THE ENERGY REQUIREMENTS OF SHEEP

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SUMMARY

The maintenance requirements of sheep fed in pens and under grazing conditions have been estimated in a series of trials. Four trials with pen-fed sheep gave a mean estimate for 100 lb sheep of 0.92 lb D.O.M. (digestible organic matter) per day. The intake of grazing sheep was measured by the chromium oxide—faecal nitrogen method. A grazing trial in 1958 with 38 sheep of widely varying liveweight grazed on pasture which permitted only slight weight changes for a period of 17 weeks gave an estimate of maintenance

$$\text{D.O.M. (maintenance)} = 0.061(\pm 0.005)\, W_{lb}^{0.69\ (+\text{ or } -\ 0.04)}$$

per day, equivalent to 1.48 lb D.O.M. per day for a 100 lb sheep. A second similar trial with 41 ewes extending over 12 weeks gave

$$\text{D.O.M. (maintenance)} = 0.062(\pm 0.003)\, W_{lb}^{0.73\ (+\text{ or } -\ 0.07)}$$

or 1.63 lb D.O.M. per day for a 100 lb sheep. A third trial with 15 ewes in which gain was permitted gave an estimate of 1.36 lb D.O.M. per day for maintenance for a 100 lb sheep. Estimates of the cost of gain gave higher figures for pen-fed sheep than grazing sheep.

The environmental conditions causing the large difference in maintenance requirement between pen-fed and grazing sheep are discussed and it is suggested that the energy of harvesting the pasture is the most important cause, together with wind and rain. It is also suggested that maintenance of grazing sheep is not a constant but decreases as the ease of harvesting the pasture increases.

INTRODUCTION

In the nutrition of farm animals it has been the custom to differentiate between the maintenance and production requirements and to define each separately. Usually each is expressed in terms both of energy, as Starch Equivalent (S.E.) or Total Digestible Nutrients (T.D.N.) and of protein as digestible protein or Protein Equivalent. In this paper it is proposed to deal with energy requirements for maintenance in particular and for liveweight gain to a lesser extent, in the sheep. It is clearly necessary to determine maintenance as a prelude to determining, in addition, the production requirements.

In sheep, a disproportionately large fraction of annual feed requirement is incurred by maintenance. This is especially true of the breeding ewe which is the main portion of the flock. In fact, in no other farm animal is maintenance such a dominant feature. For the seven months from weaning its lamb until late in pregnancy the ewe is kept virtually at maintenance. Only during the last month of pregnancy and the three to four months of lactation is the level of feeding significantly above maintenance and even then not greatly. Simple calculation, using present standards, shows that maintenance accounts for three-quarters of the total annual requirement of the ewe.

Two feeding standards for sheep are in use today. These are the Woodman standards issued by the U.K. Ministry of Agriculture and expressed in S.E. and those of the National Research Council of the U.S.A. expressed in T.D.N. The Morrison (U.S.A.) tables are almost identical with the N.R.C. ones. Close examination of the data from which these tables are derived shows how limited and unsatisfactory is the evidence upon which they are based. The Woodman figures are based largely on a series of 32 digestibility trials in which intake was related to liveweight gain or loss of the crated sheep during the trials and an assumption that maintenance varies as the two-thirds power of bodyweight.

The N.R.C. tables for sheep are really derived from the maintenance of stall-fed dairy cattle at 8.0 lb T.D.N. per 1,000 lb bodyweight and an assumption of the three-quarters power of weight.

If one assumes that 1 lb S.E. = 1.15 lb T.D.N. = 1.10 lb Digestible Organic Matter (D.O.M.) these tables can be related. They are, in fact, very similar indeed. The D.O.M. requirements for maintenance of a 100 lb sheep become 1.43 lb/day (Woodman) and 1.39 lb/day (N.R.C.). Two other conversion factors will be used in this paper, namely, that 1 lb T.D.N. = 2,000 kcal and 1 lb D.O.M. = 2,100 kcal.

In the past, most experiments have been on too small a scale or insufficiently critical to show up the inherent weaknesses in the standards. Franklin (1952) has shown in his drought feeding work done on a very extensive scale that merinos, in an only-just-surviving state, can be maintained in yards on about 60% of the Woodman and N.R.C. standards. The calorimetric work of Marston (1948) and Blaxter and Graham (1955) has shown that energy equilibrium in crated sheep is also only about 60% of the standard. At Lincoln it has been possible to maintain bodyweight of ewes concentrated on small areas with very little

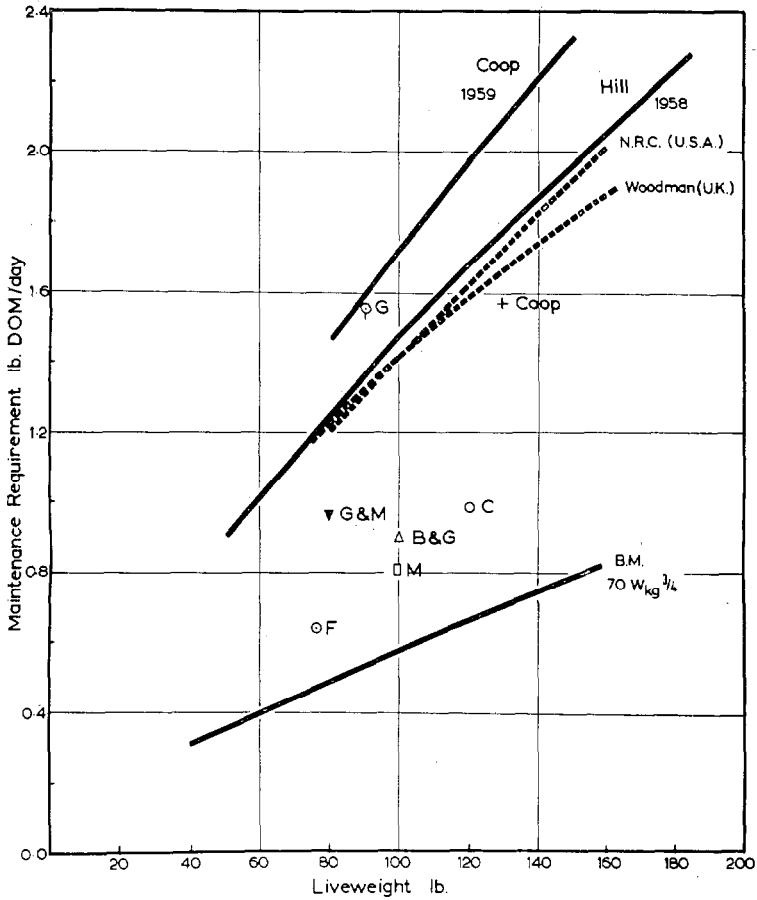

Fig. 1: Estimates of the maintenance requirements of sheep. B.M. = Basal Metabolism; F = Franklin (1952); M = Marston (1948); B & G = Blaxter & Graham (1955); G & M = Garrett, Meyer and Lofgreen (1959); C = Coop (this paper, pen-fed sheep); + Coop = Coop (this paper, Trial III); G = Greenall (1959).

grazing and fed hay equivalent to 60 to 70% of the standard. Much of this information is shown graphically on Fig. 1 in which the expression of requirement is lb D.O.M. per day.

The difference between these data and the standards cannot be explained in terms of the known or believed energy of walking, eating and climatic stress. This field was reviewed by Phillipson (1958) at the Brighton Conference on the scientific

principles of feeding farm livestock. Phillipson's opinion, which appeared to be accepted, was that "the standards are greatly in excess of the actual requirement".

Interest in this field at Lincoln stems from several factors—dissatisfaction with the existing standards, ignorance of the situation in grazing sheep which after all are the important ones, and a desire to use maintenance standards as a means of comparing the carrying capacity of sheep of different bodyweights, and in particular for making comparisons between crossbred and pure-bred sheep. The Lincoln work has centred upon determining the intake required for maintenance in both pen-fed and grazing sheep.

MAINTENANCE OF PEN-FED SHEEP

Data are available from four different trials in which known amounts of feed (and D.O.M.) have been fed to sheep in pens over extended periods. Liveweight change has been the measure of energy gain or loss, and, inaccurate though it may be, it is the most practicable index available. Provided weighing conditions are standardized, a sufficient number of weighings are made, and the trial extends for long enough, the errors are not too large. Nutrient requirements for wool growth were allowed for, and where ewes became pregnant the relatively low energy liveweight increase of the reproductive tract was also calculated. Briefly, the four trials gave the following results:

(1) Fifteen five-year Corriedale ewes of mean weight 115 lb were maintained on 0.92 lb D.O.M. per day for 13½ weeks.

(2) Six aged Romney ewes of mean weight 106 lb were put on maintenance and six of similar mean weight on sub-maintenance for 5 months.

$$\text{D.O.M. intake per day} = 0.99 + 2.29\,g$$

where 0.99 lb D.O.M. represents maintenance and g equals gain in lb/day.

(3) Twelve aged Romney ewes of mean weight 110 lb were fed, six at maintenance and six at super-maintenance levels for 8 weeks.

$$\text{D.O.M. intake per day} = 1.04 + 2.25\,g.$$

(4) Twenty-four two-year Romney ewes of mean liveweight 110 lb were fed for 10 weeks at maintenance on five different feeds—fresh wet grass, dried grass, sheep nuts, lucerne hay and ryegrass straw. There were no significant differences between feeds in the amounts required for maintenance and the mean of the four estimates equalled 1.00 lb D.O.M. per day.

By using the three-quarter power factor of bodyweight maintenance requirements were calculated from the above four estimates for a 100 lb sheep as follows:

D.O.M. intake = 0.92 (±0.08) + 2.27 (±0.22) g.

Maintenance is therefore 0.92 lb D.O.M. per day for a 100 lb sheep and the requirement for gain at the 106 to 110 lb level is 2.27 lb D.O.M. per lb.

In the writer's opinion, there is little doubt that for pen-fed sheep, not newly shorn, maintenance is 60 to 70% of the Woodman and N.R.C. standards and that the standards are in fact grossly in error for such conditions.

MAINTENANCE OF GRAZING SHEEP

The determination of intake in grazing sheep presents grave difficulties. The chromium oxide-nitrogen method was adopted in the belief that it was the best of the techniques offering.

The routine of chromium oxide dosage and faecal sampling recommended by Lambourne (1957) was followed. Technique trials involving total faecal collection from wethers gave a 97% recovery of Cr_2O_3 and indicated that 8 and 16 hour dosing and sampling intervals gave results very close to the mean of total collection. It is therefore felt that the use of chromium oxide for measuring faecal output is satisfactory and relatively free from bias and error.

The calculation of digestibility, indigestibility or faecal index from the percentage of nitrogen in the faecal organic matter (N_{om}) is much less satisfactory. The mounting criticism of a generalized regression equation for digestibility (or faecal index) and nitrogen led to an examination of this more closely. Three sources of data have been used. These are:

(1) A recalculation of Lancaster's (1949) original data using only those trials (20) which were conducted at Lincoln or Kirwee. This gave a curvilinear regression equation for digestibility of organic matter (D_{om}):

$$D_{om} = 36.57 + 15.85\,N_{om} - 1.29\,N_{om}^2$$

(2) A series of 16 digestibility trials with pasture carried out by M. K. Hill at Winchmore. Hill used 9 months old hoggets fed to appetite

$$D_{om} = 35.46 + 51.29\,N_{om} - 5.74\,N_{om}^2$$

(3) A series of 24 continuous digestibility trials conducted throughout the autumn, winter and spring of 1960 on rye-grass-white clover pasture from the paddock on which intake had been measured in 1958 and 1959. Four-tooth wethers fed at maintenance were used.

$$D_{om} = -7.80 + 36.47\,N_{om} - 3.61\,N_{om}^2$$

In none of the latter series did there appear to be any significant seasonal effect, and this is contrary to results from other centres.

Finally an analysis was made of the combined data. This gave the lowest standard error, and was of the form:

$$D_{om} = 30.84 + 17.10\,N_{om} - 1.30\,N_{om}^2$$

From this, faecal indices for converting faecal organic matter output to D.O.M. intake were derived. (See Fig. 2).

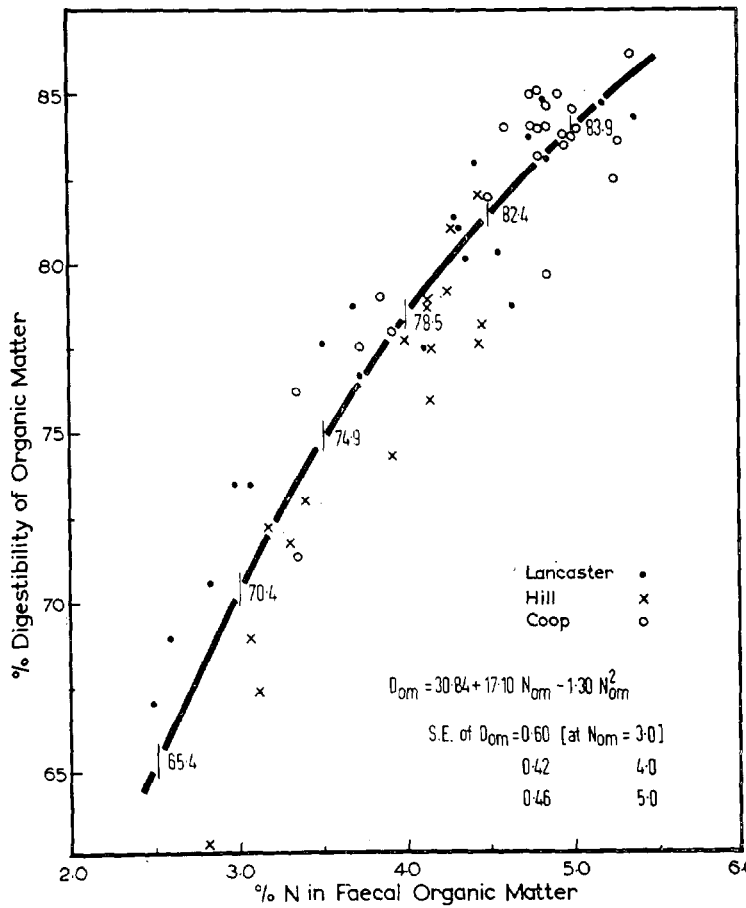

Fig. 2: Relationship between digestibility of organic matter and percentage nitrogen in faecal organic matter.

RESULTS

Trial I (1958)

This trial was conducted by M. K. Hill*. The sheep were 12 four-tooth Romney-cross wethers, 13 small or light Romney ewes and 13 large or fat Romney ewes, the mean initial liveweights being 111, 110 and 166 lb respectively. The ewes were five-year ewes with satisfactory teeth and constitutions. They and the wethers were November shorn and so carried 3 months' wool when the trial commenced at the end of February. The trial lasted for 17 weeks, and over this period the mean effective gains of the three groups, after allowing for wool growth and early pregnancy were +6½ lb, −1¼ lb, −7 lb respectively. All the sheep were run continuously as one mob. They were grazed on a 5-acre paddock of perennial ryegrass-white clover, subdivided into three temporary plots of unequal size. Occasional shifts were made from one plot to another to control liveweight change. On entering a fresh plot the intakes would probably be above maintenance and, before leaving the plot, below main-

*Now with the Department of Agriculture, Winchmore.

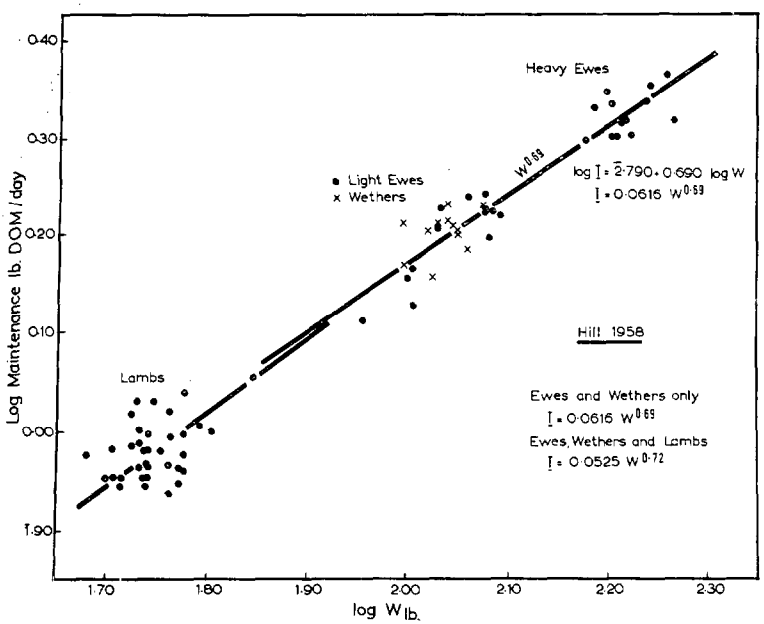

Fig. 3: Intake for maintenance of grazing sheep (Hill, 1958).

tenance. Liveweight changes were charged at the rate of 2.5 lb D.O.M. per lb for the wethers and light ewes and 4.0 lb D.O.M. for the heavy ewes.

In November, 1958, 36 weaned Romney ewe lambs were used over an 8 weeks period. Initial weight was 53 lb and final weight 60 lb. Several lambs did not gain weight, others increased by 12 to 16 lb. Requirement for gain was calculated by regression of intake on liveweight gain. Maintenance of individuals was calculated after deducting 1.5 lb D.O.M. per lb liveweight gain.

The results are plotted on log scale in Fig. 3. These data yield the following estimates for maintenance measured in lb D.O.M./day.

(a) Using ewe and wether data only :

$$\text{D.O.M.(maintenance)} = 0.0616\ (\pm 0.0030)\ W_{lb}^{0.690\ (+\text{ or } -\ 0.042)}$$

(b) Using all data (including lambs) :

$$\text{D.O.M.(maintenance)} = 0.0525)\ \pm 0.0021)\ W_{lb}^{0.724\ (+\text{ or } -\ 0.035)}$$

Where W_{lb} = liveweight in lb.

The maintenance requirement of a 100 lb sheep becomes 1.48 lb D.O.M./day which is slightly above the Woodman and N.R.C. standards.

Using the lamb intake data gives :

D.O.M. intake per day for a 56 lb lamb = 0.89 + 0.90 g.

The requirement for gain is therefore very much less than the standards laid down.

Trial II — 1959 Maintenance

A total of 41 ewes were employed in this trial consisting of 8 Southdowns (4 two-tooth and 4 four-tooth) 13 four-tooth Romneys, 12 four-tooth first-cross Border Leicester-Romneys, 8 Border Leicesters, of which half were two-tooths and half aged. The trial commenced in February and continued through to the middle of May; a total of 12 weeks.

For the first 10 weeks all 41 ewes were run together but in the last fortnight those which had lost weight were put on to better feed. For the first two weeks the sheep were set stocked on a Phalaris pasture, but for the remainder of the period were set stocked on short ryegrass and white clover upon which they barely maintained weight. For one week they were removed from this pasture to a better one to allow it to recover slightly. The mean initial bodyweights and effective gains over the 12 weeks were respectively :

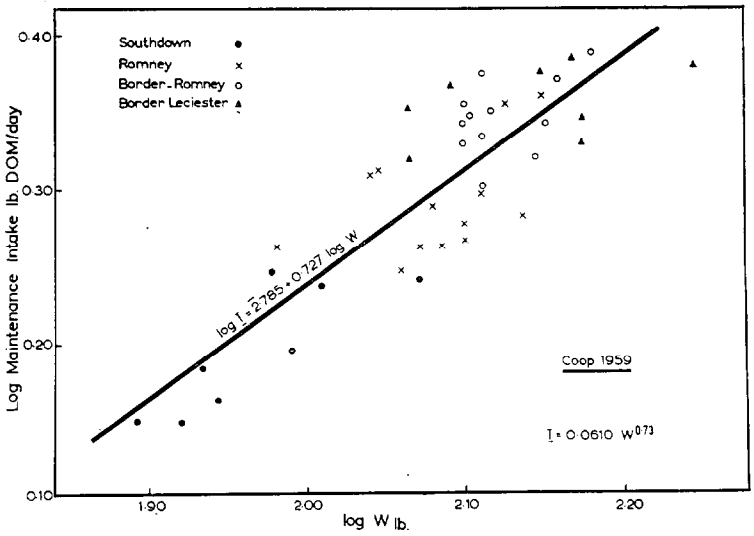

Fig. 4: Intake for maintenance of grazing sheep (Coop, 1959).

Southdowns	95 lb	and —4.5 lb
Romneys	120 lb	and —1.1 lb
Border-Romneys	130 lb	and +1.7 lb
Border Leicesters	139 lb	and +1.5 lb

Liveweight change in all sheep was charged at 2.5 lb D.O.M. per lb to bring intakes to maintenance.

Analysis of this maintenance data gives the formula:

$$\text{D.O.M.(maintenance)} = 0.0610\ (\pm 0.0049)\ W_{lb}^{0.727\,(+\text{ or }-0.072)}$$

(See Fig. 4, in which I = D.O.M. (maintenance).

This gives the maintenance requirement of a 100 lb sheep as 1.63 lb D.O.M./day.

Trial III — 1959 Maintenance Plus Gain

In the spring of 1959, fifteen 2- to 7-year-old dry Romney ewes of mean liveweight 129 lb were randomized into two groups to be placed on high and low planes of nutrition. One group of 7 ewes was set-stocked on a half-acre plot of short perennial ryegrass and white clover, while the 8 ewes were set-stocked on 1 acre of ryegrass and white clover which remained at 1 to 3 inches in height. The trial continued for eight weeks during which the mean effective gains of the two groups were —1.6 and +21 lb respectively. Intake of each sheep was corrected for the mean

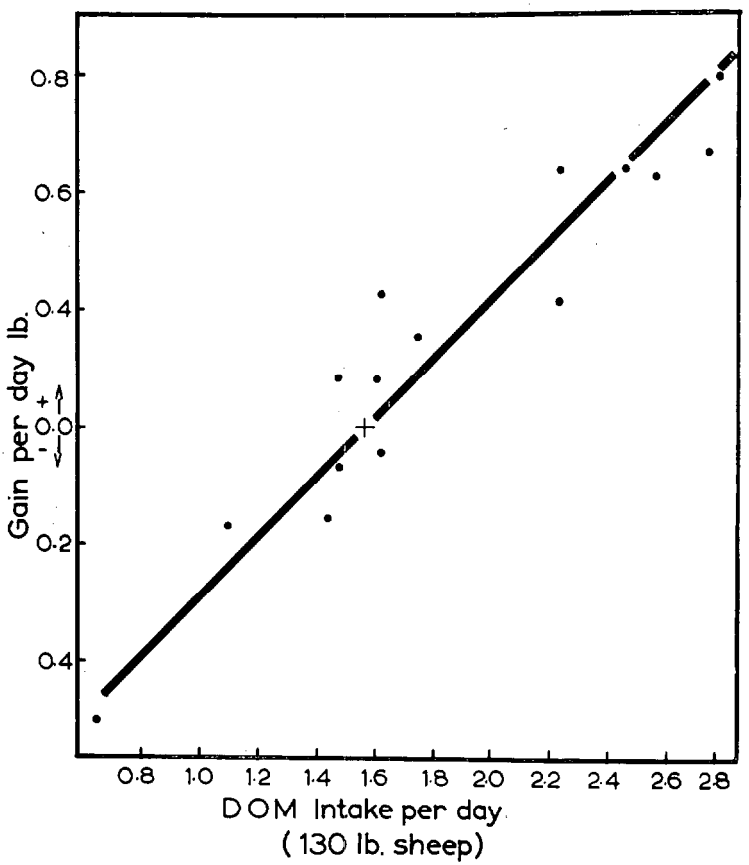

Fig. 5: Regression of intake on gain for grazing sheep, 1959.

liveweight of each sheep and a regression of intake on gain gives the equation.

$$D.O.M._{130} = 1.58 + 1.98\ (\pm 0.42)\ g_{130}$$

where $D.O.M._{130}$ is the intake in lb D.O.M. per day of a 130 lb sheep and g_{130} is the gain in lb per day of a 130 lb sheep. This equation gives the cost of maintenance of a 130 lb sheep as 1.58 lb D.O.M., and the cost of gain 1.98 lb D.O.M./lb. For a 100 lb sheep the maintenance cost would be 1.36 lb D.O.M./day.

DISCUSSION

In his review of the maintenance energy requirements of sheep Phillipson (1958) supported a figure equivalent to 0.9 to 1.0 lb D.O.M. per day for a 100 lb sheep which is 60 to 70% of

the U.K. and U.S.A. standards. The figure of 0.92 lb D.O.M./day which we have found for stall-fed sheep is therefore in complete agreement with this view.

But the figures for the maintenance requirement of grazing sheep are much higher. The three estimates which have been made at Lincoln are 1.48 (Hill, 1958), 1.63 (Coop, 1959) and 1.36 (Coop, 1959—regression on gain), and range from 50 to 80% above the pen-feeding figure of 0.92. Possible causes of these large differences will now be considered.

The first of these is that the errors and biases involved in the determination of intake by the chromium oxide-nitrogen method render the estimate of intake unreliable. Time and space do not allow much discussion on this important point but it is difficult to see how errors could be such as to account for even half of the 50 to 80% difference above.

It is inevitable that there will be energy cost of grazing. This could be associated with any or all of the following: (a) the climatic environment of temperature, wind and rain, (b) walking, (c) hormonal or metabolic factors, (d) harvesting the grass.

With regard to the climatic factor, there is as yet little knowledge of its effect. The work of Blaxter (1959) has demonstrated very clearly that heat production in shorn sheep is much greater than in full woolled ones, and increases with decreasing environmental temperature. The sheep used in these experiments had 2 to 3 months of wool on at the beginning of the trials and none of the trials was conducted in the winter so it is difficult to visualize the ambient temperature differences between the grazing and pen-fed sheep accounting for more than a fraction of the discrepancy. Wind could perhaps be significant in decreasing the insulating power of the fleece as generally the sheep were run in a windy environment. Rain could at times be an important factor and in fact it is suggested as one of the reasons for the difference between the Hill, 1958, and the Coop, 1959, results. The autumn in which the 1958 trial was conducted was warm and dry but at the end of the 1959 trial two to three weeks of very wet cold weather was experienced in which 5 inches of rain fell and the sheep were definitely miserable. This would not only reduce temperature but also the insulating capabilities of the fleece. In all, therefore, it is suggested that the climatic environment in which grazing sheep live could account for a significant increase in maintenance but the magnitude of this is unknown.

The energy cost of walking is generally considered, from indirect calorimetric work with humans and small domestic animals, to be relatively small. As the sheep involved in these trials were run on small areas, the distances walked and the energy used in yarding twice daily would be small.

It is impossible to assess at this stage whether any metabolic difference exists between pen-fed and grazing sheep. Some excitement is undoubtedly caused by the daily yarding, dosing and faecal sampling, but in the absence of any specific data it is believed that this effect would not be large. It was already shown in the 1960 pen-feeding trial that the nature of the food was not a factor, in as far as maintenance of pen-fed sheep was the same in terms of D.O.M. whether wet grass or dry feeds were given.

By difference or default, one is left with the energy cost of harvesting the grass as the probable major cause of the cost of grazing. This is an hypothesis for which there is as yet no proof.

In contrast to maintenance, the energy cost of gain in grazing sheep appears to be less than in pen-fed ones. The cost of gain in 56 lb lambs was found to be 0.90 lb D.O.M./lb, in 130 lb ewes 1.98 lb D.O.M./lb, whereas the cost in pen-fed ewes of 110 lb was 2.27 lb D.O.M./lb. The Woodman standards allow the equivalent of 1.6 lb D.O.M. for 60 lb lambs, increasing to 2.75 lb D.O.M. for 130 lb sheep. This apparent anomaly can be explained if one accepts an hypothesis that the energy used in grazing decreases as the quality of the grazing improves. When grass of sufficient length and density to promote gain is provided, the energy of harvesting each unit of grass may decrease. Maintenance is therefore not constant but decreases with increasing intake and gain. Regression of intake on gain implies that maintenance is constant. If, in fact, maintenance decreases as gain increases, then the cost of gain is underestimated by a regression. The conclusion is reached, therefore, that with grazing sheep it is not possible to partition off from total intake a constant maintenance in order to calculate the cost of gain. In other words, the energy cost of gain must depend on the energy cost of maintenance which will vary according to the grazing pressure or difficulty of harvesting the grass.

To return to maintenance, the 1958 and 1959 trials gave a bodyweight exponent of 0.724 $\pm$0.04 and 0.727 $\pm$0.07. The agreement between the two is coincidental as the standard errors of estimation show. They do, however, give no support for

increasing the exponent above the usually adopted figures of 0.7, 0.73 or ¾ used for stall-fed animals. This permits calculation of the maintenance portion of carrying capacity from bodyweight with probably greater accuracy than could be determined by pasture grazing trials. It further enables calculation of efficiency of production in animals where it is known that the major portion of intake is proportional to the 0.70 to 0.75 power of bodyweight.

REFERENCES

BLAXTER, K. L., GRAHAM, N. McC. (1955): *J. agric. Sci., 46*: 292.
BLAXTER, K. L., GRAHAM, N. McC., WAINMAN, F. W. (1959): *J. agric. Sci., 52*: 41.
FRANKLIN, M. C. (1952): *Aust. J. agric. Res., 3*: 168.
GARRETT, W. N., MEYER, J. H., LOFGREEN, G. P. (1959): *J. anim. Sci., 18*: 528.
GREENALL, A. F. (1959): *N.Z. J. agric. Res., 2*: 639.
LAMBOURNE, L. J. (1957): *J. agric. Sci., 48*: 415.
LANCASTER, R. J. (1949): *N.Z. J. Sci. Tech., 31A*: 31.
MARSTON, H. R. (1948): *Aust. J. Sci. Res. B, 1*: 362.
PHILLIPSON, A. T. (1958): *Proc. Conf. Scientific Principles of Feeding Farm Livestock*. Farmer & Stockbreeder, London.