# ENERGY REQUIREMENT FOR MAINTENANCE OF GRAZING SHEEP MEASURED BY CALORIMETRIC TECHNIQUES

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***Summary***

Merino wethers, initially 44.4 ± 1.9 kg, were reduced in weight by approximately 0, 10 or 20 kg and held at these liveweights by grazing them at various stocking intensities on pastures of *Phalaris tuberosa* and white clover (*Trifolium repens*). After nine months, their energy expenditures were estimated from respiratory gaseous exchanges, and from the rate of entry of carbon dioxide into the body pool of carbon dioxide.

The energy requirement for maintenance of the sheep was approximately 132 kcal metabolizable energy/kg$W^{\frac{3}{4}}$/24h at all liveweights (W). Energy expenditures in sheep grazing other pastures are also reported.

## I. INTRODUCTION

Many estimates have been made of the amount of energy required for maintenance by grazing ruminants by examining relationships between feed intake, liveweight and production (Wallace 1956; Coop and Hill 1962; Lambourne and Reardon 1963 ; Langlands et *al.* 1963*b*). Such estimates indicated that grazing sheep require from 10 to 270% more metabolizable energy for maintenance than do similar animals penned indoors.

The highest values were reported by Lambourne and Reardon (1963) for adult Merino wethers grazing pastures which were so heavily stocked that the animals' liveweights were much lower than those of similar sheep grazing pastures providing abundant feed. This paper reports measurements made by two calorimetric techniques of the energy expended by grazing sheep whose liveweights were regulated by controlling the availability of herbage, as was done by Lambourne and Reardon (1963). Rates of energy expenditure in sheep grazing other pastures are also presented.

## II. EXPERIMENTAL

### *(a) Animals and their management*

#### *(i) Experiment 1*

Thirty fine-wool Merino wethers, newly shorn and aged four years, were selected for uniformity of liveweight (mean and standard deviation 44.4 ± 1.9 kg). They were allotted at random into three groups of ten termed Low (L), Medium (M) and High (H). The mean liveweights of groups L and M were reduced to about 25 and 35 kg respectively over a period of 10 weeks by confining them in yards for all but a 3 to 4 h grazing period in each week. Groups L, M and H were then grazed separately and continuously on phalaris/white clover (*Phalaris tuberosa*/

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*Trifolium repens*) pastures of 0.32, 0.45 and 0.80 ha respectively. The mean liveweights of groups L and M measured two or three times weekly, less estimated fleece weights, were held constant by adding or removing non-experimental sheep; group H always had abundant herbage and was also weighed frequently. The total amounts of herbage organic matter (OM) available on the pastures were measured by the technique of Hutchinson (1967 and personal communication). All sheep were drenched each month with thiabendazole.

Measurements of energy expenditure were made during a period of 21 days that started nine months after the required liveweights had been established. Estimates were made concurrently of faeces outputs by the chromium sesquioxide ($Cr_2O_3$) technique, and of the digestibility of grazed herbage from (a) faecal nitrogen concentrations (equation used by Lambourne and Reardon 1963) and (b) the digestibility *in vitro* (Alexander and McGowan 1961) of samples collected from sheep fistulated at the oesophagus.

#### *(ii) Experiment 2*

Measurements were made of the energy expended by adult fine-wool Merino sheep grazing (a) phalaris and white clover, (b) an indigenous pasture of predominantly ***Poa caespitosa,*** and (c) a monospecific sward of rapidly growing white clover. No attempts were made to regulate the amounts of herbage available on the pastures.

### *(b) Measurement of energy expenditure*

The two techniques used were (i) measurements of respiratory gaseous exchanges of tracheostomized sheep by 'mobile indirect calorimetry' (MIC) (Corbett, Leng and Young 1967), and (ii) a carbon dioxide entry rate technique (CERT) (Young *et al.* 1967).

#### *(i) MIC*

Tracheal fistulae had been established in the sheep for at least three months before they were used. In Experiment 1, all measurements of oxygen consumption and carbon dioxide production were made over 24 h periods, each comprising four 6 h measurements; in Experiment 2, they were made either over 24 h (24 x 1 h) or from 0900 to 1800 h (9 x 1 h).

Energy expenditures (E, kcal) were calculated as by Brouwer (1965) except that no allowance was made for the excretion of nitrogen and carbon dioxide in urine or for methane production:

$$E = (\text{litres } O_2 \times 3.87) + (\text{litres } CO_2 \times 1.20).$$

#### *(ii) CERT*

Continuous infusions of $NaH^{14}CO_3$ were made subcutaneously above the transverse processes of the lumbar vertebrae. The specific radioactivity of the carbon dioxide in 5 ml samples of blood from the external jugular vein was determined as described by Leng and Leonard ( 1965).

In Experiment 1, each estimate of the daily rate of energy expenditure was derived from analyses of blood samples taken at 1630, 2400, 0630, 0930 and 1130 h; in preliminary trials the mean values so obtained were similar to those derived by bleeding every 2 h in 24 h. In Experiment 2, blood samples were taken at hourly intervals from 1100 to 1800 h.

TABLE 1

*Energy expenditure of grazing Merino sheep maintained at constant liveweights*

| Group | No. of Sheep | Measurements of energy expenditure | | Mean Liveweight† (kg) | Mean daily energy expenditure | |
|---|---|---|---|---|---|---|
| | | Method | No. | | kcal/sheep | $kcal/kgW^{\frac{3}{4}}$ |
| L | 2 | MIC* | 4 | 25.8 ± 0.6§ | 1367 ± 92§ | 119 ± 4§ |
| M | 2 | | 4 | 31.8 ± 2.1 | 1963 ± 394 | 146 ± 23 |
| H | 3 | | 4 | 42.9 ± 2.0 | 2349 ± 251 | 140 ± 17 |
| L | 5 | CERT‡ | 9 | 25.8 ± 2.0 | 1481 ± 122 | 130 ± 15 |
| M | 5 | | 8 | 32.8 ± 3.2 | 1795 ± 247 | 130 ± 16 |
| H | 4 | | 9 | 47.5 ± 4.1 | 2362 ± 271 | 130 ± 10 |
| L | 7 | Both | 13 | 25.8 ± 1.7 | 1446 ± 123 | 127 ± 14 |
| M | 7 | (from above) | 12 | 32.5 ± 1.2 | 1851 ± 296 | 135 ± 19 |
| H | 7 | | 13 | 46.1 ± 4.2 | 2356 ± 256 | 133 ± 13 |
| All results | 21 | | 38 | 34.8 ± 9.1 | 1885 ± 445 | 132 ± 16 |

†Adjusted to a shorn state; mean fleece weights of groups L, M and H were approximately 3.7, 4.5 and 6.2 kg respectively.

*Respiratory gaseous exchanges.

‡Rate of entry of carbon dioxide into the body pool.

§Standard deviations.

## III. RESULTS

### (a) Experiment 1

A total of 1042 mm (4.82 in.) of rain fell during 11 of the 21 days; screen temperatures varied from 9.5 to 27°C, and the mean run-of-wind was 231 $\pm$ 63 km/day (range 74-528). The total herbage OM available to groups L, M and H was approximately 250, 450 and 1900 kg/ha respectively.

Energy expenditures and mean liveweights are shown in Table 1. Within groups the results obtained by the two techniques were not significantly different. Expenditures did not appear to be affected by the variation in climate encountered; the rates were usually lowest during the night hours when ambient temperatures were lowest, but the sheep were also least active at these times.

There was a significant difference ($P<0.01$) between groups in the rate of energy expenditure per animal but not in the rate per unit of liveweight (W) or of $W^{3/4}$ The relationship between energy expenditure and liveweight, calculated from all results, was $E = 105W^{0.81}$; the exponent had a standard error of $\pm 0.08$ and was not significantly different from the three-quarters power recommended for general adoption (Kleiber 1965).

In group H, the two methods for estimating the digestibility of grazed herbage gave similar results, but in groups L and M the ***in vitro*** values were lower by from 12 to 18 digestibility units than those calculated from faecal nitrogen concentration. No significant amounts of chromium were detected in the faeces of sheep grazing with group H but not dosed with $Cr_2O_3$. In group M, the mean $Cr_2O_3$ concentrations in faeces (mg/g faeces OM) were 1 .0 and 10.2 for undosed and dosed (2 g $Cr_2O_3$/day) sheep respectively; corresponding values in group L were 2.1 and 13.5 mg $Cr_2O_3$/g OM.

### (b) Experiment 2

Energy expenditures are shown in Table 2. The first two measurements on the phalaris/white clover pasture were made when the herbage available was mainly dry phalaris; rain promoted a fresh growth of herbage before the third. The indigenous pasture was rank and dry and in a late stage of maturity; all sheep on this pasture lost weight, and energy expenditure per $kgW^{3/4}$ was lower than for the sheep held at constant liveweight in Experiment 1. On the clover pasture there were substantial increases in liveweight, probably owing to large changes in gut fill as well as to fattening. As with. the sheep grazing phalaris and white clover, energy expenditure per $kgW^{3/4}$ was generally higher than in Experiment 1.

## IV. DISCUSSION

It was assumed in the present work, as in that of Lambourne and Reardon (1963) and similar studies, that constant liveweight represented the state of maintenance *(i.e.* zero retention of energy) and that the energy expended by the sheep in Experiment 1 was therefore equivalent to their requirements of metabolizable energy (ME) for maintenance. No correction was applied for the energy costs of wool growth. The discrepancy between our results for sheep in groups L and M and those for sheep in similar conditions reported by Lambourne and Reardon (1963) is shown in Figure 1. The energy expended per $kgW^{3/4}$ by our sheep in group

TABLE 2

***Energy expenditure of sheep grazing various types of pasture***

| Pasture type | Sheep No. | Liveweight† (kg) | Liveweight‡ Change | Method | Period of Measurement (h) | Daily energy expenditure | |
|---|---|---|---|---|---|---|---|
| | | | | | | kcal/sheep | kcal/kg$W^{3/4}$ |
| Phalaris and clover | 8600* | 29.5 | 0 | MIC | 0900-1800 | 1823 | 144 |
| | 8600* | 29.5 | 0 | MIC | 0900-1800 | 1967 | 155 |
| | 5563 | 34.0 | + | MIC | 0900-1800 | 2833 | 201 |
| Indigenous | 3689 | 32.0 | — | MIC | 0900-1800 | 1417 | 105 |
| Clover | 5563 | 38.0 | + | MIC | 0900-1800 | 2130 | 139 |
| | | | | CERT | 1100-1800 | 2160 | 141 |
| | 3740 | 35.5 | + | MIC | 0900-1800 | 2627 | 179 |
| | | | | CERT | 1100-1800 | 2177 | 142 |
| | 3740 | 36.0 | + | MIC | 24h | 2533 | 172 |
| | 3689 | 40.0 | + | MIC | 24h | 2923 | 184 |
| | 5563 | 38.5 | + | MIC | 24h | 2285 | 147 |

*Wether sheep; all others ewes.

†Adjusted to a shorn state.

‡Including changes in gut fill; (0) approximately constant liveweight; (—) loss approximately 0.8 kg/week; (+) gain approximately 1 kg/week.

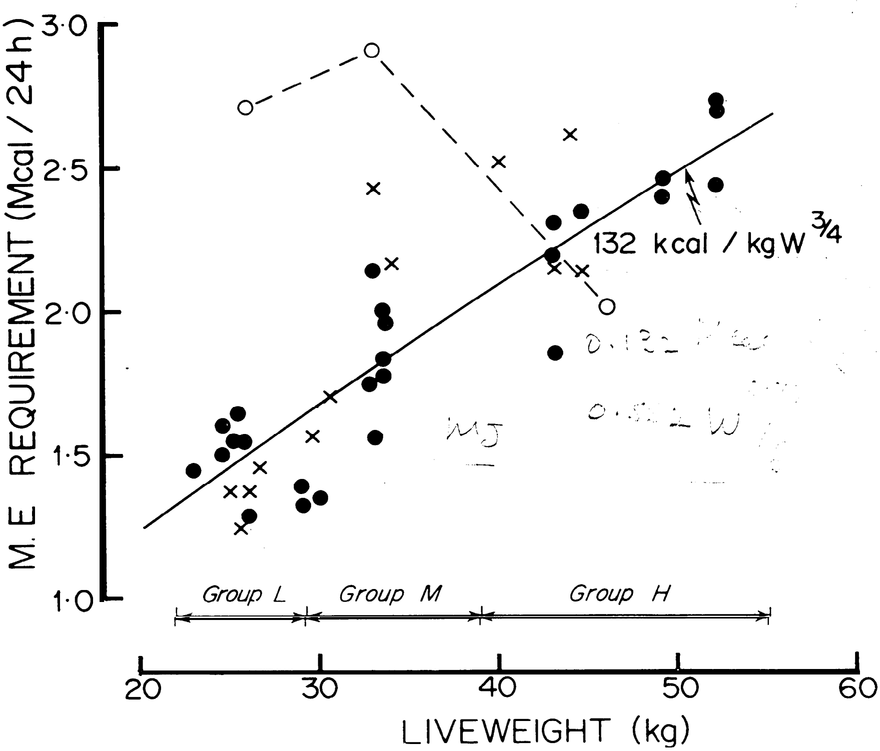


Fig. 1.—Metabolizable energy (ME) required for maintenance by grazing sheep in Experiment 1 held at various liveweights (adjusted to a shorn state).
X—values determined from respiratory gaseous exchanges (MIC); ●—values estimated from entry rate of carbon dioxide into the body pool (CERT); o—o—values from Lambourne and Reardon (1963) (feed intake for constant liveweight).
The relationship between liveweight (W) and ME requirement was:

$$\text{ME kcal/day} = 43W + 387$$

($SE_b$ ± 4, residual standard deviation ± 218 kcal).

L was no higher than that expended by sheep in the other two groups, even though some increase might have been expected because their lighter fleeces, thinner skins and (as will be reported elsewhere) lower estimated feed intakes, would render them more vulnerable to adverse climatic conditions.

Calorimetric measurements over 24 h periods of the energy expenditure of sheep held at constant liveweight are unlikely to include large errors due to storage or loss of energy in body tissues. Moreover, they exclude errors inherent in estimates of expenditure based on estimates of grazing intake. Lamboume and Reardon (1963) calculated that if the maintenance requirements of their sheep were in fact related directly to W, their estimated values indicated a bias of as much as + 20 units in digestibilities calculated from faecal nitrogen concentrations. Our determinations ***in vitro*** indicated that biasses of this magnitude may occur when a faecal nitrogen regression equation necessarily derived from herbage cut, not grazed, from pastures of the type grazed by their and our high-weight, but not low-weight, sheep is applied to sheep on heavily grazed pastures. We observed that sheep in these conditions ingested large quantities of inorganic matter, and recorded as much as 62 and 76% in the dry matter of their rumen contents and faeces respectively; this material may promote an increase in the amounts of endogenous nitrogen in faeces.

The concentrations of chromium in the faeces of undosed sheep in groups L and M were much higher than was consistent with the natural abundance of this element in the soil (equivalent to approximately 20 mg $Cr_2O_3$/kg) and presumably resulted from ingestion of herbage and soil contaminated with faeces of dosed sheep. Such recycling, an error not previously reported, would cause underestimation of faeces outputs and feed intakes but the mean biasses in this experiment of -10 (M) and -15% (L) were small compared with the overestimates of intakes that apparently can stem from overestimation of digestibility.

The results of Experiment 2 are consistent with our estimate of 132 kcal ME/kg$W^{\frac{3}{4}}$/24h for the maintenance of grazing sheep. This value is similar to some other estimates for sheep in good to fat condition on productive pastures, but is some 50% greater than a number of estimates of the requirements of housed sheep (Table 3).

Attempts have been made to predict the energy cost incurred by grazing animals by summing the costs of various activities determined in the laboratory (Graham 1964; Blaxter 1964). It is unlikely that such predictions can be other than imprecise because they do not take account of the complex interactions that occur in the field. On the other hand, our results indicate that it is probably not necessary to propose special, undefined factors peculiar to the grazing animal causing elevation of energy expenditure.

It is clear that further studies must be made on grazing animals, especially those in adverse climatic conditions. The calorimetric techniques facilitate such studies which can extend over periods of a few hours only or of several 'days. Of the two techniques, CERT, subject to further confirmation of its reliability, is the method of choice because it involves little interference with the animal, either surgically or when it is at pasture, and the equipment required in the field is simple.

TABLE 3

*Estimates of the amount of metabolizable energy (ME) required for maintenance by housed and grazing sheep at a standardized liveweight of 45 kg*

| Management | Requirement (Mcal ME/24h/45kg)* | Method of Determination | Reference |
|---|---|---|---|
| Housed | 1.61 | Feed intake for constant liveweight | Coop (1962) |
| | 1.44 | | Langlands *et al.* (1963*a*) |
| | 1.39 | Calorimetry | Langlands *et al.* (1963*a*) |
| | 1.45 | | Blaxter (1967) |
| Grazing | 2.50 | Feed intake for constant liveweight | Coop and Hill (1962) |
| | 1.80 | | Langlands *et al.* (1963*b*) |
| | 2.02 | | Lambourne & Reardon (1963)† |
| | 2.30 | MIC | Present report |
| | 2.26 | CERT | |

*Assumed that 1g digestible organic matter yields 3.6 kcal M.E.
†'High-weight' sheep of 45 to 50 kg.

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