TA-O-18 The influence of feeding on excreta characteristics of dairy cows

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1. Objectives

Nitrogen (N) is essential for any form of life and thus indispensable to sustain food production. Along the transformation process from organically bound plant nitrogen into animal protein, mobile and at the same time reactive N compounds are generated and excreted as fecal and urinary N which are recycled. However, N cycling is associated with N losses, the primary pathways being volatilization of ammonia, nitrous oxide and elementary nitrogen into the atmosphere and leaching of nitrate into aqueous systems. N losses reduce the fertilizer value of manure and the N use efficiency of animal production systems.
The most sustainable strategy to mitigate NH_3 emissions should focus on reducing its direct precursor, i.e. the urea fraction in animal manure. Urea, a metabolite of the protein metabolism, constitutes, with 50 to 85% of total urinary N, the major nitrogenous component of urinary N in ruminants (Dijkstra et al. 2013). The large body of evidence for positive correlations between N-input, ruminal protein balance, milk urea, urinary N or urea N excretion and ammonia emissions shows that diet characteristics are clearly related with the excretory patterns of dairy cows (Külling, 2000; Reijs, 2007; Van Duinkerken et al. 2011). The objective of the present study was to identify feeding measures and indicators for low N and particularly low urinary N excretion of dairy cows under Swiss conditions.

2. Methodology

In a meta-analytical approach, 13 Swiss feeding and N-balance trials mostly taken from doctoral theses were analyzed to establish relationships between N-input, N-excretion and excretory pattern and diet characteristics. The N-balance trials were based on quantitative urine and feces collection for barn-fed cows. In case of pasture trials, the n-Alcane technique was applied to estimate feed intake and digestibility. 80 % of the data set represents repeated, individual cow observations which explain the extent of data variability. A subset of 31 dry cow observations as part of a larger study (Münger, 1997) was included in the evaluation. These dry cows were subject to a restrictive feeding regime with low protein supply and thus represent the low end of N turnover. The statistical evaluation focused on univariate regressions to describe relationships between dietary factors and excretory patterns. Where appropriate, data was grouped by diet type (season), lactation stage or study. In total, 404 data sets were evaluated which are distributed over the whole lactation cycle. Winter and summer diets are represented in almost equal parts.

3. Results and discussion

3.1 Animal, diet and excreta characteristics

Table 1 summarizes average and range of animal, diet and excreta characteristics. The applied winter and summer diets and performance levels reflect situations encountered under practical farming conditions. The large range in dietary protein supply comprising protein deficient (CP <120 g/kg DM) to protein surplus diets (CP > 180 g/kg DM) clearly affected the excretory patterns with a distinct seasonal influence. Summer diets produce on average 11 kg more manure than winter diets primarily the urine volume making the difference. The higher protein content and modified protein/energy ratios of grassland based summer diets are important influencing factors. The contribution of urinary N to total N excretion increased on average from 40 % to 60 % for winter and summer diets, respectively, underlining the higher emission potential of manure produced during the vegetation period. This is supported by the augmented milk urea content indicating imbalances at the ruminal and animal level and thus causing a high N footprint of 15.3 g N/kg ECM and low N use efficiency of 27 %.

3.2 Manure volume and N excretion

N excretion is determined by N content in feces and urine and excreta volume. As shown in Figure 1, fecal N evolves little with dietary CP while urinary N concentration fluctuates considerably by a factor of up to 4. Assuming constant urinary concentration would lead to very inaccurate predictions of urinary N excretion. Moreover, the change in dietary protein content is accompanied by a shift in urinary N compounds. At low dietary CP content of 100 g/kg DM, the ratio of UUN/UN varied in our data set between 30 and 40 % while in diets exceeding 150 g CP/ kg DM, 70 – 80 % of urinary N is excreted as urea-N (data not shown).

Table 1: Average and range of animal, diet and excreta characteristics grouped by season and cow type

Parameter	Lactating cows Winter diets	Lactating cows Summer diets	Dry cows Winter diets
Animal factors			
ECM, kg/day	23.0 (1.4-42.5)	25.8 (9.4-48.0)	-
N-milk, g/kg	5.52 (3.9-8.3)	5.51 (3.7-7.2)	-
Milk urea, mg/dl	21.9 (5.0-50.5)	30.9 (11.9-57.5)	-
Dietary characteristics			
DMI, kg/day	16.6 (8.2-24.6)	17.6 (8.7-28.5)	7.5 (5.2-14.8)
DOM, g/kg DM	652.3 (539-746)	713.1 (587-795)	579.7 (523-651)
CP, g/kg DM	148.3 (98-239)	178.9 (101-259)	94.3 (65-186)
NEL, MJ/kg DM	6.25 (5.3-7.8)	6.61 (5.7-7.0)	5.1 (4.1-6.4)
Concentrate, % diet	18.4 (0-50)	13.5 (0-42)	0
Excreta characteristics			
Feces volume, kg/day	38.5 (19-63)	34.9 (16-59)	20.4 (10-34)
Urine volume, kg/day	21.5 (6-51)	34.8 (16-65)	7.0 (3-18)
Fecal N, g/kg DM	27.6 (22-36)	32.1 (18-42)	18.5 (15-29)
Urinary N, g/kg	5.3 (2.4-11.8)	6.3 (3.0-12.3)	4.0 (2.1-8.0)
Excreta/DMI, kg/kg	3.8 (2.8-5.6)	4.6 (2.9-7.4)	3.7 (2.9-4.4)
N turnover			
N intake, g/day	399.9 (157-758)	502.2 (219-824)	120.8 (65-440)
Milk-N/N-intake, %	30.7 (14-66.1)	26.9 (8.6-49)	-
Fecal-N/N-intake, %	37.9 (21.5-59.7)	28.2 (18.9-49.7)	52.2 (25.7-69.2)
UN/N-intake, %	26.1 (9.8-63.3)	43.9 (25.7-69.2)	24.0 (10.9-38.1)
UN/excreta-N, %	40.5 (14.8-64.4)	60.6 (35.2-75.2)	31.7 (17.4-48.3)
Excreta-N/ECM, g/kg	11.6 (5.6-28.8)	15.3 (5.2-47.1)	-

DM-dry matter; FM-fresh matter, ECM-energy corrected milk, DMI-dry matter intake, DOM-digestible organic matter, CP-crude protein, UN-urinary N

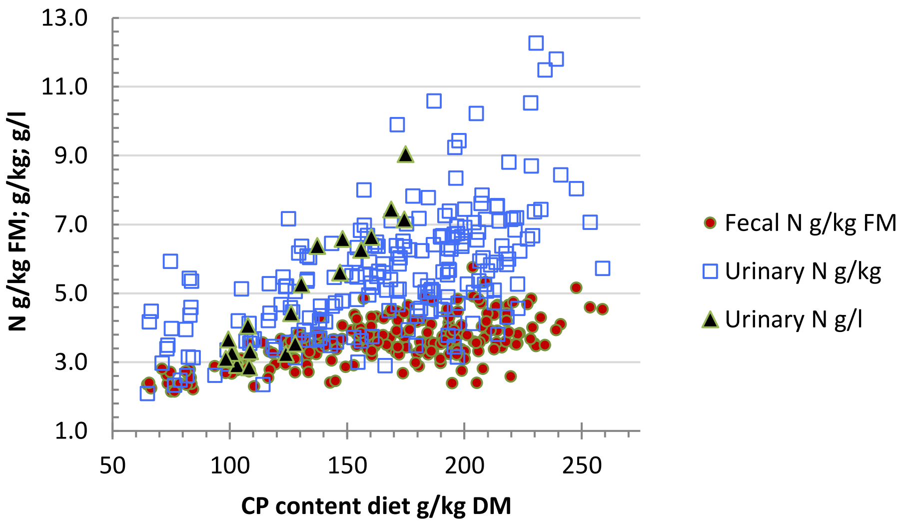

Figure 1: Relationship between dietary crude protein and fecal (g/kg FM) and urinary N (g/ kg, g/l) content in dairy cows

Manure output varied between 16 and 51.4 kg for dry cows and between 28.2 and 104.2 kg for lactating cows. Dry matter intake (DMI) can be used as a predictor of manure and feces output according to the following formulae: Manure all cows = 4.055*(DMI) + 1.0735 (R^2 = 0.71); Feces lactating cows = 2.1914*(DMI) + 2.8212 (R^2 = 0.56); Feces dry cows = 2.161*(DMI) + 2.9973 (R^2 = 0.64).

Considering the role of urine in regulating the osmotic balance and the excretion of protein and mineral metabolites, it can be expected that urine volume is more closely related to diet composition than feces which is confirmed by our findings. As shown in Figure 2, more urine is excreted at high protein diets. A power function is fitted to the data set of Münger (1997) describing the non-linear character of the relationship. At high dietary protein content, dry cows can produce as much urine as lactating cows.

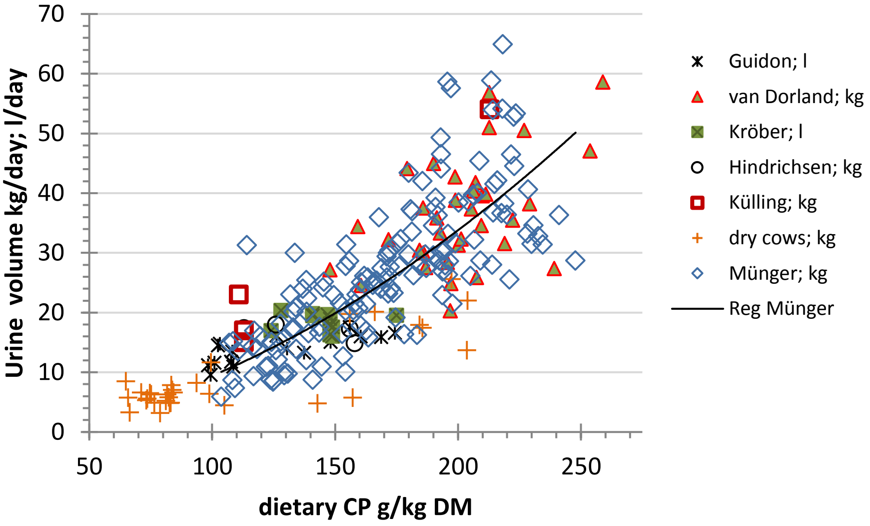

Figure 2: Relationship between dietary crude protein and urine volume in dairy cows. Urine volume (data set Münger) = $0.002*(CP)^{1.8401}$ (R^2 = 0.645).

As seen for feces volume, dry matter intake explained 80 % of the variation in fecal N excretion. Dry matter intake proved to be a better single predictor than N intake (Fecal N lactating cows (g/day) = 8.2048*(DMI) + 2.4795 (R^2 = 0.81)).

In contrast to fecal N, urinary N excretion increases with the dietary protein content in a non-linear manner (Figure 3). The power function fitted to the data set of Münger illustrates the general relationship. However, a certain study effect is visible. For a given protein content, the variation in urinary N output remains high pointing to additional influencing factors such as dietary imbalances between protein and energy supply at the ruminal and animal level.

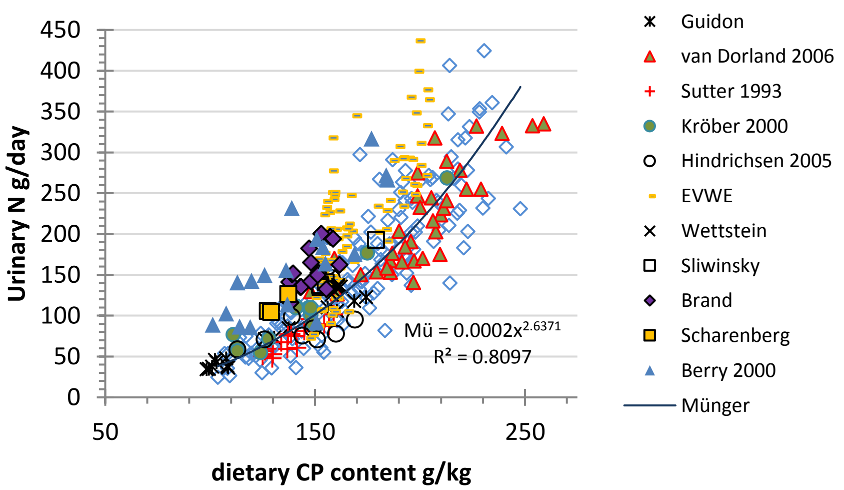

Figure 3: Relationship between dietary crude protein and urinary N in lactating dairy cows. Urinary N g/day (data set Münger) = $0.002*(CP)^{2.637}$ (R^2 = 0.81).

At the ruminal level, the so-called ruminal protein balance (RNBch = PMN-PME) quantifies the microbial protein synthesis from fermentable N (PMN = CP*[1-{1.11*(1-deCP/100)}]) and energy sources (PME = 145*FOM). Excess ruminal N is one of the major causes for high urinary urea and N output (Figure 4). Ruminal imbalances are observed for both, winter and summer diets. The resulting urinary N output raises faster for summer diets compared to winter diets. The positive correlation also exists for dry cows. Analogous effects are observed for the protein/energy ratios CP/NEL and N/DOM (deCP = protein degradability; DOM = digestible organic matter; FOM = fermentable organic matter).

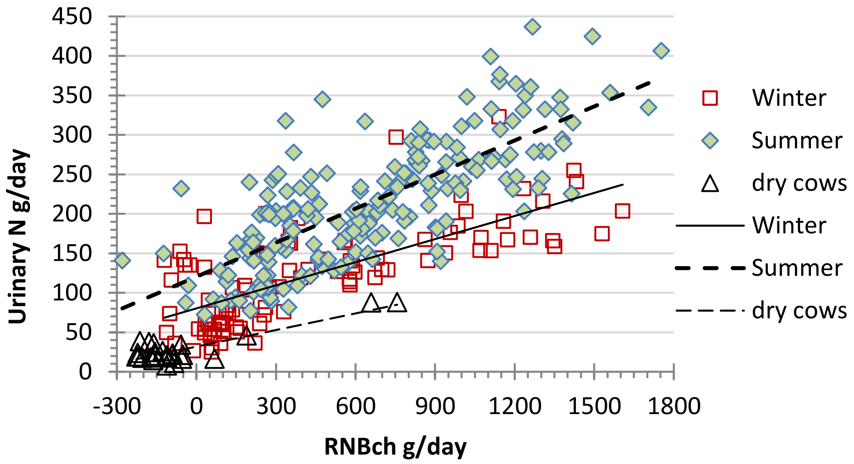

Figure 4: Relationship between dietary ruminal protein balance and urinary N excretion in dairy cows. Urinary N excretion winter (g/day) = 0.0975*(RNBch) + 80.27 (R^2 = 0.52); Urinary N excretion summer (g/day) = 0.1438*(RNBch) + 120.43 (R^2 = 0.58);

4. Conclusions and outlook

Feeding influences excreta characteristics and excretory patterns of dairy cows. Fecal N is closely related to dry matter intake while the highly variable urine characteristics correlate with protein and energy metabolism. Improving N use efficiency and reducing N losses first of all means minimizing avoidable urinary urea sources. N intake is a driving force for N losses which is superposed by protein-energy interactions. For low N emissions, the various protein/energy ratios at the dietary and ruminal level and the total protein supply need to be optimized to match requirements. Particularly summer diets prove to be difficult to balance in cases of absent or limited use of energy rich feed stuffs and prevailing pasture systems. Established relationships can be used for modeling purposes. The extension of single regressions to multiple regressions will improve prediction error.

References

[1] Berry, N. R. (2000). Production efficiency and nutrient cycling of Brown Swiss dairy and Scottish Highland sucklers on high altitude pastures under varied feeding conditions. Diss. ETH Nr. 13727, Zürich.
[2] Dikstra J., Oenema O., van Groenigen J. W., Spek J. W., van Vuuren A. M., Bannink A. (2013). Diet effects on urine composition of cattle and N_2O emissions. Animal, 7, 292-302.
[3] Hindrichsen, I. K. (2005). Methanogenesis in dairy cows and their slurry as affected by diet type and carbohydrate characteristics. Diss. ETH Nr. 15852, Zürich.
[4] Külling, D. R. (2000). Influence of feed composition and manure type on trace gas emissions from stored dairy manure. Diss. ETH Nr. 13872, Zürich.
[5] Kröber, T. F. (2000). Methionine, lysine and leucine in dairy cows: limitations and their use to improve protein utilisation and minimise nitrogen losses from manure. Diss. ETH Nr. 13568, Zürich.
[6] Münger, A. (1997). Energie- und Stickstoffverwertung bei Milchkühen verschiedener Rassen. Diss. ETH Nr. 11929, Zürich.
[7] Reijs, J. W. (2007). Improving slurry by diet adjustments: a novelty to reduce N losses from grassland based dairy farms. PhD thesis, Wageningen University, The Netherlands.
[8] Sutter, F. (1993). Einfluss einer reduzierten Proteinversorgung auf den Protein- und Energieumsatz von Milchkühen bei Laktationsbeginn. Diss. ETH Nr. 10101, Zürich.
[9] Van Dorland, A. H. (2006). Effect of white clover and red clover addition to ryegrass on N use efficiency, performance, milk quality, and eating behaviour in lactating dairy cows. Diss. ETH Nr. 16867, Zürich.
[10] Van Duinkerken G., Smits M. C. J., André G., Vereijken P. F. G., Sebek L. B. J., and Dijkstra J. (2011). Milk urea concentration as an indicator of ammonia emission from dairy cow houses in a situation with restricted grazing. J Dairy Sci. 94, 321-335.