# THE NUTRITIVE VALUE OF LEGUMES

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*Abstract*

Evidence is reviewed to show that, in most circumstances, legumes are of higher nutritive value than grasses. The reasons for such differences are explored using evidence from indoor feeding experiments. In particular, the superiority of legumes over perennial ryegrass appears to be due to a higher intake and a higher ratio of protein/energy absorbed. The mechanisms by which tannins in legumes such as Lotus and sainfoin can reduce bloat and improve nutritive value are also considered. Finally, the management of legumes in relation to their higher feeding value is discussed. It was considered that, because of agronomic factors, the superior nutritive value of legumes is not being exploited in agriculture.

## INTRODUCTION

THE ABILITY of pasture legumes to fix nitrogen and to produce large quantities of herbage is well known. It is also generally recognized that the feeding value‡ of legumes is superior to that of most grasses and graminaceous forages. The best known example is the superior feeding value of white clover *(Trifolium repens)* over perennial ryegrass *(Lolium perenne)* (Sinclair *et* al., 1956; McLean *et al.,* 1962, 1965; Hight and Sinclair, 1965; Ulyatt, 1971). The New Zealand work has been summarized by Ulyatt (1970) and shows that feeding value, expressed as the liveweight gain of lambs, is approximately 86% higher from white clover than from perennial ryegrass. Further, addition of white clover to grass pastures improves the feeding value of the pasture for sheep (Rae et *al.,* 1963; Grimes *et al.,* 1967; Davies, 1975; Suckling, 1976). Similar results with white clover have been obtained with growing calves (Collins and O'Donovan, 1970; Lancashire, 1971).

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‡Throughout this article herbage *feeding* value is defined in terms of an animal production response to a herbage and nutritive *value* as a response per unit of feed intake. Feeding value is thus a function of both intake and nutritive value (Ulyatt, 1973).

TABLE 1: COMPARATIVE FEEDING VALUES OF LEGUMES FOK GRAZING SHEEP IN NEW ZEALAND

| *Species* | *No. of Experiments* | *Relative Liveweight Gain* | Range in *Liveweight Gain (g/day)* | *References* |
|---|---|---|---|---|
| White clover | 7 | 100 | 118-309 | 1,2,3,4 |
| Lucerne | 6 | 91 | 132-291 | 1,2,3 |
| Maku lotus | 1 | 77 | 156 | 4 |

References: 1. McLean et *al. (1962)*
2. McLean et *al.* (1965)
3. Hight *et al.* (1972)
4. Ulyatt, Lancashire and Keogh (unpublished)

Although the superior feeding value of white clover for growing animals is well documented, there is little published comparative information on other legume species. Such information for sheep grazing under New Zealand conditions is given in Table 1. Most comparisons are between white clover and lucerne *(Medicago sativn)* ; it can be seen that white clover produces approximately 9% greater liveweight gain in sheep than does lucerne. Similar results have been obtained in Australia by Wilson (1966). In one trial (Table 1) white clover gave a 23% higher liveweight gain than *Lotus pedunculatus* ('Grasslands Maku') . An early report by Ewer and Sinclair (1952) indicated that red clover (*Trifolium pratense*) dominant pasture, white clover dominant pasture, and lucerne were of similar feeding value. The incidence of legume bloat has probably contributed to the small amount of data on the comparative feeding values of legumes for cattle. Indeed, Wolfe and Lazenby (1972) found that liveweight gains of cattle fed pasture of high white clover content were less than those fed a pasture of medium or low white clover content, a result they attributed to the incidence of bloat and reduced intake on the high clover treatment. Because data on nutritive comparisons between legumes are limited, emphasis will often be put on legume/grass comparisons in this paper.

## INTAKE DIFFERENCES

The causes of differences in feeding value can be divided conveniently into differences in intake and differences in nutritive value. Comparisons from the literature of the voluntary feed intakes by sheep of several legumes and perennial ryegrass are given in Table 2. Although these data are limited in extent, certain points can be made. The intake of white clover was higher than that of perennial ryegrass in all cases. There was considerable variation in legume intakes: red clover, *Lofus corniculatus* and sainfoin *(Onobrychis viciaefolia)* were all higher than lucerne. Crampton *et* al. (1960), Corbett (1969) and Ulyatt (1973) concluded from statistical analyses of such results that variation in voluntary intake is associated with between SO and 75% of the variation in feeding value between herbage species.

## NUTRITIVE VALUE

The nutritive value of a diet depends on the proportion of nutrients digested (digestibility) and on the efficiency with which these digested nutrients are absorbed and utilized within the animals' tisues. Legumes grown in New Zealand and grazed at an immature stage of growth are usually of high apparent digestibility; between 75 and 85%. However, *in vitro* digestibility decreases as the plants mature as can be seen in Fig. 1. The *in vitro* digestibility of red clover, white clover and lucerne grown in Wales (Davies *et* al., 1966) all declined with maturity. The decline was more severe with the tall growing forage species, red clover and lucerne, because of increasing proportions of stem with advancing maturity. White clover maintained a higher digestibility because the harvestable material is largely leaves and petioles and because there is a continual turnover of the leaves and petioles as aged material is replaced by new growth

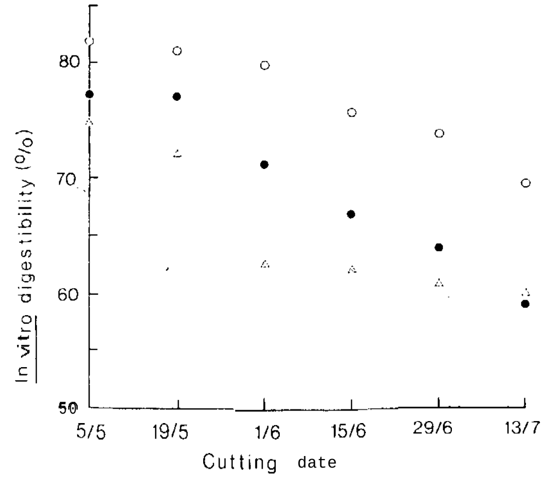


FIG. 1: *Relationship between date of cutting and* in vitro *DM digestibility of white clover (o), red clover* (●), *and lucerne* (A) *grown in Wales (Davies et* al., 1966).

TABLE 2: VOLUNTARY INTAKES OF DIGESTIBLE ORGANIC MATTER (DOM) AND DRY MATTER (DM) OF SHEEP FED PERENNIAL RYEGRASS AND VARIOUS LEGUMES

| Reference | Experimental Conditions | Units | Perennial Ryegrass | White Clover | Red Clover | Lucerne | Sainfoin | Lotus corniculatus |
|---|---|---|---|---|---|---|---|---|
| Joyce and Newth (1967) | Indoors, fresh | DOM (g/d) | 546 | 729 | | | | |
| Rattray and Joyce (1969) | Indoors, frozen | DOM (g/d) | 485 | 535 | | | | |
| Ulyatt (1971) | Grazing | DOM (g/d) | 790 | 949 | | | | |
| Michell (1973) | Indoors, dried | g DM/d/kg$^{0.75}$ | 78.2 | 87.9 | | | | |
| Crampton *et al.*' (1960) | Indoors, dried | g DM/d/kg$^{0.75}$ | | | 84.8 | 63.2 | | 79.2 |
| Osbourn *et al.* (1966) | Indoors, hay | g DM/d/kg$^{0.75}$ | | | 74.0 | 63.5 | 87.3 | |

TABLE 3: IN *VITRO* DM DIGESTIBILITIES (%) OF LEAF AND STEM FRACTIONS OF LUCERNE AND SAINFOIN
(From Terry and Tilley, 1964)

| | *Lucerne* | *Sainfoin* |
|---|---|---|
| Whole plant .... .... .... .... .... .... | 66 | 71 |
| Leaf . .... .... .... .... .... .... | 78 | 70 |
| Stem: | | |
| Average | 55 | 72 |
| 0-15 cm . | 77 | 86 |
| 15-30 cm . | 63 | 78 |
| 30-45 cm . | 50 | 64 |
| 45-60 cm | 46 | 56 |

(Brougham, 1962). Forage legumes can vary considerably in the digestibilities of their leaves and stems. Terry and Tilley (1964) compared lucerne and sainfoin of similar maturities (Table 3). The leaf of lucerne was of higher digestibility than that of sainfoin, while the reverse was true for the stems. This illustrates that large differences in digestibility can exist between legume species. There may be scope within legume species for improving the digestibility of stems.

White clover has been shown to have a higher efficiency of utilization for liveweight gain than perennial ryegrass in both field trials (Grimes et al., 1967; Ulyatt, 1971) and indoor experiments (Joyce and Newth, 1967; Rattray and Joyce, 1969). The true efficiency of utilization of the metabolizable energy (ME) of legumes for fattening ($K_f$) has been measured on only a few occasions. In Fig. 2, the $K_f$ values of lucerne, subterranean clover, white clover and sainfoin arc plotted against ME content of' the DM (an index of nutritive value). For comparison, the relationship calculated from a large number of diets by the Agricultural Research Council (1965) is also plotted in Fig. 2. This relationship shows that $K_f$ increases as nutritive value increases, that is, when diets of higher nutritive value are digested they present to the animals' tissues a better balance of nutrients for liveweight gain. The values of $K_f$ for the legumes (lucerne 5 1.8 % — Bateman and Blaxter, 1964; subterranean clover 54.0% — Graham, 1969; white clover, 51 .O% Rattray and Joyce, 1974; and sainfoin 57.1 % — Ulyatt, unpublished) are close to what would be expected from their ME content (Agricultural Research Council, 1965; Graham, 1969). In contrast, perennial ryegrass had a $K_f$ of 32.9% (Rattray and Joyce, 1974); indicating either that it was a poorly balanced diet in relation to its ME content, or that it contained a metabolic inhibitor.

TABLE 4: CHEMICAL COMPOSITION (% DM) OF SOME LEGUMES AND PERENNIAL RYEGRASS GROWN IN NEW ZEALAND

| | Cutting *Height* (*cm*) | *Readily Fermentable Carbohydrate* (*a*) | *Structural Carbohydrate* (*b*) | *Crude Protein* | *Lignin* | *a/b* |
|---|---|---|---|---|---|---|
| Ruanui ryegrass | 15 | 12.3 | 29.5 | 23.1 | 2.4 | 0.42 |
| Huia white clover | 10 | 20.3 | 17.3 | 24.4 | 2.2 | 1.17 |
| Hamua red clover | 15 | 16.8 | 22.0 | 21.9 | 3.8 | 0.76 |
| Fakir sainfoin | 45 | 19.6 | 20.5/17.0 | 26.3/16.7 | 14.6/11.8 | 0.96/0.79 |
| Maku lotus | 15 | 13.4 | | | | |
| Wairau lucerne[1]: | | | | | | |
| Leaves | Early bloom | 12.2 | 16.1 | 24.6 | 2.5 | 0.76 |
| Stems | | 18.1 | 42.2 | 11.5 | 8.5 | 0.43 |

[1] From Bailey et al. (1970).

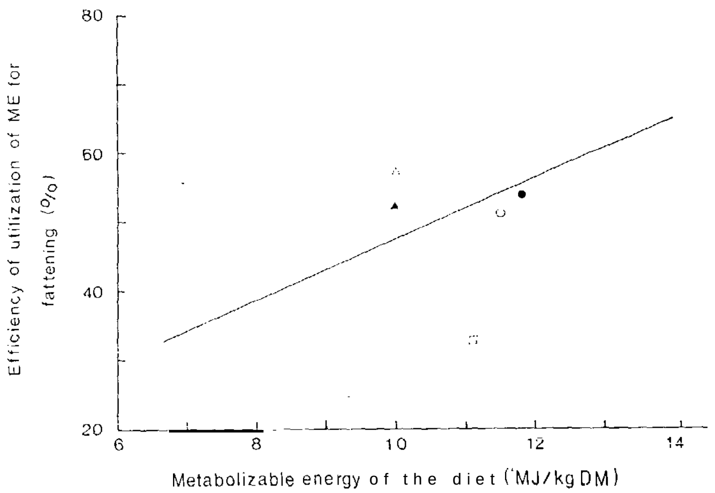


FIG. 2: *The relationship between efficiency of utilization of metabolizable energy for fattening sheep* ($K_f$) *and the metabolizable energy concentration of the diet, for the legumes white clover* (o, *Rattray and foyce, 1974*), *subterranean clover* (●, *Graham, 1969*), *lucerne* (▲ *Bateman and Blaxter, 1964) and sainfoin* (A, *Ulyatt, unpublished), and perenial ryegrass* ([], *Rattray and foyce, 1974). The solid line indicates the relationship presented by the Agricultural Research Council* (*1965*).

## CAUSES OF DIFFERENCES IN NUTRITVE VALUE

The chemical compositions of some legumes and perennial ryegrass grown in New Zealand are given in Table 4. The leafy material of the legumes had a relatively high protein content and was generally higher in readily fermentable carbohydrate (water-soluble sugars and pectin) and lower in structural carbohydrate (hemicellulose and cellulose) than perennial ryegrass. Structural carbohydrate is more diffkult to digest in the rumen than readily fermentable carbohydrate, so a high ratio of readily fermentable/structural carbohydrate is a desirable nutritional characteristic. This ratio is clearly higher for leafy-legume: material than for perennial ryegrass or for lucerne stems (Table 4). These differences in chemical composition imply that legumes would be digested in the rumen at a faster rate than perennial ryegrass. The lower digestibility of lucerne stems than leaves (Table 3) is largely explained by such differences in chemical composition.

An interesting feature of the ruminant digestive system is that there are major differences in the sites of absorption of nutrients: protein is only absorbed from the small intestine, while energy yielding nutrients are absorbed in all sections of the digestive tract (Ulyatt and MacRae, 1974; MacRae and Ulyatt, 1974). Results from studies on the sites of digestion of some herbages grown in New Zealand are presented in Table 5. The proportion of N digested in the stomach region was highest with perennial ryegrass, followed by white clover, while there was a small loss with red clover and a small net gain of N with sainfoin. High stomach N digestion is undesirable because it is largely lost to the animal as ammonia. The effect of the loss is reflected in the higher protein digestion in the intestines of sheep fed red clover and sainfoin. Such differences in protein digestion are not in line with N and energy digestibilities, which tend to be in the reverse order. The ratio of protein absorbed to non-protein energy absorbed (Table 5) is given as an index of the balance of nutrients absorbed from the various diets. Again red clover and sainfoin had the most nutritionally beneficial ratios, followed by white clover, then perennial ryegrass. These results are supported by-the simulation stuudies of J. L. black, N. McC. Graham, and G. J. Faichney (pers. comm.) who found that increasing the protein absorbed by sheep fed perennial ryegrass had a large influence, in reducing the difference in liveweight gain between perennial ryegrass and white clover. Digestion studies have thus

TABLE 5: SITES OF DIGESTION IN SHEEP OF PERENNIAL RYEGRASS AND VARIOUS LEGUMES

| | *Perennial Ryegrass*[1] | *White Clover*[1] | *Red Clover*[1] | *Sainfoin*[2] |
|---|---|---|---|---|
| N intake (g/d) | 37.8 | 35.2 | 29.4 | 34.3 |
| N digested in stomach (g/100 g N intake) | 26.5 | 17.9 | 3.7 | -0.7 |
| N digested in intestines (g/100 g N intake) | 58.2 | 63.6 | 77.6 | 75.1 |
| N apparent digestibility (%) | 84.7 | 81.5 | 81.3 | 74.4 |
| Energy intake (MJ/d) | 16.5 | 16.8 | 15.4 | 18.9 |
| Energy apparent digestibility (%) | 76.4 | 78.1 | 75.5 | 70.3 |
| Protein absorbed[3]/ non-protein energy absorbed[4] | 11.5 | 12.5 | 15.0 | 14.8 |

[1] MacRae and Ulyatt (1974), Ulyatt and MacRae (1974)
[2] Ulyatt (unpublished)
[3] Non-ammonia nitrogen absorbed X 6.25
[4] Digestible energy — protein energy absorbed

demonstrated that the high nutritive value of legumes is probably due to increased protein absorption which results in a better balance of absorbed nutrients.

## MINERALS

Given the same soil type, fertilizer treatment and climate, legumes commonly have a higher mineral content than grasses, particularly of calcium, magnesium and phosphorus (Davies et *al.,* 1966; Whitehead, 1966). However. sodium is often low in legumes. Indeed; sodium deficiency can limit animal production from lucerne in the central North Island (Joyce and Brunswick, 1975).

## DISORDERS

Although the nutritive characteristics of legumes are good, they are often associated with animal disorders such as bloat (Reid, 1960), infertility (Ch'ang, 1961), cyanosis (Gurnsey et *al.,* 1977), goitre (Butler et *al.,* 1957) and lucerne red gut (Jagusch *et al.,* 1976). However, with the exception of bloat the occurrence of these disorders is not of large magnitude and can be avoided by careful management.

## THE POTENTIAL OF LEGUME TANNINS

Bloat, which is mainly caused by the formation of a stable protein foam in the rumen, is still a major problem with cattle fed legumes. It has been observed that bloat does not occur when certain legumes such as *Lotus* and sainfoin are fed to cattle. This has been. correlated with the presence of a class of compounds known as condensed tannins in these legumes (Jones and Lyttleton, 1971; Reid *et al.,* 1974). Foaming is prevented by the formation of insoluble complexes between condensed tannins and plant protein in the rumen (Jones and Mangan, 1976). This reaction is also considered to have nutritional potential, because formation of the protein-tannin complex should reduce deamination in the rumen and therefore reduce ammonia loss. **This** is demonstrated in Table 5 by the results for sainfoin, a high tannin- legume+ N digestion was low in the stomach and high in the intestines.

The stability of the protein-tannin complex is pH dependent (Fig. 3) : in the rumen at pH 5 to 7 there is maximum binding of tannins with plant protein, while in the duodenum at pH 2 to 3 protein is released from the complex and is available for diges-

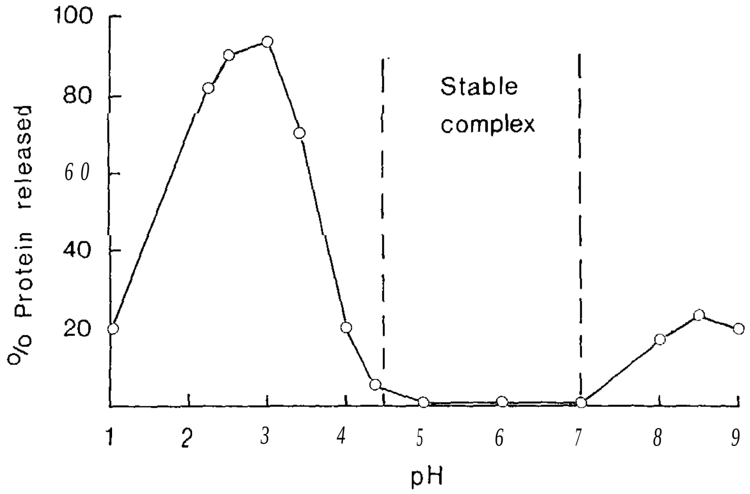


FIG. 3: *The relationship between pH and the release of protein from a protein-tannin complex (Jones and Mangan, 1976).*

tion. Thus the introduction of tannins into pastures could have the dual effect of preventing bloat and increasing nutritive value. Work at DSIR is proceeding in two directions: (1) Screening white and red clover populations for the presence of sufficient tannins, and (2) the introduction, adaptation, and breeding of known high tannin legumes such as sainfoin, *Lotus* spp., or crown-vetch (*Coronilla varia*) from overseas. So far, 420 red clover (8000 plants) and 350 white clover (1.0 000 plants) populations have been screened for tannins in leaf tissues, but without success (Jones *et al.*, 1973; L. B. Anderson, W. M. Williams, pers. comm.) . However, both red and white clover possess the biochemical mechanisms for tannin synthesis and plant breeding techniques of wide hybridization and induced mutation are being used in attempts to induce sufficient tannin production in these species.

## AGRONOMIC FACTORS

The lack of basic information on the nutritive value of legumes is surprising when one considers that virtually all pasture mixtures sown in New Zealand contain white clover, at least 50% contain red clover, and the area of lucerne has almost doubled in the last 10 years. Although the data suggest that legumes have superior nutritive characteristics to most grasses, the current utilization of these properties in agriculture is incidental to the agronomic advantages of white clover in N-fixation and the capacity of red clover and lucerne to grow well in the dry period of the year. It must be stressed that the nutritional potential of our commonly used legumes is not being exploited. For example, red clover is unlikely to yield well unless it is grazed under a lax rotation system in the summer (Brougham, 1960), while a number of management procedures are available for increasing the currently low yield of white clover in many New Zealand pastures (Suckling, 1964; Brougham, 1966; Lancashire, 1974).

Although some of the legume species mentioned in this. paper offer exciting nutritional possibilities, they may be difficult and costly to grow in New Zealand. In addition, the management rules may be unconventional. For example, Maku lotus and sainfoin may be relatively low yielding, are susceptible to defoliation and to competition from white and red clover, and are unlikely to contribute much to animal feed if sown as a small part of the legume component in a pasture mixture. Current agronomic and breeding work may solve some of these problems, but it seems likely that, initially, special-purpose pastures will be needed for the optimum utilization of these potentially valuable animal feeds.

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