CALCULATION OF THE DIGESTIBILITY AND THE STARCH EQUIVALENT VALUE OF HERBAGES FROM CHEMICAL ANALYSES

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SUMMARY

A method is described for the calculation of the digestibility of the organic matter and the starch equivalent value of roughages for ruminants from the contents of cell-wall constituents of the roughage.

CALCULATION OF THE DIGESTIBILITY

The energy value of a roughage in ruminant metabolism is closely related to the digestibility of its organic matter. Therefore it is important to be able to predict this digestibility as accurately as possible. In a previous communication (Gaillard, 1966), an equation was given by which the organic matter digestibility of a roughage could be calculated from its content of the cell-wall constituents lignin, cellulose and hemicellulose. In this equation, the composition of the hemicelluloses was indicated by its uronic acid content. The uronic acid determination was introduced into the equation since there was some evidence that the hemicelluloses from grasses and from legumes were digested in the rumen at different rates (Lyford *et al.*, 1963; Gaillard, 1962). To find the reason for this, the three major hemicellulose polysaccharides (the linear polymer from the hemicellulose A and the linear and branched polymers from the hemicellulose B fraction) from Gramineae and Leguminosae were isolated and compared (Gaillard, 1965). Distinct differences in composition were found between the two groups. The rates of action of the enzymes from rumen micro-organisms on the isolated polymers from grass and clover were then compared. For this, the enzymes from mixed rumen bacteria were used (Gaillard *et al.*, 1965) as they were known to

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hydrolyse hemicelluloses, and also from a protozoa, *Epidinium ecaudatum* (Bailey and Gaillard, 1965), which had been shown to possess hemicellulase activity (Bailey *et al.*, 1962). The results showed that the polysaccharides from grass were hydrolysed at a faster rate than corresponding ones from clover, but also that the linear B from both roughages were hydrolysed faster than the linear A and that the branched B were hardly attacked. The amounts of these polysaccharides in the hemicelluloses of different plants vary a great deal. As the linear B contains much fewer uronic acid units in its molecule than the other two, it seemed possible to indicate the amount of less digestible polysaccharides by the uronic acid determination. By analysing 29 feeds (grasses and legumes) of known *in vivo* digestibilities the following regression equation was otained:

$$\text{D.O.M.} = -5.51\ (\text{L}-5.58) + 0.37\ (\text{C}-19.19) - 0.51\ (\text{H}-18.10) + 4.11\ (\text{U}-3.80) + 65.1$$

in which D.O.M. = % digestible organic matter; L = lignin; C = cellulose; H = hemicellulose; and U = uronic acid; all in percentage of the roughage dry matter.

For this material, the correlation coefficient was 0.95 and the standard deviation 3.2. It has since been used for other different types of roughages including silages with the same results. From this equation it may be seen that the influence of the lignin and uronic acid concentrations on the digestibility of the organic matter is much more important than that of the cellulose and hemicellulose contents. Attempts were made therefore to reduce the amount of analytical work to be done by eliminating the separate determinations of cellulose and hemicellulose (Gaillard and Nijkamp, 1968). In the original analysis, total cell-wall substances were first prepared by treatment with a neutral detergent solution (Van Soest, 1963). On part of this neutral detergent residue (NDR), uronic acid was determined by titration, and, on another part, lignin was determined by a two-stage acid hydrolysis (N and 72% H_2SO_4). A sugar determination on the N H_2SO_4 hydrolysate gave the hemicellulose concentration and on the 72% H_2SO_4 hydrolysate the cellulose concentration. The correlation of several combinations of these determinations with the digestibility of the organic matter was computed. The determination of the sum of cellulose, hemicellulose and lignin as the neutral detergent residue together with determinations of lignin and of uronic acid gave the same correlation coefficient and standard

deviation as the original analysis. In this way, the sugar determinations in the hydrolysates can be omitted so that the method becomes more suitable for routine purposes. The regression equation for this analysis is:

$$\text{D.O.M.} = -4.64\ (\text{L}-5.19) - 0.14\ (\text{NDR}-48.05) + 2.95\ (\text{U}-3.47) + 66.7$$

In recent years, other methods have been proposed for the calculation of the digestibility of roughages. One method is the *in vitro* determination by Tilley and Terry (1963), another a chemical analysis by Van Soest (1965). It is impossible to compare the results of these methods as each gives a correlation coefficient and a standard deviation obtained from another set of roughages. Therefore, a large-scale comparison of the three methods on a great variety of roughages of known digestibilities is being carried out at the moment in the Netherlands.

CALCULATION OF THE STARCH EQUIVALENT VALUE

These new methods give rise to a problem in the calculation of the starch equivalent value of a food. This was usually done by the formula

$$\text{SE} = \text{D.O.M.} - 0.58 \times \text{crude fibre} - 0.06 \times \text{digestible crude protein.}$$

The crude fibre deduction was originally obtained by Kellner from animal experiments in which he correlated the differences between the calculated sum of the starch equivalent values of the nutrients of roughages and the real value obtained from the experiment (Produktions Ausfall) with the crude fibre content. As, however, the crude fibre is not determined any more in the new analyses, another indication for the Produktions Ausfall had to be found. The indigestibility of the food (100–D.O.M.) was thought suitable and from the same experiments of Kellner the correlation between 100–D.O.M. and the Produktions Ausfall was calculated (van Es and Gaillard, 1968). It appears that 0.58 × crude fibre can be replaced by 0.49 (100–D.O.M.) to give the same starch equivalent values.

RECENT INVESTIGATIONS

As in the calculation of the digestibility the uronic acid content was meant to indicate the less digestible part of the hemicelluloses, it is remarkable that it appears in the equation with a plus sign. This does not alter the

usefulness of the equation but it shows that there is more to it than originally was thought. In collaborative work with R. W. Bailey at Plant Chemistry Division, D.S.I.R., an explanation for this discrepancy is sought. There are two possibilities:

(1) It may be that, apart from the three polysaccharides of which the hemicelluloses were supposed to consist, and on which the former investigations were carried out, there might exist a fourth polysaccharide which so far has been overlooked. Indeed, an as yet unknown polysaccharide has been isolated from clover and its structure is being investigated.

(2) It may be that rumen micro-organisms other than the ones that were used in the former experiments might be able to hydrolyse the different polysaccharides at a different rate. At that time, the enzymes of mixed rumen bacteria were used but of only one protoza. It now appears that the enzyme mixture obtained from mixed rumen protozoa is very active against the grass branched B polymer and also against the clover unknown one. The rates of action of these enzymes on the four polysaccharides have yet to be compared.

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