A sampling strategy for estimating dairy pasture quality

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ABSTRACT

Rapid determination of pasture quality using near infrared reflectance spectroscopy (NIRS) makes it feasible for farmers to incorporate forage composition in feed budgeting and feed supplementation decisions for grazing animals. In grazed pastures, heterogeneity in the distribution of the mass and quality, necessitates a sampling strategy to accurately predict the diet. A single paddock was systematically sampled by selecting 60 sites according to a pre-determined grid. At 12 of these sites, 4 separate but adjacent samples of 150 x 150 mm were taken from within a 300 x 300 mm quadrat. To characterise vertical heterogeneity, the herbage at each of the 60 sites was cut sequentially into 4 equal strata, the depth of each being one-quarter of the canopy surface height at that site. These samples were used to derive a statistically-based 3-dimensional characterisation of variability of herbage mass and of several parameters of herbage quality determined using NIRS. This description was used to calculate the number of samples necessary to estimate parameters to arbitary, pre-determined levels of accuracy of ± 50 kg DM/ha for herbage mass in each stratum, ± 50 g/kg protein (PROT), acid detergent and neutral detergent fibre (ADF; NDF), ± 20 g/kg for soluble carbohydrate (CARB), ± 25 g/kg for *in-vitro* dry matter digestibility (DIG) and ± 0.5 MJ/kg for metabolizable energy (ME). A minimum of six samples bulked together is necessary to estimate PROT, CARB, NDF and ADF to the specified level of accuracy, and this number was similar for each stratum. Twelve samples are required to estimate ME and DIG for each of the 3 upper strata, but in the lowest stratum with greater variability, 48 and 19 samples would be required for ME and DIG, respectively, to reach the same accuracy. A sampling strategy should take the suggested number of samples by systematically covering the paddock area. Uncertainty in the depth of sampling because of the necessity to sample before grazing has little effect on the number of samples required or on the accuracy of estimates, providing the lowest stratum is not penetrated during either sampling or grazing.

Keywords: dairy-pasture quality; sampling; spatial variability; diet quality.

INTRODUCTION

Rapid analysis using near infrared reflectance spectroscopy (NIRS) makes it practical to incorporate pasture quality into decisions on feed allocation to grazing livestock (Parker *et al*., 1995; Parker & Ulyatt, 1996). For such data to be of value, the sample analysed must be representative of the pasture eaten. Selective grazing, and the consumption by livestock of only a proportion of the feed available at a single grazing, mean that the diet eaten differs from the pasture as a whole. To predict the quality of the diet, the pasture sample has to represent the spatial heterogeneity arising from previous defoliations, dung and urine deposition, variation in species composition, and the anticipated level of utilisation. The natural structure of pasture canopies adds a vertical component to this variation, with changes in the leaf, stem and dead proportions with depth through the canopy. As level of utilisation increases and residual height of pasture remaining after grazing decreases, the increasing proportion of old and senescing leaf and stem consumed reduces diet quality (Cosgrove *et al*., 1994). We know of no studies of variability in pasture quality for grazed swards, although sampling method has been reported for homogeneous forage-corn (Cherney *et al*., 1996).

The objective was to describe the spatial and vertical variation within a single paddock in autumn, and from this develop a protocol for taking samples from dairy pastures to predict diet quality.

MATERIALS AND METHODS

Pasture: A single, relatively flat paddock on Massey No. 4 dairy farm (paddock 38) was sampled in May 1996 on the day before grazing. It had last been grazed about 30 days before sampling.

Sampling: Five, equally spaced rows within the paddock were defined and twelve pegs, equally spaced along each row were numbered 1-60. Twelve of these 60 sites were randomly identified for intensive sampling (see below). At each site the canopy surface height was measured and using a 300 x 300 mm quadrat, four strata, the depth of each being one-quarter of the canopy height, were cut in sequence, with the lowest stratum being cut at ground level.

Intensive multi-site samples: At each of the 12 multi-sites, the four strata were taken from 150 x 150 mm subquadrats within the 300 x 300 mm main quadrat. This was done to provide data on small-scale variation within 150 x 150 mm, an area approximating that of a hand grab-sample.

Sample handling: Each sample was dried at 40°C for 40 hrs to determine dry weight within strata at each site or sub-site. These samples were ground to pass a 1-mm sieve and analysed within one week. Samples from the lowest

stratum, cut at ground level, were washed to remove soil contamination, and all samples were processed and put into the oven within 3 hours of cutting.

NIRS analyses: Many of the samples for analysis were smaller than the standard requirement of approximately 2 g and for these small samples an insert for the sample holder was used which allowed analyses of samples down to 0.5 g. A global pasture calibration, developed from New Zealand pasture samples, was used to predict protein, acid and neutral detergent fibre (ADF and NDF), soluble carbohydrate, *in-vitro* dry matter digestibility and metabolizable energy (ME) for both large and small samples, after determining a separate small-sample calibration was not required.

Data handling and statistical analysis: From the 240 samples obtained (60 sites x 4 strata), a 3-dimensional description of the herbage mass and quality was prepared. Subjectively, this was used to identify any gradients within the paddock in herbage mass or quality parameters. From this data set, standard deviation and coefficient of variation were determined and used to calculate the number of samples necessary to estimate means to pre-determined levels of accuracy. These limits were set arbitrarily as ± 50 kg DM/ha for herbage mass in each stratum, ± 50 g/kg for protein, NDF and ADF, ± 25 g/kg for *in-vitro* digestibility, and ± 0.5 MJ/kg for ME.

From the subset of 192 samples (12 multi-sites x 4 quadrats x 4 strata) standard deviation of the four samples at each multi-site was determined and used to identify any patterns across the paddock in localised variability. This localised variability was compared with whole-paddock variability to examine the relative importance of the two sources of variation.

FIGURE 1: Estimates of herbage mass (a) and metabolizable energy (b) in four strata (top = 1, bottom = 4) at 60 sample-sites in a single paddock. Vertical axis units are herbage mass in tonnes DM/ha (a1-a4), and metabolisable energy in MJ/kg DM (b1-b4). Horizontal axes are cell references for location of the 60 samples sites in the paddock. Herbage mass and metabolisable energy are presented as examples of parameters estimated with high and low variability, respectively.

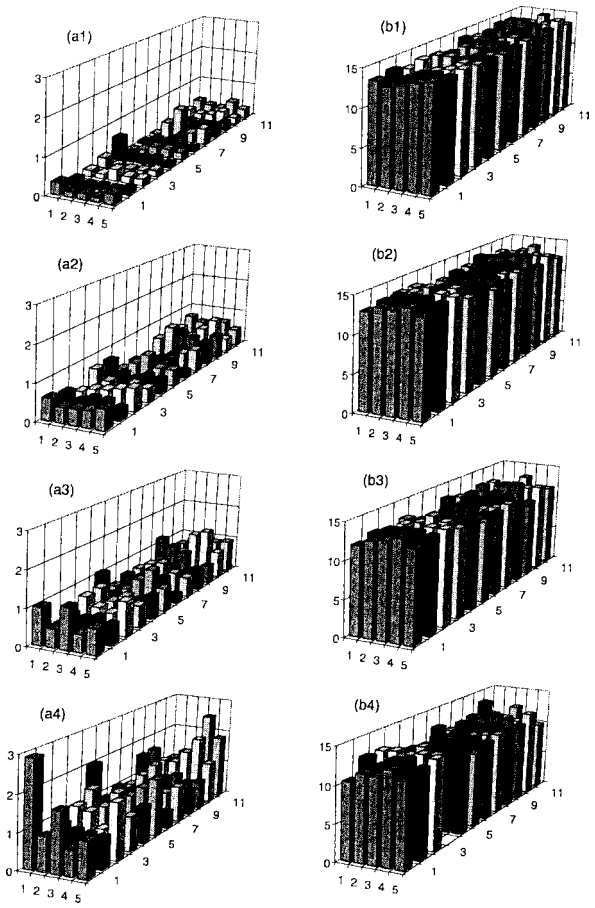
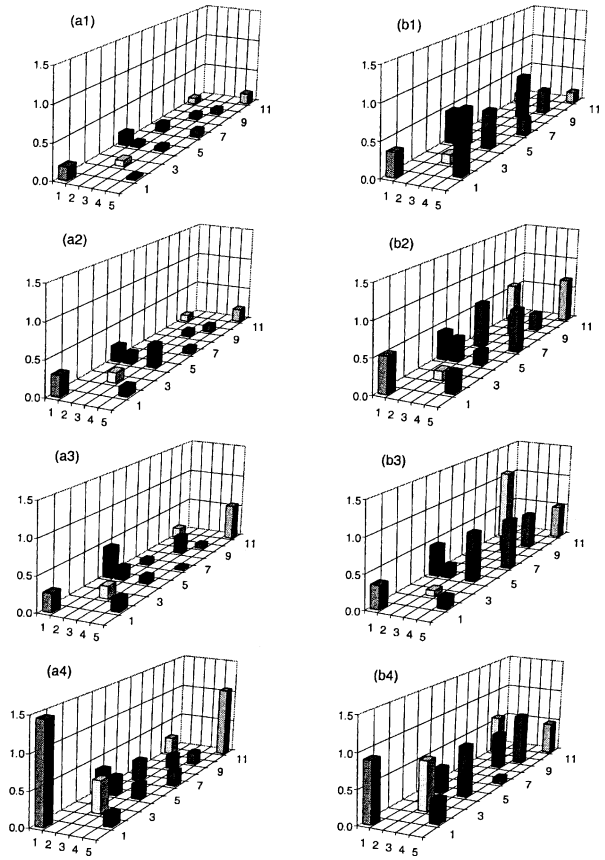


FIGURE 2: Standard deviations of estimates of herbage mass (a) and metabolisable energy (b) in four strata (top = 1, bottom = 4) at 12 multi-sites. Vertical axis is the standard deviation of estimates in units of tonnes DM/ha and MJ/kg DM, for herbage mass (a1-a4) and metabolisable energy (b1-b4). Horizontal axes are as for Figure 1. Herbage mass and metabolisable energy are presented as examples of parameters estimated with high and low variability, respectively.



RESULTS

Sample-site estimates of herbage mass, and one parameter of quality (metabolizable energy) showed no gradients in these parameters across the paddock (Fig 1). Although standard deviation differed among multi-sites there was no indication of any pattern to this localised variation (Fig 2). Similarly, even among strata within a multi-site there was no vertical pattern to standard deviations (Fig 2).

Variability (standard deviation) for all parameters of quality was less than that for herbage mass in each strata

(Table 1). Among the different parameters of quality, those for ME and *in-vitro* digestibility were estimated with greater variability than those for protein, fibre and soluble carbohydrate. For fibre, only NDF concentrations are presented in Table 1. Concentrations of ADF were higher, but variabilty of estimates was similar to those for NDF.

The mean and variability of estimates for herbage mass increased from the top to the lowest strata (Table 1). In contrast, for estimates of quality there was less change with increasing depth of stratum, and only for ME and *in-vitro* digestibility was there any marked increase in variability. There was a five-fold increase in herbage mass from the top to the lowest stratum whereas the concentration of soluble carbohydrate, the parameter of quality most sensitive to vertical distribution, changed by a factor of only 2 between the upper and lowest stratum.

For all estimates of quality, among-site (whole paddock) variability was greater than within-site variability (Table 1). For herbage mass estimates, variability was high at both scales, and only in the top stratum was variability within-sites less than that among sites.

The number of samples required to estimate mean values for protein, soluble carbohydrate and fibre to within the specified level of accuracy was 6 and this did not change with stratum. Twelve samples would be required to estimate ME and *in-vitro* digestibility, in each of the 3 upper strata, but in the lowest stratum, 48 and 19 samples were required to reach the same level of accuracy for ME and digestibility, respectively. The greater variability associated with estimates of herbage mass required much larger numbers of samples, ranging from 36 in the top stratum to 319 in the lowest stratum.

TABLE 1: Whole-paddock and multi-site variability for estimates of several parameters of forage quality, and of herbage mass.

Item	Stratum	Mean	Whole-paddock Std Dev[1]	Multi-site Std Dev[1]	Prob.[2]	No. of samples required[3]
Protein	1	31.25	3.31	1.72	.0000	5
(%)	2	29.08	2.73	1.59	.0004	5
	3	24.96	3.06	2.21	.0189	5
	4	20.45	3.47	1.84	.0000	5
Neutral	1	37.77	2.81	1.81	.0029	5
Detergent	2	40.46	3.91	1.77	.0000	6
Fibre (%)	3	45.33	4.63	2.49	.0001	6
	4	50.93	4.43	2.61	.0005	5
Soluble	1	9.66	1.91	0.86	.0000	6
Carbohydrate	2	8.28	2.08	0.68	.0000	6
(%)	3	5.97	1.55	0.87	.0002	6
	4	4.27	1.30	0.88	.0067	5
Metabolisable	1	13.47	0.57	0.40	.0112	7
Energy	2	13.21	0.59	0.46	.0551	7
(MJ/kg DM)	3	12.40	0.72	0.50	.0116	10
	4	11.46	1.73	0.53	.0000	48
Digestibility	1	89.78	3.61	2.62	.0208	10
(%)	2	86.38	3.75	2.94	.0591	11
	3	81.60	4.00	2.97	.0289	12
	4	77.13	5.34	3.35	.0018	19
Herbage	1	212	150	110	.0237	36
Mass	2	492	194	169	NS	59
(kg DM/ha)	3	706	236	255	NS	87
	4	1152	455	577	NS	319

[1] Std Dev = Standard deviation of estimates based on samples from the whole paddock, and on samples from within multi-sites.

[2] Prob = Probability of a difference between whole-paddock and multi-site standard deviations. Probability less than 0.05 means whole-paddock variability is greater than within site variability.

[3] Number of samples required to estimate means to levels of accuracy as defined in Materials and Methods.

DISCUSSION

Sampling to represent an animal's diet has to account for two sources of variability: horizontal due to the areas in the paddock where animals choose to, or not to graze from, and vertical due to the depth to which an animal bites and, therefore, the proportion the canopy profile that it harvests. The paddock selected was typical in size for a large-herd dairy farm. It was relatively long and narrow, flat, and had no unusual slope or aspect characteristics. Visually, there were no gradients in fertility, species composition or herbage mass. For this paddock, horizontal variability increased with distance (ie localised vs whole-paddock variability) and to obtain a representative sample for estimating parameters of quality, sub-samples should be taken systematically covering the whole area. Although not the main purpose of this study, variability in herbage mass was so great that sampling only locally was little worse than sampling the whole paddock The most important point for obtaining accurate estimates of herbage mass was the very large number of samples required.

The most useful single parameter of quality for on-farm use is likely to be ME because for animals grazing forage this is usually the first limiting factor. For estimating ME to within ± 0.5 MJ/kg and *in-vitro* digestibility to within ± 25 g/kg, 12 samples are necessary, although only 6 would be required for estimates of protein and fibre to ± 50 g/kg or soluble carbohydrate to ± 20 g/kg. This lower number of samples required is probably related to the relatively specific nature of the entities being assesed. For protein, fibre, and digestibility, the number of samples required is much greater than estimated by Cherney *et al*., (1996) for the same precision, reflecting the large variability in grazed, mixed-species pasture compared with forage corn. While the estimates, for this trial, of the number of samples required is likely to apply for similar paddocks, particular features of another paddock may necessitate more intensive sampling. For example, paddocks with fertility gradients, moisture gradients, slope, aspect or contour variation, particularly if these cause variation in plant-species or morphological composition, are likely to require greater numbers of samples. The most efficient way to account for this additional source of variation is to stratify the paddock into the appropriate sub-areas and sample these. An average, weighted by area, would then give an overall estimate of quality. Such stratification improves the prediction of cattle diet quality from pluck samples taken in heterogeneous rangelands (De Vries, 1995).

Quality generally decreases with depth through the canopy profile, associated with a decreasing proportion of leaf, and an increasing proportion of stem and pseudostem, and senescing and dead material. The herbage in this paddock accumulated during April and May and did not contain any reproductive stem, and had a high proportion of green leaf. As a result there was only a relatively small decrease in quality with depth through the profile and even herbage in the lowest stratum, with an ME concentration of 11.5 MJ/kg DM and in-vitro digestibility of 771 g/kg DM is good quality. With a shallow gradient in quality with depth, the importance of correctly simulating biting depth is correspondingly reduced. This is important because, by definition, sampling has to be done before grazing, requiring an estimate of likely grazing depth. The top 3 strata included 55% of the total herbage DM above ground level and it is unlikely that milking cows would be forced to achieve higher levels of utilisation at a single grazing than this.

The number of samples required for the various estimates are dependent in part on the arbitrarily-defined levels of accuracy required. As the required accuracy increases, so does sample number. The levels of accuracy were choosen as the limits of tolerance which would result in the same feed allocation decisions being made. It is assumed that estimates outside of these limits would result in incorrect nutrient allocation and would not be good enough for a quality-based feeding programme for lactating animals.

The scope of inference for these results is limited to paddocks similar to the one sampled and to the season in which sampling was conducted. Seasonal variation in pasture composition and structure is likely to result in paddocks with different vertical and horizontal heterogeneity, which may influence the number of samples required. Separate protocols will be needed to incorporate paddock to paddock, and temporal variation (eg Wilson *et al*., 1995) in longer-term nutrient allocation and intake.

In addition to spatial variability effects on sampling accuracy, there are other sources of error which affect the prediction of animal output from feed quality. Estimates based on NIRS have errors associated, firstly with the wet-chemistry derived values used in the calibration set to relate spectral data with known chemical composition, and secondly in using this calibration to predict chemical composition for an open population of unknown samples (Marten *et al*., 1989). Feed-budgeting needs to take account of both quantity of feed as well as its quality. There are large errrors associated with estimating feed quantity, and these become even larger for predicting the intake of grazing animals because of variable and unpredictable levels of utilisation.

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