

Estimating forage intake and quality in grazing cattle: A reconsideration of the hand-plucking method

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Abstract

The hand-plucking method for estimation of bite size and nutritive quality was tested for steers grazing at low stocking rates on heathland and in riverine grassland. Vegetation height, standing crop, and cover of distinct plant categories were determined in 13 sampling periods over 2 years. In each period bite size was estimated with 4 esophageally fistulated steers. Bite counts on different plant categories were made during sampling. The plant categories were sampled separately by hand-plucking and weighed to determine plucking size. Extrusa and hand-plucked samples were analyzed for concentrations of nitrogen and calcium.

Vegetation height was a more accurate predictor of plucking size than standing crop. A curvilinear relationship was derived between plucking size and bite size. The nutritive quality of extrusa and hand-plucked samples was not significantly different.

It is concluded that the application of the hand-plucking method appears successful when a stratified sampling approach to hand-plucking is followed. Future studies should examine operator-biases and how these can be minimized.

Key Words: bite size, diet quality, hand-plucking

Diet selection, food intake, and diet quality of herbivores can be estimated by simulation of the observed diet by hand-plucking. The method is rapid, inexpensive, and simple. It often is the only feasible method to investigate the diet of free-ranging or wild herbivores in heterogeneous environments. Unfortunately, it is subject to a mostly unknown bias as the simulation of the graz-

ing animal is likely to be imperfect. The hand-plucking method can be evaluated by comparing hand-plucked estimates of bite size and nutritive quality with data from esophageally fistulated animals.

Fistulated animals are widely used in studies of diet selection, as the extrusa samples offer the opportunity to assess bite size (Forbes 1988) and the botanical composition of the diet (Holechek et al. 1982a). However, biases may arise in the assessment of dietary quality, which limits the use of extrusa to certain constituents. Salivary contamination considerably raises the contents of ash, sodium, and phosphorus so as to preclude any accurate estimation of these constituents in the diet (Holechek et al. 1982b, Langlands 1987). Contents of nitrogen are altered by salivary contamination but do not differ on an organic matter basis (Little 1972, Pinchak et al. 1990). Concentrations of some minerals, calcium in particular, do not appear to be different in extrusa samples (Little 1975, Pinchak et al. 1990). The organic matter digestibility of extrusa samples is generally considered to be similar to the feed on offer, but several experiments have revealed significant differences between the 2 (Langlands 1966, Holechek et al. 1982b, Burritt et al. 1987, Armstrong et al. 1989). Thus, the estimates of dietary quality from extrusa samples are least biased for nitrogen and calcium.

A number of experiments have been conducted to test the hand-plucking method. Edlefsen et al. (1960) compared the composition of hand-plucked forage with extrusa from esophageally fistulated sheep under range conditions. Differences in nitrogen and cellulose contents were not significant. A number of other constituents (ash, lignin, carbohydrates minus cellulose, gross energy, and phosphorus) were significantly different but this was at least partly due to contamination with saliva. Kiesling et al. (1969) found that hand-plucked samples from one technician contained significantly less silica, ash, protein, ether extract, detergent fiber, and lignin than extrusa samples from steers. Langlands (1974) determined that hand-plucking underestimated digestibility and nitrogen content of sheep diets for low herbage quality and overestimated nutritive quality when herbage quality was high. Also, nutritive quality of hand-plucked samples varied between operators. Van Rees (1984) collected hand-plucked and extrusa samples from 2 steers on 3 consecutive days in high-quality grassland. No significant difference in organic matter digestibility was found between the 2 sample types. Even though

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the nutritive quality of the extrusa samples themselves may sometimes have been biased, these findings suggest that hand-plucking may lead to additional biases in the estimate of dietary quality. Yet, better results might be obtained by careful elaboration of the hand-plucking procedures.

Earlier experiments reported by Wallis de Vries (1990), indicated that hand-plucking underestimated nutritive quality of cattle diets when an average pasture sample of about 100 simulated bites was compared with an extrusa sample. However, a refinement of the method closely predicted diet digestibility. The refinement consisted of sampling different plant categories separately and estimating diet digestibility as a mixture weighted according to bite counts of these categories. This paper presents a more extensive test of the applicability of an elaborated hand-plucking method to assess both bite size and nutritive quality of cattle diets.

Materials and Methods

Study Sites

Grazing trials were conducted in 2 widely different vegetation types in a heathland and a riverine area in the Netherlands. The heathland area, the formerly ungrazed Doorwerthse Heide (50 ha), was dominated by *Deschampsia flexuosa* and *Calluna vulgaris*. It was divided into 2 compartments, 1 grazed year-round (0.18 steers/ha) and 1 with winter grazing only (0.23 steers/ha from December to March). The riverine area, the Renkumse Benedenwaarden, is a river foreland of the Rhine river with a long history of pasture use. The vegetation was dominated by *Agrostis stolonifera*, *Lolium perenne*, and *Elymus repens*. The area was also split into 2 compartments, 1 grazed year-round (0.57 steers/ha) and 1 with summer grazing only (0.96 steers/ha from April to November).

Experimental Design

Thirteen experimental periods were planned at 2 month-intervals over 2 years, from May 1989 till May 1991. On each occasion 2 plots of 40 × 50 m² were sampled in all 3 currently grazed areas. Sampling plots were fenced with electric wire on the sampling day. Four esophageally fistulated steers (aged ca. 13 months and weighing ca. 300 kg at the start of the first experiment) were used to collect samples from the selected diet. The animals were allowed to graze the area at least 3 days before experimentation. They were fasted ca. 4 hours prior to sampling to increase their willingness to graze. Samples were caught in a small bucket, with soft plastic wings, strapped to the animal. Food recovery was ensured by fitting a foam plug in the animal's esophagus. However, in 2 steers with a particularly large fistula the plug mostly fell out and was therefore not used in these 2 animals; there was no evidence that this reduced the amount of food recovered. Each extrusa sample (50–250 g dry matter) required 5–10 minutes of grazing. On average 3.2 samples were collected per plot.

Like in most rangelands, the vegetation structure in the sampling plots was heterogeneous. As a result, the extrusa samples consisted of a mixture of bites from short, tall, and flowering ('stemmy') grasses and some other conspicuous species. These plant categories were therefore distinguished (see Table 1) and used for recording biting frequencies and for sampling the avail-

Table 1. Plant categories distinguished on heathland and in riverine grassland.

Both areas:	
Short grass	: leafy sward < 7 cm high
Tall grass	: leafy sward > 7 cm high
Stemmy grass	: sward with > 2 flowering stems/dm ²
Heathland only:	
Short <i>Molinia</i>	: <i>Molinia caerulea</i> < 20 cm high
Tall <i>Molinia</i>	: <i>Molinia caerulea</i> > 20 cm high
Other grasses	: Various short broad-leaved graminoids
Short <i>Calluna</i>	: <i>Calluna vulgaris</i> < 20 cm high
Tall <i>Calluna</i>	: <i>Calluna vulgaris</i> > 20 cm high
<i>Erica</i>	: <i>Erica tetralix</i>
Riverine grassland only:	
<i>Phalaris</i>	: <i>Phalaris arundinacea</i>
<i>Butomus</i>	: <i>Butomus umbellatus</i>
<i>Cirsium</i>	: <i>Cirsium arvense</i>
<i>Rumex</i>	: <i>Rumex obtusifolius</i> + <i>R. crispus</i>

able forage. The plant categories were sampled by hand-plucking (50–100 pickings for each category) by the same person over the entire experiment. The samples were plucked between the thumb and a backward-bent forefinger, simulating the steers' grazing as closely as possible. The grazing behavior of the animals was observed during sample collection after prior familiarization, using the OBSERVER 2.0 computer programme (Noldus 1991). These data provided a weighted estimate of average bite size and nutritive quality for the extrusa samples, which could be compared with the measured values as explained below.

In each experimental period the vegetation height and available standing crop for the 3 grass categories (i.e. short, tall, and stemmy grass) were measured on 50 points within 2 (riverine grassland) or 3 (heathland) plots, including the sampling plots for the fistulated steers. The 50 points were laid out systematically in 5 equidistant lines, with 1 point every 5 meters. At every point the plant category was recorded and vegetation height was measured with a tempex disc (ca. 8 g, 10 cm diameter) which was gently lowered onto the vegetation along a measuring-rod. The standing crop was sampled every fifth point by clipping an area of 25 × 25 cm² from a single grass category down to a height of 2 cm or to the level of litter and dead plant material. At least 4 samples were clipped for each grass category (not enough stemmy grass was available for clipping in May 1991 on heathland).

Sample Analyses

The samples were stored in polythene bags at -20°C. Extrusa samples were first freeze-dried to prevent Maillard browning reactions, whereas hand-plucked and standing crop samples were oven-dried in a force-draught oven at 65°C. All samples were weighed to determine respectively average bite size per sample (total number of bites divided by sample dry weight), plucking size or standing crop. Due to a limited processing capacity, samples from only 1 full year (6 periods: May, July, September, and November 1989, and January and May 1990) were selected for chemical analysis. After grinding through a 1 mm sieve the extrusa and hand-plucked samples were analyzed for concentrations of total nitrogen (N on organic matter basis) and calcium (Ca on dry matter basis) to provide an estimate of nutritive quality according to Walinga et al. (1989). N and Ca were chosen

because these constituents appear to be least affected by salivary contamination.

Data Analysis

The data were pooled for the different vegetation types and compartments within the heathland and the riverine area, as these produced similar results. Since both areas differed widely in vegetation height and plant texture, which could influence the relation between plucking size and bite size, the data for heathland and riverine grassland were analyzed separately with respect to these parameters. Data on nutritive quality on the other hand, were pooled for both areas. This offered the possibility to extend the comparison between grazed and hand-plucked samples over a wider range of nutrient content. Moreover, there was no reason to assume that the comparison would differ between areas. All statistical analyses were carried out with the SAS (1985) computer package. Regression analysis was conducted to determine the effect of vegetation height and standing crop on plucking size.

Bite size was expressed relative to an estimated biting area to account for animal growth during the experiment. Biting area was chosen because it represents a crucial interface between the animal and the forage (Illius and Gordon 1987). It was calculated as a circle with the diameter of the incisor arcade breadth. This appears to be a realistic assumption for grassland vegetation of medium height (Illius 1989). The arcade breadth of the fistulated animals (measured in late April of 1989 to 1991) increased linearly with live weight, although individual variation was apparent (Fig. 1). This relation allowed a separate estimation of arcade breadth for each individual on the basis of live weight, which was measured at each sampling period. An average plucking size corresponding to each extrusa sample was calculated by a weighted mean of plucking size for the different plant categories in accordance to their proportion in the bite count. The sample values and sample estimates of the different animals were averaged to give one data pair per plot. Regression analysis was carried out for both vegetation types separately to determine the relation between plucking size and bite size. The regression line was forced through the origin, as it was assumed that cattle bite size and plucking size are 0 under similar conditions.

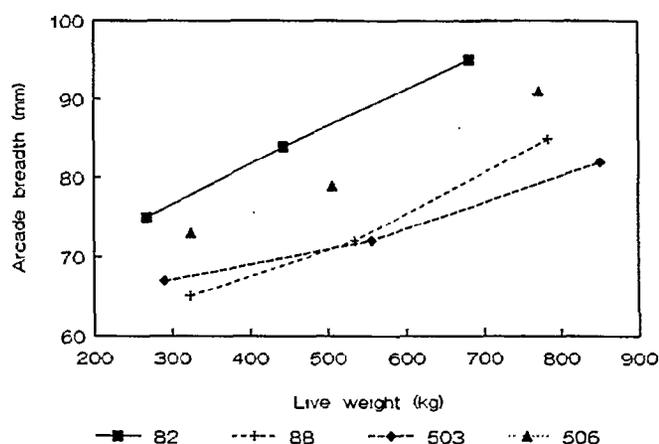


Fig. 1. Incisor arcade breadth as a function of live weight in 4 esophageally fistulated steers (numbered 82, 88, 503, and 506).

In order to assess a possible bias in the estimate of nutritive quality by hand-plucking, plot averages for the nutritive quality of extrusa samples and their estimates from hand-plucked samples were compared by regression analysis. The estimate of the nutritive quality of an extrusa sample based on hand-plucked samples was calculated as follows:

$$\%NQ = \frac{\sum (N_i BS_i \%NQ_i)}{\sum (N_i BS_i)}$$

where

- $\%NQ_i$ = nutritive quality (N or Ca) of plant category i (in % of dry matter)
- N_i = the number of bites on plant category i
- BS_i = bite size of plant category i (estimated from regression equation of bite size on plucking size) (in mg/cm²)

Results

Standing Crop and Vegetation Height of Plant Categories

Standing crop and vegetation height were generally lower on heathland than in the riverine area (Table 2), especially during the growing season. Vegetation height and standing crop showed high linear correlation coefficients in both heathland ($r=0.866$, $d.f.=48$, $P<0.001$) and riverine grassland ($r=0.921$, $d.f.=96$, $P<0.001$). The variation in plucking size, however, was better explained by vegetation height than by standing crop (Table 3). Due to the strong correlation between height and standing crop the bulk density (i.e. standing crop divided by height) did not show any significant correlation with plucking size.

Bite Size Estimation

The regression analysis revealed a close fit for a curvilinear relation between plucking size (PS, g; with 95% confidence intervals for parameters) and bite size per unit biting area (BS, mg/cm²) (Fig. 2):

$$\begin{aligned} \text{Heathland: } BS &= 47.98(\pm 8.11) PS - 28.39(\pm 17.17) PS^2 \\ R^2 &= 0.779, d.f.=22, P < 0.001 \\ \text{Riverine: } BS &= 34.87(\pm 4.48) PS - 17.53(\pm 7.57) PS^2 \\ R^2 &= 0.803, d.f.=26, P < 0.001 \end{aligned}$$

The quadratic term in the regression equation was significant for both heathland and riverine grassland ($P<0.01$ and $P<0.001$).

Table 2. Average and range (minimum-maximum) for standing crop and vegetation height from different plant categories on heathland (*Deschampsia flexuosa* type) and in riverine grassland (*Lolium perenne* type) over 13 study periods in 1989-1991. Differences in standing crop and vegetation height between plant categories were significant ($P<0.05$) in all periods.

	Standing crop (g/m ²)	Vegetation height (cm)
Heathland		
Short grass	87.6 (58.1-114.3)	5.2 (3.9-6.0)
Tall grass	187.8 (146.3-266.1)	9.6 (8.6-10.8)
Stemmy grass	297.4 (186.5-406.7)	15.8 (12.8-19.5)
Riverine grassland		
Short grass	110.1 (64.0-198.7)	5.3 (4.0-6.2)
Tall grass	246.5 (130.6-498.4)	13.1 (8.4-25.5)
Stemmy grass	364.2 (157.2-691.5)	18.6 (6.0-35.9)

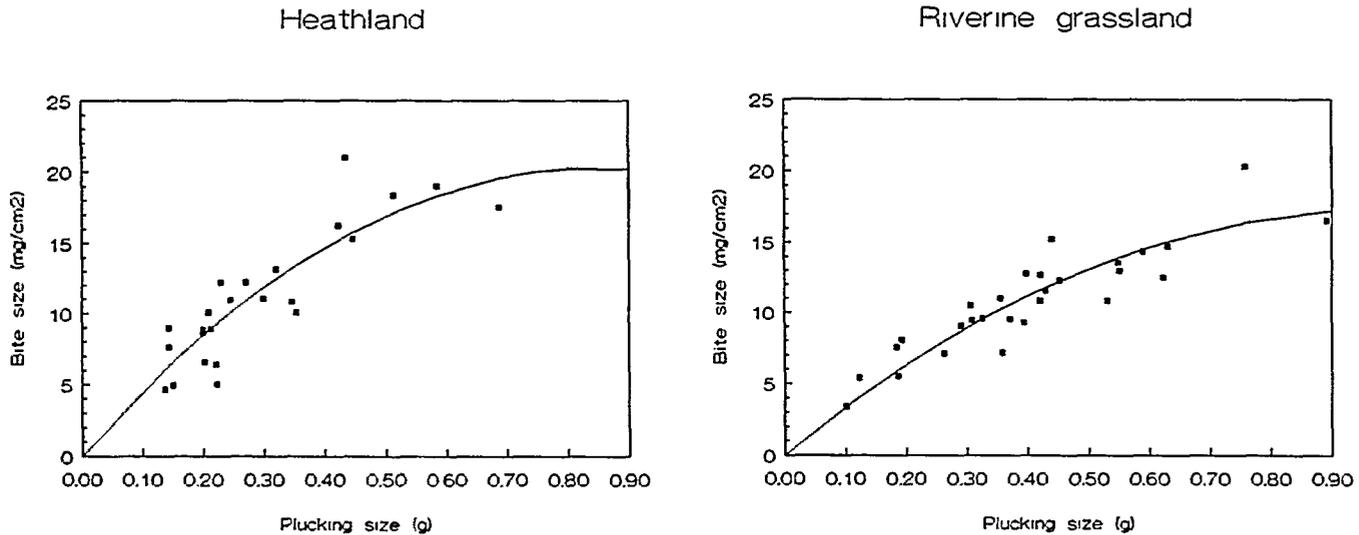


Fig. 2. Bite size per unit biting area of esophageally fistulated steers in relation to plucking size on a) heathland and b) riverine grassland (dots represent plot means, the line shows the regression equation given in the text).

respectively). Without the quadratic term the explained variation decreased respectively to 66.1% and 63.1%.

Nutritive Quality

The estimated contents of nitrogen and calcium (with 95% confidence intervals for parameters) were similar to the contents in the diet selected by the fistulated steers (Fig. 3):

$$N\text{-diet} = 0.97(\pm 0.20) N\text{-est.} + 0.11(\pm 0.51)$$

$$R^2 = 0.751, \text{ d.f.} = 30, P < 0.0001$$

$$Ca\text{-diet} = 1.14(\pm 0.14) Ca\text{-est.} - 0.04(\pm 0.06)$$

$$R^2 = 0.906, \text{ d.f.} = 29, P < 0.0001$$

For both regressions the intercept was not significantly different from 0 ($P > 0.05$) and the regression coefficients were not significantly different from unity ($P > 0.05$). Therefore, the estimate of nutritive quality by hand-plucking showed no significant bias.

Table 3. Regression equations describing the relation between plucking size (PS, g) and vegetation height (H, cm), and between plucking size and standing crop (SC, g/m²) for *Deschampsia flexuosa*-vegetation on heathland and for riverine grassland (95% confidence intervals for parameters indicated between brackets).

Heathland	
PS = 0.0825(±0.0257) H - 0.00216(±0.00110) H ² - 0.229(±0.128)	(R ² =0.880, d.f.=32, P<0.0001)
PS = 0.00269(±0.00094) SC - 2.71 10 ⁻⁶ (±1.69 10 ⁻⁶) SC ² - 0.0768(±0.111)	(R ² =0.773, d.f.=32, P<0.0001)
Riverine grassland	
PS = 0.0820(±0.0135) H - 0.00126(±0.00039) H ² - 0.220(±0.091)	(R ² =0.864, d.f.=98, P<0.0001)
PS = 0.00426(±0.00089) SC - 3.59 10 ⁻⁶ (±1.25 10 ⁻⁶) SC ² - 0.235(±0.122)	(R ² =0.765, d.f.=95, P<0.0001)

Discussion

General Remarks

The results of this experiment show that hand-plucking can be used as a method to assess bite size and diet quality. This contrasts the findings of Kiesling et al. (1969) and Langlands (1974). The applicability of the hand-plucking method relies on sub-sampling of different plant categories and recording bite counts to adjust for diet selection, rather than taking a mixed sample of different plant categories. Furthermore, extensive familiarity with the grazing habits of the animal is a prerequisite. In this respect, cattle will be easier to simulate than sheep, which are more selective grazers (Grant et al. 1985 and 1987). This may have proved a handicap in the experiment by Langlands (1974). This author also pointed to the problem of differences between operators. This aspect was not tested in the present study as the data were collected by one person only. However, calibration of the estimation of bite size and diet quality is advisable whenever possible, especially in heterogeneous vegetation.

Vegetation Structure Versus Botanical Composition for the Estimation of Diet Selection

Within a certain study area, the botanical composition needs to be taken into account to differentiate between vegetation types. Within a botanically defined grassland type, distinction of the 3 plant categories on the basis of vegetation structure—short, tall, and stemmy grass—appears a useful and practical method to quantify diet selection. It may seem more appropriate to distinguish separate plant species, even within a grassland type. This is probably true in cases where species are easily distinguished and present clear differences in nutritive quality, such as in arid range with low vegetation cover. However, in dense grassland swards the estimation of bite size would become much more difficult

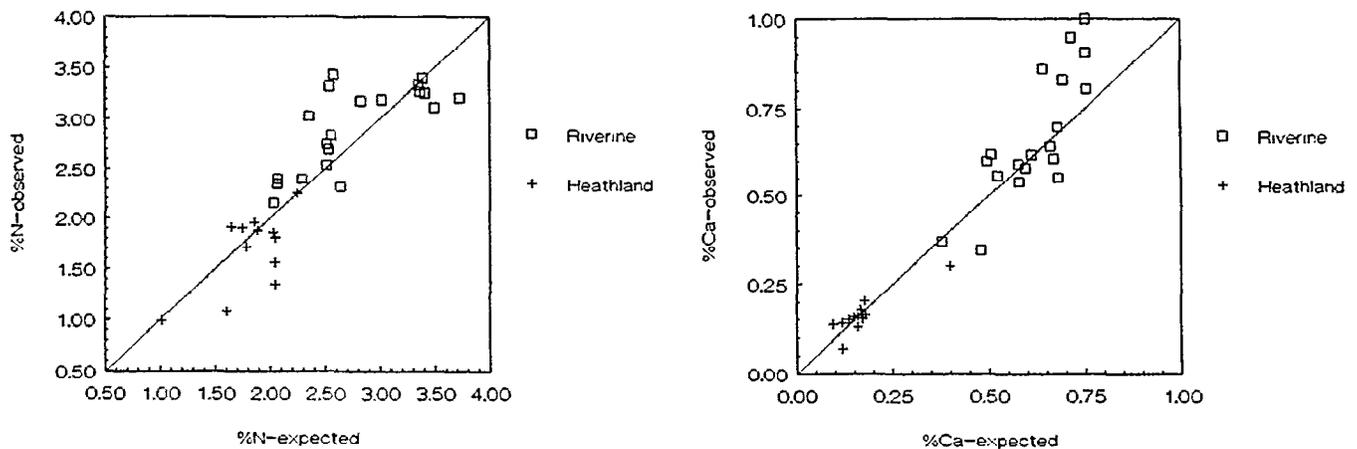


Fig. 3. Comparison of diet quality as estimated by hand-plucking (expected) and as determined in extrusa samples from esophageally fistulated steers (observed) for a) nitrogen (N) and b) calcium (Ca). Dots represent plot means from heathland and riverine grassland. The line shows the values for equality of observed and expected values.

with bite counts on a species basis. In addition, the difference in nutritive quality between grasses of different growth stage is of the same magnitude as between different grass species on the same site (Hacker and Minson 1981, Ulyatt 1981, Norton 1982, Koorevaar 1986). Distinction between species would therefore not necessarily result in a more accurate estimate of diet quality. This supposition was not specifically tested in this study, but some inferences can be made from additional data. In the riverine area, changes in botanical composition between years were significant for *Elymus repens* and *Agrostis stolonifera* (Wallis de Vries, unpubl.). Yet, there was no significant correlation between the cover of either of these species and changes in nutritive quality for nitrogen, phosphorus, calcium, sodium, and organic matter digestibility. In contrast, an ANOVA revealed a significant difference between grass categories for all 5 nutrients examined ($P < 0.05$, although the difference for calcium was only marginal: $P < 0.10$). Thus, the distinction of grass categories appears more important than the differentiation between species. A practical argument in favor of the present approach is that cattle do not appear to discriminate actively between grassland species growing in a fine mixture (Grant et al., 1985). It certainly is difficult for the observer to distinguish individual plant selection.

Extrapolation of the regression equations of bite size versus plucking size and plucking size versus vegetation height reveals a curvilinear increase of bite size with vegetation height (Fig. 4). The relationship is markedly similar for heathland and riverine grassland. This further emphasizes the impact of vegetation structure on bite size and indicates the possibility to estimate bite size from vegetation height.

Curvilinearity between Plucking Size and Bite Size

The relation between plucking size and bite size found in this study was curvilinear. It may be argued that this type of relation could have a more general applicability. The curvilinearity results mainly from the choice of 0 intercept. This seems justifiable on the ground that the allometric coefficient for bite weight declines on very short swards (Illius 1989). The ability of cattle and a hand-plucking human to harvest grass then would converge, and it seems a fair assumption that the point of a 0 harvest would be

reached at a similar sward height (ca. 3 cm when extrapolating the regression between vegetation height and plucking size). Conversely, with increasing herbage availability cattle would tend to take relatively larger bites, favored by the broader dental arcade and an extension of the reach by a sweep of the tongue, in comparison to the relatively small span of around half the size of a forefinger. With a further increase in sward height, selectivity and a decrease in bulk density would become of greater importance, leading to a smaller bite size (Forbes 1988) and, hence, a convergence of bite size and plucking size. The calibration of plucking size is more important for an accurate estimate of intake than for the assessment of nutritive quality. When plucking size instead of estimated bite size was used the additional error in the estimate of nitrogen or calcium content was less than 5%, suggesting that pluck size may be used directly with little effect on the nutritive estimate.

Conclusion

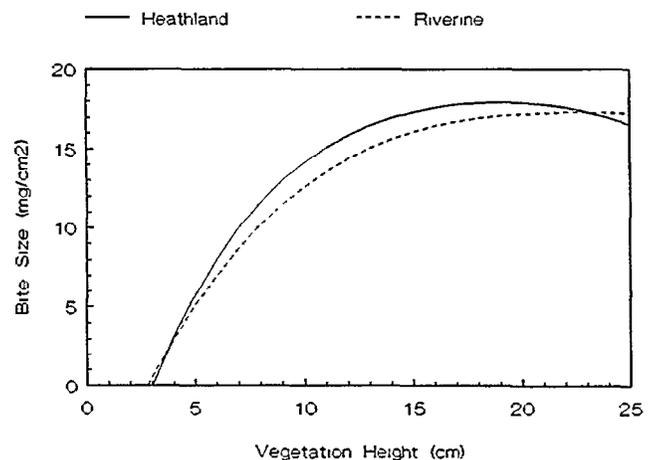


Fig. 4. Bite size in relation to vegetation height in heathland and riverine grassland, as extrapolated from the regression equations between plucking size and vegetation height and between bite size and plucking size.

The hand-plucking method offers potential for determining bite size and nutritive quality of grazing herbivores. The incorporation of stratified sampling of different plant categories in combination with observations on the selection between categories appears an essential improvement. The method should prove especially valuable in heterogeneous and sparsely grazed vegetation, where animals can demonstrate great selectivity. Moreover, hand-plucked samples are free from the contaminants precluding reliable analyses for a number of parameters for nutritive quality in esophageal extrusa or rumen samples. However, the method relies heavily on a calibration between operators and the study animal. Future studies should investigate the variation between operators and its minimization through the development of standard procedures.

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