NUTRITION OF GRAZING CATTLE

1. Estimation of Protein in Pasture Selected by Grazing Cattle

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SUMMARY

A technique for sampling pasture which is representative of pasture selected by grazing cattle is described.

Linear regressions of protein percentage in pasture sampled by this technique on protein percentage in organic-matter faeces are developed for six pasture types.

A logarithmic regression is fitted to data from all six pasture types. Data derived from this regression agree satisfactorily with similar data calculated from published digestibility trials on pasture grasses.

Based on the protein content in organic-matter faeces, the regression equations allow an assessment of the protein content of the pastures selected by grazing cattle.

I. INTRODUCTION

Raymond, Kemp, Kemp, and Harris (1954) discussed the difficulty in obtaining samples representative of pasture selectively grazed. During the course of digestibility studies in which samples of herbage similar to that actually grazed were required, these workers suggested that the composition of faeces produced by grazing stock might be used as an indirect measure of the composition of the herbage grazed. They showed a relationship between the nitrogen content of herbage grazed and that of the resulting faeces.

The object of the investigations reported in the present paper was to examine the relationship between protein content of pastures selected by grazing cattle and protein content of the resulting faeces.

II. EXPERIMENTAL

(a) Area Investigated

Seventy-four dairy properties were examined. These were located in south-eastern Queensland in an area extending 60 miles north and south and 30 miles west of Brisbane. Only those farms on which unimproved pasture was the only feed available were considered in this study. The farms ranged in size from 50 to 400 ac.

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(b) Methods of Sampling

(i) Pasture Sampling

The aim was to obtain grass samples considered to be representative of the diets selected by grazing cattle.

Paddocks to which the herd had access during the four days prior to investigation were sampled. Within paddocks, areas of pasture of at least half an acre obviously different from the remainder of the paddock were considered separately. This procedure ensured that all pasture species grazed could be represented in the sample.

In sampling, sub-samples were taken from adjacent ungrazed grasses at the height to which the same species at a similar stage of growth had been cropped. At each point the area of sampling was 9 sq. in. All sub-samples from the one farm were bulked for analysis.

The distance traversed when sampling in small paddocks was 50 yd for each acre. One sub-sample was taken within every 10 yd but only if there were obvious signs of grazing within that length. In large paddocks the distance traversed was 5 yd for each acre. One sub-sample was taken within every yard but only if there were obvious signs of grazing within the yard length. One typical sub-sample was taken in areas of less than half an acre.

On each farm at each sampling the pasture was composed predominantly of one grass species, except in the case of forest grass, which was a mixture of a number of species usually referred to as "forest grass". The pastures are classified into six types according to the species predominant in the selected diet. These species were:—

A Narrow-leaf carpet grass (*Axonopus affinis*)

C Blue couch grass (*Digitaria didactyla*)

F Forest grasses

Forest blue grass (*Bothriochloa intermedia*)
Pitted blue grass (*Bothriochloa decipiens*)
Kangaroo grass (*Themeda australis*)
Wire grasses (*Aristida* spp.)
Bunch spear grass (*Heteropogon contortus*)

R Rhodes grass (*Chloris gayana*)

P Paspalum (*Paspalum dilatatum*)

K Kikuyu grass (*Pennisetum clandestinum*)

(ii) Sampling of Faeces

As the number of faecal sub-samples within each herd must be sufficient to equalize differences in metabolism of protein and selective grazing habits of individual cows, the number of sub-samples required to give a sample representative of the total faeces from each herd was first determined. For this determination faecal samples were taken from two groups of 10 cows in each of 20 herds. From each group bulked samples comprising 150 g wet-weight faeces from each cow were analysed for protein and ash. The standard error of means of percentage protein in faeces expressed on an organic-matter basis for samples representing 10 and 20 animals are:—

—	D.F.	S.S.	M.S.
Between farms	19	83·50	4·395
Between duplicates	20	2·08	0·104

Whence the standard error of the means for 10 samples = 0·32 per cent. protein; and the standard error of the means for 20 samples = 0·23 per cent. protein.

Comparisons were made between the protein content of bulked faecal samples comprising 150 g wet-weight faeces from individual cows and the protein content of samples taken from freshly voided faeces in the field. Agreement was satisfactory. In the latter procedure about 25 g wet-weight faeces were taken from at least 10 and preferably from 20 faecal pads and the samples from each herd were bulked for analysis. This procedure was subsequently adopted in this study.

(c) Methods of Analysis

Samples were oven-dried at 100°C and milled.

Ash was determined gravimetrically on 2 g aliquots ashed at 600°C for 1 hr.

The method of analysis for protein was essentially that of the Association of Official Agricultural Chemists (1950) with a modification of the catalysts used in digestion. About 10 mg each of copper sulphate and selenium were used.

In 74 pasture samples examined, the mean ash content was 9·2 per cent. ash and the range 6·8 to 11·9 per cent. In the 74 resulting faecal samples the mean ash content was 17·5 per cent. ash and the range 11·5 to 25·8 per cent. The variations in ash contents of the pasture and faecal samples are sufficiently wide to introduce errors in the study of the relationship between protein percentage in pasture and in faeces, expressed on a dry-matter rather than on an organic-matter basis. However, as the nutritive values of feeds are usually compared on a dry-matter basis, this method of expression was used in calculating protein percentage in pastures. Errors due to variation in ash content of faeces were eliminated by expressing protein in faeces on an organic-matter basis.

III. RESULTS

(a) Relationship Between Protein in Pasture and in Faeces

Percentages of protein in dry-matter pasture and in organic-matter faeces are plotted in Figure 1. From inspection of the distribution of variates in Figure 1, linear regression appears to adequately fit the data.

Details of statistical analyses of data from the six pasture types represented in Figure 1 are given in Table 1.

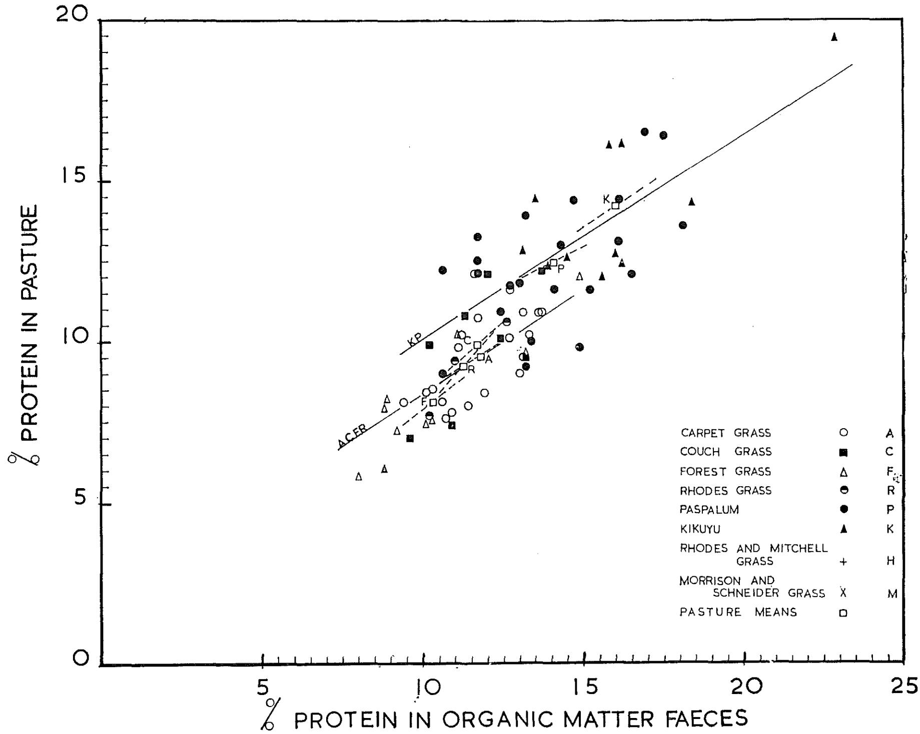

Fig. 1.—Relationship between protein in dry-matter pasture and in organic-matter faeces. Linear fitting to data from this study.

Although faecal protein content is obviously biologically dependent on feed it has been treated statistically in Table 1 as the independent variable. This is because faeces are almost certainly less affected by sampling errors than are pastures. There is no evidence of heterogeneity among the six residual mean squares (X^2 for 5 D.F. : 6·1 corresponding to a probability of about 0·3) or among the slopes of the six regression lines:—

—	D.F.	M.S.
Average regression	1	110·141
Among regressions	5	0·746
Residual	62	1·985

However, there are significant differences among the pasture means:—

—	D.F.	M.S.
Among pastures (adjusted for regression)	5	6·002 ($P < 0·05$)
	67	1·893

Adjusted means—

A	10·21
C	10·64
F	9·79
R	10·24
P	11·67
K	12·18

There are no significant differences within the brackets but highly significant differences between the two bracketed groups.

From the above analyses, it appears that the appropriate estimating equation must include an adjustment at least for the two groupings, if not for each of the six pastures. These estimating equations take the form:

$$y = 1 \cdot 9 + 0 \cdot 64 \text{ x} \pm 1 \cdot 4 \text{ (for pastures A, C, F, R)}$$

$$y = 3 \cdot 6 + 0 \cdot 64 \text{ x} \pm 1 \cdot 4 \text{ (for pastures P, K)}$$

The differences among pasture means may represent not real differences among pastures but rather errors in sampling. If this is so, the slope of the line is unaffected but choice of the y intercept value would have to be arbitrary.

TABLE 1

Statistical Analysis of the Relationship between Protein in Dry-matter Pasture and in Organic-matter Faeces

Predominant Grass in Diet	No. of Samples	Mean of y's* (%)	Mean of x's† (%)	Regression Coefficient	Residual Mean Square
Carpet (A) ..	20	9·54	11·81	0·682	1·2120
Couch (C) ..	8	9·88	11·66	0·877	2·4690
Forest (F) ..	10	8·17	10·33	0·785	0·8857
Rhodes (R) ..	3	9·23	11·27	1·143	0·3459
Paspalum (P) ..	22	12·43	14·03	0·531	2·8827
Kikuyu (K) ..	11	14·20	16·00	0·628	2·3765
Within grass types				0·642	1·8930

* y = Protein percentage in pasture.

† x = Protein percentage in organic-matter faeces.

(b) Extrapolation and Comparison with Published Data

Digestibility data derived on Rhodes grass and Mitchell grass of low protein content (Harvey 1952) and on green pastures of moderate to high protein contents (Morrison 1937; Schneider 1947) were also used in deriving the relationship between protein in pasture and in organic-matter faeces. Percentages of protein in dry-matter pasture and in organic-matter faeces, together with similar data calculated from published trials, are given in Figure 2.

Comparison of linear fitting to the three groups of data (Morrison and Schneider, Harvey and this study) is shown in Table 2.

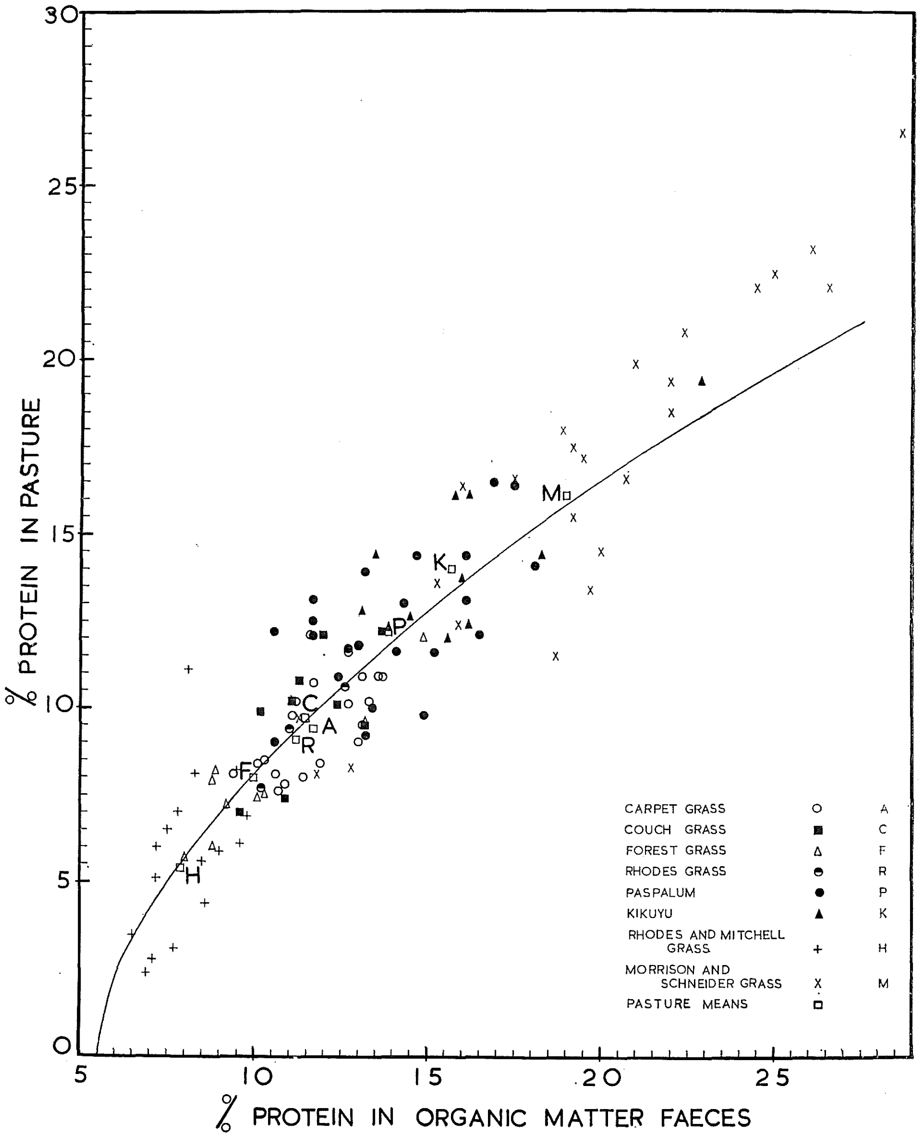

Fig. 2.—Relationship between protein in dry-matter pasture and in organic-matter faeces. Logarithmic fitting to data from this study and from published digestibility data.

TABLE 2

Comparison of Linear Fitting to Data from Morrison and Schneider, Harvey and this Study

Data from	No. of Samples	Mean of y's	Mean of x's	Regression Coefficient	Residual Mean Square
Morrison, Schneider ..	24	16·84	19·78	0·984	3·40
Harvey	16	5·79	8·08	1·089	4·26
This study (within pastures)	..	..	..	0·642	1·89

The differences among the three residual mean squares approach the 5 per cent. level of significance (X^2 for 2 D.F. : 5·7) and the slopes are significantly different at the 5 per cent. level:—

—	D.F.	M.S.
Average regression	1	568·601
Among regressions	2	10·405
Residual	103	2·535

From inspection of Figure 2 it appears that all data are related logarithmically. At zero protein intake a curve relating protein in pasture and in faeces would intersect the abscissa at a point equivalent to metabolic faecal protein. Blaxter and Mitchell (1948) found that metabolic faecal nitrogen was 0·5 g nitrogen per 100 g dry-matter intake.

To convert metabolic nitrogen to a percentage in organic-matter faeces requires a knowledge of the dry-matter digestibility of the pasture and the organic matter content of faeces. From examination of data presented by Harvey (1952) on Rhodes grass and Mitchell grass of negligible protein content, the dry-matter digestibility at a hypothetical zero protein level in pasture would be of the order of 30 per cent. On the basis of 82 per cent. organic matter in faeces, metabolic faecal protein would be equivalent to about 5·5 per cent. protein.

A logarithmic curve of the form $\log y = a + b \log (x - 5{\cdot}5)$ is therefore indicated as appropriate to the data. Statistical analyses of this form fitted to the data derived from six pasture types in south-eastern Queensland are given in Tables 3 and 4.

TABLE 3

Logarithmic Fitting to Six Pasture Types

Pasture Type	No. of Samples	Mean log y	Mean log (x – 5·5)	Regression Coefficient	Residual Mean Square	Mean y	Mean x
A	20	0·975	0·791	0·445	0·002418	9·44	11·68
C	8	0·987	0·779	0·581	0·005007	9·71	11·51
F	10	0·902	0·649	0·487	0·002638	7·98	9·96
R	3	0·961	0·754	0·747	0·000765	9·12	11·18
P	22	1·089	0·917	0·325	0·003866	12·26	13·76
K	11	1·148	1·010	0·448	0·002398	14·05	15·72
Within pasture types				0·439	0·003010	..	..

TABLE 4

Components of Variance and Co-variance for Among, Within and Among plus Within Pasture Types

—	Components of Variance and Co-variance		
	log y	Co-variance	log (x − 5·5)
Among	0·007791	0·010787	0·014532
Within	0·005576	0·005943	0·013531
Among + Within ..	0·013368	0·016730	0·028064

From these data the regression estimate from the among plus within line is calculated as—

$$\log y = 0 \cdot 52349 + 0 \cdot 59614 \log (x - 5 \cdot 5)$$

$$\text{i.e. } y = 3 \cdot 34 \ (x - 5 \cdot 5)^{0 \cdot 60}$$

Variations about this line can be ascribed to two independent sources:—

(1) Variation among pasture types (either real differences or sampling errors).

(2) Variation among samples of the same pasture type.

It is difficult to attach a standard error of estimate to this relationship. In particular, the "among pasture" components are not well determined from only six pasture types. However, it appears that this line fits the data at least as well as the linear regression. In Figure 3 is shown the distribution of variates about the line resulting from plotting values on logarithmic paper.

Results of the logarithmic fitting to the data recorded in the literature are given in Table 5.

TABLE 5

Results of Logarithmic Fitting to Data from Morrison and Schneider and Harvey

Data	No. of Samples	Mean log y	Mean log (x − 5·5)	Regression Coefficient	Residual Mean Square	Mean y	Mean x
Morrison, Schneider ..	24	1·207	1·129	0·800	0·003199	16·10	18·9
Harvey ..	16	0·729	0·377	0·599	0·023281	5·36	7·8

The residual mean squares for data of Morrison and Schneider on this transformed scale are close to the "within pastures" residual mean square of Table 3. The residual mean squares for data of Harvey are much higher than the residual mean squares in Table 3, as is to be expected at the lower end of the logarithmic curve.

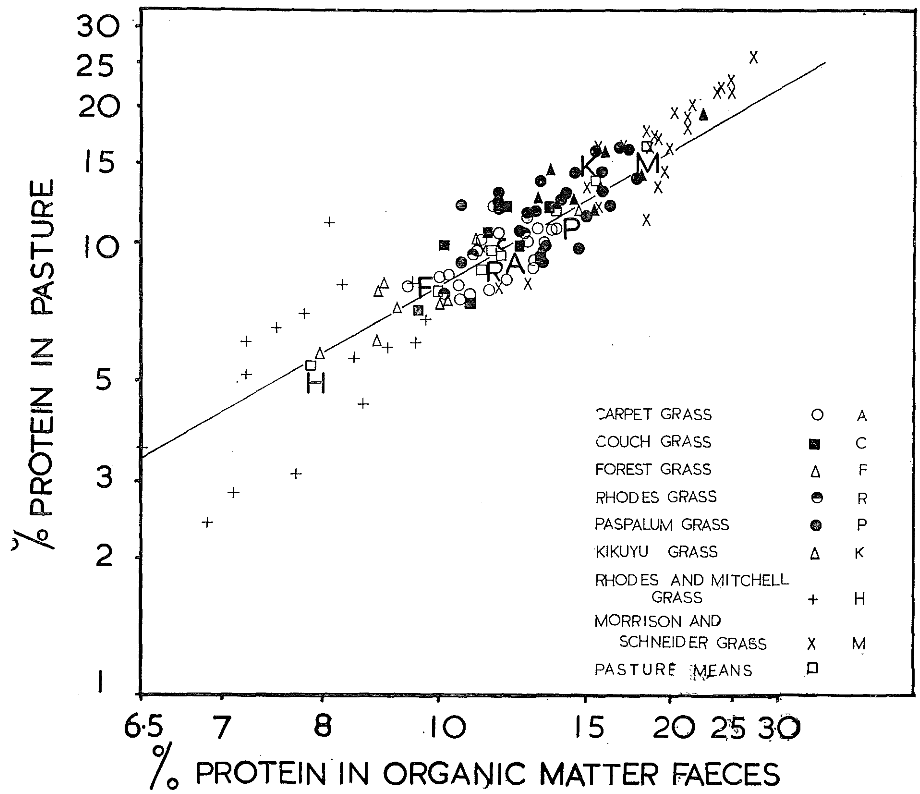

Fig. 3.—Relationship between protein in dry-matter pasture and in organic-matter faeces. Logarithmic fitting to data from this study and from published digestibility data. Plotted on log paper.

TABLE 6

Comparison of Apparent Protein Digestibilities

Protein in Pasture Dry-matter (%)	Apparent Protein Digestibility (%)		
	This Study	Mitchell	Glover *et al.*
25	80·4	81·2	83·5
20	76·7	76·3	76·8
15	71·1	70·0	68·1
10	61·5	60·3	55·8
5	35·1	0	34·8

Percentages of protein in pasture and in faeces may be used to calculate apparent protein digestibility when the feed-to-faeces ratio is known. Lancaster (1954) derived an equation for estimating the feed-to-faeces ratio on an organic-matter basis from protein percentage in organic-matter faeces. Using the Lancaster estimating equation as a functional relationship to derive the feed-to-faeces ratio from faecal protein and the logarithmic curve of this study relating pasture and faecal protein as a functional relationship, together with correction for an average ash content of 9·0 per cent. ash in pasture, the apparent protein digestibilities at various levels of protein in pasture were calculated. These apparent protein digestibilities are compared in Table 6 with those calculated from equations relating apparent protein digestibility to protein percentage in forage derived by Mitchell (1942) and Glover, Duthie, and French (1957). These equations are:—

$$y = 42\cdot64\ (x - 5)^{0\cdot2148}\ \text{(Mitchell)}$$

$$\text{and } y = 69\cdot7 \log x - 13\cdot9\ \text{(Glover \textit{et al.})}$$

IV. DISCUSSION

Percentages of protein in the pasture species predominant in the diets of cattle in south-eastern Queensland and percentages of protein in pasture grasses recorded in the literature are similarly related to the percentages of protein in the resulting organic matter faeces by a logarithmic curve. Estimates of protein in pasture over the more linear range of the logarithmic curve derived in this paper agree within 7 per cent. of the percentage protein estimated from the linear regression equation derived by Raymond *et al.* (1954) on grasses used in digestion trials.

In Table 6 there is good agreement of estimates of apparent protein digestibilities betwen those derived in this study and those derived by Mitchell for protein levels between 10 and 25 per cent. protein, and fair agreement with those derived by Glover *et al.* over the whole range of protein levels in pasture. The generally satisfactory agreement supports the validity of the logarithmic curve derived in this study and the Lancaster estimating equation in a broad overall application.

The linear regressions developed for six pasture types in south-eastern Queensland could be used to estimate the order of magnitude of protein percentage in these pastures within the range of protein values of the 74 samples. With other pasture types or towards or outside the limits of these protein values for these pasture types, the logarithmic curve would be preferred.

The uniform distribution of varieties found in this investigation for many different pastures supports the validity of the sampling technique in its overall application.

V. ACKNOWLEDGEMENTS

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