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USE OF THE COMPARATIVE SLAUGHTER TECHNIQUE TO ESTIMATE THE NUTRITIVE VALUE OF PASTURE FOR HOGGETS

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SUMMARY

Fresh white clover and perennial ryegrass, both of similar levels of digestibility, were fed either on *ad libitum* or restricted basis to wether hoggets over a 100-day period in autumn, 1966. The comparative slaughter technique was used to measure net energy values of each feed.

White clover tended to be higher in crude protein and water-soluble sugar content and lower in cellulose and hemicellulose than perennial ryegrass. Sheep on *ad libitum* feeding of white clover ate 34% more crude protein and gross energy than similar sheep fed perennial ryegrass. Liveweight gains were higher for sheep fed white clover but this was only partly related to the level of digestible organic matter intake. Both energy and nitrogen retentions were greater for sheep fed white clover at high levels of food intake than for perennial ryegrass but differences in energy retention between the two feeds disappeared at feeding levels approximating to maintenance.

These results are discussed in relation to present-day knowledge of rumen metabolism.

ALTHOUGH perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) together represent a large proportion of the feed available to sheep on the more improved pasture-land of New Zealand, these pasture species have been little studied under controlled feeding conditions to determine their nutritive value for either maintenance or productive purposes.

An ever-increasing number of field trials have established that young sheep have higher growth rates on white clover dominant pastures as compared with perennial ryegrass pastures (Sinclair, *et al.*, 1956; Rae, *et al.*, 1963; McLean, *et al.*, 1965; Hight and Sinclair, 1965). However, it is difficult to assess from the results of these trials what proportion of the faster growth rates of sheep grazing white clover as opposed to perennial ryegrass is due to greater intakes of digestible energy associated with increased palatability or to higher levels of digestibility.

At least some part of the increased growth rate may be a reflection of white clover having a higher nutritive value unassociated with any differences in digestibility or palatability.

The experiment described here was designed to measure the voluntary intake of hoggets fed either perennial ryegrass or white clover at similar levels of digestibility and to determine the net energy of each feed using a comparative slaughter technique.

EXPERIMENTAL

PLOTS

A four-acre area, Hamilton clay loam and Te Kowhai silt loam soil types, was cultivated and sown down in six strips, four with white clover and two with perennial ryegrass in the autumn of 1965. Species purity of the strips were maintained by spraying with either paraquat or mecoprop. The purity of each stand was high except for a slight infestation of docks (*Rumex obtusifolius* L.). All the area could be spray irrigated when required.

FERTILIZER

A month prior to the start of the experiment, 30 cwt of lime per acre was applied to the whole area, together with 2 cwt of 30% potassic superphosphate per acre. The potassic superphosphate dressing was repeated half-way through the experimental period. In addition, to compensate for the lack of nitrogen normally received from clovers in a mixed sward, nitrogen in the form of Nitrolime was applied at a rate of 2 cwt per acre at monthly intervals over the perennial ryegrass areas.

HARVESTING OF PLOTS

Each day at 7 a.m. sufficient grass and clover was cut to feed the sheep on experiment. Samples were taken for quick dry matter determinations using the method of Hutton (1962). Both pasture species were cut when 3 in. to 4 in. in height; if longer than this, the herbage was removed with a flail harvester and discarded. Prior to weighing out the grass and clover feeds for the sheep, further samples were taken for both slow oven dry matter determinations at 100°C and freeze drying for future chemical analysis.

SHEEP

Forty-eight lambs (approximately 165 days of age) were selected on a basis of their 24-hour fasted liveweights and divided into 12 groups of 4 sheep, the sheep in each group being of the same liveweight, but the liveweight of the sheep in the 12 groups ranged from 50 to 69 lb. The sheep in each group of four were randomized into four subgroups as follows:

Subgroup 1: Fed fresh white clover to appetite plus 15% refusal (W.C. group).

Subgroup 2: Fed fresh perennial ryegrass to appetite plus 15% refusal (P.R. group).

Subgroup 3: Fed white clover restricted to the same dry matter intake as eaten the previous day by the P.R. counterpart in subgroup 2 (W.C.R. group).

Subgroup 4: Slaughtered on day 1 of experiment.

FEEDING OF SHEEP

Sufficient feed was weighed out into two meals to provide for the requirements of each sheep for the ensuing 24 hours. The sheep were fed at 8.30 a.m. and 5.00 p.m. At 7 a.m. the feed refusals were collected, weighed and sampled for D.M. determination and for freeze drying for chemical analysis. From these data, D.M. intakes for the previous 24 hours by individual sheep were assessed. This information was used to calculate the current day's requirements and an allowance of 15% of the D.M. eaten was added where appropriate.

To determine the herbage digestibility, a continuous series of 10-day trials was run in which the total faecal output of all 36 penned sheep was measured. Urine output was measured on 15 sheep (3 groups of 5 sheep). Liveweights were recorded at 7-day intervals, prior to the the morning feed being given. All sheep were drenched at fortnightly intervals with thiabendazole to minimize intestinal parasite levels.

The experiment covered the 100-day period February 1 to May 12, 1966. On this last date all animals on the experiment were slaughtered.

SLAUGHTERING

All sheep were slaughtered for body composition studies, 12 at the beginning of the experiment to provide information on the initial body composition, and the remaining 36 at the end of the experiment to determine the effects of the different dietary regimes. At slaughter each animal was divided into five components: blood, carcass, skin, offal and wool.

Blood

All the blood was collected and weighed after the addition of heparin to prevent coagulation.

Skin, Carcass and Offal

These components after freezing and storing at −15°C were finely minced into a homogeneous paste using a Jeffco mincer. Samples were freeze-dried prior to analysis. The offal consisted of head, heart, lungs, alimentary tract (after emptying and washing), feet and liver. Weights of fresh and frozen individual components were recorded.

Wool

The wool was removed prior to slaughter, using the conventional shearing handpiece followed by fine Oster clippers. Chemical analyses were made on the greasy wool after drying.

RESULTS

CHEMICAL ANALYSIS OF FEEDS

The crude protein content of W.C. was higher than that of P.R. (Table 1), the difference being greatest during the initial stages of the experiment and becoming progressively less during the later cutting periods. The gross energy value of the W.C. feed was also higher than that of the P.R. This higher heat of combustion value was probably a reflection of the higher crude protein content,

TABLE 1: CHEMICAL COMPOSITION OF W.C. AND P.R. HARVESTED DURING PERIOD FEB. 1 – MAY 12, 1966

	W.C.	P.R.
Crude protein %	29.48	25.51
Water-soluble sugars %	5.28	3.98
Hemicellulose %	7.03	14.07
Cellulose %	17.52	27.60
Lignin %	6.49	5.93
Ash %	10.20	9.47
Cal/g D.M.	4,376	4,282
D.M. digestibility %	79.7	78.5
C.P. digestibility %	83.7	80.0

since the calorific value of protein is 5.65 kcal/g compared with 3.8 to 4.1 kcal/g for carbohydrates (Brody, 1945). Cellulose and hemicellulose levels in P.R. were approximately twice those determined in W.C. Although the water-soluble sugar content of W.C. was nearly 30% higher, the levels in both pasture species were extremely low.

DIGESTIBILITY OF ORGANIC MATTER (O.M.) AND CRUDE PROTEIN (C.P.)

Although D.M. digestibilities of both species were very similar, 79.7% W.C. and 78.5% P.R., because of the slightly higher ash content of W.C., O.M. digestibilities showed a slightly wider divergence (83.6% W.C. 80.7% P.R.). Crude protein digestibilities were very similar to O.M. digestibilities (83.7% W.C. 80.0% P.R.). The changes in D.M. digestibility for W.C. and P.R. over the 100 day trial period at 10 day intervals are shown in Fig. 1.

INTAKE

Intakes of O.M., C.P. and gross energy (G.E.) are given in Table 2. Sheep on *ad libitum* feeding of W.C. ate 28% more O.M., 34% more C.P. and G.E. than their counterparts on *ad libitum* feeding of P.R. Despite attempts to keep the W.C.R. and P.R. groups to identical O.M. intakes, four of the W.C.R. group ate considerably less than their P.R. counterparts. Hence, 8 out of 12 pairs only were used to compare P.R. and W.C. fed at identical feeding levels. With these 8 pairs of hoggets, O.M. and D.O.M. intakes differed by less than 1% for the two groups on average.

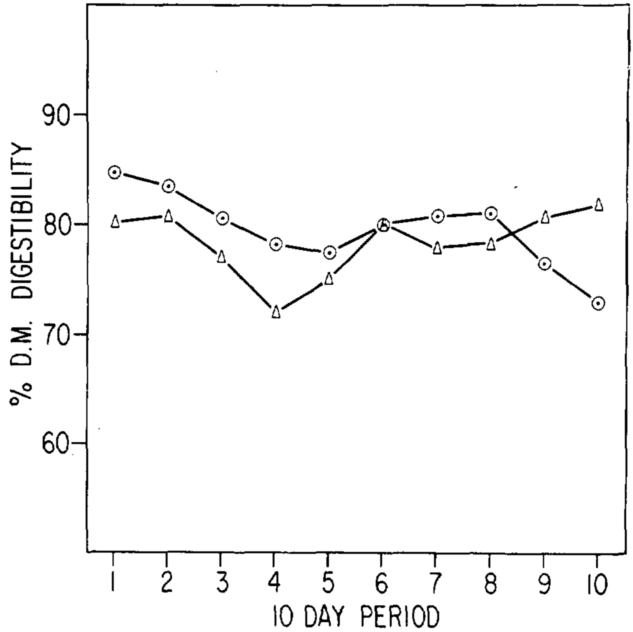

Fig. 1: Percentage dry matter digestibility of white clover (circles) and perennial ryegrass (triangles) over period February 1 to May 12, 1966.

LIVEWEIGHT GAIN

Liveweight gains were low (Table 3), the maximum rate of gain being 92 g/day for the W.C. group and the two other groups being only half this rate. The W.C. group gained at a 91% faster rate than the P.R. group. In the two selected groups, the W.C.R. group grew 27%

TABLE 2: INTAKE OF W.C. AND P.R. BY PEN-FED HOGGETS

	W.C. ad lib.	P.R. ad lib.	W.C. Restricted	Selected Animals P.R. ad lib.	Selected Animals W.C. Restricted
O.M. intake (g/day)	867	677	637	633	625
D.O.M. intake (g/day)	729	546	523	511	513
C.P. intake (g/day)	282	211	227	197	223
G.E. intake (kcal/day)	4,327	3,220	3,055	3,006	3,014

TABLE 3: RATE AND EFFICIENCY OF LIVEWEIGHT GAIN

	W.C.	P.R.	W.C.R.	Selected Animals P.R.	Selected Animals W.C.R.
Liveweight gain (kg/100 days)	9.17	4.81	4.54	4.36	5.54
kg liveweight gain/100 kg D.O.M.I.	12.58	8.81	8.68	7.94	10.36
Final slaughter wt. (kg)	26.33	21.54	22.07	20.95	22.85
Slaughter wt. gain (kg/100 days)	7.58	1.89	2.42	1.93	3.83
kg slaughter wt. gain/100 kg D.O.M.I.	8.74	2.79	3.79	2.84	5.88
Wt. of intestinal tract contents (kg)	1.87	2.73	1.50	2.33	1.51
Wt. of contents as % empty body-weight	7.1	12.7	6.8	11.1	—
Rumen papillation (0–10 scale)	6.3	3.8	5.1	—	—
Wool growth (g/100 days)	1,267	858	957	—	—

faster on average than their counterparts in the P.R. group. Efficiency of liveweight gain, calculated as kg L.W. gain/100 kg D.O.M. intake, was of the following order, W.C. > W.C.R. > P.R. When rate of gain was calculated on a slaughter empty body-weight basis, the differences in favour of W.C. and W.C.R. were further magnified. This disproportionate increase as opposed to liveweight is partially a reflection of the greater proportion of the P.R.-fed animal body-weight that was intestinal tract contents. Despite the greater or equal food intakes of the W.C. and W.C.R. groups, the tract fill of the P.R. group was almost 100% greater.

Rumen Papillation

The degree of rumen papillation, based on visual estimates of the size and number of papillae in the ventral sac of the rumen, using a scale of 1–10, was least in those animals fed P.R. and increased according to the level of W.C. intake.

Wool Growth

The rate of wool growth (Table 3) was greatest for the W.C. group. The difference between the W.C.R. and P.R. groups of almost 100 g/100 days per animal in favour of the W.C.R. group was significant at the 1% level.

Energy Retention

The amount of energy retained per unit of feed intake differed considerably between the groups fed different pasture species (Fig. 2). The regression equations relating energy retention to O.M. intake were calculated as:

$$\text{W.C. } y = 2.46x - 48.62$$
$$\text{P.R. } y = 1.165x - 26.41$$

where y = Mcal energy retained over 100-day period,
x = g O.M.I./day/L.W. kg $^{0.75}$

While the two regression coefficients differed significantly at the 1% level, the regression lines converged at zero energy retention (F: $(f(x)/So) < 1$) and the estimated point of concurrence was $x = 19.91$ (g O.M.I./L.W. kg $^{0.75}$/day) with 95% confidence limits of 21.15 and 18.29

(Tocher, 1952). These results thus suggest that, while large differences appear to exist between the nutritive values of W.C. and P.R. at high levels of feeding, these differences diminish as the feeding levels fall closer to maintenance level, and finally disappear at this point. This intimates that, while net energy figures for production differ, net energies calculated for maintenance do not.

The method used in this experiment to determine energy retention on each feed was to measure the whole body energy values of similar groups of animals at the beginning and end of the experiment and any differences were attributed to the dietary regime imposed. Energy values of the various body components were directly determined

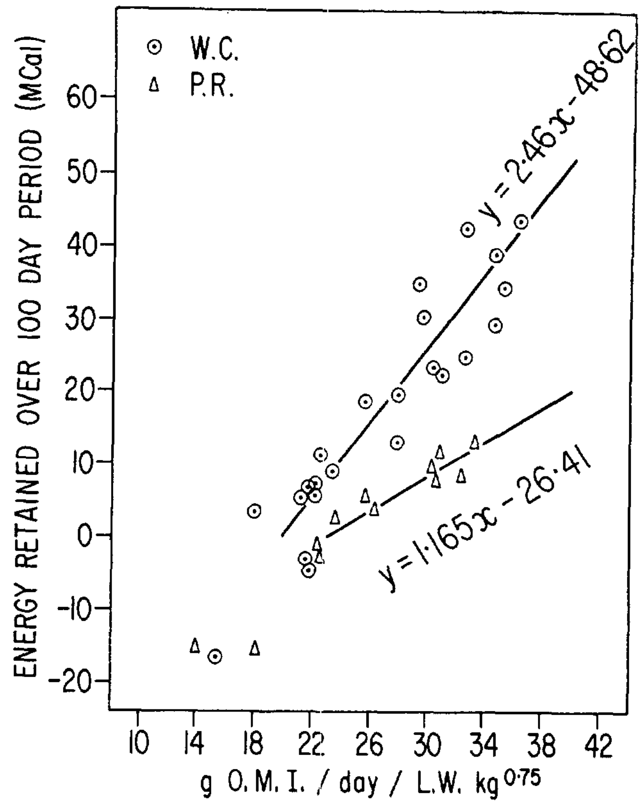

Fig. 2: Effect of level of organic matter intake of W.C. and P.R. on the amount of energy retained.

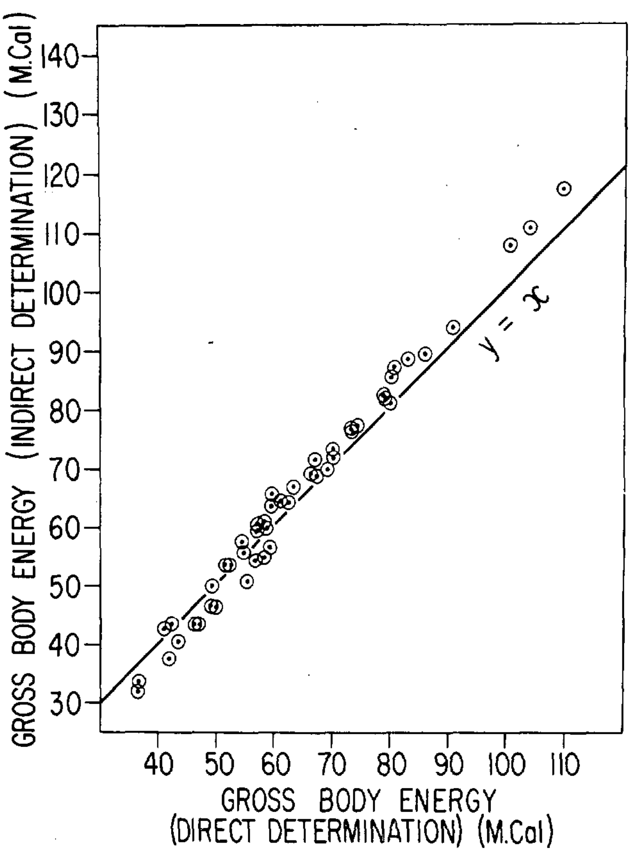

Fig. 3: Relationship between direct and indirect methods of measuring gross body energy.

by bomb calorimetry of the freeze-dried minced samples. An alternative method is to determine the percentage ether extract and crude protein on the ash-free sample by normal chemical methods and then use some conversion factors to convert ether extract and crude protein into energy values to determine indirectly the energy value of the whole body. In this instance the conversion factors of Paladines *et al.* (1964) were used, namely, 1 g E.E. = 9.405 cal, 1 g C.P. = 5.379 cal.

These two methods have been used on the same samples in the present experiment and a comparison of both methods is shown in Fig. 3. While the two methods are generally in good agreement, there is a tendency for the indirect method to overestimate the energy value of the body at high levels and underestimate at low values. The error involved appears to be related to the percentage of ether extract in the carcass as illustrated in Fig. 4.

Nitrogen Retention

Nitrogen retention per unit of N intake was considerably greater for sheep on W.C. diets than those on P.R. The

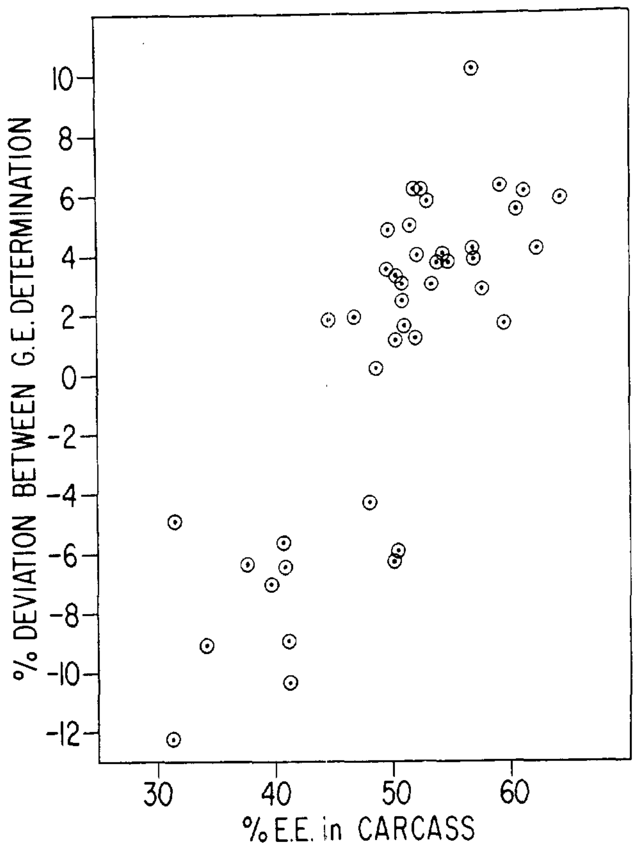

Fig. 4: Effect of percentage ether extract on the determination of gross body energy.

results obtained are given in Table 4 and Fig. 5. The regression equations relating N retention to O.M. intake were calculated as:

$$\text{W.C. } y = 18.18x - 246.2$$
$$\text{P.R. } y = 10.58x - 186.3$$

where y = g N retained/100 days,
x = g O.M.I./day/L.W. kg$^{0.75}$.

The lower N retention for sheep fed P.R. (2.67%) than for sheep fed W.C. (4.68–6.65%) was associated with both a decrease in apparent N digestibility and a slightly elevated urinary N excretion of the apparently digested N by the P.R. group.

TABLE 4: FATE OF INGESTED NITROGEN

	W.C.	P.R.	W.C.R.
Total N intake (kg N/100 days)	4.51	3.37	3.63
Faecal N output (kg N/100 days)	0.70	0.67	0.62
Urinary N output (kg N/100 days)....	3.51	2.61	2.84
N retained (kg N/100 days)	0.30	0.09	0.17
g N retained/100 g N intake	6.65	2.67	4.68

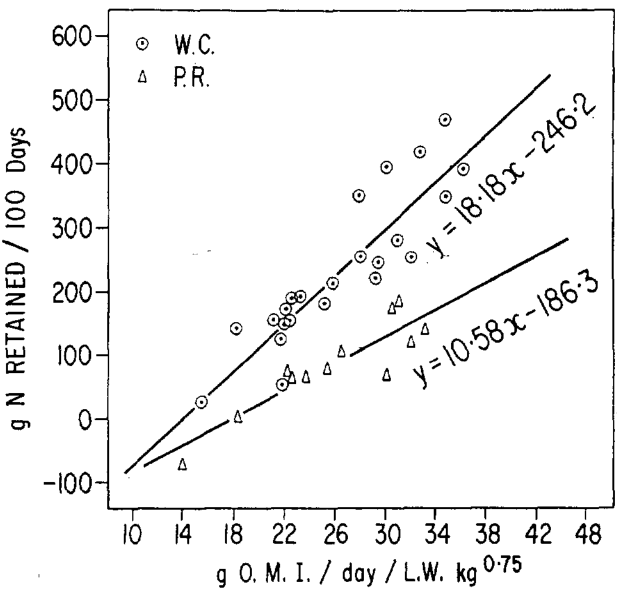

Fig. 5: Effect of level of organic matter intake of W.C. and P.R. on the amount of nitrogen retained.

DISCUSSION

The comparative slaughter technique has been used in previous studies with sheep (Garrett *et al.*, 1959; Milford and Minson 1965; Thomson, 1965). With sheep as opposed to cattle, the energy content is normally determined directly using a bomb calorimeter. For cattle, the more common procedure is to estimate the energy content of the carcass from specific gravity figures using published equations and average calorific values of fat and proteins. This technique requires only simple individual feeding facilities, cold storage, mincer, drying facilities and a bomb calorimeter. If no bomb calorimeter is available, then the use of average calorific values for fat and protein determined by chemical methods can be used, although some slight bias may be incurred which appears to be related to the amount of fat present in the carcass. The main disadvantages of the method compared with the use of respiration chambers for indirect calorimetry are:

(1) The time involved in laborious slaughter, mincing, drying and analytical procedures.
(2) The necessity of slaughtering stock.
(3) The larger number of animals needed in each experimental group.

In the experiment reported here, feeding to appetite of hoggets on fresh autumn-grown white clover resulted in greater and more efficient liveweight gains than similar hoggets fed fresh perennial ryegrass. When both pasture species were fed at a level approximating to maintenance, no difference in feeding value could be shown between the two species. These greater liveweight gains on W.C. have been reported on previous occasions (Rae *et al.*, 1963; Hight and Sinclair, 1965; Wilson, 1966; Gallagher *et al.*, 1966).

Increased animal performance on any feed type will probably be a function of two inter-related factors—the level of food intake, and the efficiency of utilization of energy in the feed.

Bailey (1964) has pointed out that, the higher the level of insoluble cell wall carbohydrates, such as hemicellulose and particularly cellulose, in a feed, then the slower will be its fermentation and rate of passage through the rumen. Thus, white clover with a hemicellulose and cellulose content only half that of the ryegrass would be expected to pass through the intestinal tract at a faster rate than perennial ryegrass. Supporting evidence is that, despite the equal or higher intakes of sheep on W.C. than P.R., intestinal tract contents at slaughter for W.C. fed sheep were only half that of those animals fed on P.R. High soluble sugars in a ration favour fermentation to propionate and butyrate in the rumen and cellulose to higher acetate production. Thus, from the chemical analysis of the two species shown earlier in Table 1, W.C. would be expected to give a lower acetate/propionate-butyrate ratio than P.R. owing to the higher cellulose content of the latter. Supporting evidence for this supposition comes from the results of Johns *et al.* (1963) in which rumen volatile fatty acid patterns of sheep grazing ryegrass swards containing a proportion of white clover compared with ryegrass alone showed the expected higher levels of propionate and butyrate and lower levels of acetate.

Infusion studies to compare the utilization of isocaloric quantities of V.F.A. mixtures (Armstrong *et al.*, 1958; Armstrong and Blaxter, 1957a, b) have suggested that mixtures containing high proportions of propionate and butyrate are utilized most efficiently for lipogenesis. Similarly, V.F.A.s given singly or as mixtures by Armstrong and Blaxter (1957b), and Armstrong *et al.* (1957, 1961) as the major source of energy to fasting sheep have shown that, despite wide variations in the ratios of the different acids, the efficiency with which they were used to meet maintenance varied little about a mean value of 85%.

In the present trial, no measurements were made of V.F.A.s and hence differences in the feeding value of W.C. and P.R. cannot be interpreted by variations in the proportions of these V.F.A.s. More research which includes these facets is needed on the feeding value of the more common pasture species under controlled conditions to determine if real differences do exist at similar stages of maturity and to what causes these differences may be ascribed.

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