Manipulating cow diets to reduce nutrient wastage to the environment

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Summary

- Increasing Nitrogen losses to the atmosphere (ammonia and nitrous oxide) and water (nitrate) will place a limit on intensification of New Zealand dairy systems.
- Pasture breeding, improvements in pasture management and increased use of N fertiliser have all increased the protein (N) content of pasture.
- Urinary N excretion per cow increases dramatically with high protein diets.
- There are other reasons to be concerned about high protein diets- including milk taints and possible effects on cow fertility.
- Increased stocking rates with improved pasture quality, increased N fertiliser use and increase use of purchased supplements further compound the problem with excess N (increased urinary N/hectare).
- There is little evidence for beneficial reductions in urinary N excretion by changing the nature of protein within pasture species that grow well in New Zealand.
- Major reductions in urinary N excretion can be achieved by reducing dietary N content. An important long-term breeding goal is to replace protein in grasses and clover with lipids or available carbohydrates. There is already evidence for high-sugar ryegrass cultivars reducing urinary N excretion whilst increasing milk protein yields.
- Reducing fertiliser N applications will reduce urinary N, both per cow and particularly per hectare.
- Supplementation of average to high-quality pasture with high protein supplements will exacerbate the problem, with a high proportion of the supplement N excreted in urine.
- Low-protein supplements, such as maize silage, may reduce urinary N excretion per unit of milk protein produced, but are still likely to increase urinary N excretion per cow and per hectare.

Introduction

Our industry has substantial targets for growth over coming years (*Strategic Framework for Dairy Farming's Future*). Increasing production will tend to increase the levels of waste products produced, which is consequently a direct obstacle to achieving industry growth targets. Nitrogen is an important component of waste products from dairy farms with ammonia and nitrous oxide released into the atmosphere and nitrate leached to groundwater being of particular concern. Problems with urinary N are particularly acute in New Zealand because of its concentration within urine patches.

These losses will tend to increase whether production gains are as a result of growing and utilising more feed on-farm or importing feeds into the farm (or country) (Dewhurst et al., 1992). The Strategic Framework sets a target for a 50% increase in ME grown and utilised per hectare over a 10 year period from 2005 to 2015. Results over three years at Lincoln University Dairy Farm (LUDF) show that the targeted 15 tonnes of DM per hectare at 12+ ME (MJ/kg DM) can be achieved with a combination of good cultivars and excellent pasture management.

A major issue with the high-quality pasture approach is that whether high digestibility pasture is achieved by breeding or management, it has invariably been associated with excessively high pasture protein contents. High-quality pasture typically contains much more protein than is required by dairy cows (averaging 23% and often over 25% Crude Protein (in DM) at LUDF, so urinary excretion per cow is high. Legumes typically lead to increased milk production and have the further benefit of producing this without requiring N fertiliser. However, they also typically contain 1.5 to 2-times as much protein as grass and result in low N efficiency (high urinary N excretion) (e.g. Dewhurst et al., 2003).

Figure 1 summarises some results about the efficiency of conversion of feed protein into milk protein from UK-based studies with grass and legume silages and either 4 or 8 kg/day of concentrate supplement (Dewhurst et al., 2003). Two effects are clear (1) decreased efficiency with higher N intake, and (2) lower efficiency with low levels of concentrate feeding. It is not surprising that the efficiency of conversion of pasture protein into milk protein is even lower for typical New Zealand cows grazing high-quality (high protein) pasture with few supplements. The shaded area in Figure 1 shows the expected range for cows grazing high-quality pasture. In other words, New Zealand cows are excreting a large proportion of their protein intake as urinary N.

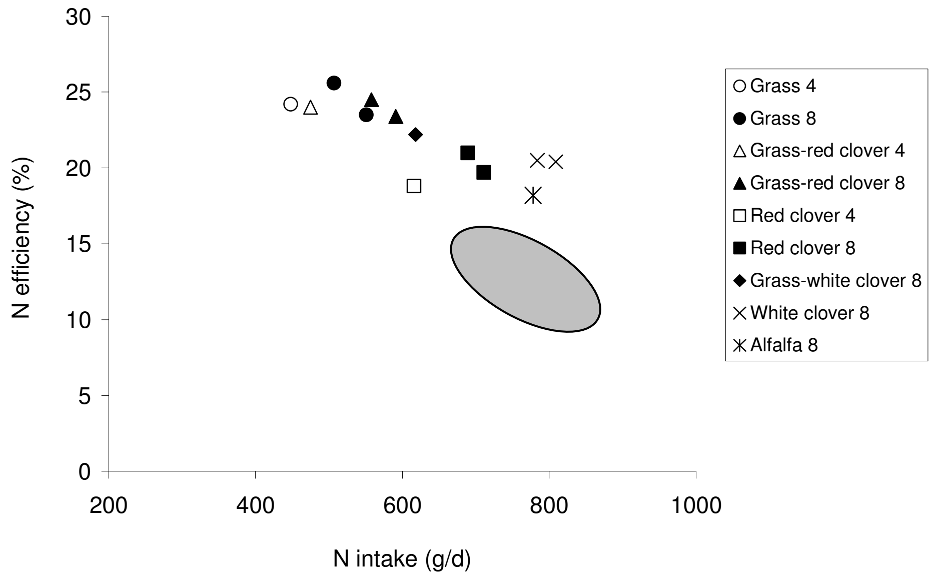

Figure 1 *Effect of Nitrogen intake (g/day) and concentrate feeding level (4 or 8 kg/day) on the efficiency of conversion of feed N into milk N.*

An analysis of nitrogen balance experiments conducted on 91 diets and 580 dairy cows in different countries (Castrillo et al., 2000) revealed that the average efficiency of utilisation of N intake for milk protein production is 28%. The detailed measurements needed for these studies mean that they have usually been done with stall-fed cows, occasionally with cut grass. The limited available evidence suggests that problems of urinary N are greater with cows grazing pasture than when fed silages and concentrates or total mixed rations. Castrillo et al. (2000) showed that faecal N averaged 21% of N intake. Urine was that main route for excretion of N in dairy cows, particularly when they consume over 400 g N/day- which is the case with high-quality pasture. They identified a curvilinear relationship with urine N levels accelerating at high N intakes:

Urine N (g/d) = 30.4 ($e^{0.0036 \text{ N intake (g/d)}}$) ($R^2$=0.76).

This equation is illustrated graphically in Figure 2.

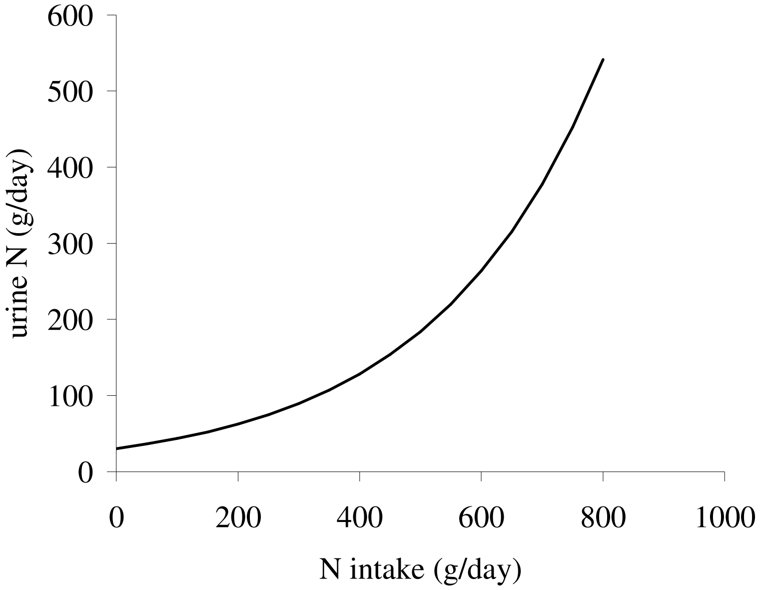

Figure 2 *Relationship between N intake (g/day) and urinary N excretion (g/day) [Castrillo et al., 2000]*

The problem with high-quality pasture is compounded by the fact that high pasture yields and excellent utilisation of pasture lead to high stocking rates (e.g. currently 4 cows per hectare at LUDF). Whilst high-yielding Holsteins fed total mixed rations may produce less than 150 g/day urine N, less productive Kiwi cows grazing high-quality pasture can excrete more than 250 g/day urine N. At a stocking rate of 4 cows per hectare this represents over 1 kg/day of urine N deposited on each hectare. A cow eating 18 kg DM/day of 25% protein pasture is taking in 720 g N/day and would be predicted to produce 406 g/d urine N using the above equation, or 1.6 kg urinary N/ha/day. Put another way, whilst it is possible to produce balanced diets where urinary N (g/day) is less than milk N (g/day), cows on high-quality pasture may be producing 3- to 4-times as much urinary N as milk N.

<u>Pasture composition</u>

The problem with low utilisation of plant protein has often been characterised as an imbalance between the rapid degradation of plant protein and the slow fermentation of most plant carbohydrate (fibre) in the rumen. This has been described as the rumen synchrony concept and has led to investigation of strategies to produce diets with slower protein degradation and faster carbohydrate availability (e.g. from increased water-soluble carbohydrate levels).

A number of researchers have tried to improve rumen synchrony by identifying plant mechanisms, such as condensed tannins (CT) and polyphenol oxidase (PPO), which reduce protein degradation rates in the rumen. Unfortunately, the forages that contain these mechanisms- notably birdsfoot trefoil (CT) and red clover (PPO)- do not fit into dairy systems for other reasons: the action of PPO is most apparent when red clover is ensiled before feeding, whilst birdsfoot trefoil is not agronomically suited to most conditions. The more widely-used white clover has been selected for enhanced CT in the flowers, and this appears to reduce protein degradation in the rumen and rumen ammonia concentrations in cows compared with a control line of white clover (Burggraaf et al., 2004). There is scope to select grasses on the basis of activities of the proteolytic enzymes associated with plant cell death which is induced when grass is ingested and living cells enter the rumen. For example, there are significant differences between ryegrasses and Fescues in rates of plant-enzymes mediated proteolysis (Kingston-Smith et al., 2005).

In general, altering the characteristics of pasture proteins has not had major effects on Nitrogen utilisation in practice. In contrast, there is much greater evidence for beneficial effects of increasing the supply of fermentable carbohydrates- particular when simultaneously reducing protein content. Ryegrass cultivars with a high water-soluble carbohydrate content led to a significant improvement in the utilisation of pasture N (from 30 to 37% in late lactation cows; Miller et al., 2001). High protein and low water-soluble carbohydrate levels in autumn pasture are associated with low efficiency of utilisation of feed Nitrogen (Beever et al., 1978). Orr et al. (2001) in the UK and Trevaskis et al. (2004) in Australia demonstrated improved intakes and a tendency for improved production when cows are given new pasture allocations in the afternoon, when water-soluble carbohydrates are higher. It is likely that this would also increase Nitrogen utilisation.

In fact the synchrony concept is probably too simplistic as a description of the complex interactions within the rumen and most gains in Nitrogen efficiency can be attributed to reducing protein content in the pasture or total diet (Cabrita et al., 2006). Further the fact that cows spend quite a high proportion of daylight hours grazing means that it is less relevant in the grazing situation anyway- energy consumed in the morning will help the rumen use protein from afternoon grazing bouts, for example. Nitrogen partitioning studies with diets based on grass showed little effect of rumen synchrony on Nitrogen efficiency (Kolver et al., 1998). The success of high-sugar grasses in improving Nitrogen utilisation (Miller et al.,

2001) may be as much to do with reduced protein content as increased levels of water-soluble carbohydrates. Indeed, an important breeding goal for pasture species must be to produce high-digestibility material without concomitant high levels of crude protein. This would be most usefully achieved by replacing protein with sugar, starch or lipid rather than with fibre. However, there will be limits to this process because of the inevitable associations with cytoplasm (cell contents). Cell contents are the non-fibrous part of plants and are highly digestible and rich in protein. Cell contents, particularly proteins involved in photosynthesis, are integral to the basic plant functions of capturing light energy and converting it into forage yield.

Studies in France, reviewed by Peyraud and Astigarraga (1998), have investigated effects of fertiliser N applications on Nitrogen efficiency. The efficiency of conversion of pasture N into milk N decreased with increasing use of fertiliser N. Reduced utilisation of pasture N was associated with increased levels of pasture protein, increased rumen degradability of protein and reduced levels of water-soluble carbohydrates in pasture (Peyraud and Astigarraga, 1998). Again, this is a problem which is compounded by the increased stocking rates that result from increased pasture production resulting from N fertiliser use.

Level and type of supplement

Studies and commercial practice in Europe and the US suggest possible solutions to the low efficiency of utilisation of pasture N through the use of low-protein supplements such as maize silage. North American dairying is based on the complementary characteristics of a high-protein legume (Lucerne) and low-protein forage (maize silage). Similarly, UK work has shown good levels of milk production with low urinary N output by combining legume silages with maize silage (70% less urinary N per kg milk protein; Dewhurst et al., 2005). Of course, there are other reasons- pasture substitution, effects on pasture management and cost- why we need to be careful about the use of maize silage in our pasture-based system.

When concentrate supplements are offered, the use of low-protein supplements rich in fermentable carbohydrates has increased Nitrogen efficiency (e.g. Keady et al., 1998), whilst supplementation of pasture with soyabean meal (around 48% protein) led to a substantial increase in urinary N excretion (Delagarde et al., 1997). However, even when low-protein supplements are used, the increased stocking rates achieved and importation of protein on to the farm make it likely that urinary N production per hectare will increase.

Alternative strategies to deal with the urinary N problem

The use of nitrification inhibitors (Di and Cameron, 2005) is an alternative approach to dealing with urinary N after it has been released to the environment. The previous discussion illustrates the scale of the problem and the importance of both reducing urinary N and ameliorating its effects once produced. Further discussion of this approach, which has been reviewed at previous SIDE meetings, is beyond the scope of this paper.

Other effects of excess dietary protein

There are other reasons why reducing pasture protein content would be beneficial to New Zealand dairy systems. Excess protein has implications for milk taints and may be involved in causing reduced fertility. Compounds such as skatole and dimethyl sulphide, which contribute to the aroma/taint of milk, are derived from amino acid degradation. These compounds are increased when dietary protein is in excess and contribute to the distinctive aroma of New Zealand milk in comparison with milk from cows fed typical North American total-mixed rations (Bendall, 2001). Excess protein in our cows is identified as high levels of urea in plasma or milk. There remains scientific controversy over the impact of high levels of urea on the uterine environment and consequent reproductive performance (Mann et al., 2005).

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