Limitations to Milk Production from Pasture

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Summary

A milk yield of 20–25L per day from Friesian cows appears to be achievable from pasture as a sole feed. Genetic merit of stock grazing the pasture, availability of pasture and pasture species all influence the actual level of production, although to a surprisingly small extent. For example, even with extreme differences between cows in genetic merit (Australian Breeding Value for fat plus protein of 41 v 2kg/cow) there was only a 3.5L difference in daily milk yield/cow from pasture. Recent studies in France with high producing cows have shown that available pasture (DM on offer) has to increase by 27kg DM/cow/day to increase milk yield by 2.6L from 20.4L/cow/day. In extreme species comparisons, C_4 grasses produced 5L milk/cow/day less than C_3 grasses whilst clover may give 3.5 L more, although these studies were with relatively low producing animals.

Lifting the ceiling on production with the factors discussed above may be wasteful (increased feed availability) or may not be sustainable (pure clover swards).

The potential exists to increase milk production from pasture by improving the protein:carbohydrate ratio, which is too high in most pastures, by supplementing cows with carbohydrates. However, there are practical problems in synchronising the availability of carbohydrates, in cows fed twice-a-day at milking, to promote use of excess dietary N from pastures.

Two possible approaches to this problem are:

- Feed a readily fermentable carbohydrate to stimulate microbial activity pre-grazing
- Feed a slowly degrading source of carbohydrate to match the release of N from pasture during grazing.

However, a better option may be to ensure a high level of non-structural carbohydrates in the pasture by adjusting grazing times and perhaps species. Dependant on time of day, regrowth stage and season of the year, and within practical reality, soluble carbohydrate levels in ryegrass have been shown to vary from <2% to over 3 0% with protein levels usually tending in the opposite direction. This provides potential to manipulate the CP: WSC ratio substantially.

Introduction

What limits milk production capacity of dairy cows grazing pasture? This question is being increasingly asked by dairy farmers as they strive to improve financial margins by reducing costs or by increasing production, or both.

Is it the physical limitation imposed by ingestion of pasture by the animal (see de Jong, 1986) or is it within the rumen, or is milk production limited by a lack of certain nutrients in pasture?

There is evidence that production per cow is limited to 20-25 L milk/day when temperate pasture is the sole feed. Van Soest (1982) claims that the primary determinant of intake is Neutral Detergent Fibre (NDF) content of feed. There is certainly a very significant positive linear relationship between forage digestibility and intake (Hodgson, 1977). However, van Vuuren (1993) has shown that with high quality forages, rumen capacity changes in a positive way with NDF content, indicating that NDF may not be the major limitation.

According to Beever and Siddons (1986), production of milk from abundant pasture is limited by insufficient amounts of essential amino acids bypassing the rumen to the small intestine. However, there is little evidence for a production response of cows grazing pasture to two of the most limiting amino acids – methionine and lysine – when fed in a form protected from degradation in the rumen, at least in Australia (Kikuyu; L. Trevaskis, unpub.data.) and New Zealand (Ryegrass; M. van Houtert, pers. comm) when production is 20–28L milk/cow at peak lactation. This is in line with observations of Oldham (198 1) that, in animals whose demand for metabolisable protein/unit of metabolisable energy is around 6.5g MP/MJ of ME, the quantity and quality of amino acids in microbial protein alone should be enough to satisfy their needs and this equates to a milk production level of 20L/cow/ day. In fact, Virtanen (1966) showed yields of milk up to 5000L/cow per lactation can be sustained on diets where the sole source of N is urea. Therefore on pasture-only diets, where dietary N levels may already be excessive, amino acid supplementation would not be expected to result in a production response in cows producing 20L milk/day or less.

The more likely restriction would appear to be energy (Meijs, 198 1) and van Vuuren (1993) has calculated that, under ideal conditions, energy in pasture restricts milk yield to 27 L/cow/day.

In practice, 5,500–6,000L milk/cow/lactation has been obtained from cows grazing well-managed ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture as the sole feed (plus silage made from that pasture) (M. Blacklock, pers. comm.). Such pastures can also be the basis for a total yield of 8000–9000L milk/cow/lactation when there has been judicious use of concentrates (G. Hough, pers. comm.). These levels are equivalent to an average production of 20–22L milk/ cow/day fiom pasture, over the entire lactation.

What possibilities exist for breaking through this production ceiling?

The following factors may all have a major influence on potential milk production from pasture.

- Genetic merit of stock grazing pasture;
- Pasture availability;
- Variation between pasture type/species in chemical composition and digestibility;
- Balancing nutrients deficient in pasture with appropriate supplements.

Genetic merit of stock grazing pasture

The parentage of the Australian Friesian dairy herd is becoming increasingly based on cows selected within a total mixed diet/feed lot system of farming in North America. These cows are not selected for foraging ability (bite size, grazing time), nor for good feet to walk the increasing distances required in larger and larger herds at pasture, nor tolerance to heat or other adverse weather conditions. It is true that progeny are tested under Australian conditions but perhaps we are simply comparing North American genes.

A study at Wollongbar, underway for 2.5 years, aims to see if high genetic merit cows retain their production advantage if they are fed on pasture alone. Comparisons were made between farmlets whose pastures were initially similar but stocked with high or medium genetic merit cows.

The results in Table 1 show that high genetic merit animals produced more on ryegrass/white clover pasture than medium genetic merit cows given the same feed availability.

Thus, at constant body weight (and by inference, all nutrients for milk coming from pasture) high ABV cows (in the top 2-3 herds in NSW for ABV) produced 3.5L more milk/cow/day than medium genetic merit cows (ABV equivalent to 1988 national herd) without affecting protein content.

The ability of high genetic merit cows to produce more was due to their ability/willingness to partition more feed to milk and to graze harder to achieve the higher intake. Post-grazing residues were more than 200kg DM/ha lower on the high genetic merit farmlet than the medium genetic merit farmlet. These results are consistant with studies in New Zealand (Anon, 1983; Grainger *et al.* 1985;) and in Ireland (see Halleron, 1994), also on pasture.

Table 1 Condition score, liveweight and production of Friesian cows of high and medium genetic merit in early-mid lactation at a time of constant liveweight.

Genetic Merit ABV (fat + protein/cow)	Cow condition[a]	Daily production/cow[b] L milk	kg fat	Liveweight (kg)
41	4.1	24.5 ± 0.3	1.68 ± 0.02	481
2	4.6	21.0 ± 0.6	1.48 ± 0.07	495

[a] Score from 1 to 8

[b] At nil liveweight change in early–mid lactation and excluding first–calf heifers still growing. No concentrates were fed.

Pasture availability

Increasing pasture availability (kg DM/cow) increases intake and hence production per cow in a curvilinear fashion, but the utilisation of pasture offered is substantially reduced and unless steps can be taken to remedy this, the benefits may be negligible or negative.

Recently, Peyraud et *al.* (1996) found that herbage available per cow had to rise from 19 to 46kg OM/cow/day to achieve a rise in OM intake of 2.9 to 16.7 kg/cow and to raise milk yield from 20.4 to 23 .0 kg/cow/day. The provision of an extra 27 kg OM per cow would be of dubious benefit unless other measures could be taken to offset the consequent wastefully low utilisation, such as using followers (dry stock).

Pasture type/species

There is a marked difference in milk production potential between C_3 (temperate) and C_4 (tropical) grass pastures. A production ceiling of 12L/cow/day has been claimed for C_4 grasses (Cowan, 1975), but up to 15L/cow/day on kikuyu (***Pennisetum clandestinum)*** has been achieved with appropriate management (Reeves ***et al.*** 1996). This management relies on developing a dense canopy of leaf with the stem being removed mechanically after grazing. The stem of kikuyu has a ME value of about 7.5 MJ/kg DM whilst the leaf may be up to 9.5 MJ/kg DM.

Intake of kikuyu appears to be restricted to 13 kg DM/cow/day, probably due to the high NDF levels (65-75% v 35–45% for kikuyu and ryegrass, respectively) and perhaps by the low levels of fermentable carbohydrates (2–6% water soluble carbohydrates (WSC) plus starch) (Fulkerson *et al.* 1997). The sodium and phosphorus concentrations and the availability of calcium are also low (Reeves ***et al.*** 1996).

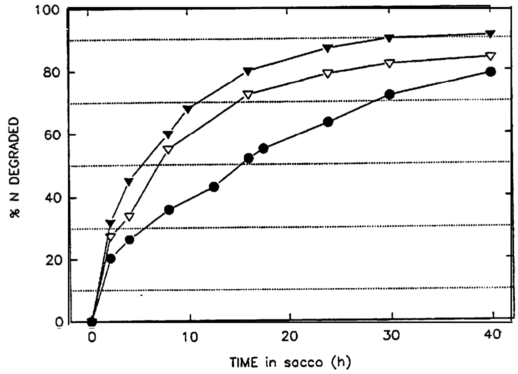

Figure 1 Percent N degraded in sacco for white clover (t), perennial ryegrass (∇) and kikuyu grass (1). Values are means for at least 5 samples, plucked pre–grazing to simulated grazing height for milking cows during the recognised growing season for each species.

Intake of short rotation ryegrass (*L. multiflorum*) by dairy cattle has been shown by Wilson (1966), to be higher than of perennial ryegrass although a difference in milk production has not been shown. The difference in intake may be due to higher levels of fermentable carbohydrates (Fulkerson *et* ***al.*** 1994) and preferential selection for the short rotation ryegrass if they have a choice (W Fulkerson, unpub data).

Cows giving rather low production (13.4 L milk/d) on abundant ryegrass produced about 25% more milk (16.7L milk/d) on pure white clover pastures, with milk fat plus protein 35% higher. These production increases were associated with a 33% increase in DM intake (Rogers *et al.* 1982). The higher intake of clover is believed to be due to its lower cell wall content and higher levels of protein and cell constituents (Dermarquilly and Jarrige, 1973) and can be expected to result in a higher amino acid flow from the rumen. Beever ***et al.*** (1986) showed that the quantity of amino acids entering the duodenum was 30% higher in dairy cows fed white clover than those fed ryegrass.

A comparison of the rates of degradation of N for these three pasture species is shown in Figure 1 and reflects their milk production potential.

Balancing nutrients in pasture

In ideal dairy pastures, the rate of microbial growth in the rumen is dependent on the availability of protein (N) and carbohydrates (energy) (Van Vuuren, 1993). Protein content is nearly always too high whilst the levels of non-structural carbohydrates (free sugars, fructosans and starch) are too low. This results in high rumen ammonia levels and inefficient use of N which is reflected in high urine N loss and milk urea levels. For example, the mean milk urea levels in cows grazing pasture in Australia is over 400 mg/L (L Trevaskis unpub. data) compared to 150-300 mg/L for cows receiving a completely balanced ration in North American feed-lot dairies.

Excess dietary protein intakes leading to high rumen NH_3 levels, can potentially reduce production, because of the energy required to synthesize and excrete urea (Blaxter, 1962). Sometimes (Elrod and Butler, 1993), but not always (Howard ***et al.*** 1987), high protein intake may reduce reproductive performance, although this has not been shown in Australia under grazing conditions (L. Trevaskis, unpub. data).

Supplementing with carbohydrate

Work by Hoover and Stokes (199 1) indicates that the ratio (g/g) of non-structural carbohydrates to degradable intake protein should be about 2.0 to optimise microbial activity. Apart from the ratio of carbohydrate to protein in the feed, studies by Sinclair ***et al.*** (1993) have shown the importance of synchronising the availability of these three feed components for the rumen microbes in stall-fed sheep.

The provision of additional carbohydrates to match (synchronise with) the release of the high levels of N liberated from pasture at grazing is difficult. Supplements are usually fed twice-a-day at milking whilst the most intense grazing activity is for 4h following milking (Cowan 1975). The option of moving cows to and from feeding stalls at this time, to increase frequency of supplementary feeding, completely compromises effective grazing management and would probably negate any benefit.

One option may be to feed a carbohydrate source which has its highest rate of degradation coinciding with the peak period when protein N in pasture is being liberated by microbes in the rumen following grazing as shown in Figure 2.

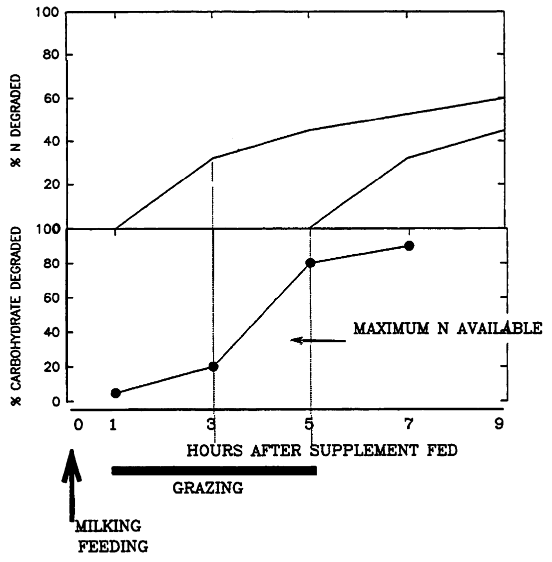

Figure 2 Schematic representation of the degradation of pasture N in the rumen in a 4h grazing period after feeding a carbohydrate-based concentrate with carbohydrate degradability characteristics to match N availability in the rumen.

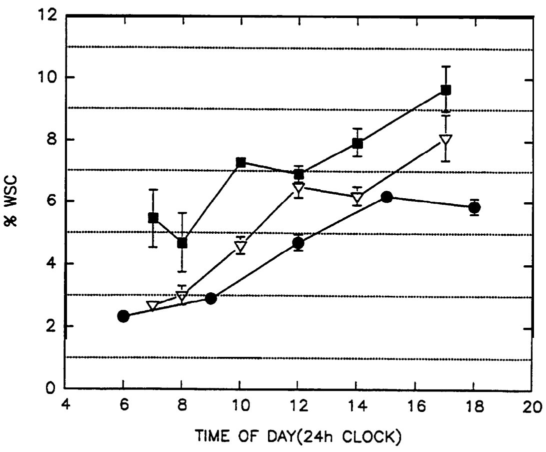

Figure 3 Percent water soluble carbohydrates in the leaf of annual ryegrass (■), perennial ryegrass (V) and kikuyu (1) estimated for samples taken between 06.00 and 18.00h.

An alternative proposal may be to feed readily fermentable carbohydrates in the dairy at milking in order to increase microbial numbers to cope with the inflow of forage at the subsequent grazing. For this to be effective, the following conditions may need to apply:

- The level of soluble carbohydrates in the grass would need to be adequate to maintain a larger microbial population. This may not be the case with young grass (Fulkerson and Slack, 1994).
- Work by Hesbell(1979) has shown that up to 60% of rumen microbes die within 2h if they have an inadequate supply of energy. Hence the time between concentrate feeding and start of grazing would have to be less than 2h.

Generally, however, the effect on N-utilisation of feeding carbohydrate-based concentrates to cows grazing pasture has been small. There may be two explanations for this. Firstly, that the efficiency of microbial synthesis from pasture is already high (J. Peyraud, pers.comm.). Secondly, if the metabolisable protein received from pasture diets is adequate for milk production of up to 20L/cow/day, any increased flow of metabolisable protein to the small intestine would be absorbed and could lead to increased absorption and catabolism of amino acids and increased urinary N output (Peyraud *et al.* 1996).

Changes in crude protein (CP) to water soluble carbohydrates (WSC) ratio with time of grazing

It seems more appropriate to improve the ratio of CP to WSC in the plant itself. Studies at Wollongbar and elsewhere have shown large differences in this ratio dependent on time of grazing.

Time of day

The level of non-structural carbohydrate in the pasture plant is the result of the balance between gains from photosynthesis and loss through respiration. As a consequence, WSC levels are lowest at sunrise, after respiration during the night, and highest in late afternoon. Diurnal changes in the levels of WSC in the leaf of perennial, and 'annual', ryegrasses (Fulkerson *et al.* 1997) and kikuyu grass (Reeves et *al.* 1996) in the subtropical environment of Wollongbar are shown in Figure 3.

The absolute values for ryegrass are relatively low because samples were taken in early autumn. Overall, there is about a 0.5% rise in WSC/hour during daylight hours.

Thus, a cow eating 15kg DM of perennial ryegrass from 3 to 6 pm would ingest 0.8 lkg more WSC than if she grazed her pasture allocation at 5 to 8am. There is some potential to take advantage of this by providing a new block of pasture after the PM, rather than AM, milking. Intake is always highest when a fresh block of pasture is given and declines with time (Walker and Heitschmidt, 1989).

Incoming solar radiation

Leaf carbohydrate levels can be markedly depressed by cloudy weather as shown in Figure 4.

There is a very close relationship between solar radiation, sunlight hours and WSC in both leaf and stem. The WSC in leaf appears to fluctuate less than in the stem-consistent with the function of the stem as a storage organ.

The fall in WSC in cloudy weather may be a factor responsible for the decline in milk yield observed in the field after prolonged cloudy weather and carbohydrate supplementation might then be beneficial.

Regrowth

There are major changes in the carbohydrate and protein contents of grass with regrowth time and this is affected by season, as shown by the information from Wollongbar in Figure 5.

In June, the ratio of CP to WSC changes from 4: 1 to 1:2 as ryegrass regrows to 3 leaves/tiller. Clear skies at this time of year ensure ample incoming solar radiation, and the cool nights minimise carbohydrate loss through respiration. In September, with higher temperatures, the change in ratio of CP and WSC with regrowth is not as marked, while in November there is no clear pattern.

The time scale in Figure 5 is related to leaf number/ tiller in the knowledge that as ryegrass expands 3 leaves per tiller, and then each new leaf initiated is balanced by senescence of the oldest leaf In this way regrowth curves can be validly compared between seasons. Delaying defoliation to optimise the **CP:WSC** ratio will not reduce sward quality provided plants do not produce more than 3 leaves/tiller. The levels of NDF in ryegrass do not change significantly during the regrowth cycle in June (mean 38%, SE ± 1.4) or September (mean 41.3± 1.14%).

Season

The seasonal variation in CP and WSC in a ryegrass/ white clover pasture is in accordance with the assumptions previously outlined (see Figure 6).

The ratio of CP:WSC is lowest in early spring and highest from late spring to autumn. It is conceivable that leaf WSC may be 2% or less for samples of young grass (1 leaf/tiller) taken in the morning in autumn to well over 30% for mature grass (<3 leaves/tiller) in the afternoon in early spring. At the same time, protein changes in the reverse manner resulting in extremes of nutritive value. 'Grass ain't Grass'.

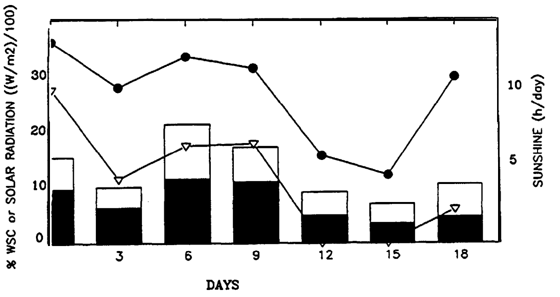

Figure 4 The percent WSC in the dry matter of perennial ryegrass stubble (■) and leaf (•) measured over an 18 d period. Corresponding mean values are given for solar radiation, ($W/m^2/100$) (●) during the periods of sunlight of varying duration (V).

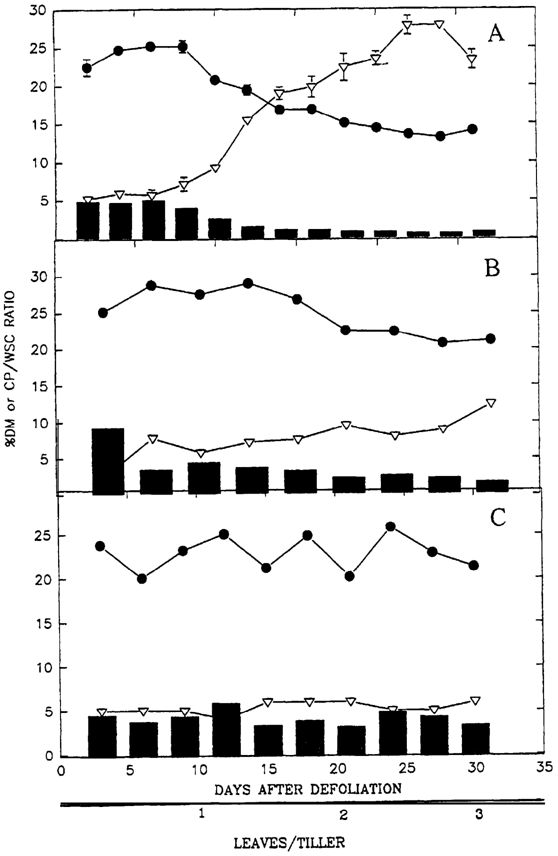

Figure 5 Percentages of crude protein (CP) (●) and WSC (V) and the **CP:WSC** ratio (■) for leaf of perennial ryegrass taken at 3h after sunrise in July (A), September (B) and November (C).

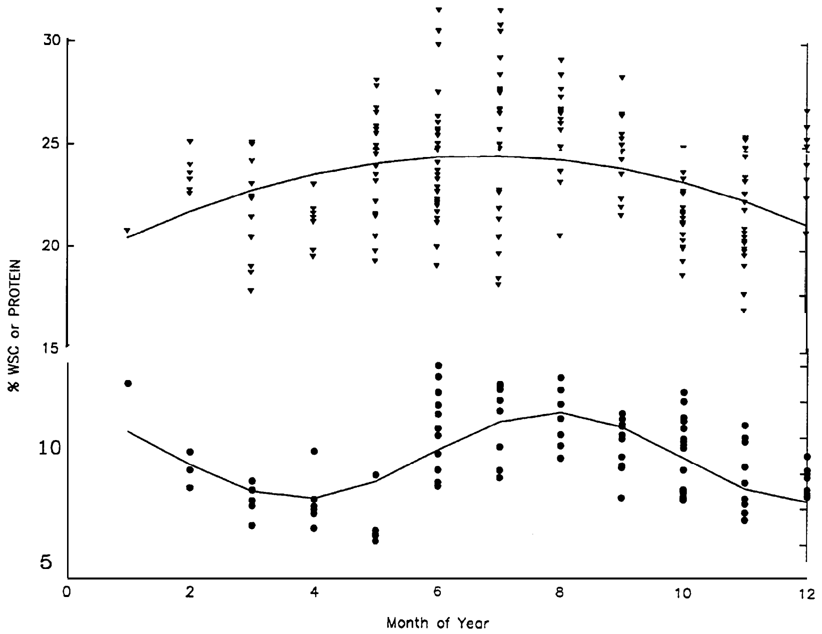

Figure 6 Percentages of crude protein (t) and WSC (1) in samples of perennial ryegrass plucked pre-grazing over a two year period. Samples were plucked to simulate grazing height for milking cows and were fitted using Table Curve (Jandel Scientific, San Rafeal, California, USA).

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