficiency are very variable. For example, a herd of 100 sows maintained under identical feeding regimes will include sows producing litters of from 2 to 20 pigs at birth varying in birth weight from 0.9 to 1.8 kg.

Secondly, there is the problem of defining satisfactory criteria for the performance of pregnant animals.

Thirdly, nutrient requirements for maintenance during pregnancy are not clear.

Fourthly, efficiencies of utilization of dietary energy and protein by fetuses and placentas are also not elucidated.

Lastly, the pregnant animals have an ability that protects the offspring against protein and energy deficiency of the diets by drawing on her own reserves to allow fetal survival.

As mentioned above, there is the problem that what kinds of the index for determining nutrient requirements during pregnancy should be used for judging enough or deficiency of nutrients. This is a serious obstacle to elucidate nutrient requirements for pregnant animals.

This study has been done to lay the foundation for determining the minimum nutrient requirements during pregnancy using rats prior to the experiments with pregnant swine.

Nutrient requirements for maintenance during pregnancy[5,6]

Nutrient requirements for pregnancy can be estimated by addition of nutrients required for production to maintenance requirements. Nutrient requirements for maintenance were estimated in maternal body and non-pregnant body.

In this study, it was assumed that metabolizable energy (ME) and digestible crude protein (DCP) requirements for maintenance corresponded to ME and DCP intakes when both energy and protein retentions were zero.

As shown in Figs. 1 and 2, the curves of zero energy retention and zero protein retention intersected at 2 points in both maternal body and non-pregnant body. In these figures, it was shown that ME intakes corresponding to the intersecting points of the two curves did not differ so much whereas the considerable differences were found in DCP intakes for the intersecting points. Therefore, the authors selected the points corresponding to the smaller values for DCP intakes as ME and DCP requirements for maintenance (Table 1).

In Table 1, ME requirement (129 kcal/day/$W_{kg}^{0.75}$) for maintenance of maternal body was similar to that (127 kcal/day/$W_{kg}^{0.75}$) of non-pregnant body. This fact clearly demonstrates that ME requirement for maintenance was not affected by pregnancy. This result was good agreement with that in pregnant swine reported recently by Lodge et al.[2].

On the contrary, DCP requirement (6.91 g/day/$W_{kg}^{0.75}$) for maintenance of maternal body was 5 times higher than that (1.30 g/day/$W_{kg}^{0.75}$) of non-pregnant body. It was considered that DCP required for maintenance determined in this experiment includes a part

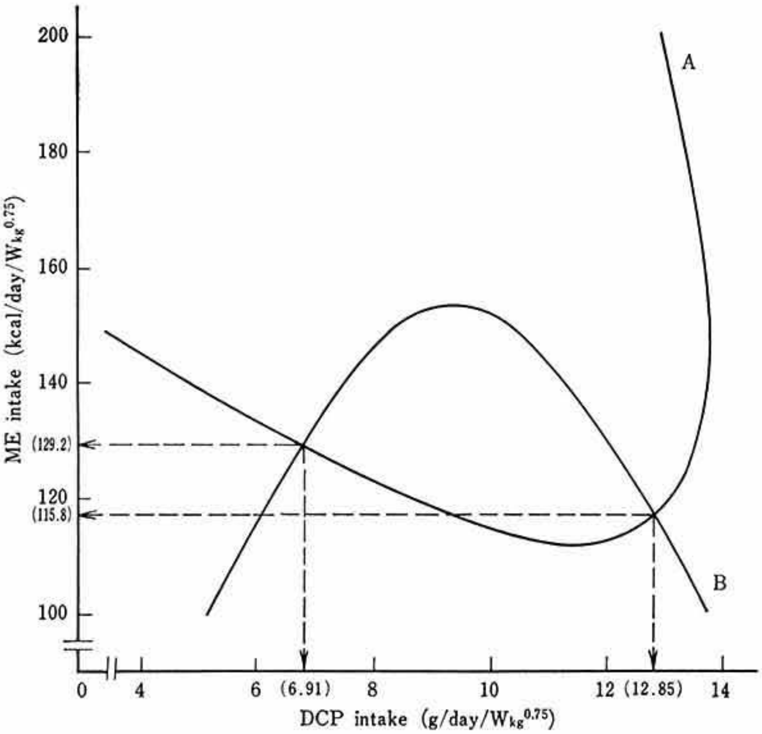

Fig. 1. Determination of DCP and ME requirements for maintenance in the maternal body. Curves A and B denote the curves of 0 protein and 0 energy retention, respectively

of protein consumed for production of fetus and placenta[7]. Therefore, it is necessary to substract the amount of protein consumed for production from DCP required for maintenance determined in this experiment.

To resolve this problem, we are investigating aspects of the amounts of metabolic fecal nitrogen and endogenous urinary nitrogen in pregnant and non-pregnant rats.

Efficiency of utilization of metabolizable energy for energy retention in rat's fetus[8,9]

Efficiency of utilization of ME by the products of conception (fetuses, placentas, amniotic fluids and uterus) was estimated under different conditions. The method for the estimation of the efficiency by the products of conception involved the use of multiple regression analysis to partition ME intake (y) among maternal maintenance (a), maternal energy gain (x_1) and energy gain of the products of conception (x_2), and the efficiency was calculated from a reciprocal number ($1/c \times 100$) of a coefficient (c) of x_2 in the model equation ($y=a+bx_1+cx_2$) which fits the data.

As shown in Table 2, the efficiencies of utilization of ME by the products of conception were 24.3, 22.3, 21.5 and 24.0% under different conditions, mean being 23.0±1.3% (±S.D.). From these results, it is considered that the efficiency is not greatly affected by differences in feeding levels, body weights and stages of pregnancy of rats used for the estimation. This efficiency obtained by rats was about 31 to 64% higher than that (14 to 17.5%) in ruminants[1,3,4].

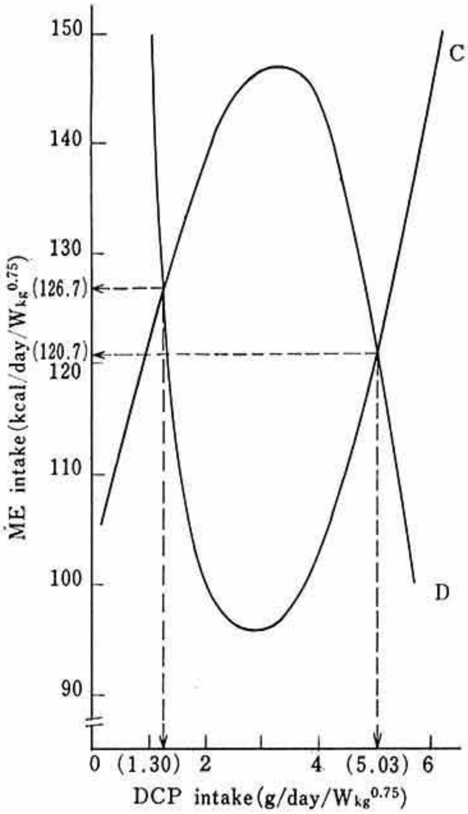

Fig. 2. Determination of DCP and ME requirements for maintenance in non-pregnant body
Curves C and D denote the curves of 0 protein and 0 energy retention, respectively

Table 1. Minimum ME and DCP requirements for maintenance in the maternal body and non-pregnant body

Maternal body (M)		Non-pregnant (N)		M/N ratio	
ME*	DCP**	ME*	DCP**	ME	DCP
129	6.91	127	1.30	1.02	5.32

*: kcal/day/$W_{kg}^{0.75}$ **: g/day/$W_{kg}^{0.75}$

Reliability of the method used for the estimation of the efficiency[10]

The reliability of the method described in the preceeding section for the estimation of the efficiency of ME utilization by the products of conception was investigated. Three experimental diets which contained ME required for maintenance and for the products of conception were prepared and these diets contained enough other nutrients except for ME. The amount of ME required for the products of conception was calculated setting up the efficiency of ME utilization by the products of conception to any 3 levels (generally 10, 20 and 30%). Rats given these diets were sacrificed on day 14 or 20 of pregnancy, and the efficiency of ME utilization was estimated as the index whether the products of conception contains energy content near to set value and energy retention in the maternal body becomes zero. As shown in Table 2, the efficiencies under 3 different conditions were 24.6, 24.7 and 20.4%, mean being 23.2±2.5% (±S.D.). No significant difference ($P>0.05$) was observed between this value and value (23.0±1.3%) estimated from a coefficient of multiple regression equation. This fact shown with rats is regarded to prove the reliability of the method which has been used for estimation of the efficiency in ruminants up to today.

Minimum metabolizable energy requirements for pregnant rats and reproductive performances[11]

Minimum ME requirement for pregnancy was calculated by addition of ME required for production of products to ME requirement for maintenance of the maternal body. Minimum ME requirements during early- (day 0–7), mid- (day 8–14) and late- (day 15—parturition) pregnancy were determined in rats on the bases of both values of ME requirement for maintenance (129 kcal/day/$W_{kg}^{0.75}$, Table 1) in the maternal body and of the efficiency (23.1%, mean of 7 values shown in Table 2) of utilization of ME by the products of conception. Minimum ME requirements during early-, mid- and late-pregnancy in rats from 160 to 300 g of body weight at mating were about 1–2%, about 7–11% and about 46–70% increase of ME

Table 2. Efficiency of utilization of metabolizable energy by the products of conception*

Periods of pregnancy estimated	Body weight of rats used	Feeding level	Efficiency**	
			"A"	"B"
Until mid-pregnancy (day 0~14)	Growing (about 200 g)	Restriction	24.3%	24.6%
Until late-pregnancy (day 0~20)	Growing (about 200 g)	Restriction	22.3	24.7
	Growing (about 200 g)	Ad libitum	21.5	—***
	Mature (about 340 g)	Restriction	24.0	20.4

*: Products of conception consist of fetuses, placentas, amniotic fluids and uterus.
**: "A" denotes the estimation from a coefficient of multiple regression equation. "B" shows the data from the reliability experiment.
***: No estimation was possible.

Table 3. Minimum metabolizable energy requirement for pregnant rats*

Body weight at mating	ME** requirement for maintenance in the maternal body	Days of pregnancy		
		0~7	8~14	15~parturition
g	kcal/day	—kcal/day—		
160	32.6	33.2	36.2	56.6
180	35.6	36.2	39.2	59.6
200	38.6	39.2	42.2	62.6
220	41.4	42.0	45.0	65.4
240	44.2	44.8	47.8	68.2
260	47.0	47.6	50.6	71.0
280	49.7	50.3	53.3	73.7
300	52.2	52.8	55.8	76.2

*: These were calculated as 0.9, 6.8 and 40 kcal of energy retentions in products of conception on days 7, 14 and 20 of pregnancy, respectively.
**: Metabolizable energy.

requirement for maintenance in the maternal body, respectively (Table 3).

Reproductive performances in rats given the diet corresponding to the minimum ME requirement during each stage of pregnancy (experimental group) were compared with those of control group. The diets (control and experimental diets) in both groups differed only in ME content and contained adequate amounts of protein, vitamins and minerals for good growth and reproduction. Control diet was given to rats ad libitum throughout gestation and lactation in control group and only during lactation in experimental group.

The data shown in Table 4 clearly demonstrate that no hindrance in reproductive performances of experimental group is observed.

Future problems

As a theory for the determination of ME requirement during pregnancy was established using rats, we hope to adapt a theory obtained with rats to pregnant swine in the near future. Further, it is necessary to establish the method for estimating the efficiency of utiliza-

Table 4. Data of body weights of young and mother rats and the number of living young rats after parturition

		Control	Experimental
No. of dams		8	12
Day 0*	Y (g)**	6.0±0.3***	5.7±0.6
	M (g)**	280±45	228±18
	LY**	11.1±1.7 (100%)****	10.8±2.9 (100%)
Day 7	Y (g)	11.9±2.6	13.5±2.2
	M (g)	307±34	248±20
	LY	10.5±1.6 (94.6%)	10.2±2.2 (94.6%)
Day 14	Y (g)	23.0±4.5	25.1±4.8
	M (g)	284±46	247±26
	LY	9.9±1.5 (90.1%)	9.6±2.2 (90.8%)
Day 21	Y (g)	40.7±6.0	43.9±7.1
	M (g)	274±30	246±20
	LY	9.5±1.9 (86.6%)	9.2±2.4 (88.2%)

*: Days after parturition. Day 0 denotes that day of parturition.
**: Y and M show body weights of young and mother rats, respectively. LY denotes the number of living young rats.
***: Mean ± S.D. Significant difference ($P<0.05$) was observed only in body weights of mother rats in each day after parturition.
****: Figures in parentheses indicate survival rate of young rats.

tion of dietary protein by the products of conception.

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