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Pathways to improving the N efficiency of grazing bovines

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Abstract

Livestock production has been identified as a major source of nitrogen (N) losses. Therefore, it is important to reduce N output through animal excretions by improving N utilisation by the animal. The objective of this paper is to identify pathways for producing grass-based diets that maximise bovine N utilisation during grazing, based on literature on the interface of plant and animal sciences. The focus is on Western-European perennial ryegrass-based systems under rotational grazing and both beef and dairy production systems are considered.

Three pathways have been identified through which more efficient N utilisation by grazing bovines can be achieved by manipulation of the chemical composition of the grass forage: (1) matching protein supply to animal requirements, (2) balancing and synchronising carbohydrate and N supply in the rumen, and (3) increasing the proportion of rumen undegradable protein (RUP).

Matching the diet requirements of grazing bovines through herbage manipulation encompasses the manipulation of carbon (C) and nitrogen (N) contents of growing herbage. These C and N contents vary both spatially within the grass sward and over time. Under grazing conditions, grassland management tools, such as the length of the regrowth period, grazing intensity, fertiliser N application rate and herbage variety are the main pathways to manipulate C and N dynamics. Regrowth length, N application rate and high sugar varieties were shown to be the most promising grassland management tools with respect to manipulating herbage quality and subsequent bovine N efficiency. However, these management tools are interrelated and may show adverse effects on production.

Due to the complex nature of interactions, modelling is essential in order to quantify and predict the effect of any combination of herbage management tools under specific circumstances.

Areas in which additional research is required are the fractionation of N compounds in herbage as affected by herbage management, and the effect of high sugar varieties on bovine N efficiency under a range of herbage management combinations.

Keywords: Grassland management; Herbage management; Herbage quality; High sugar variety; Nitrogen utilisation

1. Introduction

Livestock production has been identified as a major source of nitrogen (N) losses. N excreted in dung and urine contributes to environmental N pollution either as ammonia and N oxides in air, or as nitrate in soil and ground water (Tamminga, 1992). Therefore, it is important to reduce N output through animal excretions by improving N utilisation by the animal (Jonker et al., 1998).

Indoor feeding experiments have provided evidence that it is possible to increase the bovine N utilisation substantially through changing the composition of the diet, resulting in a significant reduction of N losses to the environment (Jonker et al., 1998; James et al., 1999; Kröber et al., 2000). Pathways for increasing animal N efficiency using mixed diets of herbage and supplements have been reviewed by Castillo et al. (2000, 2001a,b). However, in many parts of Europe, a large proportion of the bovine's diet consists of grass taken up by grazing (Beever and Reynolds, 1994; Lantinga et al., 1996). Specifically, in Ireland and UK, livestock production systems are increasingly dependent on grass-only diets, which is accompanied by increasingly longer grazing seasons. Manipulating the nutritional composition of this grazed grass poses a more complex challenge than changing the diet when animals are kept indoors, since (1) it is much harder to control the diet under grazing compared to stable feeding, and (2) it is difficult to reconcile the optimum composition with the imperative of productivity, as the high N fertiliser application levels required for high grass production levels reduce N utilisation.

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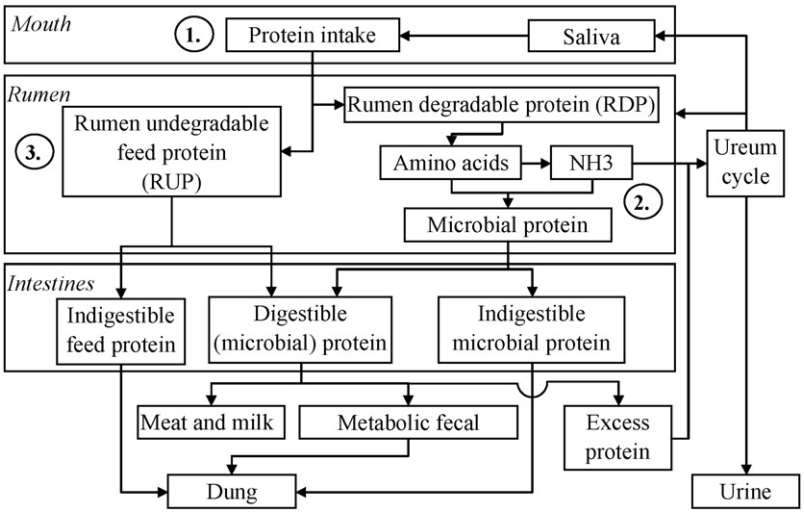

Fig. 1. Simplified schedule of nitrogen digestion by bovines and pathways to improve nitrogen efficiency. (1) Matching protein supply to animal requirements; (2) balancing and synchronising carbohydrate and N supply in the rumen; (3) increasing the proportion of rumen undegradable protein (RUP).

One of the major challenges associated with diets consisting of grazed grass is the low efficiency of protein utilisation. This can be largely attributed to impaired rumen function due to (1) the relatively high concentration of soluble protein, and (2) the imbalance in the supplies of carbohydrate and protein (Beever and Reynolds, 1994; Lantinga and Groot, 1996). When supplies of readily available energy (mainly water-soluble carbohydrates) in the rumen are sufficiently high, amino acids taken up by the microbes can be incorporated into microbial protein. However, when the availability of water-soluble carbohydrates is relatively low, either amino acids or structural carbohydrates of the plant are used by rumen microbes for the bulk of their energy supply. These compounds are relatively slowly degradable and, as a result, there can be a lack of both balance and synchronisation of N and energy release in the rumen. This leads to ammonia accumulation in the rumen, which is absorbed across the rumen wall and subsequently converted into urea (Nocek and Russell, 1988; Miller et al., 2001). This urea is mainly excreted through the urine and rapidly converted to ammonia, which is highly prone to volatilisation (Jarvis et al., 1989), and to nitrates, which can either be used by crops or lost through leaching (Smith and Frost, 2000).

The objective of this paper is to identify pathways for producing grass-based diets that maximise bovine N utilisation during grazing, based on literature on the interface of plant and animal sciences. The paper consists of the following topics: (1) evaluation of the optimum diet composition required for maximum bovine N utilisation, (2) short overview of N and C dynamics in perennial ryegrass during growth, (3) review of individual grassland management tools aimed at producing herbage for maximum bovine N efficiency, and (4) integration of these tools at farm scale, i.e. strategies at farm system level.

Throughout the paper the focus will be on Western-European perennial ryegrass-based long term grassland under rotational grazing and both beef and dairy production systems will be considered.

2. Pathways for improving bovine N efficiency

Throughout this paper bovine N efficiency is defined as N utilisation, i.e. the N output in milk and meat, divided by the N intake through diet. In addition to N efficiency, the partitioning of the N loss over urine and faeces is important, as N in urine is a much more important source of pollution than faecal N (Van Horn et al., 1996). Three pathways have been identified through which more efficient N utilisation by grazing bovines can be achieved by manipulating the chemical composition of the grass forage: (1) matching protein supply to animal requirements, (2) balancing and synchronising carbohydrate and N supply in the rumen, and (3) increasing the proportion of rumen undegradable protein (RUP).

2.1. Matching protein supply to animal requirements

Matching the herbage protein content to animal requirements is an important way to improve bovine N efficiency (Fig. 1(1)). Animal requirements for N change with physiological state and may vary from 11 g kg^{-1} of dry matter (DM) intake for maintenance to up to 32 g kg^{-1} DM for lactation and growth (Thompson and Poppi, 1990). The minimum N content in pasture DM required in order to avoid impaired ruminal digestion is approximately 24 g N kg^{-1} pasture DM (Thompson and Poppi, 1990; Tamminga and Verstegen, 1996). Herbage protein contents vary depending on environmental variables and herbage management, resulting in either excess or shortage of forage protein supply to the animal. N consumed in excess of animal requirement is excreted in faeces and urine (Kirchgessner et al., 1994). A number of studies have shown that decreasing N intake not only reduces total N excretion, but also the proportion of urinary N (James et al., 1999; Kröber et al., 2000; Castillo et al., 2001b; Kebreab et al., 2001), which should in turn reduce the potential for ammonia emissions (Table 1, Fig. 2).

On the other hand, shortage of protein will limit ruminal microbial yield and animal performance (Beever and Reynolds,