Limitations to increasing nutrient supply from forages

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Abstract: Nutrient supply from pastures is the main factor influencing growth rate and milk production from pasture. The major factor affecting nutrient supply is the intake of the pasture which is influenced by how the pasture is grazed and the digestibility of the pasture. Protein supply with respect to the energy intake by the animal is the important nutrient supply and shows large variation from expected values because of variation in the efficiency of microbial crude protein production. This seems to be most influenced by the level of water soluble carbohydrate and non-structural carbohydrate. There are a number of strategies which can be used to supply more protein to an animal, all of which will have similar outcomes so there is no fixed approach to increasing nutrient supply. The traditional approaches of grazing management and supplementation can be just as effective as the high technology molecular gene approaches.

Growth, milk production and fibre production depend on the level and type of nutrients presented to the target tissues. This is primarily a function of intake and digestion as these two parameters show the widest variation in forages from different sources. The efficiency with which tissues utilize the balance of absorbed nutrients also influences the final level of production, but the variation in efficiency of use of nutrients is not as quantitatively important as the variation in intake and digestibility. Intake of forages can vary from less than 1% liveweight (W) (maintenance) to 4%W (in lactating cows) and digestibility from 40% (*eg.* straws) to 85% (*eg.* ryegrass and white clover).

Pasture attributes

The objective in a production feeding system is to maximize the intake of digestible nutrients and to ensure they are within an acceptable nutrient balance range so that they can be utilized most efficiently. Intake of an existing forage base is maximized by ensuring good sward structure is achieved and that sufficient feed is allocated. Good sward structure is difficult to define but plants which are erect and have high leaf bulk density in the upper horizons promote the highest rates of intake and average daily intake. The intake of temperate pastures is particularly sensitive to sward structure and the amount of leaf allocated on a daily basis to each animal (Hodgson 1982; Poppi *et al.* 1987).

Tropical pastures have a much lower bulk density of leaf and intake is less sensitive to the sward structure and more sensitive to the allowance of green leaf dry matter (DM) (kg green leaf DM/100 kg W/day). This arises partly because the rate of intake of tropical pastures is much less than that of temperate pastures (Stobbs 1974). From these studies have arisen the general recommendation to keep herbage mass above 1500 kg DM/ha, herbage height above 6-8 cm and allocate feed on the basis of an allowance (kg DM/W/d) or residual herbage mass system (kg DM/ha) depending on the desired level of production. The quadratic asymptotic nature of the response curve of animal production (growth and milk production) to allowance or residual herbage mass is well documented such that high allowance and low utilization is associated with high production/animal and low allowance and high utilization is associated with low production/animal (Poppi *et al.* 1987). Many grassland managers do this intuitively and in New Zealand this has been quantified into very intensive systems with some simple rules. The point of this is that in seeking to increase production or identify limits to animal production, sward structure and its influence needs to be clearly understood before one embarks on an investigation into more traditional nutritive value indices. Some aspects of nutrient supply are examined in this paper but the importance of sward structure and allowance of leaf should be noted.

Nutrient supply

Intake and digestibility are the two key features influencing nutrient supply and this is quantified in terms of metabolizable energy (ME) and metabolizable protein (MP). ME is available to the animal in the nutrient forms of volatile fatty acids (mainly acetic, propionic and butyric acid), amino acids, glucose and fatty acids. The balance of these nutrients can be influenced by the diet and in some cases this can have a marked effect on animal production, *eg.* the feeding of large amounts of grain to dairy cows can lead to high propionic acid levels and depressed milk fat. Manipulation of the forage either through supplements, plant breeding etc. will never alter just one nutrient. There is a shift in the balance of nutrients towards one or more types. Since individual nutrients are rarely measured, the most common balance is the protein/ energy (P/E) ratio of the absorbed nutrients which for practical purposes is listed as crude protein content.

The most effective way to increase nutrient supply is to increase intake. Intake of pasture can be increased by allocating a sufficient amount of pasture through appropriate allowance, by removing any specific nutrient deficiencies, *eg.* protein or minerals which occur at the rumen or tissue level or by replacing the existing pasture base with one that has an inherently higher intake. Plants may be selected in a breeding program for characteristics that promote higher intake but generally this procedure is slow and has been of limited success (Burton 1969). However, for agronomically competitive species this may still be the best way forward, *eg.* those species such as *Chamaecrista* sp. (Cassias) which are adapted to acid soils and there are few alternative species which will grow in this environment. The most successful approach has been to replace the existing pasture species with a new pasture species. This may have two separate objectives. One objective may be to replace the pasture species with another of much higher DM production but of similar intake and nutritive value. This is the rationale of the successful use of forage sorghums, maize silage *etc.* The other objective is to replace the pasture species with another of higher intake, *eg.* replace tropical species with temperate species or create special purpose paddocks of lucerne or leucaena, or to introduce into the pasture base a plant to provide limiting specific nutrients or increase intake, *eg.* introduce a legume into the system. The second objective, that of increasing intake and nutritive value as a strategy to improve animal production, needs to be examined a little further.

The role of intake and digestibility

There is a general positive relationship between intake and digestibility but there is a lot of variation about this relationship. Separate regressions can be fitted for temperate grasses, temperate legumes, tropical grasses, tropical legumes and within species (Minson 1990). Within species large differences can be found in intake and digestibility of various cultivars at the same physiological stage.

Table 1: Dietary Crude Protein (CP) levels above which losses in net transfer of ingested protein to the intestines occur, for diets of varying digestibility (from Poppi and McLennan 1995).

OM digestibility	CP (g/kg DM)
0.80	151
0.70	132
0.60	113
0.50	94

Protein supply

Protein supply to the intestines is the most important characteristic outside ME intake to influence liveweight gain, milk production or fibre production. ME intake is the most important parameter as any change in ME intake also has an associated change in MP intake because MP supply is intimately linked to microbial protein production in the rumen from the fermentable ME (Webster 1992, Poppi and McLennan 1995). The supply of protein to the intestines comes from microbial protein, undegraded dietary protein and endogenous protein. Microbial protein (MCP) usually comprises the majority of the protein entering the intestines, about 72% (Beever and Siddons 1986). Thus, because there is a fixed amount of MCP synthesized per unit of ME (or digestible organic matter, DOM) then the P/E ratio falls within a narrow range, much smaller than the dietary CP content range.

Such studies have shown that there is complete net transfer of dietary CP to the intestines as MCP, undegraded dietary CP and endogenous protein when the CP/DOM is about 210 g/CP/kg DOM (Poppi and McLennan 1995). Below this value there is complete net transfer and above this value there is loss of N across the rumen wall. This loss can be as high as 40% for lucerne (Cruickshank *et al.* 1992). This does not mean lucerne is not the superior nutritive value plant we know it to be but rather it indicates an inefficiency in the plant in the process of transferring plant protein to MP. The CP levels in the plant which equate to this value of 210 g CP/kg DOM for varying levels of digestibility are given in Table 1. Above these CP levels some protein will be lost in the transfer from dietary CP to MP. The table indicates that this is a common feature of temperate pastures with high CP and digestibility but not so for tropical pastures with low CP and digestibility.

In examining how we might increase protein supply to animals in the form of MP there are two features we need to examine, the degradability of the plant protein and the microbial protein production in the rumen.

Degradability of plant protein and the role of legumes

Most plant protein is highly degradable and the Australian feeding standards (SCA 1990) use a high value [63-92% SCA (1990) Cruickshank *et al.* (1992)]. This is because 35-40% of it is in the form of Rubisco, the rate limiting enzyme in photosynthesis. Degradability is a function of the rate of degradation and the rate of passage and as generally fractional passage rate is much slower than fractional digestion rate then degradation is usually high. However, when high quality temperate legumes (lucerne or white clover) are grazed by early weaned lambs, rumen conditions are such that passage rate is very fast and degradability can be as low as 63% (Cruickshank *et al.* 1992).

Degradability is also influenced by condensed tannins which bind to the protein at the pH within the rumen. Plants with condensed tannin have lower degradability of plant protein, *eg. Lotus* sp., *Desmodium* sp. and *Leucaena* sp.

Reducing the degradability of plant protein is often suggested as a strategy to improve MP supply and certainly benefits are observed where condensed tannins are present (Barry *et al.* 1986, Perez-Maldonado and Norton 1996). Too high a level of condensed tannin can cause irreversible binding such that no extra or even less protein is absorbed.

Including a legume in a pasture is also often suggested as a means of increasing protein supply. However if the legume is highly degradable then Poppi and McLennan (1995) have shown that unless it increases intake it will not markedly increase MP supply (Table 2).

Microbial protein supply and plant soluble carbohydrates

The amount of MCP produced depends primarily on the organic matter (OM) fermented in the rumen. This is why a higher intake will lead to more protein supply to the animal. However, the amount of MCP produced per kg of OM fermented varies. The feeding standards such as the AFRC (1992) have values from 132 to 162 g MCP/kg DOM depending on dilution rate as influenced by level of feeding. The Australian Feeding Standards (SCA) (1990) uses a similar range (130-170 g MCP/kg DOM) but points out that many forages, especially tropical forages, have values much lower than this (d g MCP/kg DOM).

Dilution rate as influenced by level of feed intake and pasture type will have most influence on MCP synthesis (Bannink *et al.* 1997). However, the level of soluble carbohydrate either expressed as water soluble carbohydrate (WSC) or non structural carbohydrate (NSC) also has a major effect (SCA 1990). They recommend a minimum level of 90 g WSC/kg DM. The efficiency of MCP production (g MCP/kg DOM) has a major effect on the final supply of MP. Dove and Milne (1994) showed a 2 fold increase in the efficiency of MCP production from 90 (autumn) to 169 (spring) g MCP/kg DOM which they related to differences in the level of soluble carbohydrate between the seasons. Thus a change in level of fermentable carbohydrate brought about by an increase in NSC or WSC would have a much greater increase in MCP than that simply resulting from the extra fermentable carbohydrate.

NSC and WSC are perhaps under-rated in their influence on MP supply and certainly overlooked in the use of feeding standards for grazing animals.

Chatterton *et al.* (1989) have provided the most comprehensive investigation of environmental effects on levels of NSC and WSC. Briefly, growth at high temperatures reduced NSC for C3 and C4 plants and the level of NSC was so low in many species as to likely affect the efficiency of MCP production.

Similarly, short daylength and shading also reduces the level of NSC (Samarakoon *et al.* 1990). Fulkerson and Slack (1995) showed that defoliation of ryegrass at the three leaf stage resulted in high WSC levels (175 g/kg DM) but more frequent defoliation at the 1 leaf stage caused a marked depression in stubble WSC (21.5 g/kg DM). Smouter *et al.* (1995) demonstrated that WSC in the leaf was highest in a low density sward compared with a high density sward (113 vs. 71 g/kg DM) and declined markedly during senescence to 30 g/kg DM. Poppi *et al.* (1997) collated these responses and discussed their quantitative significance and suggested they are a major factor in determining the nutritive value of a plant, the significance of which for protein supply can be seen in Table 3.

The issue is not quite as simple as level of NSC and WSC and certainly the interaction with dilution rate is important. Bolam *et al.* (1998) used various carbohydrate sources (starches and sugars) and were not able to rapidly increase the efficiency of MCP production. For this study on tropical rhodes grass hay, the efficiency of MCP production was low (ca. 80 g MCP/kg DOM) but only increased slowly as extra carbohydrate was added and only reached "normal" values of ca. 130 g MCP/kg DOM when

Table 2: The estimated effect of including white clover in a grass of about 10% crude protein content for cattle (adapted from Poppi and McLennan 1995).

	Grass	Grass (70%) + white clover (30%)	Grass (70%) + white clover (30%). Intake increased by 30%
OM intake (kg/d)	4	4	5.2
Intestinal protein supply g/d	360	456	593