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GRAZING RUMINANTS: EVALUATION OF THEIR FEEDS AND NEEDS

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SUMMARY

Some developments in methods for quantitative studies of pastoral production are discussed, including an electronic probe that measures pasture dry matter yield, the determination of energy requirements of grazing animals and detailed measurements on the digestion of grazed herbage. An explanation is given of an erroneously high estimate of the feed required for maintenance by undernourished grazing sheep. Requirements estimated with a calorimetric technique have shown agreement with factorial estimates. Differences among grasses and legumes in nutritional value appear to reflect complexities in the sites, rates, extent, and products of their digestion.

INTRODUCTION

Definition of the energy and nutrient requirements of hand-fed animals and of nutritional values of their feed has a long history, but for grazing animals is relatively recent. During the last three decades, approximately, a range of techniques required for quantitative studies of grazing nutrition has been established, promoting definition of important characterictics in feed supplies and relationships with animal production. Feed budgeting in rotational grazing management (MAF, 1976) has stemmed from information on the intake of herbage and production by various classes and liveweights (W) of animals in relation to herbage allowance (kg DM/kg W). Intake is more appropriately related to herbage mass (kg DM/ha) with objective description of its nutritional qualities (Christian *et al.*, 1978) and spatial distribution in the canopy (Stobbs, 1973), when pastures are continuously grazed as in much of Australia. Herbage mass can be estimated by various means ('t Mannetje, 1978) including visual, harvesting to a variety of stubble heights, and by electronic capacitance meter ("Charlie") which was first developed into a practical tool by Campbell *et al.* (1962). Further development by Vickery *et al.* (1980) has now produced an inexpensive instrument that measures herbage mass and can be adapted to measure yields by strata within the canopy. This makes possible the standardization of measurement among studies to give greater comparability between the results. Widespread use of the instrument by advisers and farmers will confer important practical benefits.

ENERGY REQUIREMENTS OF GRAZING ANIMALS

A prime factor in the relationship between intake and production is the quantity of dietary energy used by the animal for maintenance, including grazing activities. Raymond (1948) and Lancaster (1949) originated the faecal nitrogen technique for estimating the digestibility of grazed herbage and thence, with estimation of faeces output, the intake of digestible organic matter (DOMI). The first major outcome was the report by Wallace (1956) on the DOMI of more than 200 dairy cows, their milk production, W, and changes in W. A multiple regression equation was derived for prediction of DOMI from the other variables, but the greatest interest lay in the regression coefficient for W which indicated that the cows required 57 g DOM (0.86 MJ ME)/kg $W^{0.75}$ for maintenance. This value is greater by 55 to 75% than those for housed cows of MAFF (1975), NRC (1978) and van Es (1978). Numerous other estimates followed and many problems in estimating DOMI had been identified and resolved (CAB, 1961) when Lambourne and Reardon (1963) reported that the requirement for maintenance (DOM g/kg W) of freely grazing but severely undernourished sheep was more than twice that of sheep provided with abundant herbage, and nearly four times that of severely undernourished sheep in pens. In contrast, calorimetric estimates (kJ ME/kg) of Young and Corbett (1972a), obtained from measurements of respiratory gaseous exchanges and by the CO_2 entry rate technique (CERT), varied little over a wide range in body condition. The sheep grazing sparse herbage ingested much soil; faeces DM contained up to 70% ash. Soil mineral matter, similar in type and particle sizes, was administered to penned and grazing sheep and increased faecal N excretion by about 0.5 g/100 g soil. However, the effects of such extra N excretion on N concentration in faeces OM and thence estimated OM digestibility could not account for the very high estimates of DOMI from Lambourne and Reardon's data. Excretion of Cr_2O_3 by grazing sheep not dosed with this marker (Young and Corbett, 1972b) showed that faeces are ingested from bare pasture, and it was noted that the high DOMI (Table 1) relected high faeces outputs. Pastures for the low-weight sheep had been kept bare by intermittent grazing with large numbers of other sheep, so their faeces were probably part of the intake of

TABLE 1: OUTPUT AND COMPOSITION OF FAECES AND CALCULATED DIGESTIBLE ORGANIC MATTER INTAKES OF SHEEP STUDIED BY LAMBOURNE AND REARDON (1963)

	Mean Liveweight (kg)		
	High (46)	*Medium* (33)	*Low* (26)
Faeces organic matter (g/d)	168	273	266
Faeces ash %	19.9	23.4	29.0
Nitrogen % in faeces OM	3.89	3.91	3.79
Digestible OM intake (g/d)			
— original values[1]	475	795	751
— recalculated[2]	475	781	723

[1] Calculated by Lambourne and Reardon and not adjusted to zero liveweight change.

[2] Excess soil mineral matter consumed by Medium and Low groups relative to High, calculated by reference to faeces ash % and faeces OM g/d. Excess assumed to increase N excretion by 0.5 g/100 g soil, faeces N% adjusted to exclude this, and OM digestibility and DOMI recalculated.

the experimental animals. Organic detritus was collected from a heavily grazed pasture and two fractions, one mainly faecal of 70% OM containing 4.33% N and the second of faeces plus plant litter, 72% OM and 4.05% N, were administered to sheep in amounts up to 500 g/d. Regression analysis of faeces OM on detritus OM, g/d, indicated that digestibility of the two fractions was 7.2 and 10.2%, respectively, and that N digestibilty was similarly low.

On the assumption that true maintenance needs of the sheep of Lambourne and Reardon (1963) were similar to those indicated by Young and Corbett (1972a), it was calculated that those at low and medium weights had probably been consuming about 400 and 250 g/d, respectively, of faeces and/or litter. Low digestibility of the N would have maintained a high N% in the increased faeces output and falsely indicated high digestibility of intake. Had the technique for collecting grazed herbage from sheep with oesophageal fistulas then been established, this source of error would have been detected; digestibilities of the detritus determined *in vitro* were similar to the *in vivo* values.

Estimates of DOMI remain imprecise, though errors, which are often biasing errors, are minimized. Estimation of maintenance from multiple regression of DOMI on W, change in W and milk production has additional problems, including errors of measurement and correlations between these and among the independent variables. The ME required for 1 kg of 4% fat-corrected milk is unlikely to vary much from 5.1 MJ, equivalent to about 0.33 kg DOM, and regression coefficients that differ substantially from that value are suspect. There is often uncertainty about the composition of changes in W of grazing animals, especially short-term changes, and it is difficult to assess the validity of coefficients for this variable. The difference between grazing and penned animals in maintenance need, such as indicated by Wallace (1956), is however within the range that can be calculated (Graham, 1966) from knowledge of the energy costs incurred at pasture.

If energy expenditures of grazing animals are estimated by CERT, then, with reference to DOMI, animal performance can be expressed as a single value, energy retention, without having to attribute fractions of this to various animal functions. Methods have been devised for infusing $^{14}CO_2$ and sampling body CO_2 (Engels *et al.*, 1976) so that CERT can be used readily on many animals. Nearly 500 measurements of 24 h energy expenditures were made on Merino ewes at three stages of pregnancy and concurrently on non-pregnant ewes (Corbett *et al.*, 1980). ME requirements for maintenance (ME_m) were estimated from these results and their DOMI (Table 2), and for pregnant compared with non-pregnant ewes were greater by 0.46, 0.66 and 1.95 MJ/sheep/d at 54, 100 and 130 days of gestation, respectively; with

TABLE 2: ESTIMATES OF METABOLIZABLE ENERGY FOR MAINTENANCE (ME_m) OF GRAZING MERINO EWES PREGNANT (P) 54, 100 AND 130 DAYS, AND NON-PREGNANT (NP), FROM (i) ENERGY RETENTION (ER) AND (ii) DOMI, LIVEWEIGHT (W kg) AND GAIN (ΔW g/d)

	Period I (May)		*Period II (July)*		*Period III (Aug.)*	
	P (54 d)	*NP*	*P (100 d)*	*NP*	*P (130 d)*	*NP*
(i) [2]$ER = a + bMEI + cMEI^2$						
Mean W (kg)	38.1	37.4	40.0	36.8	43.0	37.9
ME_m: kJ/kg W/d	← 153[1] →		← 123[1] →		222	202
kJ/kg $W^{0.75}$/d	← 377[1] →		← 304[1] →		564	496
MJ/sheep/d	6.37	5.91	4.91	4.25	9.25	7.30
(ii) [3]$DOMI = b_1W + b_2\Delta W$						
$ME_m(b_1)$: kJ/kg W/d	← 192[1] →		← 200[1] →		281	356
kJ/kg$W^{0.75}$/d	← 477[1] →		← 498[1] →		716	898
ME kJ/ΔW (b_2)	-2.0^{NS}	4.6^{NS}	54	51	60	-17^{NS}

[1] P vs. NP non-significant.

[2] Approx. 20 ewes per group. Equation solved for ER=MEI-heat production (CERT) = zero.

[3] Approx. 30 ewes per group. NS: Coefficients non-significant ($P > 0.05$).

allowance for foetal growth, calculated ME requirements at 130 d were 0.23 MJ/kg W or 0.58 MJ/kg $W^{0.75}$. In contrast, ME_m from regression of DOMI on W and change in W were all greater than those from CERT, and in late pregnancy were less than for non-pregnant ewes, the outcome of the statistical calculations which ascribed 60 kJ ME/g ΔW to those pregnant, while gain by the empty ewes was apparently without cost.

The ME_m from CERT in July, midwinter, were similar to the values of 124 kJ/kg W or 320 kJ/kg $W^{0.75}$ of Langlands *et al.* (1963) for adult penned sheep, but greater in May and August (non-pregnant) by about 25 and 60%, respectively. These results may indicate seasonal effects on animal behaviour and metabolism at pasture corresponding to those discussed by Milne (1980).

The ME_m from CERT in May and August are similar to factorial estimates made by summation of fasting metabolism and the probable energy costs of the several activities at pasture and of gestation (*e.g.*, Graham, 1966). Considerable confidence in factorial estimates is justified, though these might not yet be able to allow for possible variation in energy expenditure with season, or factors such as modification of behaviour in response to temperatures below critical. There must be further direct estimates of ME_m for various classes of sheep and cattle in a wide range of environments, not because these estimates only are reliable, but to increase confidence and understanding in the assembly of information from detailed studies on animals in controlled conditions into predictive models.

NUTRITIONAL EVALUATION OF PASTURES

Pastures differ in nutritional value; for example, lambs generally grow more rapidly on leguminous than on grass pastures. Reasons for such differences must be identified to assist the introduction and use of improved pasture plants. Variation in DOMI though herbage is *ad libitum* is one reason, but not the only one. Perez *et al.* (1976) reported that lambs grazing lucerne and phalaris gained 151 and 106 g/d, respectively, though DOMIs were little different (23.6 and 21.0 g/kg W/d). More rapid growth on legumes might sometimes reflect the presence of oestrogenic substances. Another possibility is a difference in plant lipid content. If 0.3 MJ net energy/lamb/d of the above difference in gain could not be attributed to a difference in DOMI, it would be promoted by an additional intake of about

15 g lipid (Nehring annd Haenlein, 1973); for the mean DM intake of about 850 g/d this would be equivalent to an increase in lipid content from 2%, say, to 3.8%.

Many studies have been made with penned sheep of the sites and extent of digestion of various types of herbage and of the products of digestion, including microbial products. Similar studies are being made with grazing sheep (Corbett *et al.*, 1979) because their diet can differ substantially in quantity and quality from that of sheep given herbage cut from the same pastures. Flows of digesta are estimated by reference to the markers ^{103}Ru-phenanthroline and ^{51}CrEDTA infused into the rumen, but it was found that estimates of OM flows from the stomach, from analyses of abomasal digesta sampled through simple cannulae, varied with time of sampling. Differences were small between the patterns of variation observed in several experiments with 5 to 10 sheep, each sampled every 3 h, when allowance was made for changes during the year in the time of end of daylight. Nightfall always coincided with increases in flows towards the maxima of, generally, about 130% of the 24 h mean. The equation (Fourier) that described the general pattern is used to adjust results obtained with a particular sampling timetable to estimates of true daily OM flow; variation in its N content was small. Re-entrant cannulation appears impracticable for grazing animals, and evidence such as that of Wenham (1979) and from IVVO (1978) of serious physiological disturbance in animals with this type of preparation may lead to greater use of simple cannulation in penned animals.

Abomasal OM flow showed substantial diurnal variation ($\pm$30%) in penned sheep fed chaffed or ground and pelleted lucerne twice daily, but less variation when the same diets were given as hourly meals.

OM flows through the ileum, with simple cannulae, of grazing sheep showed little variation. While concentrations of the two markers in faeces OM varied little and in a random manner, the ratios of their concentrations compared with those in the infusates have consistently indicated a loss by absorption of more than 5% of the daily dose of ^{51}CrEDTA; as much as 10%, but no ^{103}Ru-P, has been excreted in urine.

Ulyatt and Egan (1979) examined many studies on the digestion of herbage, and found similarities between results from dried material and those from fresh. Our results from 23 experiments on phalaris, lucerne and native pastures, usually grazed by three or four cannulated sheep, agree with their finding of a positive relationship between OM apparent digestibility and OM digested in the stomach; the ranges for our sheep were, respectively, 54.3 to 83.3%, and 23.2 to 59.1 g/100 g OMI or 41 to 73 g/100 g DOMI. One difference from dried feeds is the consistently greater rumen dilution rate in grazing sheep as estimated from fractional outflow rate of ^{51}CrEDTA. This dilution has tended to be more rapid on lucerne than phalaris (Corbett and Pickering, 1979). Ulyatt (1971) reported short rumen retention times of grazed OM. Another difference is that whereas Roy *et al.* (1977) concluded there was synthesis of microbial protein equivalent to 30 g N per kg OM apparently digested in the rumen, the mean value ($\pm$SE) from 19 determinations on phalaris, lucerne and native pastures was 41.1 $\pm$2.2 g/kg. Walker *et al.* (1975) obtained a similar value with sheep given fresh grasses and clover. Synthesis, and the degradability of dietary protein, were estimated at pasture by infusing $Na_2{}^{35}SO_4$ into the rumen, determining the specific radioactivity of sulphur in abomasal digesta and an isolated microbial fraction (Hume, 1974), and OM and N intakes and of flows of OM and non-ammonia N from the stomach. The mean percent degradability ($\pm$SE) of protein from, respectively, six, six and seven observations was phalaris 89.3 $\pm$3.8, lucerne 91.8 $\pm$3.2 and native pastures 73.6 $\pm$3.1.

Apparent digestibilities of non-ammonia N (NAN) in the intestines of grazing sheep were similar to the 70% adopted by Roy *et al.* (1977), though positively related to the quantities leaving the stomach. Ulyatt and Egan (1979) concluded there was insufficient information to predict these quantities accurately, but Corbett and Perez (1979) derived an equation which could be used to predict the ratio of NAN leaving the stomach (expressed as g/d crude protein, CPLS) to crude protein intake from the digestible organic matter and crude protein intakes:

$$\text{CPLS} : \text{CPI} = 0.22\ (\pm 0.05)\ \text{DOMI} : \text{CPI} + 0.32\ (\pm 0.14)$$

The coefficients are similar to those reported by Hogan and Weston (1974), who established this type of relationship with dried forages.

It appears there will often be no simple explanation for differences in nutritional value between various types of pasture herbage because they reflect complex interactions between many factors. These factors will include the extent and rate of degradation in the rumen of various chemical components of the diet and fractional outflow rates from that organ, and variation in the utilization by the animal of the consequent products of digestion with variation in their composition. Dynamic computer models such as those of Baldwin *et al.* (1977) and Black *et al.* (1980) are required to help draw together the variety of information that must continue to flow from studies with animals.

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