Effect of herbage on N intake and N excretion of suckler cows

Jürgen Schellberg, Karl-Heinz Südekum, Thomas Gebbing

► To cite this version:

Jürgen Schellberg, Karl-Heinz Südekum, Thomas Gebbing. Effect of herbage on N intake and N excretion of suckler cows. *Agronomy for Sustainable Development*, 2007, 27 (4), pp.303-311. hal-00886367

HAL Id: hal-00886367

<https://hal.science/hal-00886367>

Submitted on 1 Jan 2007

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Effect of herbage on N intake and N excretion of suckler cows

Jürgen SCHELLBERG^{a*}, Karl-Heinz SÜDEKUM^b, Thomas GEBBING^a

^a Institute of Crop Science and Resource Conservation, University of Bonn, Katzenburgweg 5, 53115 Bonn, Germany

^b Institute of Animal Science, University of Bonn, Endenicher Allee 15, 53115 Bonn, Germany

(Accepted 24 May 2007)

Abstract – The release of nitrogen on pastures by the grazing animal is a significant source of N load to soil and water and hence a possible source of nitrate pollution. Here we studied the effect of forage quantity and quality related to N intake to examine excretion and loss. A two-year grazing experiment on an intensively managed *Lolium-Cynosuretum* was established in Rengen Research Station, Germany. Two groups of 4 suckler cows each were grazed along a gradient of forage mass and quality consisting of 16 plots each in 4 replicates per year. Our results show that in the final plots of the gradient, forage mass exceeded by far the recommended optimum of herbage allowance. At the same time, herbage quality decreased along that gradient from about 11 to 9.5 MJ metabolisable energy per kg dry matter, but daily N intake increased from 140 to 600 g N per animal. The related N excretion per animal was constant, with faeces at about 60 to 75 g N. In contrast, daily N excretion with urine increased linearly depending on N intake from less than 100 g to more than 500 g per animal. Thus, N loss was estimated to increase in the same way and was determined as about 22% of total N intake. We conclude that low quality in tall swards, including partly senesced plant material, does not imply low herbage and N intake and N excretion. Our findings indicate that in grassland extensification schemes, where late turning out to pasture is common, N intake and hence excretion might disagree with the intention of limiting forage N conversion and subsequent release to the environment. We also provide a simple spreadsheet with which farmers can quantify the N excretion as a factor of herbage allowance, faeces N content, daily N retention and stocking density. This appears useful not only under standard conditions on improved grassland, but also in environmentally sensitive areas where N release is required to be kept under strict control.

1. INTRODUCTION

In some farmland areas of the world a reduction in income over feed costs is currently pressing cattle farmers to intensify the utilisation of pastures and to obtain as much feed energy from grazed grass as possible (McCall et al., 1999). The economic benefit of extended and intensive grazing of cattle as compared with confinement feeding is still a matter of research, some of which indicates that grazing is likely to gain more profit, especially when product prices are declining (Hanson et al., 1998; Dartt et al., 1999; White et al., 2002; Tozer et al., 2003).

From an environmental viewpoint, however, an increase in frequency and duration of grazing appears crucial. For example, lengthening the grazing season has been shown to reduce overall NH_3 losses due to a reduction in slurry volume on the farm. However, on the other hand, it inevitably raises potential N leaching from urine patches (Stout et al., 2000; Webb et al., 2005). Further, recent trends towards improving the conversion of grassland into milk and beef requires highly digestible forage to ensure adequate daily intake rates of energy and protein (Peyraud and Astigarraga, 1998). As a consequence, N excretion increases, especially when forage protein concentration is high in relation to the offered energy supply (James et al., 1999).

By far most of the research on N excretion on pastures as affected by diet and grazing intensity has been conducted with

dairy cattle (Wang et al., 2000; Kohn et al., 2002). In contrast to intensive milk production, grazing on extensified grassland with beef cattle is widely accepted as being harmless from the nutrient-cycling viewpoint (e.g. van Horn et al., 1995). With more profitable beef production with suckler cows, however, utilisation frequency, stocking rate and N intake are usually improved such that N excretion per hectare can exceed even that of dairy cattle (Schellberg et al., 2006). This is mainly caused by a high proportion of non-utilised nutrients and low beef N export as compared with milk N export from grazing dairy cows (Estermann et al., 2001). The rumino-hepatic circulation of excess nitrogen consumed with the diet enhances the overall N, and particularly the urea-N excretion with urine, and hence boosts the risk of N leaching, especially with high intake rates of leafy and protein-rich pasture (Haynes and Williams, 1993).

Considering economic benefit as well as animal welfare and farmers' contentment with extended grazing, on the one hand, and potential environmental risks on the other, research is required to develop grazing strategies allowing the minimisation of the impact of N release and leaching on pastures. Moreover, farmers need basic and straightforward advice about the driving forces of N excretion and urine deposition and strategies to avoid N surplus through appropriate grazing management.

The present study focuses on the intake-related N excretion along with progressively increasing sward height and forage allowance on permanent grassland swards grazed by suckler cows. In a field trial, we simulated grazing situations like

* Corresponding author: j.schellberg@uni-bonn.de

those under German grassland management rather than systematically investigating variables influencing N excretion in a multi-factorial experiment. Further, from the experimental results we developed a spreadsheet with which farmers and experimentalists can simply quantify the nitrogen return with urine and faeces depending on forage allowance, faeces N concentration, stocking density and N retention with daily live-weight gain on a pasture.

2. MATERIALS AND METHODS

2.1. Experimental layout and management

Two very similar grazing experiments were conducted during the growing seasons in 2003 and 2004 at the Grassland Research Station, Rengen (Eifel Mountains, 50°13'N, 6°51'E, 475 m above sea level), of the University of Bonn (Germany). The mean annual precipitation is 811 mm, and the long-term annual temperature mean is 6.9 °C. Rengen switched to ecological farm management in 1996 and has since then been run without any synthetic fertiliser input. The experiment was placed on a 50-year-old permanent mowing pasture (*Lolio-Cynosuretum*) dominated by *Lolium perenne*, *Poa pratensis*, *Dactylis glomerata*, *Alopecurus pratensis*, *Taraxacum officinale* and *Trifolium repens*. The plots were not fertilised with manure or slurry in 2002 and remained completely unfertilised throughout both subsequent grazing seasons and experiments.

An experimental layout was designed with which a gradual increase in herbage allowance and a corresponding decrease in forage quality with progressing biomass were accomplished. In both years, we let 2 groups of 4 suckler cows (Limousin breed) each graze along that gradient from lower to higher plot numbers (Fig. 1). Group 1 grazed along lines A and B, and group 2 grazed along lines C and D with an offset of 24 and 14 days in 2003 and 2004, respectively. The intention of offsetting and overlapping two groups of grazers was to receive 4 replicates (A to D) of grazed strips throughout the first half of the grazing season and so to compensate for environmental effects on herbage quality, biomass and intake (Fox and Tylutki, 1998).

Each of the 4 split strips A to D was subdivided into 16 plots. Odd-numbered plots in Figure 1 were grazed 3 and 2 days in 2003 and 2004, respectively, to observe forage allowance and intake. Immediately thereafter, animals were turned to smaller even-numbered plots for exactly 24 hours to collect the faeces currently excreted. Hence, along each strip the sampling resulted in 8 parameter values corresponding to 8 odd-numbered and the following 8 even-numbered plots. At 14 days before turning the suckler cows to any of the strips A to D, the respective area was mown to allow uniform and comparable regrowth and sward height at the starting points in plots 1, 17, 33 and 49. Before and after the grazing period, the live weight of the suckler cows was determined on a conventional livestock weigher. The average live weight was 649 and 636 kg animal⁻¹ half-time of the experiment and live weight gain per animal was 154 g d⁻¹ and 290 g d⁻¹ in 2003 and 2004,

Figure 1. Layout of the grazing experiment with four grazing strips A (plot 1–16), B (plot 17–32), C (plot 33–56) and D (plot 57–64), each strip split into two due to restricted field length. Numbers in brackets indicate the day of the year of grazing start in the respective strips. The layout of both the experimental years 2003 and 2004 was identical except the size of plots with odd numbers. The arrow alongside strip A indicates the overall feeder direction. Further details are given in the text.

respectively. Before the start of the experiment and when turning from one strip to the next, animals were grazed at least two weeks on short swards in the vicinity of the plots to acclimate to the environment.

2.2. Herbage measurements, plant and faeces sampling and analyses

Six forage samples ($1.25 \times 3 \text{ m}^2$) were taken in 6 randomly distributed replicates at a cutting height of 5 cm from odd-numbered plots before grazing to determine herbage allowance (H_A). After turning the animals to the subsequent smaller even-numbered plots, residual biomass (H_R) in the odd-numbered plots was measured to calculate herbage DM intake (H_I) as the difference between herbage allowance and residual herbage. Herbage samples were oven-dried at 60 °C and N concentration of the herbage (N_H) was determined using a gas analyser (CARLO-ERBA type 1500, Milan, Italy). Total daily N intake per animal (IT_N) was calculated as the product of herbage intake and N concentration in herbage. Herbage was analysed for metabolisable energy concentration (ME) and in-vitro digestibility of organic matter ($IVDOM$) as described by Steingass and Menke (1986) and Menke and Steingass (1987). The analysis measures the gas volume produced by the bacteria in the rumen fluid mixed with the ground

herbage sample within a glass cylinder during a defined period of time. Applying the equations presented by Steingass and Menke (1986), metabolisable energy (ME) and in-vitro digestibility of organic matter ($IVDOM$) were calculated from the sample gas volume (GV in mL) as well as from the N-free extract (NfE), ash and crude protein in herbage ($CP_H = N \cdot 6.25$) concentration given in $g\ kg^{-1}$ as follows (Eqs. (1, 2))

$$ME[MJkg^{-1}DM] = 2.20 + 0.1357GV + 0.0057CP_H + 0.0002859NfE^2 \quad (1)$$

$$IVDOM[\%] = 15.38 + 0.8453GV + 0.0595CP_H + 0.0675A_H \quad (2)$$

Herbage ash contents (A_H) in equation (2) were not measured but assumed constant at $75\ g\ kg^{-1}$, following national recommendations and standard values for forage (Universität Hohenheim – Dokumentationsstelle, 1997).

2.3. Excreta sampling and analyses

Immediately after turning the suckler cows from the smaller even-numbered to the odd-numbered plots, the number of faeces patches in the abandoned even-numbered plot was counted, and eight faeces samples were collected and combined into one representative sample. Referring to experiments by Spanghero and Kowalski (1997), the effect of the time span between disposal and collection of faeces was considered negligible in view of faeces N concentration and N loss. Fresh faeces samples were weighed, deep-frozen directly, freeze-dried later in the lab and analysed for faeces N concentration (N_F) and dry matter as described for herbage samples. Total daily faeces N excretion (N_{excf}) per animal was calculated by weighting the total number of faeces patches counted per plot with the average N concentration derived from eight represented samples divided by the number of animals per plot. Faeces ash (A_F) was estimated by ashing the freeze-dried samples at $550\ ^\circ C$ overnight, and faeces organic matter (OM_F) was calculated as the difference between dry matter (DM) and ash content as $OM_F = DM - A_F$. As urine sampling was impossible on the pasture, daily urinary N excretion (N_{excU}) was determined by subtracting faeces N concentration from total daily N intake (IT_N), assuming a daily mean N retention (N_R) of $19\ g\ N\ animal^{-1}$.

2.4. Statistics

Linear and polynomial fit of experimental data was conducted using Origin Vers. 7.0 SRO (OriginLab, Northampton, MA, USA). A total of 2 outliers of the regression of N content in herbage to N content in faeces was eliminated based on the 95% confidence interval of the original data, as these data derived from measurements immediately after turning the animals to a new grass strip.

Figure 2. Accumulated herbage allowance (H_A) on a fifty-year-old grassland with low farmyard manure input (since 1996) successively grazed in 8 plots in four offset strips, A to D, in the pasture experiment in 2003 (upper) and 2004 (lower). The number of regrowths differed among the strips as pastures needed to be cut before grazing later in the season: B was cut once and C and D were cut twice before turning out to pasture. Vertical bars indicate standard deviation. First and second growth in spring dominated over regrowths in summer. (DM = dry matter).

3. RESULTS AND DISCUSSION

3.1. Herbage allowance and quality

When setting up the layout of the experiment, we anticipated a strong mass increase in herbage with time, whereas other factors potentially influencing intake were imagined to remain constant in this experiment, e.g. weather conditions and floristic composition of the sward. As Figure 2 shows, herbage allowance (i.e. dry matter yield) sharply increased with time in both years in nearly all the grazed strips A to D. Values ranged from $713\ kg\ ha^{-1}$ (strip C in 2004) to $6949\ kg\ ha^{-1}$ (strip B in 2003). Early growths mostly dominated over subsequent growths accumulating later in the season. A visual observation of the swards exhibited short, leafy and green plant material at the onset of each strip grazing, whereas plants were tall, partly senesced and rich in stem material at the end of each growth curve and were even lodging in some cases. The standard deviation of yield data was mainly affected by sward inhomogeneity within the plots.

Increasing biomass brought about changes in morphology of the plants and their constituents. Hence, the concentration of metabolisable energy decreased steadily along the strips

Figure 3. Temporal change in metabolisable energy concentration (*ME*) throughout growth on a mowing pasture successively grazed in 8 plots in four offset strips, A to D, in the pasture experiment in 2003 (upper) and 2004 (lower). Plant age effect on *ME* was increased by a typical seasonal effect. For number of regrowths see Figure 2. (DM = dry matter).

from grazing the first plot onwards, except in summer 2003 (strip B and D) (Fig. 3). Further, a well-known seasonal effect on metabolisable energy was found (Wilson et al., 1995); concentrations varied from about 11 MJ kg⁻¹ dry matter in April 2003 and 2004 to nearly 9 MJ kg⁻¹ dry matter at the end of the final grazing in July 2004. However, in 2003 permanent summer rain provided regrowth of leafy and green plant material. Hence, higher metabolisable energy values at the end of the experiment were observed. These values correspond to in-vitro digestibility ranging from 78.7% to 70.4%.

Along with the changes in metabolisable energy, herbage N concentration declined steadily in nearly all the observed growths (Fig. 4). The range of herbage N concentration and the pattern of change were similar in both years. Especially during the first growth (strip A) in spring 2003 and 2004, herbage N concentration decreased linearly by about 3.4 and 3.0 g kg⁻¹ per week, respectively. As with dry matter accumulation and metabolisable energy concentration in herbage, the change in herbage N concentration was less pronounced during the final growths in late summer of both years (strip D). The corresponding crude protein content in dry matter calculated from N content ($N \cdot 6.25$) varied from about 24.5 to 10.4% and 23.6 to 11.9% in dry matter in 2003 and 2004, respectively.

Parallel measurements of N content in the faeces exhibited similar patterns to herbage N (Fig. 4). However, N in faeces was found to be higher in most cases. When immediately turning the suckler cows from strip A to B and from C to D in 2003, i.e. from tall-growing to short swards, an offset in faeces N concentration was observed. However, in 2004 the time lag between the start of grazing the strips was too long (11 days) to observe the same phenomenon.

3.2. Intake, excretion, loss and use efficiency of nitrogen

For both years, the relation between herbage allowance and herbage intake is summarised in Figure 5a. The estimated herbage intake ranged from below 5 kg dry matter animal⁻¹ day⁻¹ in short swards to more than 20 kg dry matter animal⁻¹ day⁻¹ in tall ones. Although there was a positive trend towards increasing intake with herbage allowance, the scatter was found to be considerable. It has to be considered that each data point in Figure 5a represents the result of one individual and independent plot that was grazed only once for 3 and 2 days in 2003 and 2004, respectively.

Although grazing conditions were thoroughly controlled in this experiment, the spatial and temporal variability of the 50-year-old permanent grassland as well as selective grazing on the paddocks induced significant scatter of observed data and hence reduced the statistical reliability of the herbage intake estimations. However, the curvilinear approximation to the herbage intake (H_I) to herbage allowance (H_A) relationship agrees well with already existing and well-proved equations. Differences between parameters of the equation in Figure 5a to those provided by Peyraud et al. (2004) with $A = 18.04$ and $B = -0.0466$, and a previous experiment on Rengen Experimental Farm (Schellberg et al., 2006) with $A = 18.04$ and $B = -0.066$, are only slight.

The variation in herbage intake and N intake was much higher, as can be expected with feeding experiments in confinement. It is also well known that herbage allowance, the driving force in this experiment, is only one factor influencing herbage intake on pastures (Holden et al., 1994; Freer et al., 1997; Gibb et al., 1997). Under controlled conditions in confinement, a similar experimental study would have permitted better control over forage allowance and intake, N on offer and N digested as well as over the amount and N concentration of excreted urine and faeces. Despite such uncertainties, experiments under grazing situations are required as confinement results are not transferable to outdoor conditions.

The apparent daily intake of N per suckler cow results from the product of actual herbage N content with daily dry matter intake. Most of the values given in Figure 5b lie within the range of 150 to 600 g animal⁻¹ day⁻¹ and demonstrate possible short-term variations on the pasture. A clear trend in N intake could not be observed with any of the grazed strips A to D and the two herds in 2003 and 2004. The curvilinear relationship indicates that N intake was primarily determined by dry matter intake ($r^2 = 0.730$; Fig. 5b) rather than by N content ($r^2 < 0.001$ in 2003, $r^2 = 0.008$ in 2004; data not shown), although the latter varied considerably from early growth until maturity.

Figure 4. Temporal change in N concentration in faeces (closed symbols) of suckler cows on a pasture and in N concentration in the offered herbage (open symbols) grazed in 4 offset strips, A to D, on 8 consecutive plots each in 2003 (upper) and 2004 (lower). In nearly all strips, faeces N decreased similarly to herbage N, except when animals were turned to another strip and hence turned from tall swards to leafy and N-rich herbage. (DM = dry matter).

The daily amount of N excreted with either faeces or urine was plotted against daily total N intake per suckler cow in Figure 5c. Faeces N excretion remained completely unaffected by N intake and was estimated at about 60 g animal⁻¹ d⁻¹. In contrast, N excretion with urine followed a strong linear relationship in both years with slopes close to 1. With increasing N intake, the percentage contribution of urine N to total N excretion increased from about 51 to 91%. The effects were exactly the same in both years regardless of differences in herbage intake and grazing conditions (2 vs. 3 days).

As an outcome of herbage and nitrogen allowance and intake, the sum of N losses related to N excretion is plotted in Figure 5d. Averaged over both years and two herds, the amount of N loss from urine and faeces, i.e. the sum of N leaching and volatilisation, ranged from about 30 to 225 g animal⁻¹ day⁻¹ depending on intake and N content of forage. In a previous experiment with 2 suckler herds in the vicinity of the present experiment on Rengen Research Station (Schellberg et al., 2006), the average percentage loss of N with grazing throughout two growing seasons was calculated as 29.3% of the total N ingested. In the same experiment, the estimated urine N losses were about 41% of total urine N excreted as an average.

In both years, the experimental arrangement of the present study induced a gradient from low to high herbage allowance and, at the same time, from high to low quality, which influenced herbage intake. This gradient helped to create a range of parameter values wide enough to estimate N excretion during grazing relevant for the environment. Two main factors determined the excretion of N, i.e. the herbage intake and herbage N content. The product of both might be quite similar in either short or tall swards, depending on the capability of the ruminants to physically manage feed intake. Dove (1996) indicated that under pasture conditions in Australia, the point at

which rumen fill begins to limit intake, rather than the capacity of the animal to use energy, is at about 75% digestibility. This value lies within the range of in-vitro digestibility observations in this study, so that animals grazing the more mature swards were probably limited by rumen fill. As long as ruminants accepted long-standing and partly senesced biomass, they continued to consume and excrete considerable amounts of N. Even when animals were allowed 40 to 50 kg DM animal⁻¹ d⁻¹, N intake seemed not to be restricted.

In grassland extensification schemes, late turning out to pasture is a common sanction to control vegetation height and structure, aiming to support biodiversity and to improve species richness (Marriott et al., 2004). In such situations, considerable amounts of N are likely to be ingested and excreted. Grazing in taller and unimproved swards on extensive grassland does not implicitly prevent N load into the environment through urine excretion because N intake might be considerably high. One major reason behind high N intake is selective grazing. This has been indicated in the present study by the differences in faeces N as compared with forage N (Jarvis et al., 1989).

This experiment provides quantitative data over a wide range of values on the relationship between N intake and the amount of N excreted with urine, which has been demonstrated with sheep and cattle in classical studies previously (e.g., Barrow and Lambourne, 1962; Kreuzer and Kirchgessner, 1985). Although N loss from both the urine and faeces excretion was not the centre of interest in this study, a simple calculation of daily N loss on the pasture could be provided with the data set. It has been shown elsewhere with Highland suckler cows that ruminants are able to maintain high N intake rates by selective grazing, also on unimproved Alpine pastures, and so to contribute considerable N returns and N losses to the environment (Berry et al., 2003).

Figure 5. Relationship between herbage allowance, herbage intake, N intake, N excretion and N loss on a pasture grazed with suckler cows. Dotted line in figure (a) indicates the curvilinear relation derived from a 2-year nutrient-cycling study in the vicinity of the present experiment on Rengen Research Station (Schellberg et al., 2006) with $H_I = 18.4(1 - e^{-0.066 H_A})$ and $r^2 = 0.818$. H_I = herbage intake, H_A = herbage allowance, IT_N = N intake, N_{exc} = total daily N excretion, N_{loss} = loss of N.

3.3. Upscaling the N excretion of suckler cows on pastures

Under field situations and on farms, the excretion of ingested N with both the faeces and urine can be calculated following a simple spreadsheet as outlined in Figure 6. When turning out the cattle, farmers decide mainly on the offered amount of herbage and the number of animals grazed per hectare, i.e. the stocking density (S_D). As a prerequisite of using the spreadsheet, herbage allowance estimates are needed. It has been revealed through systematic testing and validation that time-saving estimates of herbage allowance can be accomplished with different types of easy-to-handle herbage meters

(Sanderson et al., 2001; Correl et al., 2003). Further, based on principle functional relations between herbage allowance and N content in herbage, as described in detail by Lemaire and Gastal (1997), the N content of the herbage can be derived from such yield estimates, which are given for the present experiment in Figure 7. Once herbage and nitrogen intakes have been calculated, the equations given in Figure 5c for N excretion with faeces ($N_{exc f}$) and urine ($N_{exc u}$) can be applied to determine total N excretion (N_{exc}) as well as the nitrogen-use efficiency (NUE) of the current grazing rotation.

Examples for total N excretion and nitrogen-use efficiency estimations under the conditions given in the present grazing experiment and based on the spreadsheet are outlined in

Figure 6. Spreadsheet for the determination of N excretion and N-use efficiency of suckler cows on a permanent pasture. Grey boxes indicate required input parameters.

Statistics:

(a) $N_H = A H_A^B$					
A	error	B	error	r^2	n
35.98	± 1.098	-0.2540	± 0.030	0.525	64

Figure 7. Relationship between herbage allowance and herbage N content on a permanent pasture DM: dry matter.

Figures 8 and 9. As expected, urine N excretion exceeded by far that of faeces on a per hectare basis. However, as herbage N content decreased with plant age and the amount of herbage intake saturated at a certain level (Fig. 5a), daily urine N excretion did not exceed 20 kg ha^{-1} . Additionally, stocking density increased total N excretion more than herbage

Figure 8. Simulated daily nitrogen excretion of suckler cows with urine and faeces as influenced by herbage allowance and stocking density from 10 to 60 livestock units per hectare on a pasture. N excretion with urine exceeds by far that of faeces, but levels off with high herbage allowances due to decreasing N concentration. Stocking density increases urine N excretion more than herbage allowance and related N intake.

allowance (Fig. 8). As compared with urine N, faeces N remained nearly unaffected by herbage allowance but increased significantly with stocking density.

The present study provides experimental results directly applicable to the farm environment. The advantage of the spreadsheet in Figure 6 is seen in its easy handling and suitability for farm situations as well as for agricultural advice and on-farm research. It can neither compete with nor replace sophisticated scientific N-cycling models that have been set up for basic research (Rotz et al., 2005). With beef cattle, a control

Figure 9. Simulated nitrogen-use efficiency (*NUE*) of forage as influenced by N intake of suckler cows on a pasture. *NUE* was calculated assuming 4 different values of daily N gain in animal carcasses from 19 g animal⁻¹ d⁻¹ (top curve) to 8.5 g cow⁻¹ d⁻¹ (lowest curve).

and prediction of N excretion and N-use efficiency similar to dairy cows based on daily available milk urea N (Jonker et al., 1998) is impossible. On suckler farms, two of the four input values required to run the spreadsheet in Figure 6 are easily available in any case, i.e. the stocking density and the daily N retention. The permanent control of sward height and grazing success by means of a pasture meter is recommended to improve pasture utilisation and so might provide additional input to the spreadsheet to keep a check on the intake, excretion and use efficiency of nitrogen.

In earlier studies, a model for dairy cow N metabolism and excretion was developed to simulate the N pools and N flows in dairy cows (Kebreab et al., 2002). The N intake was identified as the driving input variable of the dietary N pool together with three outputs, the faeces (N in undigested microbial matter plus intestinally indigestible dietary N sources), urine N deriving from rumen-degradable N as well as milk N excretion, with the effect that the N excretion (N_{exc}) to N intake (IT_N) relation calculation is much lower (~66% with 300 g IT_N ; ~68% with 500 g IT_N) as compared with beef production. With dairy cows, the N-use efficiency is mainly determined by daily milk production per cow in relation to daily N intake. In contrast, marginal N retention in the animal carcass and N-use efficiency is inherent in beef production systems on pastures and is hence inevitably accompanied by considerable N consumption and excretion.

4. CONCLUSION

Even with decreasing N concentration in offered herbage, sward height and herbage allowance strongly affect the N intake of grazing animals, regardless of additional effects of N fertiliser application (Astigarraga et al., 1992). With beef cattle, the N excretion with urine and faeces, potential N loss per hectare and N-use efficiency of the grazing animal can be calculated from herbage intake and N concentration on a daily basis. Experimental data as well as calculated averages from

polynomial and linear fit exhibited considerable N turnover with offered herbage and conversion of N into labile forms favouring N losses to the environment. Consequently, grazing on extensified pastures with low N content but high herbage allowance does not prevent environmental interference.

REFERENCES

- Astigarraga L., Peyraud J.L., Delaby L. (1992) Effect of fertiliser rate and protein supplementation on the herbage intake and the nitrogen balance of grazing dairy cows, *Anim. Res.* 51, 279–293.
- Barrow N.J., Lambourne L.J. (1962) Partition of excreted nitrogen, sulphur and phosphorus between faeces and urine of sheep being fed pasture, *Aust. J. Agr. Sci.* 13, 461–471.
- Berry N.R., Jewell P.L., Sutter F., Edwards P.J., Kreuzer M. (2003) Selection, intake and excretion of nutrients by Scottish Highland suckler beef cows and calves, and brown Swiss dairy cows in contrasting Alpine grazing systems, *J. Agr. Sci. Camb.* 139, 437–453.
- Correll O., Isselstein J., Pavlu V. (2003) Studying spatial and temporal dynamics of sward structure at low stocking densities: the use of an extended rising-plate-meter method, *Grass Forage Sci.* 58, 450–454.
- Dartt B.A., Lloyd J.W., Radke B.R., Black J.R., Kaneene J.B. (1999) A comparison of profitability and economic efficiencies between management-intensive grazing and conventionally managed dairies in Michigan, *J. Dairy Sci.* 82, 2412–2420.
- Dove H. (1996) Constraints to the modelling of diet selection and intake in the grazing ruminant, *Aust. J. Agr. Res.* 47, 257–275.
- Estermann B.L., Wettstein H.-R., Sutter F., Kreuzer M. (2001) Nutrient and energy conversion of grass-fed dairy and suckler beef cattle kept indoors and on high altitude pasture, *Anim. Res.* 50, 477–493.
- Fox D.G., Tylutki T.P. (1998) Accounting for the effects of environment on the nutrient requirements of dairy cattle, *J. Dairy Sci.* 81, 3085–3095.
- Freer M., Moore A.D., Donnelly J.R. (1997) GRAZPLAN: decision support system for Australian grazing enterprises - II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS, *Agr. Syst.* 54, 77–126.
- Gibb M.J., Huckle C.A., Nuthall R., Rook A.J. (1997) Effect of sward surface height on intake and grazing behaviour by lactating Holstein Friesian cows, *Grass Forage Sci.* 52, 309–321.
- Hanson G.D., Cunningham L.C., Morehart M.J., Parsons R.L. (1998) Profitability of moderate intensive grazing of dairy cows in the northeast, *J. Dairy Sci.* 81, 821–829.
- Haynes R.J., Williams P.H. (1993) Nutrient cycling and soil fertility in the grazed pasture ecosystem, *Adv. Agron.* 49, 119–199.
- Holden L.A., Muller L.D., Fales S.L. (1994) Estimation of intake in high producing Holstein cows grazing grass pasture, *J. Dairy Sci.* 77, 2332–2340.
- James T., Meyer D., Esparza E., DePeters E.J., Perez-Mont H. (1999) Effects of dietary nitrogen manipulation on ammonia volatilization from manure from Holstein suckler cows, *J. Dairy Sci.* 82, 2430–2439.
- Jarvis S.C., Hatch D.J., Roberts D.H. (1989) The effects of grassland management on nitrogen losses from grazed swards through ammonia volatilization; the relationship to excretal N returns from cattle, *J. Agr. Sci. Camb.* 112, 205–216.
- Jonker J.S., Kohn R.A., Erdman R.A. (1998) Using milk urea nitrogen to predict nitrogen excretion and utilization efficiency in lactating dairy cows, *J. Dairy Sci.* 81, 2681–2692.
- Kebreab E., France J., Mills J.A.N., Allison R., Dijkstra J. (2002) A dynamic model of N metabolism in the lactating dairy cow and an assessment of impact of N excretion on the environment, *J. Anim. Sci.* 80, 248–259.

- Kohn R.A., Kalscheur K.F., Russek-Cohen E. (2002) Evaluation of models to estimate urinary nitrogen and expected milk urea nitrogen, *J. Dairy Sci.* 85, 227–233.
- Kreuzer M., Kirchgessner M. (1985) N-Ansatz und N-Verwertung bei Kühen während und nach überhöhter Proteinversorgung. 2. Zum Einfluß von Proteinfehlernährung bei laktierenden Kühen und daraus entstehenden Nachwirkungen, *Z. Tierphysiol. Tierernährg. Futtermittelkde.* 53, 270–279.
- Lemaire G., Gastal F. (1997) N uptake and distribution in plant canopies, in: Lemaire G. (Ed.), *Diagnosis of the Nitrogen Status in Crops*, Springer Berlin, pp. 3–43.
- Marriott C.A., Fothergill M., Jeangros B., Scotton M., Louault F. (2004) Long-term impacts of extensification of grassland on biodiversity and productivity in upland areas, A review, *Agronomie* 24, 447–462.
- McCall D.G., Clark D.A., Stachurski L.J., Penno J.W., Bryant A.M., Ridler B.J. (1999) Optimized dairy grazing systems in the Northeast United States and New Zealand. I. Model description and evaluation, *J. Dairy Sci.* 82, 1795–1807.
- Menke K.H., Steingass H. (1987) Schätzung des energetischen Futterwerts aus der in-vitro mit Pansensaft bestimmten Gasbildung und der chemischen Analyse. II. Regressionsgleichungen, Übers. *Tierernährg.* 15, 59–94.
- Peyraud J.L., Astigarraga L. (1998) Review of the effect of nitrogen fertilisation on the chemical composition, intake, digestion and nutritive value of fresh herbage: consequences on animal nutrition and N balance, *Anim. Feed Sci. Tech.* 72, 235–259.
- Peyraud J.L., Mosquera-Losada R., Delaby L. (2004) Challenges and tools to develop efficient dairy systems based on grazing: how to meet animal performance and grazing management, *Grassl. Sci. Eur.* 9, 373–384.
- Rotz C.A., Taube F., Russelle M.P., Oenema J., Sanderson M.A., Wachendorf M. (2005) Whole-farm perspectives of nutrient flows in grassland agriculture, *Crop Sci.* 45, 2139–2159.
- Sanderson M.A., Rotz C.A., Fultz S.W., Rayburn E.B. (2001) Estimating forage mass with a commercial capacitance meter, rising plate meter, and pasture ruler, *Agron. J.* 93, 1281–1286.
- Schellberg J., Lellmann A., Kühbauch W. (2006) Nutrient flows in suckler farm systems under two levels of intensity, *Nutr. Cycl. Agroecosyst.* 74, 41–57.
- Spanghero M., Kowalski Z.M. (1997) Critical N balance experiments with lactating cows, *Livest. Prod. Sci.* 52, 113–122.
- Steingass H., Menke K.H. (1986) Schätzung des energetischen Futterwerts aus der in-vitro mit Pansensaft bestimmten Gasbildung und der chemischen Analyse. I. Untersuchungen zur Methode, Übers. *Tierernährg.* 14, 251–270.
- Stout W.L., Fales S.L., Muller L.D., Schnabel R.R., Weaver S.R. (2000) Water quality implications of nitrate leaching from intensively grazed pasture swards in the northeast US, *Agr. Ecosyst. Environ.* 77, 203–210.
- Tozer P.R., Bargo F., Muller L.D. (2003) Economic analyses of feeding systems combining pasture and total mixed ration, *J. Dairy Sci.* 86, 808–818.
- Universität Hohenheim – Dokumentationsstelle (1997) (Ed.) *DLG-Futterwerttabellen Wiederkäuer*, 7th ed., DLG, Frankfurt.
- van Horn H.H., Newton G.L., Kunkle W.E. (1995) Ruminant nutrition from the environmental perspective: factors affecting whole-farm nutrient balance, *J. Anim. Sci.* 74, 3082–3102.
- Wang S.J., Fox D.G., Cherney D.R.J., Chase L.E., Tedeschi L.O. (2000) Whole-herd optimisation with the Cornell net carbohydrate and protein system. II. Allocating homegrown feeds across the herd for optimum nutrient use, *J. Dairy Sci.* 83, 2149–2159.
- Webb J., Anthony S.G., Brown L., Lyons-Visser, H., Ross B., Cottrill B., Johnson P., Scholefield D. (2005) The impact of increasing the length of cattle grazing on emissions of ammonia and nitrous oxide and on nitrate leaching in England and Wales, *Agr. Ecosyst. Environ.* 105, 307–321.
- White S.L., Benson G.A., Washburn S.P., Green J.T. (2002) Milk production and economic measures in confinement or pasture systems using seasonally calved Holstein cows, *J. Dairy Sci.* 85, 95–104.
- Wilson G.F., Moller S., Parke W.J., Hodgson J. (1995). Seasonal differences in pasture composition and nutritional implications, *Massey Dairy Farming Annu.* 47, 46–56.