DETERMINANTS OF FEEDING VALUE OF PASTURE
AND SUPPLEMENTARY FEED

(Invited Paper)

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Summary

Animal production from pasture is determined by the voluntary intake of net energy. This is usually measured as voluntary intake and the digestible energy content of the feed. The effects of stage of growth, species and varieties, supplements, fertilizer application and processing on the voluntary intake and digestibility of pasture are discussed. Indirect methods for estimating voluntary intake and digestibility are reviewed with emphasis on their accuracy. It was shown that net energy could be predicted as accurately from the digestible energy content of the pasture as from metabolisable energy.

I. INTRODUCTION

Animal performance from any pasture is determined by the voluntary intake of net energy. Although this is the most precise measure of feeding value, it is rarely used in pasture evaluation studies because it is difficult to measure. The feeding value of pasture is generally expressed as voluntary intake of dry matter and the digestible energy per unit of feed. In this review, the effect of a number of agronomic factors on the feeding value of pasture will be discussed under the headings of voluntary intake and digestibility.

The digestible energy value of a feed takes into account only the energy lost in the faeces, whereas with net energy, the energy lost as methane, urine and heat increment are also accounted for (Harris 1962). The relation between net energy and digested energy will be discussed in the third section of this paper. The relation between the parameters of feeding value used in this review are shown in Figure 1.

In this review, the protein, mineral and vitamin contents are regarded as factors which may affect intake and digestibility and not as independent components of feeding value.

II. VOLUNTARY INTAKE

Voluntary intake is an important determinant of feeding value (Crampton 1957; Mott 1959; Blaxter 1960; Milford 1960a; Blaxter, Wainman & Wilson 1961; Milford & Minson 1965; Vercoe & Hall 1965) and, in recent years, data on voluntary intake of pasture have been published and some of the controlling mechanisms studied.

Voluntary intake can be measured directly in pens, while a number of indirect methods using faecal indicators have been proposed for use with grazing animals. A number of reviews of these methods have been published. (Raymond 1954, 1963; Raymond et al, 1954; Corbett 1963; Minson 1963a). In this review

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voluntary intake will be discussed in relation to: stage of growth; species and varieties; supplements; fertilizer treatment; processing; and indirect laboratory methods of measurement.

(a) Stage of growth

With tropical species, Milford (1960b) found voluntary intake declined with advancing maturity. The same generally applies to temperate species (Sphar et al. 1961; Blaxter & Wilson 1963; Minson et al. 1964; Reid & Jung 1965; Demarquilly 1965). However, some exceptions have been reported for temperate (Minson et al. 1964) and tropical species (Milford & Minson 1965).

Crampton (1957) and Blaxter, Wainman and Wilson (1961) suggested that voluntary intake of pasture is determined mainly by the rate at which it is digested in the rumen. More recent work has shown this to be correct (Campling, Freer & Balch 1962; Balch & Campling 1962). The increase in the proportion of structural to non-structural components associated with ageing is likely to be the reason for a reduction in the rate of digestion. Thus, Van Soest (1965) found a significant correlation between intake and the percentage of cell wall constituents.

(b) Species and varieties

It is important that comparisons are made at similar stages of maturity and, whenever possible, data on age, physiological development and yield are quoted. Minson et al. (1964) found differences in the intake of six temperate species cut every 28 days. Differences between tropical species of the same age have also been reported by Milford and Minson (1965). A striking result was the high intake for mature frosted tropical legumes which at this stage was almost equal to that for young grass. Milford (1960c) also found differences in voluntary intakes among five varieties of Chloris gayana and two of Paspalum plicatulum.
Supplements fed to grazing animals can increase the feeding value of the entire diet either by direct addition of energy over and above that supplied by the pasture or by increasing the intake of the pasture. Corbett (1963) pointed out that dairy production from well managed temperate pasture was generally limited by intake of energy but, when high energy concentrates were fed (Corbett & Boyne 1958), only small increases in production were obtained. This was due to a reduction in pasture intake by the animals given concentrates which acted as substitutes rather than supplements and had relatively little effect on total feed intake. With poor quality pasture, energy supplements caused only a small depression in pasture intake and sometimes even increased intake (Blaxter & Wilson 1963). Holmes and Jones (1964) showed that the increase in total feed intake (I) for each pound of concentrates fed was related to the organic matter digestibility percentage of the roughage (D).

\[ I = 2.8 - 0.34D \]

Deficiencies of dietary protein generally have a depressing effect on intake and there are many reports that supplementary nitrogen either as protein rich concentrates or as non protein nitrogen (mainly urea) increase voluntary intake of low protein pastures and roughages (Campling 1964). Blaxter and Wilson (1963) found that the intake of temperate pasture hays was limited when the crude protein content of the ration was less than 8.5% and Milford and Minson (1965) found that the intake of two tropical grasses fell rapidly when the crude protein content fell below 7%. Information is required to determine whether the intake of low protein feed is depressed solely because of decreased micro flora activity (Moir & Williams 1950; Williams et al. 1953) or whether the depletion of body protein reserves under such a regime has an effect.

Huffman et al. (1933) and Kleiber, Goss and Guilbert (1936) found that the addition of phosphate to phosphate deficient diets resulted in increased intake but, as far as the authors are aware, no work has been done to show if this important fact applies to pasture.

Intake of pasture may be limited also by trace element deficiencies. Thus Marston et al. (1938) found that the intake of cobalt deficient pasture by sheep was low and that oral administration of 1 mg cobalt per day increased intake by 60%. McLean et al. (1962) found that the feeding of selenium supplement to lambs grazing deficient pastures in New Zealand increased the intake of digestible organic matter. This resulted in higher live weight gains.

**Fertilizer treatment**

Reid and Jung (1965) found that application of N, P and K fertilizer did not significantly affect the intake of pasture, while Milford (1960c) found that fertilizer N could have a depressing effect. These findings are not surprising since the fertilizers were probably not supplying elements that were deficient in the diet. When pasture diets are deficient, it is reasonable to expect that intake will be increased by applying the appropriate fertilizer(s) to correct the deficiency. Thus Minson (unpublished data) obtained a 50% increase in intake when the N content of mature *Digitaria decumbens* was raised from 0.6 to 1.2% by the late application of urea fertilizer. No data are available for other fertilizers.
(e) Processing

Intake of cut pasture is not affected by freezing (Pigden et al. 1961) or by drying (Minson, unpublished data). However, the ensiling of pasture depresses intake; the extent of the reduction depends on the moisture content of the ensiled material (Murdoch 1964). Grinding and pelleting increases intake of poor pasture but has little effect on high quality pasture (Minson 19633; Heaney et al. 1963). Wafering has no effect on intake unless the feed has been ground (Haenlein & Holdren 1965).

(f) Indirect laboratory methods of measurement

Indirect methods for estimating intake using small samples are required by the plant breeder and plant introduction worker. Regression equations relating in vivo voluntary intake to chemical composition (Donefer et al. 1963; Dehority & Johnson 1964; Van Soest 1965) and 12 hour in vitro fermentation (Donefer, Crampton & Lloyd 1960; Barnes 1965) have been calculated.

Relations between voluntary intake and in vivo digestibility have been reported (Blaxter, Wainman & Wilson 1961; Minson et al. 1964; Demarquilly 1965; Campling 1964; Reid & Jung 1965). These relations could be used to estimate intake from estimates of digestibility determined in vitro. However, the use of digestibility data to predict intake is limited and with some species the relation is poor (Reid & Jung 1965; Demarquilly 1965; Milford & Minson 1965).

Many plant breeders have used leafiness as a selection index but leafiness is unlikely to be of value in selecting towards higher intake of species and varieties since there is no general relation between leafiness and voluntary intake for either temperate (Minson et al. 1964) or tropical species (Milford & Minson 1965).

The value of the indirect methods of estimating voluntary intake does not depend on the statistical significance of the correlation coefficient but on the magnitude of the prediction error relative to the differences in voluntary intake between species and varieties (Minson 1963a).

III. DIGESTIBILITY

It has been recommended that the results of digestibility experiments should be quoted as digestible energy (Harris 1962). However, most data for pasture are expressed as dry matter or organic matter digestibilities. This is unlikely to introduce any serious discrepancies when comparing digested energy values because the three parameters are highly correlated (Moir 1961; Heaney & Pigden 1963). In this review, all three are considered under the general heading of digestibility. The digestibility of pasture will be discussed under the same headings as for voluntary intake.

(a) Stage of growth

The process of ageing and maturation of pasture is associated with a decline in digestibility (Louw 1938; Milford 1960a, 1960b; Weir, Jones & Meyer 1960; Minson et al. 1964; Armstrong 1964). With temperate pasture, the daily rate of decline is about 0.5 digestibility units (Homb 1953; Reid et al. 1959; Minson, Raymond & Harris 1960a, 1960b), but tropical species decline at approximately half this rate (Milford & Minson 1966,). The difference between temperate and tropical species is probably due to the much higher digestibility values for temperate grasses at a young stage of growth:
Reid et al. (1959) concluded that the digestibility of spring growths of pasture in the N.E. of the U.S.A. was independent of the pasture species. However, Minson, Raymond and Harris (1960a,1960b) found that S23 and S24 ryegrasses had similar digestibility when cut at the same stage of growth and these were six percentage units higher than S37 cocksfoot. Differences in the digestibility of some tropical species and varieties have also been reported by Milford (1960b,1960c). Recently, in vitro studies by Cooper et al. (1962) have shown that there are clonal and family differences of up to 20% and 10% respectively for ryegrass and cocksfoot. Dent (1963) also established differences in in vitro digestibility for varieties of rape, kale and red clover.

(c) Supplements

Increases in cellulose digestibility have been obtained in vitro from nitrogen supplementation (Belasco 1954). Urea has been found to increase dry matter digestibility of low nitrogen roughage fed to sheep (Harris & Mitchell 1941; N. Graham, personal communication) and cows (Campling, Freer & Balch 1962). Other workers have found that nitrogen supplements have no effect on the digestibility of poor quality pasture hays (Clark & Quinn 1951; Morris 1958).

A number of workers have reported increases in digestibility when trace element supplements were given. Following in vitro studies by Burroughs et al. (1950), who found that alfalfa ash increased digestion of cellulose and fibre, responses have been obtained in vivo (Burroughs, Gerlaugh & Bethke 1950; Tillman et al. 1954). This response may have been due to molybdenum (Ellis et al. 1958).

No data are available on the digestibility of low phosphate pasture when supplemented with adequate phosphate although Kleiber, Goss and Guilbert (1936) found no effect when phosphorus was added to a deficient ration.

(d) Fertilizer treatment

The digestibility of crude protein is increased by the application of fertilizer nitrogen due to an increase in crude protein percentage (Reid & Jung 1965) but the effect on dry matter or organic matter digestibility is not consistent. Increases have been reported by some workers (Markley, Cason & Baumgardt 1959; Barth, Van der Noot & Cason 1959; Milford 1960c; Reid & Jung 1965) but others have found little or no response (Woodman, Norman & French 1931; Ferguson 1948; Minson, Raymond & Harris 1960b; Poulton, Macdonald & Van der Noot 1957; Woelfel & Poulton 1960).

Reid and Jung (1965) found that neither phosphate nor potassium fertilizer increased the digestibility of pasture but in this study these elements were probably not limiting animal performance.

(e) Processing

The digestibility of cut pasture is only slightly affected by freezing (Raymond, Harris & Harker 1953; Pigden et al. 1961), by drying (Watson & Ferguson 1932; Kivimae 1959; Graham 1964) or by the process of ensiling (Harris & Raymond 1963). Grinding and pelleting usually depresses digestibility (Minson 1963b; Beardsley 1964).
**Indirect laboratory methods of measurement**

It is generally assumed that leaf is more digestible than stems, the leafier the plant the higher its digestibility. Sotala (1946) found that the digestibility of sweet clover leaf was 7 to 8% higher than the stems while good correlation has been reported between leaf percentage and digestibility of first growth temperate pastures (Reid et al. 1959; Minson, Raymond & Harris 1960b). However, Minson, Raymond & Harris (1960a, 1960b) found that the digestibilities of two ryegrasses and one cocksfoot remained constant before ear emergence despite a marked change in leaf percentage. Reid et al. (1959) reported a poor correlation for aftermath forages and Milford (1960c) showed that leafiness was not related to the digestibility of a subtropical grass *Panicum maximum* var. *trichoglume*. These findings are not surprising in view of the large differences found in the digestibility of both leaf and stem at different stages of growth (Pritchard, Folkins & Pigden 1963).

Regression equations relating in vivo digestibility to the concentration of a number of chemical constituents have been derived; nitrogen (Watson & Horton 1936; Forbes 1950; Kivimae 1959; Minson & Kemp 1961), lignin (Lancaster 1943; Forbes & Garrigus 1948, 1950; Sullivan 1955, 1959; Meyer & Lofgreen 1956; Kivimae 1959), crude fibre and normal acid fibre (McMeekan 1943; Hallsworth 1949; Griffith & Thomas 1955; Kivimae 1959; Sullivan 1959), methoxyl (Richards, Weaver & Connolly 1958). All the quoted standard errors of estimation of these regressions are too high to enable any of the published differences between species to be detected with significance (Minson 1963a).

**In vitro rumen** fermentation techniques for estimating digestibility have recently been reviewed by Barnes (1965) who concluded that the two stage technique of Tilley & Terry (1963) was the most accurate. Using this method, in vivo dry matter digestibility percentage can be predicted with an error of ±2.3 which is much smaller than the errors of estimates based on chemical composition (Minson 1963a). Although this method appears satisfactory for temperate species, Milford (unpublished data) found large discrepancies between in vitro and in vivo digestibilities for tropical species.

**IV. THE RELATION BETWEEN NET ENERGY AND DIGESTED ENERGY**

Since the energy value of feed has been discussed in terms related to energy digestibility, this review would not be complete without briefly considering the relation between net energy and digested energy. Regression equations calculated from data published by Armstrong (1964) show that the net energy values for both maintenance and production and digestible energy content are highly correlated (Table 1). Also net energy can be predicted with a small standard error from the digestible energy content of herbage.

It has recently been suggested that the energy value of feeds should be measured in terms of their metabolisable energy content (Blaxter 1962, 1964). This might be expected to be more closely related to net energy than digested energy since it takes into account energy lost as urine and methane in addition to that lost in the faeces. However, the relation between net energy for maintenance and production and metabolisable energy calculated from the data of Armstrong (1964) shows no improvement in accuracy over those for digested energy (Table 1).
Regressions of net energy values of 12 herbages on their digested energy and metabolisable energy contents

<table>
<thead>
<tr>
<th>REGRESSION</th>
<th>STANDARD ERROR OF ESTIMATE</th>
<th>CORRELATION COEFFICIENT</th>
</tr>
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<tbody>
<tr>
<td>Nm = 0.76Dm - 0.55 ± 0.06</td>
<td>0.984</td>
<td></td>
</tr>
<tr>
<td>Nf = 0.69Df - 0.93 ± 0.09</td>
<td>0.964</td>
<td></td>
</tr>
<tr>
<td>Nm = 0.92Mn - 0.51 ± 0.07</td>
<td>0.975</td>
<td></td>
</tr>
<tr>
<td>Nf = 0.81Mf - 0.89 ± 0.10</td>
<td>0.957</td>
<td></td>
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</tbody>
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N = net energy (kcal/g); D = Digested energy (kcal/g); M = metabolisable energy (kcal/g); m = maintenance; f = fattening.

The measurement of metabolisable energy requires facilities for gas analysis and urine collection in addition to those required to measure digestible energy. In practice, the widespread adoption of the metabolisable energy system would rely on estimated values obtained by multiplying digested energy by 0.82 or assuming the metabolisable energy value of pasture is 3.6 kcal/g digested organic matter (Blaxter 1964). When facilities for measuring net energy are not available, there appears to be no advantage in using metabolisable energy in preference to digestible energy as an index of the energy value of pasture.

V. REFERENCES


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