
VOLUME 62 2002

PROGRESS IN DEFINING THE DIFFERENCES IN NUTRITIVE VALUE TO SHEEP OF PERENNIAL RYEGRASS, SHORT-ROTATION RYEGRASS AND WHITE CLOVER.

M. J. ULYATT

Plant Chemistry Division, DSIR, Palmerston North.

Measurements of intake and subsequent digestion of perennial ryegrass (P), short-rotation ryegrass (S) and white clover (C) were made on free-grazing sheep under conditions where there were significant differences in liveweight gain between the treatments.

The difference in animal response between P and S was attributed to differences in physical breakdown of the feed in the rumen. S which is physically weaker, and has less cellulose, was digested less in the rumen and more in the lower digestive tract than P. It is thought that the S-animals might benefit from this post-ruminal digestion. There was no difference in the intakes of P and S.

Clover contained less structural carbohydrate and had a higher ratio of readily fermentable to structural carbohydrate than the ryegrasses. This led to a more intense rumen digestion, a higher concentration of end-products of rumen digestion, and a higher intake of C than S or P.

Differences in rumen volatile fatty acid proportions between the treatments were not thought to contribute significantly to differences in animal performance.

OVER the past 12 years, the nutritive value to sheep of various ryegrass species and white clover has been studied at Palmerston North in a series of collaborative experiments between DSIR and Massey University staffs. The main findings of this work are that greater liveweight gains are produced in sheep grazing the more annual than the more perennial ryegrasses and that white clover (C) is of higher nutritive value again and when mixed with the ryegrasses improves the nutritive value of the mixture. These results have been found with different classes of stock, under various environmental conditions and at different seasons of the year (for a review see Butler *et al.*, 1968).

The finding that sheep grow faster on white clover than on ryegrass species is certainly not new; indeed this had been shown by Roberts (1931) at Aberystwyth and by Sinclair *et al.* (1956) in this country. However, the work at Palmerston North has demonstrated considerable differences between the varieties of ryegrass which are agronomically New Zealand's most important grass species. The approach has been to discover the reasons for these differences, because if the reason why sheep grow faster on short-rotation (S) than perennial ryegrass (P) can be found, a powerful tool may be discovered for increasing the nutritive value of the major pasture species based on a parameter of animal production.

Considerable progress has been made in defining the reasons for the differences between the herbage species. Johns *et al.* (1963) showed that there were differences in rumen volumes and in rumen volatile fatty acids (VFA) and they interpreted this information to mean that S and S + C pastures were fermented more rapidly, and gave end-products of ruminal digestion more favourable to liveweight gains, than P and P + C pastures. They suggested that these differences in fermentation end-products might be due to differences in the carbohydrate composition of the pasture species. Bailey (1964) then showed that there were differences in the carbohydrate composition and that P contained more cellulose and less soluble sugars than S. At the same time, Evans (1964) showed that the leaves of P were physically stronger than S and that this difference correlated well with cellulose content. It was then suggested that S is broken down in the rumen more quickly, has a faster rate of passage along the digestive tract, and thus a higher intake than P. This theory has been criticized on the grounds that it is based mainly on chemical and physical examination of the herbage and has never been substantiated by data on food intake.

In the experiment to be described (Trial X in the series), measurements of herbage intake and subsequent digestion were made with sheep grazing pure swards of P, S and C.

EXPERIMENTAL

PASTURES

Three pasture species were compared: 'Grasslands Ruanui' perennial ryegrass (P), 'Grasslands Manawa' ryegrass (formerly short-rotation ryegrass) (S), and 'Grasslands 4700' white clover (C).

Three plots, each approximately of one acre, were used for each treatment. Nitrolime was applied to the grass plots at 1 cwt per acre per month to maintain a high nitrogen status. All plots received an annual dressing of 2 cwt 30% potassic superphosphate. The aim of pasture management, as in all previous experiments, was to provide a moderate excess of herbage so that herbage availability did not limit animal intake. Excess herbage was removed when necessary with a forage harvester.

Animals

Romney Marsh wether sheep approximately one year old were used in the experiment. They were set-stocked at 12 sheep per plot. Four of these sheep on each plot were trained to wear harnesses for faeces collection. The remaining eight sheep per plot were used to provide additional data on liveweight gains. Thus there were 36 sheep per treatment, 12 of which were harnessed. In addition, sheep prepared with oesophageal fistulae were grazed on two plots per treatment for work on grazing behaviour and herbage selectivity.

Design

The sheep were allotted at random to their plots on October 6, 1967. Seven-day faeces collection periods were commenced on October 27, November 10, November 24 and December 8, 1967. At the end of the last faeces collection period (December 15, 1967) the 36 harnessed sheep were slaughtered. Throughout the experiment, the sheep were weighed at weekly intervals.

Estimation of Herbage Intake

Faeces were collected from the sheep once a day starting at 8.30 a.m. The faeces from each sheep were weighed, mixed and sampled each day. One sample was dried in a forced-draught oven at 90° C for 24 hr for dry matter determination, and an aliquot of 10% was frozen, bulked on a weekly basis, and freeze-dried for chemical analysis.

Pasture samples were hand-cut from each plot between 3.00 and 6.00 p.m. (the period of maximum grazing intensity) on the days faeces were collected. These samples were frozen, bulked on a seven-day basis, and freeze-dried for analysis. Organic matter (OM) digestibility of the freeze-dried herbage sample was determined by the method of Tilley and Terry (1963).

Slaughter Procedure

The harnessed sheep were slaughtered within one hour of removal from pasture. The rumens were dissected out, the contents weighed and samples of rumen liquor and total contents obtained. These samples were cooled in dry ice before being transported to a deep-freeze.

Analytical Methods

All samples for chemical analysis were freeze-dried in a drum freeze-drier. Carbohydrate fractions of the herbage were determined by the methods of Bailey (1964). Lignin was determined by the method of van Soest (1963). Volatile fatty acids in rumen liquor were collected by steam distillation and the individual acids separated on a Varian Aerograph gas chromatogram. Other analyses were by conventional methods.

RESULTS

The mean composition of herbage during the experiment is given in Table 1.

It confirms that the herbage available to the animals was similar to that of earlier experiments (*e.g.*, Bailey, 1964) where P was lower in soluble sugars but higher in cellulose than S, and C contained a high pectin fraction. Clover had a much higher ratio of readily fermentable to structural carbohydrate.

Data on animal performance and the intakes of various food fractions are given in Table 2.

As in previous experiments, there were significant differences in liveweight gain between all treatments in the order C > S > P. There were no differences in *in vitro* OM digestibility. OM and digestible organic matter (DOM) intakes were not statistically different between treatments, but on average there was a 6% difference between P and S and a 20% difference between P and C. A major difficulty with this type of work is that variation between animals is such that it is logistically difficult to work with enough replicates per treatment to obtain statistically significant differences between treatments. There was probably no difference between P and S but it is considered that the difference between the grasses and white clover was nutritionally significant. The intakes of cellulose, readily fermentable carbohydrate and nitrogen were statistically different between treatments. There were no significant differences in the efficiencies of utilization of DOM for

TABLE 1: MEAN CHEMICAL COMPOSITION OF THE HERBAGE (% DM)

	Readily Fermentable Carbohydrate (a)			*Structural Carbohydrate (b)*				
	Total Soluble Sugars	*Water-soluble Polysaccharides*	*Pectin*	*Hemi-cellulose*	*Cellulose*	*Lignin*	*Nitrogen*	*a/b*
P	14.13	0.94	1.61	13.21	16.39	2.86	4.04	0.56
S	16.95	1.15	1.29	12.56	13.27	2.57	4.39	0.75
C	10.21	0.91	8.77	9.13	7.48	3.10	4.54	1.20

TABLE 2: ANIMAL PERFORMANCE AND THE INTAKES OF VARIOUS FOOD FRACTIONS

	P	*S*	*C*	*S.E.*	*Correlation with Liveweight Gain*
Liveweight gain (g/day)	226	270	333	7.2***	
In vitro OM digestibility (%)	76.7	77.2	78.9	1.7	
OM intake (g/day)	1066	1118	1243	59	+ 0.66*
DOM intake (g/day)	818	868	988	46	+ 0.73*
Cellulose intake (g/day)	197	164	103	9.1***	— 0.81**
Readily fermentable carbohydrate intake (g/day)	195	241	276	12.1**	+ 0.81**
Nitrogen intake (g/day)	47	54	62	1.2***	+ 0.83**
Efficiency of gain $\left(\frac{\text{liveweight gain}}{\text{DOM intake}} \times 100\right)$	27.8	31.4	33.8	1.9	+ 0.53

$*P < 0.05$, $**P < 0.01$, $***P < 0.001$

liveweight gain. Correlations between various parameters and liveweight gain are also included in Table 2. The most notable feature is the strong negative correlation between cellulose intake and liveweight gain. The intakes of other food fractions have positive correlations, which suggests they are a function of OM intake.

Some of the data based on the slaughter period are presented in Table 3.

TABLE 3: RUMEN CHARACTERISTICS FROM THE SLAUGHTER PERIOD

	P	*S*	*C*	*S.E.*
Wet rumen contents wt (kg)	4.33	3.97	2.78	0.20**
Concentration of VFA in rumen liquor (mM/100 ml)	13.1	13.9	20.4	0.64***
Molar proportions of VFA (%):				
Acetic	60.3	59.2	57.2	0.69**
Propionic	21.4	21.9	24.4	0.53**
Butyric	14.7	15.3	15.2	0.41
Higher acids	3.7	3.8	3.8	0.18
Concentration of N as NH_3 in rumen liquor (mg/100 ml)	38.1	41.5	59.1	3.85**

$**P < 0.01$, $***P < 0.001$.

These again confirm that similar results to earlier works were obtained. The rumens of the animals fed C contained significantly less contents than those fed P or S. The animals fed C were also significantly different from those fed S or P in the ruminal concentrations of ammonia and VFA and in the molar percentages of acetic and propionic acids present in the rumen. There were no significant differences between P and S in any of the variables given in Table 3.

In Table 4 a lignin ratio technique (Ulyatt *et al.*, 1967) was used in an attempt to partition OM digestion in the digestive tract.

TABLE 4: PARTITION OF ORGANIC MATTER DIGESTION DURING PERIOD 4

	P	*S*	*C*
OM intake (g/day)	955	1003	1153
OM digested in the rumen (g/day)	628	518	770
Apparent digestibility of OM in the rumen (%)	65.5	51.8	66.7
OM passed from the rumen (g/day)	327	485	383
OM digested distal to the rumen (g/day)	83	224	115
Faecal OM output (g/day)	244	261	269
Turnover time of OM in the rumen (hr)	10.0	8.5	6.0

The figures in Table 4 are based on intake data from the last measurement period and on slaughter data. There were considerable differences in the pattern of OM digestion. There was less digestion in the rumen and a greater rate of passage beyond the rumen on S than on P and C. As a consequence, more OM appeared to be digested in the lower gut on the S treatment. In these trials it has always been considered that there must be some physiological significance in the differences observed in rumen "fill". This has been taken into account in the parameter described in Table 4 as the turnover time of OM in the rumen. This is derived by dividing the rumen OM content by OM intake and has been used extensively by Scandinavian workers (*e.g.*, Makela, 1956). It indicates the time a unit of OM stays in the rumen and thus the time a unit of OM is subject to microbial digestion. While the method is not precise, it does indicate that the OM of P stays in the rumen longer than S. The low turnover time for C, coupled with its high rumen digestibility, indicates that the digestion of C in the rumen is more intense than either of the ryegrasses.

DISCUSSION

The nutritive value of pasture species as ruminant feeds must ultimately be evaluated under field conditions. Although this approach is technically more difficult than indoor feeding, the results can at least be interpreted in direct relationship to the ecosystem in which the plants and animals perform.

The causes of the nutritional differences between P and S and between the grasses and white clover will be discussed separately.

Differences between the Ryegrass Species

The following reason for the difference between S and P is offered. It has been shown that S is physically weaker and contains less structural carbohydrate than P (Evans, 1964; Bailey, 1964). S appears to be broken down physically and passed from the rumen more quickly than P. In fact, S may be passed out of the rumen well before the micro-organisms have the opportunity to attack all its OM. To support this theory, it was possible to demonstrate a lower rumen digestibility, a quicker turnover and greater passage of OM out of the rumen of S compared with P. Conversely, the OM of P appears to be tough and difficult to reduce in particle size in the rumen. However, because the OM of P stays in the rumen longer than S, it can be digested more completely, as is shown by the higher rumen digestibility of P.

This theory is supported by recent work by Thomson *et al.* (1969) who compared the digestion of chopped and ground lucerne by sheep and found that grinding reduced the percentage digested in the rumen and increased the percentage digested in the small intestine.

Additional support comes from the work of P. S. Evans (pers. comm.) of Grasslands Division, DSIR. He has studied the anatomical composition of digesta taken from various parts of the digestive tract of sheep grazed on P and S. Significantly greater proportions of tissue particles in the rumens and caecums of sheep fed S had mesophyll cells attached to them. The mesophyll cells are the soft sappy cells containing much of the soluble cell components of the plant. It seems that higher proportions of these cells are passed to the intestines on S compared with P. Because of the greater digestion of S than P distal to the rumen, it is tempting to suggest that part of the enhanced liveweight gains on S might be due to the effects of post-ruminal digestion of protein (McDonald, 1968).

Clover Effect

The additive effect on liveweight gain of C is due to a different combination of factors than the difference between the ryegrasses. This is clearly shown in the present experiment where there were significant differences between C and the grasses in most variables. Such a result is hardly surprising considering that the nutritive value of members of two entirely different plant families are being compared.

It is considered that the superiority of C over the ryegrasses is due to its low cellulose content and to a high ratio of readily fermentable to structural carbohydrate. There appears to be a more intense fermentation and physical breakdown of C in the rumen as seen by the high concentrations of VFA and ammonia and the rapid turnover time of OM. These circumstances are thought to lead to the higher intake of OM, readily fermentable carbohydrate and nitrogen compared with the ryegrasses.

The Importance of Volatile Fatty Acids

Much comment has been made in this type of work on the nutritional significance of differences in rumen VFA concentrations and molar proportions. There is little published evidence of differences in the rumen concentrations of VFA between P and S (Johns *et al.*, 1963; McLean *et al.*, 1962; Wilson, 1966; present paper) whereas C has consistently been shown to give a higher rumen VFA concentration than the grasses (McLean *et al.*, 1962; present paper). In the work of Johns *et al.* (1963), VFA proportions were compared on the treatment extremes, P and S + C, and considerable differences were demonstrated. In the present work small differences have been shown in the molar proportions of VFAs between clover and the grasses but in common with Wilson (1966) it has not been possible to repeat the large differences of the earlier work. Johns *et al.* (1963) interpreted their results on the basis of work by Armstrong and Blaxter and their colleagues (Blaxter, 1960) as meaning that the end-products of ruminal digestion were more efficiently utilized for liveweight gain on treatments containing more clover. However, recent criticism of the results of Armstrong and Blaxter by Orskov and Allen (1966) and Bull *et al.* (1967) throws some doubt on the nutritional importance of small differences in VFA proportions. It is considered that the small differences in rumen VFA proportions found in sheep fed S, P or C in the present work are not of nutritional significance. The differences in rumen VFA concentration found between clover and the ryegrasses may be important. However, it is difficult to interpret these differences in the absence of data on rumen VFA production rates. VFA production rates in the rumens of sheep fed S, P and C have been measured using an isotope dilution technique, but the results are not yet available.

In conclusion, it must be stressed that it is very important to understand fully the causes of differences in nutritive value of the common pasture species in New Zealand. This knowledge can be used to breed pasture plants of higher nutritive value and to develop pasture management techniques to produce herbage of optimum nutritive value and thus give rise to increase in animal productivity per acre.

ACKNOWLEDGEMENTS

The author acknowledges the skilled technical assistance of P. Vlieg, I. D. Shelton, M. R. Whitcomb, A. S. D. King and Mrs M. A. Th. Edmonds and her analytical group. The advice and criticism of Drs C. S. W. Reid and R. W. Bailey and L. A. Thomas are gratefully acknowledged.

REFERENCES

Bailey, R. W., 1964: *N.Z. Jl agric. Res.*, *7*: 496.
Blaxter, K. L., 1960: In *Digestive Physiology and Nutrition of the Ruminant*. Ed. D. Lewis. Butterworths, London. p. 183.
Bull, L. S.; Johnson, D. E.; Reid, J. T., 1967: *Cornell Nutr. Conf.*, p. 83.
Butler, G. W.; Rae, A. L.; Bailey, R. W., 1968: *N.Z. agric. Sci.*, *3*: 8.
Evans, P. S., 1964: *N.Z. Jl agric. Res.*, *7*: 508.
Johns, A. T.; Ulyatt, M. J.; Glenday, A. C., 1963: *J. agric. Sci. Camb.*, *61*: 201.
McDonald, I. W., 1968: *Aust. vet. J.*, *44*: 145.
McLean, J. W.; Thomson, G. G.; Iversen, C. E.; Jagusch, K. T.; Lawson, B. M., 1962: *Proc. N.Z. Grassld Ass. Conf.*, *24*: 57.
Makela, A., 1956: *Acta agralia fennica*, *85*: 1.
Orskov, E. R.; Allen, D. M., 1966: *Br. J. Nutr.*, *20*: 519.
Roberts, E. J., 1931: *Welsh J. Agric.*, *7*: 187.
Sinclair, D. P.; Clarke, A. E.; Filmer, D. B., 1956: *Proc. N.Z. Soc. Anim. Prod.*, *16*: 23.
Thomson, D. J.; Beever, D.; da Silva, J. F. C.; Armstrong, D. G., 1969: *Proc. Nutr. Soc.*, *28*: 24A.
Tilley, J. M. A.; Terry, R. A., 1963: *J. Br. Grassld Soc.*, *18*: 104.
Ulyatt, M. J.; Blaxter, K. L.; McDonald, I., 1967: *Anim. Prod.*, *9*: 463.
van Soest, P. J., 1963: *J. Ass. off. agric. Chem.*, *46*: 829.
Wilson, G. F., 1966: *N.Z. Jl agric. Res.*, *9*: 1053.