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Nutritional and genetical factors influencing Nitrogen metabolism and excretion in dairy cows: A review

Daniel Cătălin Necula[1,2], Igori Balta[3,4], Nicolae Corcionivoschi[1,3], Lavinia Stef[1*]
[1]*Banat University of Animal Sciences and Veterinary Medicine – King Michael I of Romania, Faculty of Bioengineering of Animal Resurces, 300645, Timişoara, România*
[2] *Alltech Biotechnology Romania, 60102, București, România*
[3]*Agri-Food and Biosciences Institute, Bacteriology Branch, Veterinary Sciences Division, 18a Newforge Ln, BT9 5PX, Belfast, Northern Ireland, United Kingdom*
[4]*University of Agricultural Sciences and Veterinary Medicine, Faculty of Animal Science and Biotechnologies, 400372, Cluj-Napoca, România*

Abstract: *This paper aimed to review the literature concerning nitrogen metabolism and excretion in dairy cows in the light of actual global climate change picture. Nutritional factors like dietary crude protein or dietary carbohydrate concentration have a significant effect on nitrogen balance, through the decreasing capacity of the total N excretion and improving the milk nitrogen efficiency. At the same time, the protein and carbohydrate degradability rates and dietary minerals will impact the route of excretion from urinary to a more faecal path. Shifting between urinary to faecal pathway could benefit to the mitigation of air pollution as the faecal nitrogen content is less prone to volatilisation compared to the urine nitrogen. Feed additives such as direct feed microbials, plant secondary metabolites and rumen-protected amino acids can mitigate and shift the N excretion from the urinary to the faecal pathway. Finally, breeding animals for lower MUN traits could also be considered as an efficient approach for a longer-term strategy to reduce N emissions.*

Introduction

Nitrogen (N) emission from livestock production is a global concern and is accounted for one-third of human-induced nitrogen emissions globally. Ruminants due to the complex fermenting processes of the stomach, the digestion of the feed differs from monogastric species. The difference is represented by the fermentation processes which occur in the non-glandular forestomach (rumen, reticulum and omasum) level providing a proportion of volatile fatty acids and microbial biomass. However, the ruminants are not the most efficient in converting N into milk or meat. In dairy cows, the N efficiency (N milk / N intake) percentage varies from ≈ 15-35. The rest is excreted into faeces (FN) and urine (UN). The excretion of N in faeces is mainly in the form of organic compounds; while the excretion in urine is in the form of urea. Under bacterial urease action, the urea is transformed in ammonia which volatilizes in the air, after that contributing to the air pollution These losses contribute to environmental acidification, eutrophication which negatively affects the biodiversity. From total livestock N emissions, the ruminants are accounted for ≈ 71 percent.

The scope of this paper is to review the factors that are influencing the N metabolism in dairy cows.

• Nutritional factors

Dietary protein concentration and rumen degradation rate

Dietary crude protein higher than 15-16% in dry matter base is decreasing the N efieciency and it will increase the UN excretion, mainly as urinary urea. The reduction of protein degradability at rumen site is leading to a shift of N excretion from urinary to faecal path.

Dietary carbohydrates and their degradation rate

The amount of dietary carbohydrates in the ration is having positive effect on N efficiency and UN excretion. However an increased in degradability rate of carbohydrates could have an impact shifting the excretion from urinary to faecal path.

Water

Water restriction may lead to a lower N balance ($N_{intake} - N_{milk} - N_{faeces} - N_{urine}$) and an improved N efficiency. The dietary minerals have a positive effect by lowering the milk urea nitrogen (MUN) and plasma urea nitrogen (PUN) level. A shift between urinary to faecal path of N has been spotted but, overall, N efficiency and N balance was not statistically affected as dietary minerals increase.

Additives

Feed additives like direct feed microbials, plants secondary metabolites or protected amino acids may have the potential to mitigate and shift from the urinary to faecal path the N excretion.

• Genetical factors

Animal with low MUN are presume to excrete reduced amount of urinary nitrogen. The modern dairy cows breeds are excreting lower amounts of N in urine and feces than their mates 15 years ago. The association between single nucleotide polymorphisms, heritabilities, correlations and variances could play as quintessential genetical key-indicators for the determination and consistent implementation of metabolic characteristics for cattle selection-breeding strategies and consequently to improve the N metabolism. It is noteworthy that farming indeed plays a significant role towards the control of phenotypic variances of MUN that are intimately dependent on herd-test-day effects which could indicate that correctly adjusted dietary programs interconnected with proper managerial conditions are essentially necessary for the improvement of phenotypical datasets for genetic investigation of cattle breeds.

Conclusions

- Reducing crude protein concentration is one of the most critical strategies that affect N metabolism and excretion. Increasing the high available carbohydrates at the expense of high fat rations is another reliable approach.
- The synchrony between protein and carbohydrate fractions have impact of ruminal ammonia formation. Great care must also be taken in supplementing the ration with minerals, especially cations. This can lead to an increase in urine volume and UN excretion.
- Shifting between urinary to faecal excretion via dietary nutritional changes or supplementation with additives could benefit to the mitigation of air pollution as the FN content is not prone to volatilize compared to UN.
- Breeding animals for lower MUN traits could be considered as an efficient approach for a longer-term strategy to reduce N emissions.