PASTURE COMPOSITION FOR MEAT, WOOL AND MILK PRODUCTION

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Australia's sheep and cattle rely almost exclusively on pasture to provide the nutrients for meat, wool and milk production. The annual cost of producing this herbage has been estimated at $400 million (Weston and Hogan 1986); with such a huge investment, it is important that the pasture resource be husbanded and utilised as efficiently as possible.

As the pasture growth season progresses, pasture on offer changes in terms of amount, botanical composition and chemical composition. This paper will emphasize the last two of these, with a view to establishing the link between botanical composition (regarded only in terms of legume/grass balance), chemical composition and animal production.

NUTRITIONAL COMPOSITION OF PASTURE

This topic has been reviewed in detail by Norton (1982). In simple terms, plant tissue can be conveniently considered as consisting of two types of tissue; cell walls and cell contents.

Cell wall material

This comprises 30-85% of the plant tissue and consists mainly of complex polysaccharides, chiefly cellulose and hemicellulose. As the plant matures, there are increasing amounts of the phenolic polymer lignin. This may make up 2-20% of the plant dry weight and dramatically influences the digestion of plant material in several ways. First, lignin is itself essentially indigestible. Second, it is intimately associated with the cellulose in the plant cell wall and physically exerts a 'protective' effect on the cellulose during digestion, thus reducing the extent of cellulose digestion. It is significant that, when the lignin content exceeds about 6%, this protection tends to be considerably less in legumes than grasses (see Norton 1982), with the result that legume digestibility decreases less with increasing lignification than it does in grasses. The third effect of lignin is that it contributes to the mechanical strength of the plant tissue. This increases the physical resistance of plant tissue to physical breakdown during chewing and rumination and can thus reduce digestibility.

Cell contents

These consist mainly of proteins, soluble or storage carbohydrates (glucose, fructose, sucrose, fructosans and starches), organic acids and minerals. In general, cell contents are rapidly released during chewing and digestion, and are almost completely digested.

The two factors which most influence herbage composition are species and stage of maturity. As plants grow and mature, the proportion of cell wall material increases quickly, and that of cell contents declines. The nature of the cell wall material also changes. Cellulose becomes more resistant to digestion, while lignin content rises, with the consequences mentioned above. The proportion of cell walls is generally higher in stem than in leaf, so that as plants mature and reach the reproductive stage, the combination of increased stemminess and increased levels of cell wall constituents results in a sharp increase in the physical effort required for eating, chewing and rumination and a decline in digestibility. These effects are especially evident in grasses, as can be seen in Table 1. With the possible exception of lucerne, pasture legumes tend to maintain higher leaf:stem ratios at maturity.

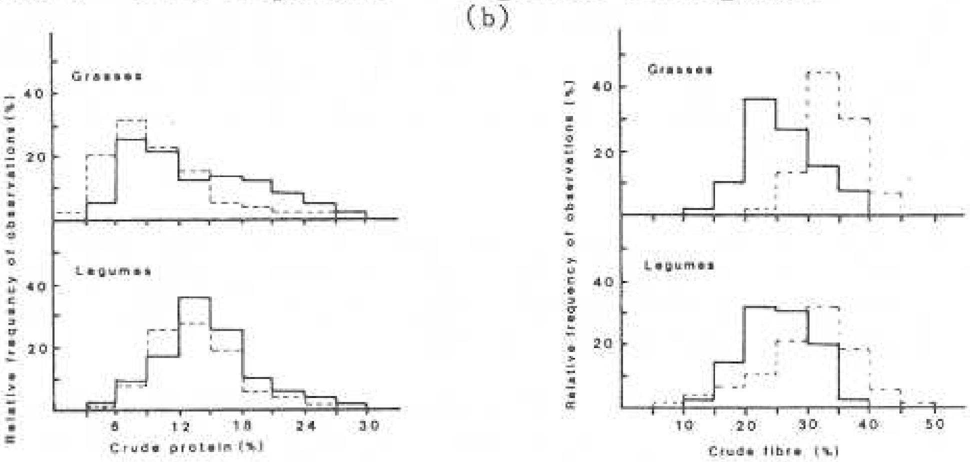
Table 1. Some characteristics of herbage composition and digestion in maturing *Phalaris aquatica* (for further details, see Ulyatt 1973).

	Stage of Maturity		
	I	II	III
Chemical composition (%DM)			
Structural carbohydrate	40.6	58.7	67.5
Soluble carbohydrate	20.9	15.1	11.3
Crude protein	26.1	19.9	11.3
Lignin	3.0	4.1	7.4
Eating time (h/kg of OM)	3.9	6.4	7.2
Ruminating time (h/kg of OM)	6.0	7.7	10.9
Intake (g/d of OM for a 30kg weaner lamb)	787	688	594

The effect of plant species on composition has been reviewed in detail by Minson (1981) who drew attention to major differences between grasses and legumes, and between tropical and temperate pasture species. In general, legumes tend to have higher protein contents than grasses, especially the tropical grasses (Fig. 1a). Within the legumes there is little difference between the temperate and tropical species. The fibre content of temperate legumes and temperate grasses tend to be similar and the major difference to note here is the much higher fibre content of the tropical legumes and grasses (Fig. 1b).

Fig 1. The distribution of crude protein (a) and crude fibre (b) in temperate (——) and tropical (- - -) grasses and legumes.

(a) (b)



As might be expected, these differences translate into differences in dry matter digestibility. In general and over a wide range of species, stages of maturity and environmental conditions, the temperate species tend to have similar digestibilities, but tropical species have lower digestibilities, especially in the grasses.

HOW DOES PASTURE COMPOSITION AFFECT ANIMAL PRODUCTION?

The `feeding value' (FV) of herbage has been defined (Ulyatt 1973) as the product of the intake (I) and the utilisation (U) of the consumed pasture:

$$FV = I \times U$$

The utilisation of the consumed pasture can itself be thought of as having two components, the digestion of what is consumed and the tissue utilisation of the products of digestion. These concepts are central to the understanding of how pasture composition affects animal production, so we need to examine what happens during the processes of digestion and tissue utilisation.

The processes of digestion

Since it has no enzymes of its own to digest plant fibre, the ruminant animal relies on its rumen population of bacteria, fungi and protozoa to digest plant cell wall material. The advantage conferred by this association is gained at some costs to intake and to protein digestion.

In the rumen, plant cell wall material is broken down by physical means (initial chewing, rumination, mixing) and by biochemical processes. It will pass out of the rumen only when broken down to a particle size small enough to be washed out into the hindgut. Therefore, if plant material breaks down faster and leaves the rumen more quickly, more material can pass into the rumen. That is, the animal can eat more. The rate of breakdown differs between species and can be impeded by physical characteristics such as fibre strength or by chemical characteristics, such as low protein content, which can reduce microbial activity to the point that fibre digestion is reduced. At the other extreme, the intake of very highly digestible pastures can be reduced by their great bulk arising from their high water content.

Dietary protein entering the rumen may pass through unaffected or, as is the case with most plant protein, may be broken down to ammonia by rumen microorganisms. If fibre digestion is rapid, its products will be coupled with the ammonia to make microbial protein, which then becomes the main source of protein to the animal. More usually, the rate of fibre digestion lags behind that of protein degradation to ammonia so that, to avoid toxicity, ammonia must be excreted as urea in urine. This represents a major avenue of protein loss to the animal. For example, for a grown sheep consuming 1.5 kg/d of pasture dry matter, containing 25% protein, 375 g/d of protein is consumed, but only 200 g/d would be expected to flow out of the rumen (Ulyatt and Egan 1979). The effective protein content of the diet is thus only 13.3%. Very high herbage protein contents may thus not confer the nutritional advantage that might be expected.

These transactions have other consequences. First, high levels of protein and soluble carbohydrate, coupled with extensive gas production during digestion, can lead to the formation of stable foam in the rumen, which we refer to as bloat. The so-called `bloat-safe' legumes, such as lotus and sainfoin, exert their effect because they contain condensed tannins, which precipitate the plant proteins in the rumen and prevent foam formation. At the same time, this prevents wasteful protein degradation in the rumen, so that these pasture species can provide more protein to the host animals. A second major consequence of the protein interchanges in the rumen results from the fact that the sulphur-amino acid content of microbial protein is considerably less than that of herbage protein. Since these amino acids are the major `building blocks' of wool protein, the resultant level of wool production is usually less than would be expected from the herbage protein level and its sulphur-amino acid content.

As a generalisation, if extensive protein degradation in the rumen can be avoided and the site of protein digestion shifted to the hind-gut, then these losses of protein and sulphur-amino acids can be reduced. For this to occur, herbage must pass out of the rumen quickly.

Utilisation of the products of digestion

Ruminants utilise the products of rumen or intestinal digestion with different efficiencies. It might therefore be expected that, depending on the site of digestion and the mix of nutrients which results, the overall efficiency of utilisation of nutrients would change. These aspects have been examined experimentally and reviewed in detail (e.g. Ulyatt 1973; Armstrong 1982), but for the present purpose, it is sufficient to discuss them principally in terms of the effects of digestibility, as in Table 2.

Table 2. The effect of herbage digestibility on the efficiency of utilisation of absorbed energy for weight maintenance, growth and milk production.

Digestibility (%)	Efficiency of Conversion (%) for: Maintenance	Growth: Grasses	Growth: Legumes	Lactation
50	64.5	14.8	31.2	54.5
60	67.6	24.6	37.9	57.6
70	70.7	34.4	44.6	60.7
80	73.9	44.2	51.3	63.9

The efficiencies shown were calculated from the material reviewed by the Agricultural Research Council (1980); several points should be noted.

(a) The efficiency of utilisation for maintenance increases gradually with increasing digestibility.
(b) The efficiency for milk production increases at a similar rate, though at a lower level.
(c) As digestibility increases, the efficiency of utilisation for growth (weight gain) increases sharply. Moreover, the expected efficiencies with legumes are considerably greater than with grasses. In effect, to achieve the same efficiency with a grass as with a legume, the digestibility has to be at least 10 percentage units higher.

Hence, in addition to allowing greater intakes, pastures of higher digestibility are also utilised better after digestion and absorption. In this regard, legumes are better than grasses, and this has major consequences for animal production.

COMPARISONS OF ANIMAL PRODUCTION FROM LEGUMES OR GRASSES

The relative superiority of legumes for supporting high rates of gain in young stock has been demonstrated in many trials. The results of two such comparisons are shown in Table 3; for ease of comparison, the weight gain on the ryegrass is in each case set to 100.

Table 3. Relative liveweight gains of young sheep grazing pure swards of a range of pastures in New Zealand (Ulyatt 1981) or in southern Australia (Freer and Jones 1984)

Reference	Pasture species	Relative liveweight gain
Ulyatt	Perennial ryegrass	100
	Short-rotation ryegrass	148
	Italian ryegrass	160
	Timothy	129
	Browntop (*Agrostis tenuis*)	
	Spring	100
	Summer	83
	White clover	186
	Lucerne	170
	Lotus pedunculatus (Maku)	143
Freer & Jones	Wimmera ryegrass	100
	Phalaris (Australian)	109
	Subclover (Bacchus Marsh)	124
	Lucerne (Hunter River)	134

The consistent superiority of legumes for liveweight gain is obvious. It is also of interest to note that, in studies where cocksfoot is included in the comparisons, it consistently ranks worse than perennial ryegrass. There has been less work done with growing cattle; the little data available suggest that the rankings of the pasture species are similar.

The evidence to date suggests that these differences between legumes and grasses are about half due to the extra intake of legume and about half due to the extra efficiency with which the products of legume digestion are used (Ulyatt 1973; Armstrong 1982; Freer and Jones 1984). At the same level of digestibility, legume breaks down faster in the rumen and flows out quicker (e.g. Freer and Jones 1984). As a result, the intake of legume is higher than of grass with the same digestibility. For example, Freer and Jones (1984) found that, at similar digestibilities, the intake of lucerne or subterranean clover was similar, and was 187 g/d higher than the intake of Wimmera ryegrass or phalaris. In both grasses and legumes, they found that the intake rose by 20 g/d for every percentage unit increase in digestibility.

Due to the more rapid disappearance of legume from the rumen, protein digestion shifts more towards the intestines and there is a higher protein:energy ratio in the products of digestion (see Armstrong 1982 for details). This would be expected to result in higher efficiencies of utilisation of the nutrients from legume digestion; there are experimental data to support this expectation, as shown in Table 4. Hence, an increase in the legume content of pastures would be expected to confer the twin benefits of increased intake of pasture and more efficient utilisation of the products of digestion.

Table 4. Effect of pasture type on the efficiency of utilisation of absorbed energy for liveweight gain, at equivalent digestibilities

Pasture species	Efficiency of utilisation (%)	Reference
Perennial ryegrass	33	Rattray & Joyce 1974
White clover	51	
Phalaris	35	Freer & Jones 1984
Subclover	48	
Lucerne	54	

FIELD RESPONSES TO INCREASED LEGUME CONTENT OF PASTURE

Under field conditions, changes in the availability of pasture and in the balance of legume and grass often occur together. For example, in a study of a sheep-meat production system near Canberra, we found that superphosphate application (250 kg/ha) resulted in a 40-50% increase in total pasture availability in a phalaris/subclover pasture, but also resulted in a 200-300% increase in the supply of legume. Lamb sales were increased by 40-50%. Was this due to increased pasture supply, increased legume content of pasture or both?

Since it can be costly to increase the legume content of the pasture, either by sowing or by fertilizer, it is important to explore the relative contributions of pasture supply and legume content. However, this can be difficult because, at pasture, so many aspects of the grazing system are interacting. One approach to assessing pasture and animal responses is to use computer-based animal nutrition packages, such as GRAZFEED, developed by Dr M. Freer of CSIRO, Canberra. This package takes a very large mass of information about ruminant nutrition and applies it to the Australian grazing system in such a way that we can explore the above question. In Figures 2 and 3, the GRAZFEED model has been used to assess the response to either increased pasture supply or increased legume content, of liveweight gain or wool growth respectively.

Figure 2

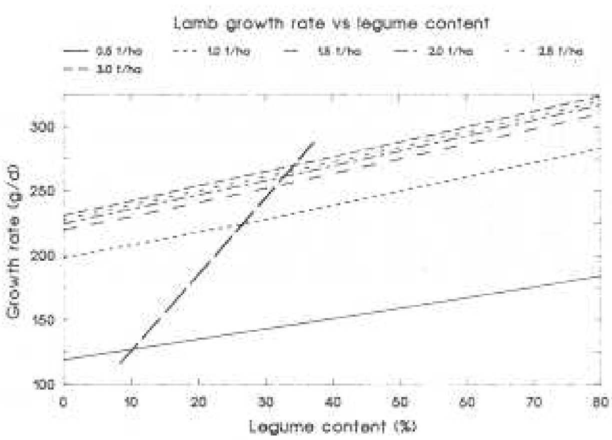
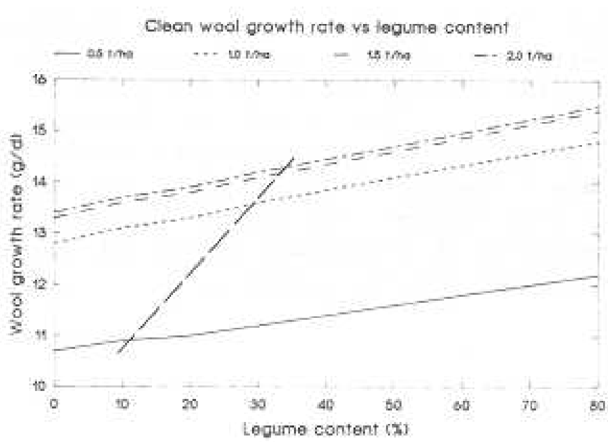


Figure 3



The responses in Fig. 2 indicate that, when pasture availability is low (500 kg/ha of dry matter), increasing the pasture legume content from 0 to 80% increases lamb growth rate by 65 g/d, as a result of both increased intake and better utilisation. Note, however, that it is both difficult to increase pasture legume content by such a large amount and difficult to maintain it at this level. By contrast, increasing pasture supply from 500 to 1000 kg/ha increases average lamb weight gain by 90 g/d. The implication is that if pasture supply is sparse, it is better to concentrate on increasing the supply rather than increasing the proportion of legume. When pasture supply exceeds 1000 kg/ha, the extra response in lamb liveweight gain progressively decreases, as the animal's intake limit is approached. However, the response to increasing the proportion of legume remains the same. Hence, if management can sustain a pasture supply of say, 1500 kg/ha, then major gains can still be made by increasing the proportion of legume. In practice, and as suggested above, the same management manipulations (e.g. fertilizer application) tend to increase both pasture supply and legume content. In this case, both gains are reaped, as shown by the transecting heavy dotted line. For these reasons, the provision of adequate pasture with a high legume content is crucial for getting meat lambs to market, or for getting well-grown wool weaners, before the pasture growth season finishes.

In the wool-growing wether (Fig. 3), the responses are essentially very similar, since wool growth responds both to increased intake and to the increased post-ruminal supply of protein which results from increasing the legume content. It is also worth noting that, even in a pasture with high-legume content, it is likely that the absorbed protein is still deficient in sulphur-amino acids, relative to the demands of wool growth, and that wool growth would be likely to increase if extra sulphur-amino acids could be delivered to the animal in some way.

In a number of studies, the milk production of ewes or cows grazing grass pastures has been increased by the provision of protein supplements (see Thomson 1982 for details), implying that grass pastures are inadequate in terms of providing protein for milk production. Moreover, substitution of white clover for perennial ryegrass has increased the weight gain of suckling lambs (Gibb and Treacher 1983) and has led to increased milk production in dairy cows (see Thomson 1982). Hence, there is considerable evidence that there are also advantages for milk production in increasing the legume content of pastures. However, graphs such as Figs 2 and 3, which might allow an assessment of the effects of pasture supply and legume content, are very difficult to produce for milk production, because of the complications caused by the animal's body reserves of energy. When animals are lactating and pasture supplies are sparse, the nutrients for milk production come not only from the diet but also from the mobilisation of body reserves (fat). Similarly, when pasture is abundant, the absorbed nutrients will be used not only for milk production but for repletion of the body reserves. The response of milk production to changing pasture conditions is thus more difficult to predict.

ECONOMIC PAYOFFS FOR INCREASING LEGUME CONTENT?

Studies of grass-based versus legume-based pastures in large-scale field trials have indicated profitable responses to increasing the legume content of pasture. For example, over several years and with both merino and crossbred enterprises, studies near Canberra (Donnelly et al., 1983, 1985) showed that wool production and meat production per hectare were greater, over a wide range of stocking rates, on lucerne-based rather than on phalaris-based pastures. (There was subclover in the pasture in both systems). Total gross margins per hectare were much higher from the legume-based system.

Similarly, studies in the Western District of Victoria, with a wool growing system (Saul 1986) showed that, on high legume pastures, weaners grew faster in spring, were heavier at shearing, grew more wool and needed less supplementary grain over summer.

CONCLUSION

Pasture composition changes continually throughout the year, and there are major differences between grasses and legumes. Within a pasture species, the major determinant of animal intake and production is the digestibility of the pasture on offer. When comparing grasses and legumes, differences in intake and efficiency of utilisation are apparent when comparisons are made at the same digestibility. Since legumes allow greater intake, increased protein supply and better utilisation of absorbed nutrients (at least for weight gain), there are nutritional and probably economic advantages to be gained by attempting to maintain a high and stable proportion of legume in the pasture. The practical means by which this can be achieved remain a major challenge for both researchers and for farmers.

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