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ENERGY REQUIREMENTS FOR PREGNANCY IN SHEEP

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SUMMARY

A comparative slaughter experiment involving 138 mature ewes was conducted to determine the efficiency of utilization of metabolizable energy (ME) during pregnancy and the energy requirements for pregnancy in sheep. ME was used for pregnancy and conceptus development with efficiencies of 16.1 and 12.5%, respectively. Energy gain of the conceptuses increased from 121 kJ/day at day 80 to 946 kJ/day at day 140 for singles and 259 kJ/day at day 80 to 1 034 kJ/day at day 140 of gestation for twin conceptuses. Total energy requirements of ewes increased from maintenance in early gestation to 1.7 and 2.1 × maintenance at term for grazing ewes carrying single and twin foetuses and to 2.0 and 2.6 × maintenance at term for penned ewes carrying single and twin foetuses, respectively.

INTRODUCTION

Calculated energy requirements for pregnancy in sheep have been quite variable and range from approximately 520 to 1 670 kJ metabolizable energy (ME) per kg lamb birthweight per day, as parturition approached (Graham, 1964; Graham, 1966; Langlands and Sutherland, 1968; Reid, 1963; Robinson *et al.*, 1971; Russel *et al.*, 1967). Several methods have been used in these studies and include comparative slaughter, indirect calorimetry, regression analysis of ewe intake on lamb birthweight and regressions of ewe intake on levels of blood metabolites.

Estimates of the efficiency of utilization of ME for pregnancy are also very variable and range from 5 to 22% (Graham, 1964; Langlands and Sutherland, 1968; Rattray *et al.*, 1973a; Russel *et al.*, 1967; Sykes and Field, 1972).

The present experiment was designed to study the pattern of energy retention, the efficiency of utilization of ME and the energy requirements during pregnancy in sheep and to ascertain how level of nutrition, stage of gestation and number of foetuses carried influenced the estimates.

EXPERIMENTAL

ANIMALS AND FEEDING

One hundred and thirty-eight mature Targhee ewes averaging 55 kg liveweight were used in the experiment. There were 28 non-pregnant ewes of which 12 were killed in an initial slaughter group at commencement of the feeding trial; 6 were fed at maintenance and 10 were fed *ad libitum* for 108 or 115 days. One hundred and ten ewes were mated to Suffolk rams equipped with mating harnesses. These ewes were individually fed from approximately day 45 of gestation and were killed at the following stages of gestation: day 70, 100, 125 and 140. They were offered a maintenance ration until day 70 of gestation after which they were offered approximately 1.5 or 2.0 times maintenance (Table 1). The ewes

TABLE 1: NUMBERS OF SHEEP ON TREATMENTS AND LEVELS OF FEEDING

Group	*Level of Feeding*	*No. of Animals*
Initial slaughter		12
Non-pregnant	Maintenance	6
Non-pregnant	*Ad libitum*	10
Pregnant	Approx. maintenance	20
Pregnant	Approx. 1.5 × maintenance	46
Pregnant	Approx. 2.0 × maintenance	44

killed at each stage of gestation were chosen randomly in an attempt to get at least five single or twin-bearing ewes at each stage. All animals were shorn at commencement of the feeding experiment and were then housed in an open barn and individually fed once daily on a blended pelleted diet of the following composition: 70% lucerne hay; 20% rolled barley; 5% oat hay; 4.5% molasses and 0.5% salt and minerals.

Two non-pregnant and pregnant ewes at each level of nutrition were fed in metabolism crates for collection of faeces and urine. Energy contents of the faeces and urine were determined using an adiabatic bomb calorimeter. The relationships of Blaxter and Clapperton (1965) were used to estimate the methane production.

Slaughtering and Sampling

Prior to slaughtering all animals were shorn. After slaughter the animals were divided into carcass, offal (viscera, head, skin and hooves), blood, reproductive tract, mammary gland and wool. The reproductive tract of the pregnant ewes was severed at the cervix and the gravid uterus was dissected into uterus, foetus, foetal membranes (plus placenta) and foetal fluids.

The frozen offal and carcass of each animal were separately ground and mixed by four serial passages through a 50 h.p. Autio meat grinder. Triplicate samples of each were wrapped in cheesecloth, oven-dried in aluminium dishes, then extracted with ether in large soxhlet apparatuses. To obtain the energy contents of the offal and carcass, heats of combustion were determined on the fat and fat-free portions separately. The larger foetuses (over day 120) and the mammary glands were handled similarly to the carcass and offal. Energy contents of oven-dried samples of the various other products of conception, blood and wool, were also determined from heat of combustion in an adiabatic bomb calorimeter.

Utilization of ME by Non-pregnant Sheep

Energy retention was estimated by the comparative slaughter technique. The ME maintenance requirement was estimated from the regression of the logarithm of heat production on ME intake (at the point where heat production was equal to ME intake). The efficiency of utilization of ME for gain was estimated from the slope of the regression of energy gain/$kg^{3/4}$ on ME intake/$kg^{3/4}$. These methods were similar to those used by Lofgreen and Garrett (1968) and Rattray *et al.* (1973b) for estimating these parameters in cattle and sheep.

Utilization of ME for Pregnancy

Energy retention of the maternal tissues and conceptuses was estimated by the comparative slaughter technique. The initial energy and weight of the conceptuses were estimated from a few pregnant ewes killed prior to day 70 of gestation. The composition of the body tissues (minus wool, ingesta and conceptus) of the pregnant ewes at commencement of the feeding trial was assumed to be similar to the initial slaughter group and on chemical analysis the composition of those maternal tissues of the ewes killed at day 70 of pregnancy was not significantly different from the initial slaughter animals (Rattray *et al.*, 1974a).

Two methods were used to obtain an estimate of efficiency of utilization of ME for pregnancy. The first was "factorial" and assumed that the pregnant ewes had efficiencies of utilization of ME for maintenance and gain similar to the non-pregnant animals. The part of the ME intake required for maintenance and gain was calculated using the values for non-pregnant animals, and the remaining ME intake was assumed as being used for synthesis of the products of conception.

The second procedure used was multiple regression analysis to partition ME intake of the ewe between maintenance, maternal energy gain and pregnancy.

Energy Requirements of Pregnancy

The net energy (NE) requirements for conceptus development and pregnancy can be regarded as the energy stored in the foetus, fluids and membranes; and foetus, fluids, membranes, uterus and mammary gland, respectively. These parameters were actually measured. The ME requirement for pregnancy was computed from these values plus the estimates of efficiency of utilization of ME for these different processes.

RESULTS AND DISCUSSION

Utilization of ME by Non-pregnant Ewes

The average ME content of the diet (± standard error) was 10.1 ± 0.7 kJ/gDM, and was not changed by either level of feeding or stage of pregnancy. This is similar to the findings of Graham (1964) who fed a high roughage diet to sheep. Flatt *et al.* (1969), using dairy cows fed high concentrate diets, found that pregnancy depressed digestibility and lowered methane losses resulting in a net lowering of ME content by about two percentage units.

The maintenance requirement of the non-pregnant ewes was 534 ± 25 kJ ME/kg$^{3/4}$. This is high for mature penned sheep possibly because the sheep were shorn at the start of the trial and the trial was conducted during the winter. Low temperatures, wind, and rain all increase the heat losses and metabolic rate of an animal (Blaxter *et al.*, 1966; Joyce and Blaxter, 1964) and shearing further increases these energy losses (Coop and Drew, 1963). Garrett (1970) reported that when cattle were fed diets that were high in protein content, their maintenance requirement increased by 20%. The diet fed to the ewes in the experiment reported here was predominantly lucerne and the protein content was 17.1%. These two causes could have had some effect in raising the maintenance requirement.

The efficiency of utilization of ME for gain (including wool) was 56.0 ± 8.1%. This value appears relatively high but this could be because the gains of these mature ewes were predominantly fat and it appears that, in sheep, fat is synthesized more efficiently than protein (Rattray *et al.*, 1974b).

Utilization of ME during Gestation

Relationships were derived to describe foetal growth. In the first instance foetal growth was treated as a first order process, *i.e.*, it was the exponential part of a normal growth curve. However, it was found that while regressions of $\log_e$ foetal weight against time removed 95% of the variability they did not fit the data in late pregnancy because of a slowing in growth rates. This phenomenon appeared to be normal and has been noted before. It may be due to a limitation in nutrients available for foetal growth because of a decline in voluntary intake in late pregnancy (Cloete, 1939; Graham, 1964). For this reason polynomial regressions were fitted to the data using a step-wise computer program. The regressions were of the model $Y = a + bX + cX^2 + d X^3 + c X^4$, where Y is foetal weight and X is day of gestation. Most of the relationships were third degree polynomials and had r^2 values greater than 0.99. The relationships derived from these regressions are shown in Fig. 1. In the relationship for the low

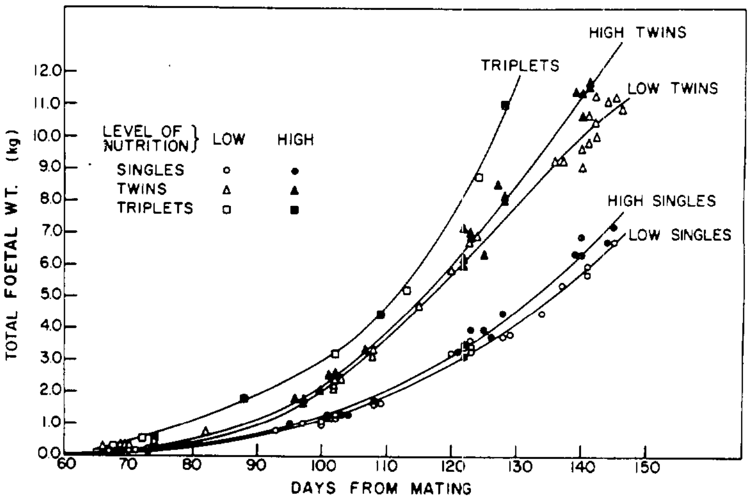

FIG. 1: *Relationships between foetal weight and day of gestation.*

twins there is an obvious point of inflection and slowing of growth in late gestation. This was probably because nutritional limitations would be more obvious in twins because they have higher energy requirements than singles. Level of nutrition had no significant effect on foetal weight until after day 125 of gestation. This agrees with other work, where the requirements of pregnancy are substantial only in the last trimester. It appeared, therefore, that a feeding level of 1.5 × maintenance could support near maximum foetal growth rate throughout most of pregnancy.

In the first method of estimating the efficiency of utilization of ME during pregnancy, it was assumed that pregnant

TABLE 2: UTILIZATION OF ME FOR CONCEPTUS DEVELOPMENT AND PREGNANCY

Day of Gestation	*125*	*125*	*140*	*140*	*140*	*140*
Foetuses Carried	*Singles*	*Twins*	*Singles*	*Singles*	*Twins*	*Twins*
Level of Nutrition[1]	*H & L*	*H & L*	*H*	*L*	*H*	*L*
kJ/day						
ME intake	17 753	18 833	20 420	14 345	20 943	16 032
ME for maintenance[2]	10 920	11 514	11 317	10 124	11 313	10 689
ME for maternal body energy gain[3]	4 995	3 844	6 297	1 248	5 773	1 675
ME available for pregnancy	1 838	3 475	2 806	2 973	3 856	3 668
Energy stored in total products of conception	243	532	477	360	816	662
ME for maternal body, mammary and uterine energy gain[3]	5 075	4 112	6 565	1 373	6 264	1 968
ME available for conceptus development	1 758	3 207	2 538	2 848	3 346	3 375
Energy stored in conceptus	201	368	331	276	548	456
Utilization of ME for pregnancy (%)	13.2	15.3	17.0	12.1	21.2	18.0
Utilization of ME for conceptus (%)	11.4	11.5	13.0	9.7	16.3	13.5

[1] Level of nutrition after day 70 of gestation: H = 2.0 × maintenance; L = 1.5 × maintenance.
[2] Assumed maintenance 534 kJ/kg$^{3/4}$ for average ingesta-free conceptus-free body.
[3] Assumed ME used with an efficiency of 56.0% for maternal energy gain.

ewes have a maintenance requirement similar to non-pregnant sheep, and that the efficiency of utilization of ME for maternal body gain was not changed by pregnancy. The estimates of efficiency of utilization of ME for pregnancy (gravid uterus contents plus mammary gland development) and conceptus development (foetus, fluids and membranes) are shown in Table 2. The estimates for day 70 and day 100 were not significantly different from zero and were therefore not included in the table. The estimate for pregnancy in the 140-day low singles was also not significant. At day 125 gestation, there was no significant difference in energy retention of the reproductive processes due to level of nutrition, so one estimate was obtained for single foetuses and one for twin foetuses at that stage of pregnancy. The weighted means obtained for the efficiency of utilization of ME for pregnancy energy retention and conceptus energy retention were 16.1 ± 2.0% and 12.3 ± 2.2%, respectively. The value for pregnancy was similar to that obtained with pregnant ewe hoggets by Rattray *et al.* (1973a) and the estimate of 12.3% for conceptus energy retention is within the range of 12 to 14% found for sheep and cattle (Graham, 1964; Langlands and Sutherland, 1968; Moe *et al.*, 1970; Rattray *et al.*, 1973a; Sykes and Field, 1972).

The second method of estimating the efficiency of utilization of ME during gestation was by using multiple regression analysis to partition the ME intake of the pregnant ewes between maternal maintenance, energy gain and the energy costs of gestation. Separate estimates of the ME cost of pregnancy (energy gain of foetus, membranes, foetal fluids, uterus, and mammary gland), conceptus energy retention (foetus, membranes and foetal fluids) were derived.

There was no significant difference between single-bearing ewes or ewes bearing multiple foetuses in these estimates. At the earlier stages of gestation (days 70 and 100) the regression coefficients associated with the gestation factor were not significantly different from zero. Pooled regressions for all pregnant animals were derived, and the regression coefficients were highly significant ($P < 0.001$). The regression coefficients for the ME cost of pregnancy and conceptus energy retention are 4.15 ± 1.15 and 7.81 ± 1.55 kJ ME/kJ retention, respectively. These values yield estimates for the efficiency of utilization of ME of 24.1 ± 6.7% and 12.8 ± 2.5%, respectively.

The estimates for efficiency of utilization of ME by the conceptus are very similar for the two methods, but the estimates for pregnancy are rather different. The value (16.1%) calculated by the former method appears more precise and was the preferred estimate. The efficiency of utilization of ME may vary with the type of diet fed or if the composition

TABLE 3: TOTAL ENERGY CONTENT AND ENERGY GAIN OF THE CONCEPTUS AND GRAVID UTERUS PLUS MAMMARY GLAND AT DIFFERENT STAGES OF GESTATION

Product of Conception	*Conceptus*			*Gravid Uterus plus Mammary Gland*		
No. of Foetuses	1	2	3	*1*	2	3
Stage of Gestation (days)	*Total Energy Content (MJ)*					
80	1.90	3.13	3.88	10.25	10.63	10.88
100	5.56	9.81	13.07	14.50	19.33	21.74
120	13.60	25.47	32.48	23.06	41.21	47.67
140[1]	29.71	50.16	—[3]	47.27	80.41	—
140[2]	25.91	42.58	—	39.60	68.31	—
	Energy Gain (kJ/day)					
80- 85	121	259	268	184	222	260
100-105	306	632	779	301	837	1 013
120-125	582	992	1 290	720	1 490	1 767
140-145[1]	1 084	1 599	—	2 135	2 596	—
140-145[2]	808	469	—	1 151	1 051	—

[1] Fed at 2.0 × maintenance after day 70 of gestation.
[2] Fed at 1.5 × maintenance after day 70 of gestation.
[3] Data for triplets did not extend beyond day 125 of gestation.

of the energy gains of the products of conception were vastly different from that found in this work.

When pregnancy is regarded solely as an energy retention process it is quite inefficient when compared with estimates for the efficiency of utilization of ME for maintenance of 60 to 80%; for body gain of 30 to 75% and for milk production of 60 to 70% (A.R.C., 1965; Blaxter, 1967; Moe *et al.*, 1970; Rattray *et al.*, 1973a, b). If a maintenance requirement were allowed for the foetus the process of pregnancy would be much more efficient.

Energy Retention during Pregnancy

From Table 2 the energy stored in the conceptus or in the total products of conception can be regarded as NE requirements, and averaged 70 ± 5 kJ $NE_{pregnancy}$/kg foetus and 51 ± 4 kJ $NE_{conceptus}$/kg foetus, respectively. There was no significant difference due to level of nutrition, stage of pregnancy or number of foetuses carried. These estimates are average values for the last 80 or 100 days of pregnancy and would grossly underestimate requirements in late pregnancy.

Similar to the growth data, polynomial regressions were derived relating total energy of the conceptus or pregnancy (Y) to day of gestation (X), because first order relationships were found inappropriate. The relationships were mainly third degree polynomials with r^2 values of 0.98 to 0.99. These regressions were used to predict the total energy content and daily rates of energy retention of the conceptus or conceptus plus uterus and mammary gland at different stages of gestation and these are shown in Table 3.

The daily energy gains can be regarded as the net energy requirements for conceptus development or pregnancy at the different stages of gestation. The slowing in growth rate of the twin foetuses from the ewes fed at the lower level of nutrition became quite evident in late pregnancy. Some of the predicted daily gains appear inconsistent, especially in early pregnancy when the conceptuses alone for ditocous and tritocous ewes appeared to be retaining more energy than the total products of conception (including the mammary gland). This would be due to the different slopes of the polynomial regressions at that stage of gestation and would be covered by experimental errors.

Langlands and Sutherland (1968) using the comparative slaughter technique found that the daily rate of energy storage in the gravid uterus increased from 155 kJ at day 90 to 674 kJ at day 145 for Merino ewes carrying single foetuses. These are lower than the values given in Table 3. However, the Merino foetuses were also substantially lighter at all stages of pregnancy than those of the Targhee × Suffolk cross in this experiment. When converted to ME requirements for pregnancy, the estimates for ditocous ewes at the higher level of nutrition and for monotocous ewes at the lower level of nutrition are quite similar to the estimate obtained by Robinson *et al.* (1971) for late gestation. Their estimates for early gestation are substantially higher than those found in this work. The estimates (Table 3) are much higher than those Graham (1966) for single foetuses.

Energy Requirements for Pregnancy

The total energy requirements during pregnancy are obtained by summation of the requirements for maintenance and pregnancy. In the case of young animals which are still growing, total requirements are the sum of the requirements for maintenance, gain and pregnancy.

Maintenance requirement itself is probably the greatest variable, and ranges from approximately 380 kJ/kg$^{3/4}$ for pen-fed ewes (Jagusch and Coop, 1971) to an average of approximately 535 kJ/kg$^{3/4}$ for grazing ewes (or some penned ewes as in this experiment).

Total ME requirements were calculated for mature 55 kg ewes (*i.e.*, conceptus-free, wool-free weight) bearing 4.5 kg singles, 8.5 kg twins or 10.0 kg triplets under penned and grazing conditions as shown in Table 4. The maintenance requirements would be 7.60 and 10.70 MJ/day under penned and grazing conditions, respectively. For a grazing ewe it can be seen that the total requirement in the last four to six weeks of pregnancy averages approximately 1.5 and 1.9 × mainten-

TABLE 4: TOTAL METABOLIZABLE ENERGY REQUIREMENTS DURING PREGNANCY (MJ/day)

Foetuses	*Stage of Pregnancy (day)* *180*	*100*	*120*	*140*
	Pen Fed			
Single	8.3	9.0	10.9	15.0
Twin	8.6	11.3	14.4	19.5
Triplets	8.8	12.3	15.7	21.6
	Grazing			
Single	11.4	12.1	14.0	18.2
Twin	11.7	14.4	17.5	22.6
Triplets	11.9	15.4	18.8	24.7

ance for a single- and twin-bearing ewe, respectively, while for a penned ewe total ME requirement is a somewhat greater multiple of maintenance. These results are quite similar to practical recommendations for feeding pregnant ewes (Jagusch and Coop, 1971). In early pregnancy the requirements of the conceptuses are quite low and overall feed requirements of the ewe would not be significantly different from a maintenance ration.

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