Studies of protein requirements of ruminants

2.* Protein requirement for maintenance of three breeds of cattle

BY R. C. ELLIOTT† AND J. H. TOPPS

Department of Agriculture, University College of Rhodesia and Nyasaland, Salisbury, S Rhodesia

(*Received* 4 *March* 1963—*Revised* 22 *July* 1963)

Balance experiments with two breeds of African cattle have shown that these animals were in positive nitrogen balance when given diets of low protein but high energy content (Elliott & Topps, 1963). This apparently low protein requirement was associated with low endogenous N loss and high efficiency of N utilization by the cattle at N equilibrium.

Elliott & Topps suggested various reasons for these two effects which probably result in a low protein requirement for maintenance. African cattle may, through natural selection in a protein-deficient environment, have evolved some physiological process for conserving N under such stress conditions. The studies of Schmidt-Nielsen, Schmidt-Nielsen, Houpt & Jarnum (1957) with camels and of Somers (1961) with sheep have indicated the importance of the re-cycling of katabolized N in the ruminant on low-protein diets. The low endogenous N loss of the African cattle would be consistent with this hypothesis. Secondly, the reason may be related to the nature of the diets used in the N balance studies. The work of McDonald (1948), Chalmers & Synge (1954) and Lewis (1957) has stressed the importance of bacterial degradation of protein in the rumen and has shown that low efficiency of N utilization is invariably associated with high ruminal ammonia and high blood urea values. The wasteful effect of this bacterial deamination can be considerably reduced when diets with a high content of readily fermentable carbohydrate are given to ruminants. Such diets were used in the N balance studies previously referred to. Further, many workers (e.g. Rosenthal & Allison, 1951) have noted in monogastric animals the protein-sparing action of energy-rich foods. The same or similar mechanism may be present in ruminants quite apart from the purely ruminal effect.

The object of the feeding trial now described was to ascertain to what extent the low maintenance requirement for protein, previously obtained, is applicable in practice over a long period and to examine the effect of two levels of energy intake on this requirement. In addition, it seemed desirable to find whether cattle of a European breed have similarly low protein requirements for maintenance.

* Paper no. 1: *Brit. J. Nutr.* (1963) 17, 539.

† Seconded from the Department of Research and Specialist Services, Federal Ministry of Agriculture.

EXPERIMENTAL

Animals. Eight Africander, eight Mashona and six Aberdeen–Angus steers were used. Each breed of African cattle comprised two groups of four animals aged approximately 1 and 2 years. They were strictly similar with regard to previous treatment. The animals in these four breed–age groups were divided at random and allocated to the two levels of energy feeding. The Aberdeen–Angus steers were similarly divided and allocated. They were not strictly similar to the steers of the other two breeds in age, condition or previous treatment, and for this reason critical comparison between them and the African cattle has not been attempted.

Diets. Although N balance trials (Elliott & Topps, 1963) had indicated a maintenance requirement for digestible protein about one-third of that advocated by Brody (1945), it was considered that this method of evaluating protein requirements may underestimate the animals' needs. For this reason a safety margin was allowed and the two maintenance rations were designed to provide about half the amount of apparently digestible N recommended by Brody. The two rations had approximately the same dry-matter and crude-protein contents but differed widely in their digestible-energy content. This difference was obtained by adjusting the relative amounts of roughage and concentrate feeds. The high-energy diet consisted of equal weights of roughage and concentrates and was offered in amounts to supply the steers with about 150 % of the total digestible nutrients prescribed by Brody for maintenance. The low-energy diet comprised 18 parts of roughage and 1 part of concentrates and was designed to provide the steers with Brody's maintenance requirement for total digestible nutrients (TDN). The ingredients of the diets offered are shown in Table 1.

Table 1. *Percentage composition of the diets*

Ingredient	High-energy diet	Low-energy diet
Rhodes grass hay	50·0	94·7
Groundnut cake	4·5	5·3
Cassava	25·5	—
Maize meal	15·0	—
Molasses	5·0	—

Methods. The diets were given to the Africander and Mashona steers for 15 weeks and to the Aberdeen–Angus steers for 13 weeks. The latter joined the trial 2 weeks after it had begun. Since only small weight changes were expected, efforts were made to obtain an accurate estimate of the body-weight of the steers and of weight changes. The animals were weighed twice each week, on Wednesdays and Fridays, and the mean weight for that week was computed from these two values and from the weight on the previous Friday. This system of 'moving averages' proved satisfactory in avoiding large and unaccountable variations. Weight changes of individual animals from one week to the next rarely exceeded 2–4 kg.

The animals were housed in individual pens and were fed once daily at 7 a.m. The amount of food offered was related to metabolic size and was calculated from the equation:

$$\text{food offered (kg)} = 0{\cdot}10\ W^{0{\cdot}73}\ \text{(kg)},$$

W being the body-weight. The initial weights of the animals were used in these calculations and this scale of feeding was adhered to throughout the trial, irrespective of weight changes. Animals of similar weight in the two energy groups were offered equivalent amounts of air-dry food. Waste food was removed daily immediately before the next feeding, and weighed. Food samples were taken daily and bulked over a week for dry-matter and crude-protein determinations.

The dry-matter content of the food and of the food refusals was obtained by heating samples to constant weight at 105°, and the crude-protein content by a macro-Kjeldahl method. The apparently digestible crude-protein content of the rations was estimated from the equation:

$$\text{digestible crude protein (\%)} = 0.9 \times \text{total crude protein (\%)} - 3.$$

To check this method estimates were obtained also by the method of French, Glover & Duthie (1957):

$$\text{digestibility of crude protein} = 70 \times \log \text{crude protein (\%)} - 15.$$

They were similar but slightly smaller. It was decided to use the formula that gave the larger estimate. The total digestible nutrient content of the hay and concentrates was estimated from concurrent digestibility trials with sheep.

RESULTS

Composition of consumed rations. The estimated nutritive value of the two diets consumed by the steers is given in Table 2. The diets were similar in their content of crude protein but differed widely in TDN. Small uneaten amounts of roughage caused slight deviations from the planned intake of roughage.

Table 2. *Mean percentage composition and nutritive value of the diets consumed by the steers*

Component	High-energy diet	Low-energy diet
Roughage	49·5 ± 1·60	93·8 ± 0·49
Concentrate	50·5	6·2
Crude protein*	6·4 ± 0·12	6·5 ± 0·26
Digestible crude protein*	2·8	2·8
Total digestible nutrients*	65·2	47·5

* Percentage of the dry food.

Table 3 shows the derived mean relative consumption (g/kg $W^{0.73}$) of dry food, digestible crude protein, and TDN by the six groups of steers. The expected differences in the relative TDN intake occurred. Unfortunately, however, highly significant ($P < 0.01$) differences occurred in the consumption of dry food, the animals receiving the low-energy diet eating less than their counterparts receiving the high-energy diet. These differences in consumption of dry food caused highly significant differences in the intake of digestible crude protein. These differences in protein consumption complicate the interpretation of the results for performance but do not necessarily invalidate any comparison between energy groups.

Differences between the intakes of dry food, energy and protein by the Mashona and Africander cattle were not significant. The Aberdeen–Angus steers appeared to consume slightly less than the other two breeds.

Table 3. *Mean intakes (g/kg $W^{0.73}$) of dry matter, digestible crude protein* (DCP) *and total digestible nutrients* (TDN) *by four Mashona, four Africander and three Aberdeen–Angus steers*

Breed	Dry matter	DCP	TDN
		High-energy groups	
Mashona	83·2	2·32	54·2
Africander	85·7	2·33	55·4
Aberdeen–Angus	78·4	2·29	51·6
Mean	82·4 ± 4·06	2·31	53·8
		Low-energy groups	
Mashona	76·7	2·15	36·3
Africander	74·1	2·13	35·2
Aberdeen–Angus	73·2	2·05	34·7
Mean	74·7 ± 6·47	2·11	35·4

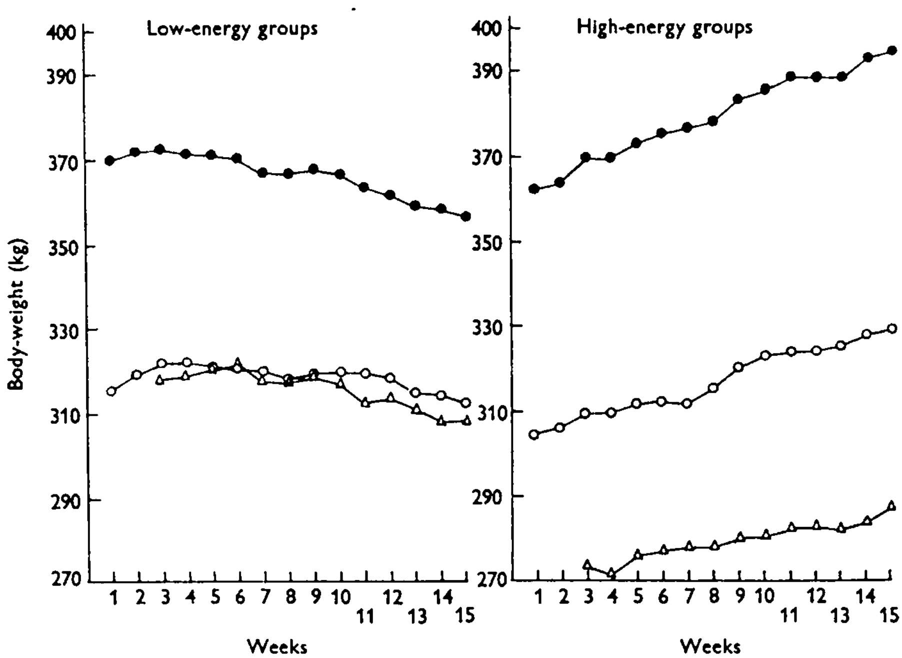

Fig. 1. Mean weekly body-weights of four Mashona (○—○) four Africander (●—●) and three Aberdeen–Angus (△—△) steers given either high- or low-energy maintenance rations.

Changes in body-weight. The weekly mean body-weights of the steers in the six groups are shown in Fig. 1, and individual performances over the 14 weeks for the Africanders and Mashonas and over 12 weeks for the Aberdeen–Angus are summarized in Table 4.

All the animals given the high-energy ration gained weight, whereas all but two of the animals given the low-energy ration lost weight. It should be noted that these

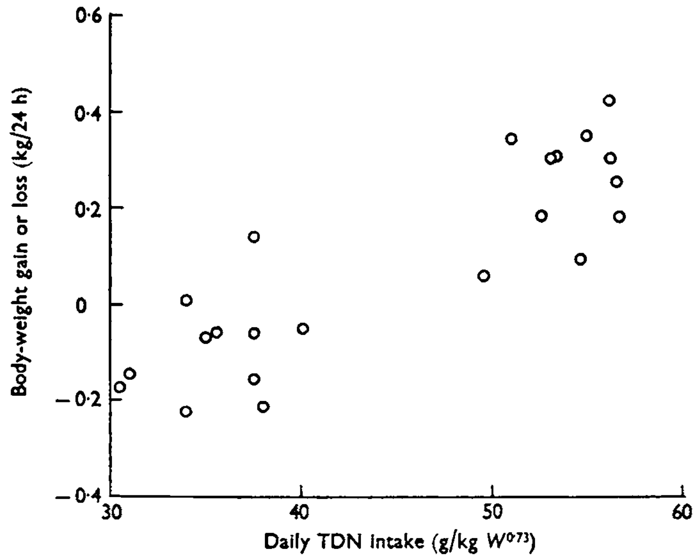

Fig. 2. Mean daily weight changes of twenty-two steers as a function of their intake of total digestible nutrients (TDN).

Table 4. *Body-weights and weight changes of individual steers given high- or low-energy maintenance rations*

Breed	Weight (kg) Initial	Final	Change	No. of days	Mean daily gain or loss (kg)
			High-energy group		
Mashona	251	269	18	98	0·18
	257	287	30	98	0·31
Africander	268	298	30	98	0·31
	315	340	25	98	0·25
Mashona	345	379	34	98	0·35
	364	382	18	98	0·18
Africander	426	456	30	98	0·31
	441	482	41	98	0·42
Aberdeen-Angus	189	194	5	84	0·06
	244	273	29	84	0·35
	388	396	8	84	0·10
Mean					0·26 ± 0·112
			Low-energy group		
Mashona	261	262	1	98	0·01
	288	302	14	98	0·14
Africander	296	279	−17	98	−0·17
	330	324	−6	98	−0·06
Mashona	341	319	−22	98	−0·22
	371	366	−5	98	−0·05
Africander	413	406	−7	98	−0·07
	438	417	−21	98	−0·21
Aberdeen-Angus	329	316	−13	84	−0·15
	234	223	−11	84	−0·13
	390	385	−5	84	−0·06
Mean					−0·12 ± 0·107

performance figures reflect steadily increasing or decreasing body-weights (Fig. 1) and are not accounted for by wide fluctuations in mean weight either at the beginning or the end of the experimental period. Analyses of variance of weight changes showed that differences between energy levels were highly significant ($P < 0.01$). Differences between the Africanders and Mashonas were not significant in this respect, and the performance of the Aberdeen-Angus appeared to be similar to that of the African breeds, though, for reasons outlined above, critical comparisons were not undertaken.

To obtain some assessment of the influence of digestible-nutrient consumption on performance, the mean TDN intake of each animal was plotted against the mean daily weight changes (Fig. 2). The pronounced difference due to the energy content of the two rations is readily apparent although appreciable between-animal variance occurred within these groups. From these findings it is tempting to suggest some relationship between digestible-nutrient consumption and performance. However, differences in the intake of digestible crude protein associated with the two levels of energy preclude any direct comparison.

DISCUSSION

Eleven steers receiving a high-energy ration all gained weight and achieved a mean daily gain of 0.26 ± 0.112 kg over a period of 98 days when their intake of digestible crude protein was only about 60% of that advocated by Brody (1945) for maintenance. During this time their mean intake of TDN was approximately 150% of Brody's maintenance standard. This finding suggests that, provided energy is adequate or in excess, the maintenance requirement of beef cattle for protein is less than 60% of this standard and agrees with the conclusions arrived at in the N balance trials previously reported (Elliott & Topps, 1963). It is worth noting that a low protein requirement has now been confirmed for beef cattle by two different methods.

Although there were slight differences in consumption of digestible crude protein, the pronounced effect of energy intake on performance is apparent from these results. On average, the group of steers receiving the low-energy ration lost weight (mean loss 0.12 ± 0.107 kg/day) despite their mean TDN intake being approximately 101% of the Brody standard. Hence it could be argued that either the intake of digestible crude protein (58% of Brody's maintenance standard) or the TDN intake was inadequate. However, neither of these alternatives need be the major cause of weight losses. A more likely effect is a very poor efficiency of N utilization by the cattle receiving diets which consisted of poor-quality hay and a protein-rich concentrate.

This inadequacy of readily fermentable carbohydrate, which invariably results in high levels of ruminal ammonia and low N retention, and the possibility of a protein-sparing effect of energy-rich diets, could adequately account for the large differences in performance of animals given the two rations. Unfortunately the TDN system of measuring nutritive values and requirements does not take account of the nature of the energy-yielding constituents of the diets. This is a further limitation to its use as a nutritional measure.

The performance of the Aberdeen-Angus steers was similar to that of the two African breeds of cattle, which indicates that the protein requirements of European breeds are probably not greatly different from those of African. Recent work in the USA (Bond, Everson, Gutierrez & Warwick, 1962) in which grade Angus steers maintained weight when given a high-energy ration with a protein content of only 4·9% supports this finding. It is, however, contrary to the postulate that cattle indigenous to Africa have evolved a special mechanism to conserve N when their diet is low in protein. Conversely, it does not exclude the presence of such a mechanism in all cattle.

The relatively good performance of cattle receiving diets high in energy but low in protein may be of considerable practical importance. The production of such diets may be economically feasible in certain parts of Africa where widespread protein deficiencies occur in the grazing but where crops such as maize and cassava are capable of producing high yields.

SUMMARY

1. Long-term feeding trials were made with twenty-two steers which received maintenance rations of high or low energy content. These animals were of three breeds and comprised eight Africander, eight Mashona and six Aberdeen–Angus animals.

2. The performances of the Africanders and Mashonas at the two energy levels of feeding were not significantly different. Though the animals were not strictly comparable, the performance of the Aberdeen–Angus steers seemed to be similar to those of the two African breeds.

3. When high-energy diets were given containing only 63% of Brody's (1945) standard for digestible crude protein all the animals gained weight (0·26 kg daily). This finding supports the results of nitrogen balance studies in which the requirements for digestible crude protein were found to be less than the recognized standards.

4. Animals fed on the low-energy diet generally lost weight (0·12 kg daily). This ration provided about 58% of the Brody allowance for digestible crude protein and appeared to be adequate in total digestible nutrients.

5. The differences in the performance of the steers fed at the two levels of energy intake are discussed. It is suggested that these differences were due mainly to the low efficiency with which N is used by cattle when they are given rations which contain inadequate amounts of available carbohydrate.

This work was supported by the Rockefeller Foundation. We acknowledge the co-operation of the Federal Ministry of Agriculture in providing facilities at the Henderson Research Station, the advice of Dr J. Oliver and the expert attention of Mr C. H. French and Mr I. Wedderspoon in the care and feeding of the cattle.

REFERENCES

Bond, J., Everson, D.O., Gutierrez, J. & Warwick, E. J. (1962). *J. Anim. Sci.* **21**, 728.
Brody, S. (1945). *Bioenergetics and Growth*. New York: Reinhold Publishing Corp.
Chalmers, M. I. & Synge, R. L. M. (1954). *J. agric. Sci.* **44**, 263.
Elliott, R. C. & Topps, J. H. (1963). *Brit. J. Nutr.* **17**, 539.
French, M. H., Glover, J. & Duthie, D. W. (1957). *J. agric. Sci.* **48**, 379.
Lewis, D. (1957). *J. agric. Sci.* **48**, 438.
McDonald, I. W. (1948). *Biochem. J.* **42**, 584.
Rosenthal, H. L. & Allison, J. B. (1951). *J. Nutr.* **44**, 423.
Schmidt-Nielsen, B., Schmidt-Nielsen, K., Houpt, T. R. & Jarnum, S. A. (1957). *Amer. J. Physiol.* **188**, 477.
Somers, M. (1961). *Aust. J. exp. Biol. med. Sci.* **39**, 145.

Printed in Great Britain