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The Estimation of Digestibility

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IN the previous paper were discussed methods for estimating the output of faeces by cows. The figures so obtained have to be converted to intake of grass by means of digestibility coefficients. Before describing methods by which these coefficients may be obtained, I would like first to ensure that everyone understands how digestibility and related data are applied to the calculation of intake.

The digestibility of a feed is the amount of the feed extracted by an animal, and may be defined as the weight of feed minus the weight of dung, divided by the weight of feed. The indigestibility on the other hand is the weight of dung divided by the weight of food. Neither of these quantities is used directly to calculate the intake. The quantity so used, which I shall call the "intake factor" is simply the reciprocal of indigestibility, i.e., feed weight divided by dung weight. This is the factor we are really seeking—the factor by which faeces weight must be multiplied to yield the intake. These three terms are obviously very simply related, but it is well that they should be clearly understood, and differentiated since each of them will be referred to during the course of this paper.

It is necessary at this point to draw attention to a misinterpretation regarding the errors in digestibility data as they affect the calculation of intake. A simple example will illustrate the point. It is quite common to encounter differences in digestibility data of the order of two units, e.g. 74 and 76. Such a difference reckoned on percentage basis becomes 2.7%. If, however, the data be regarded from the indigestibility angle, it becomes apparent that a difference of 24 and 26 indigestibility units constitutes a difference of 8%. It would appear then that digestibility data usually obtained with two or three animals will, under normal circumstances, introduce into the calculation of intake an error of the order plus or minus 5%.

We will consider now the experimental methods of obtaining digestibility or related data. Naturally one would expect to use cows to obtain digestibility data for use in calculating the amount of grass eaten by cows. This can be done satisfactorily, but is not a practical proposition for routine purposes. It appears, from both New Zealand and overseas data, however, that the cow and the sheep are both very similar as regards digestive capacities. A series of experiments was conducted at Ruakura to confirm this. Five different digestibility trials were run using three sheep and three cows in each trial. The results of these trials indicated that the indigestibility coefficients determined by sheep are about 5% lower than those found with cows. In addition, the differences between individual observations are in some cases considerable. Furthermore, the observations have been made over a very small range of pasture in terms of indigestibility. The evidence we have then is by no means convincing that sheep can be used instead of cows if accurate indigestibility data are required. Nevertheless, for want of something better or more reliable, the sheep has been extensively used at Ruakura for the purpose indicated.

In the hope of overcoming this weakness in technique, chemical methods for estimating digestibility have been investigated, and the rest of this paper will be devoted to the discussion of one of these methods. The possibility of using the concentration of nitrogen in sheep dung to calculate digestibility for that animal was announced at the 1947 Conference of this Society (Lancaster 1947). More recently, Gallup and Briggs (1948), two American investigators have published a method for estimating the intake of lucerne hay by cows, using the same principle. The method has since been confirmed by myself by study of overseas data (Lancaster 1949), and with suitable modifications, it has been extended to include cattle. In order that you understand the relationship found with cattle, it is thought very desirable to recapitulate the ground covered when I spoke on this subject in 1947.

The calculation of sheep digestibilities depends on the observation that the amount of nitrogen voided in the dung of sheep per 100 grams of grass eaten is relatively constant, irrespective of the nitrogen content of the grass. The amount of nitrogen was found to be 0.72 plus or minus .09 grams per 100 grams of grass dry matter eaten. The use to which this data may be put is illustrated as follows:—

0.72 grams of nitrogen is voided in faeces per 100 grams of grass dry matter eaten. If x = grams of nitrogen contained in 100 grams of faeces dry matter voided (x being found by analysis), then the amount of faeces corresponding to 100 grams of grass is:

$$+ \frac{0.72}{x} \times 100 = \text{indigestibility.}$$

When the data from cattle digestibility trials were examined, it was found that the nitrogen excreted in faeces per 100 grams of grass eaten, was not constant, but varied as the nitrogen in the grass varied. It would be possible therefore to calculate the nitrogen excreted in faeces per unit intake from the nitrogen content of the grass eaten. The value so obtained could then be substituted for 0.72 in the sheep indigestibility equation, and the indigestibility coefficient for cows calculated. This would necessitate a determination of nitrogen on the pasture sample—an undesirable course to adopt since an unknown sampling error would be introduced.

A direct relationship between faeces nitrogen concentrations and digestibility or one of the related factors seemed likely in view of this observation, and investigations showed that a linear relationship existed between the nitrogen concentration in the faeces, and the intake factor. For purposes of developing as accurate an equation as possible for use under Ruakura conditions, the data from Ruakura experiments only were analysed. This comprised eight digestibility trials on paspalum and paspalum dominant pastures, and fourteen digestibility trials on rye grass—white clover—cocksfoot types of pasture using cows and calves.

The equation calculated by Mr. A. Carter is shown below:

$$F = \frac{100}{I} = 1.114 + 0.97x$$

This equation, Mr. Carter points out, predicts the intake factor for a group of cows, or the population mean, from the average nitrogen content of the cows' faeces. The accuracy of the prediction may be calculated from the expression—

$$\text{Error of Estimate} = \text{sq. root of } \frac{0.125}{n} \quad 1.019 + 0.059\ (x - 2.348)$$

where x = nitrogen concentration in faeces.
n = number of animals from which samples drawn.

This accuracy depends on the value of x, and on the number of animals from which the value of x was derived. For high digestibility pasture, that is for high values of x, when three or more animals are used, the prediction error is at least as good as could be attained with orthodox digestibility data, but the error increases considerable when x is of low order. Although this error is a substantial one, it is nevertheless finite. This is an important advantage resulting from the elimination of the unknown, and unpredictable, pasture sampling error to which digestibility trials must always be subject.

We have then a satisfactory means of calculating the intake of grass knowing the weight of dung derived from the grass, and the nitrogen content of that dung. The question naturally arises as to whether this relationship, obtained with stall fed animals, will hold for the free grazing animal. We have no answer to this question, but I shall present shortly some experimental data from animals grazing at pasture which throw some light on this matter. Before looking at these data, it would be pertinent to consider the question "What factors could determine the concentration of nitrogen in cow dung?"

Faeces nitrogen is generally classified into two types—

(1) That derived directly from the feed as undigested nitrogen.

(2) Metabolic nitrogen, or that fraction which is derived from excretions into the gut and undigested remnants of micro-organisms. It is thought to be relatively constant for roughages as a class, and continues to be excreted for a time even though the ingested feed contain no nitrogen.

The nitrogen excreted in faeces per unit intake of nitrogen free feed has been calculated from the Ruakura data, yielding a figure of 0.46 grams of nitrogen per 100 grams of dry matter intake. This figure can be regarded as an estimate of metabolic nitrogen, and agrees very well with experimentally determined values recorded by overseas workers using nitrogen free or low nitrogen diets. The difference between 0.46 and the total nitrogen excreted in faeces per unit intake of feed, might be considered to represent undigested feed nitrogen. This proved to be some 12% of the total nitrogen in the grass eaten.

Although this no doubt represents an oversimplification of the situation, it provides a basis for considering now "What factors could determine the nitrogen concentration in cow dung?" These may be set out as follows:—

(1) The indigestibility of the feed eaten. This must be the major factor if the thesis of this paper be correct. It is known that the indigestibility of a feed is governed largely by the chemical nature of the feed itself. There is some evidence, however, which suggests that individual animals may exhibit distinctive digestive capacities.

(2) The content of nitrogen in the feed. About half of the total nitrogen in faeces is derived from this source, when the feed is high in nitrogen content, but becomes insignificant with low nitrogen diets.

(3) The amount of metabolic nitrogen excreted. Since much of this is of animal origin its excretion rate might well be closely associated with some animal factor such as heredity, or weight. Indeed, rat weights have been correlated with metabolic nitrogen output. The output might also be associated with level of intake and the nature and bulkiness of the feed.

These then constitute some of the factors which could operate in determining the concentration of nitrogen in cow dung. During the course of the measurement of grass consumption by a number of sets of identical twin cows, a large mass of faeces nitrogen data has been accumulated. As part of the procedure, faeces samples combined on a fortnightly basis in accordance with the method already outlined by Mr. Coup, were obtained from each animal and analysed for nitrogen among other things. An analysis of variance of the nitrogen concentration in the dung of nine sets of twins for eight fortnightly periods yielded the following results.

Source of Variation.	**Significance of Variance.**
Between sets.	Highly significant.
Within sets.	Not significant.
Between fortnights.	Highly significant.
Sets x fortnights.	Highly significant.

These results may be interpreted in the light of what has been said about the factors determining faeces nitrogen concentrations. The large, and highly significant differences from one fortnight to the next may be attributed logically to seasonal variations in the digestibility of the pasture eaten. The smaller, though still highly significant differences between the sets of twins, and the very small and non-significant differences between single members of a pair of twins are explainable in the following ways:—

(1) Differences in digestive capacities of different pairs.

(2) Differences in the output of metabolic nitrogen by the different pairs.

(3) Differential grazing habits of the different pairs.

It is important that these explanations be tested if the faeces N—intake relationship is to be placed on a less empirical basis and also in order that an answer be found to the question "Can we justify the extension of a relationship obtained with stalled animals to free grazing animals?"

Assuming that we can justify this step, and we must make this assumption meanwhile, the following tentative estimates of the error of the measurement of grass eaten by cows, using the chromium-nitrogen technique, have been calculated.

Single animal	plus or minus 18%
Single animal in group of 10	plus or minus 9%
Group of 10	plus or minus 3%

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