Calculation of nitrogen excretion of dairy cows in Austria

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Ermittlung der Stickstoff-Ausscheidung von Milchkühen in Österreich

1 Introduction

For most of the Austrian grassland and dairy farmers both home-grown forage from grassland and farm manure are the main natural nutrient resources. On the other hand the use of external inputs like concentrates and mineral fertilisers is very low compared to intensive production areas in Europe (TAUBE and PÖTSCH, 2001). Low input strategies are strongly supported by the Austrian environmental program for agriculture "ÖPUL", which is highly accepted by the farmers. Livestock manure is an essential part of the farm nutrient budget and therefore reliable data about excretion amount and nutrient concentration are of great importance both for increasing the nutrient efficiency and for reducing nutrient losses.

2 Material and methods

Concerning the Austrian livestock structure, dairy cows (557,900) and suckler cows (240,000) are the most important cattle categories (BMLFUW, 2004). Principally, the calculation of nitrogen excretion of dairy cows and suckler cows in Austria follows the guidelines of the EUROPEAN COMMISSION (2002):

$N_{manure} = N_{diet} - N_{products} - N_{gaseous\ losses\ (15\%\ from\ buildings\ and\ storage)}$

$N_{diet} = DM\ Intake\ x\ N\ content$

2.1 Calculation of the N content of the diet

It is assumed that the feeding of the dairy cows is mainly practiced according to their requirements. This seems justi-

Zusammenfassung

Im Rahmen der Anforderungen zur innerstaatlichen Umsetzung der EU-Nitratrichtlinie und der Aktualisierung der bestehenden Düngungsrichtlinien wurden die österreichischen N-Ausscheidungswerte für Milch- und Mutterkühe überarbeitet. Grundsätzlich wurde dazu eine den aktuellen Empfehlungen entsprechende, bedarfs- und leistungsgerechte Fütterung unterstellt. Die Futteraufnahme als ein weiterer, wichtiger Aspekt für die Höhe der N-Exkretion wurde nach der Futteraufnahme-Schätzgleichung von GRUBER et al. (2001) kalkuliert. Der im Vergleich zu intensiv genutzten europäischen Grünlandregionen niedrige Rohproteingehalt des Grünlandfutters ist auf die im Berggebiet vorherrschende extensive Wirtschaftsweise zurückzuführen. Dadurch kommt es zu einer reduzierten und überschussvermeidenden N-Aufnahme über die Futterration und somit zu geringen N-Ausscheidungen der Milch- und Mutterkühe.

Schlagworte: N-Ausscheidung, Rohprotein, Grundfutterqualität, Grundfutteraufnahme, Milchharnstoffgehalt.

Summary

According to the requirements of the European Nitrate Directive, the Austrian data for the N-excretion of dairy and suckler cows have been recalculated following the guidelines of the European Commission. It was assumed that the feeding of the dairy cows is mainly practiced considering the actual requirements for energy and protein. The dry matter intake as another crucial aspect for N-excretion has been calculated using the feed intake prediction equation of GRUBER et al. (2001). The relatively low crude protein content of forage from mountainous meadows and pastures as a consequence of low input management is in strong contrast to data from intensively managed grassland regions in Europe. It is finally the main reason for the low N input via feed stuff and therefore the low N excretion level of livestock in Austria.

Key words: N-excretion, crude protein, forage quality, forage intake, milk urea content.

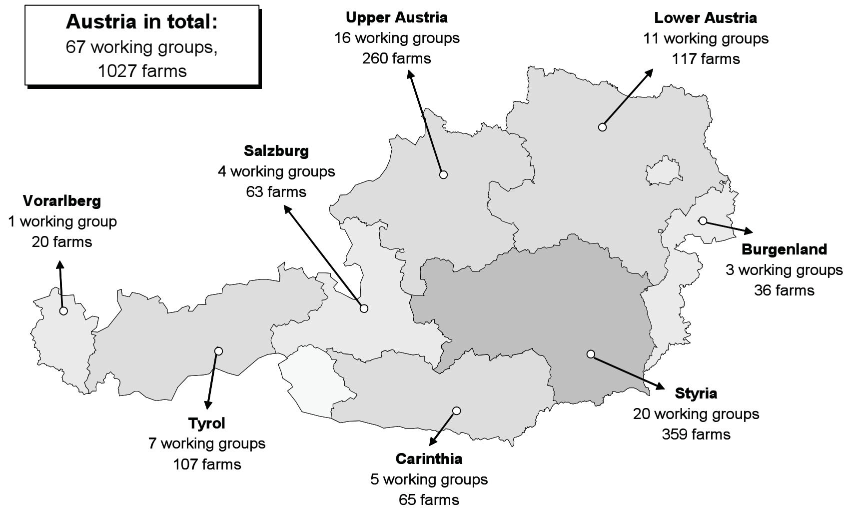
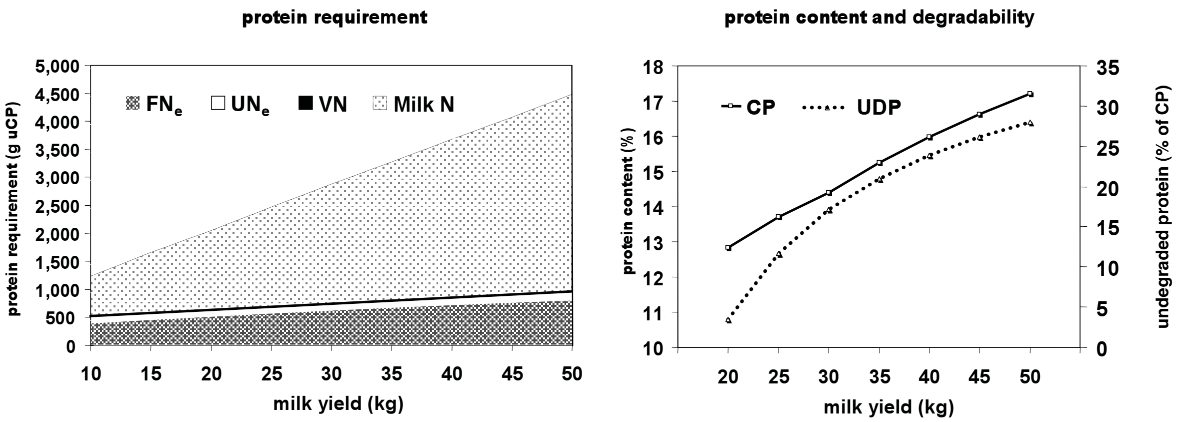


Figure 1: Working groups – dairy production in Austria (BMLFUW, 2003)
Abbildung 1: Verteilung der Milchvieharbeitskreise in Österreich (BMLFUW, 2003)

fied since there is an extensive advisory service established.

Further, all over the country and especially in the main regions of milk production so called "Working groups – dairy production" have been constituted (BMLFUW, 2003; Figure 1). These groups are managed by well-trained advisors and the members, i.e. farmers, regularly exchange their knowledge and experience.

As feeding standards, the "Recommendations for the Supply of Energy and Nutrients of Cows and Heifers" of the German Society of Nutrition Physiology are used (GfE, 2001). In these standards – as in all modern protein evaluation systems – the maintenance requirements are consisting of endogenous losses in urine and faeces as well as N losses via skin. Of course, the requirements for production are dependent on the milk yield and its protein content. The supply of protein to the host animal is met mainly by microbial protein (dependent on energy supply) and undegraded feed protein (dependent on feedstuff and its processing and conservation etc.). The requirements for utilisable crude protein as well as the resulting ration contents of crude protein and its degradability are presented in Figure 2. The main consequences of these standards are that the necessary protein content is essentially dependent on milk yield. The required protein content of the diet is low at low levels of milk yield and increases considerably with yield (e.g. 11.4, 13.7, 15.3 and 16.7 % CP at milk yields of 15, 25, 35 and 45 kg milk per day, respectively). Additionally, the need for undegraded feed protein also increases with milk yield, which has considerable consequences on the composition of the ration, especially the choice of concentrates.



FN_e = Faecal Nitrogen excretion, UN_e = Urinary Nitrogen excretion, VN = Dermal losses

Figure 2: Protein requirements of dairy cows and corresponding protein parameters (GfE, 2001)
Abbildung 2: Proteinbedarf von Milchkühen und korrespondierende Proteinkennwerte (GfE, 2001)

2.2 Calculation of the cows dry matter intake

Following the principles of EC (2002), the estimation of dry matter intake (DMI) is the second crucial aspect of the calculation of N excretion. The DMI has been calculated using the feed intake prediction equation of GRUBER et al. (2001). In this equation both nutritional (forage quality and composition, concentrate level) and animal factors (milk yield, live weight, stage of lactation, breed) are used as predictors of feed intake. It is well established that feed intake of dairy cows is controlled by these physiological and nutritional factors (e.g. WANGSNESS and MULLER, 1981; VAN SOEST, 1994; FORBES, 1995). This feed intake prediction equation is based on feeding experiments performed at HBLFA Raumberg-Gumpenstein during 20 years (n = 4,555, R^2 = 0.914, RSD = 0.88 kg DM).

To cover the practical situation of milk production in Austria the calculations were carried out for different production levels (3,000 to 10,000 kg milk per lactation). According to milk production the energy and protein content of the forage, the concentrate level, breed and season were adopted to ensure a realistic model.

2.3 Forage quality and crude protein content

More than 90 % of the Austrian farm land, conned with grasses, clover and herbs, is permanent grassland, which by the definition of SCHECHTNER (1978) is at least 20 to 25 years old and has never been ploughed up and renewed within that period.

Due to climatic (low temperatures, frost periods, long period with snow cover) and topographical constraints (steepness) as well as for shallow and stony soils most of the Austrian grassland has to be described as obligatory grassland (SCHECHTNER, 1993; TAUBE et al., 2002; PÖTSCH, 2005). About half of the total permanent grassland is used in a very moderate way with low stocking rates and is cut or grazed once or twice a year. Permanent grassland in more favourable regions of the mountains can be at least used three times per year (silage cut, hay cut, second cut hay or alternatively grazing in the autumn). Only in some very productive lowland areas even up to five cuts per year can be harvested (Figure 3).

The crude protein respectively the N content of the feed ration is the main drive for the level of N excretion. Figure 3 shows the average crude protein content of forage from different grassland types in Austria, which ranges from 8 % in very extensive grassland to about 22 % in intensively used ley farming areas. Forage from permanent grassland, which is with 54 % the main source for dairy cattle feeding, shows a variation in the crude protein content ranging from 12 to 14 %. This relatively low level is in strong contrast to data from intensively used grassland regions in Europe and is the main reason for the low N input via feed (DLG, 1997; NOZIÈRES et al., 2006).

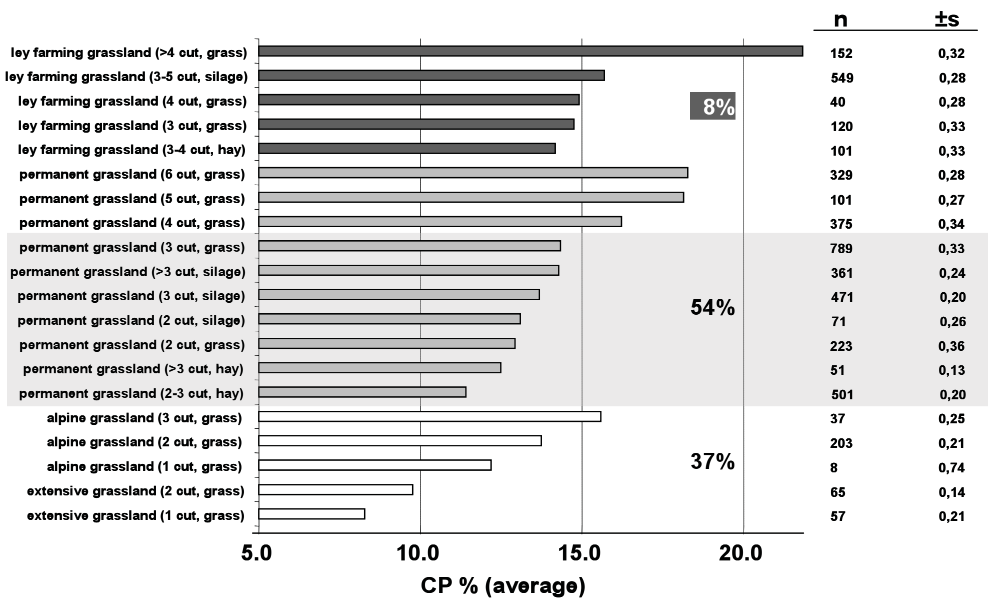


Figure 3: Crude protein content of forage from different grassland types in Austria (PÖTSCH, 2005)

Abbildung 3: Rohproteingehalt von Grundfutter unterschiedlicher Nutzungsformen in Österreich (PÖTSCH, 2005)

3 Results and discussion

3.1 Feeding and production data of the dairy cows

In Table 1 the forage composition, the estimated feed intake as well as the energy and protein content of the rations are presented, based on the model as outlined in section 2. The data are computed for both the winter and summer season and from these results the average was computed. In the winter season the forage for dairy cows was composed of 60 % grass silage, 20 % hay and 20 % maize silage as well as of 70 % grass silage and 30 % hay for suckler and nurse cows. In the summer season fresh grass was the only forage for suckler and nurse cows (100 %). With increasing milk yield (5,000–10,000 kg), in the summer rations for dairy cows the percentage of fresh grass decreased from 90 to 38 % and grass silage increased from 0 to 40 % as well as maize silage from 0 to 13 % to simulate practical conditions.

As expected, concentrate and total feed intake increase with milk yield whereas forage intake is more or less constant. This is due to the fact that the so called forage substitution on the one hand is more or less balanced by the higher feed intake capacity of higher yielding dairy cows on the other hand (KIRCHGESSNER and SCHWARZ, 1984). As a result the energy concentration increased from 5.6 to 6.5 MJ NEL/kg DM and the CP content from 11.9 to 13.9 % for milk yields of 3,000 and 10,000 kg, respectively.

To reach realistic results when modelling milk production, it is necessary to account for the stage of lactation and the dry period since nutrient requirements and therefore feed intake are changing during lactation and dry period as

Table 1: Ration composition, feed intake of the cows1) 2) 3), energy and protein concentration of the total ration
Tabelle 1: Zusammensetzung der Ration sowie Futteraufnahme der Milchkühe1) 2) 3), Energie- und Rohproteingehalt der Gesamtration

	forage composition				feed intake (per day)			concentration	
yield per lactation	**fresh grass**	**grass silage**	**hay**	**maize silage**	**forage**	**concentrate**	**total**	**NEL content**	**CP content**
	% DM	% DM	% DM	% DM	kg DMI	kg DMI	kg DMI	MJ/kg DM	% DM
winter									
3,000 1), 3)	-	70.0	30.0	0.0	13.39	0.56	13.95	5.50	11.6
4,000 1), 3)	-	70.0	30.0	0.0	13.37	1.32	14.69	5.62	11.8
5,000 1)	-	60.0	20.0	20.0	12.74	2.51	15.25	5.95	12.5
6,000 1)	-	60.0	20.0	20.0	12.57	3.66	16.23	6.14	13.0
7,000 2)	-	60.0	20.0	20.0	13.17	4.13	17.30	6.22	13.2
8,000 2)	-	60.0	20.0	20.0	13.02	5.24	18.26	6.37	13.5
9,000 2)	-	60.0	20.0	20.0	12.88	6.35	19.23	6.51	13.9
10,000 2)	-	60.0	20.0	20.0	12.72	7.47	20.19	6.63	14.2
summer									
3,000	100.0	0.0	0.0	0.0	14.35	0.28	14.63	5.74	12.1
4,000	100.0	0.0	0.0	0.0	14.70	0.51	15.21	5.77	12.1
5,000	90.0	0.0	10.0	0.0	14.92	1.03	15.95	5.80	12.2
6,000	87.5	0.0	10.0	2.5	14.97	1.89	16.86	5.91	12.5
7,000	75.0	10.0	10.0	5.0	15.49	2.54	18.03	5.97	12.6
8,000	62.5	20.0	10.0	7.5	15.42	3.60	19.02	6.12	12.9
9,000	50.0	30.0	10.0	10.0	15.37	4.62	19.99	6.26	13.3
10,000	37.5	40.0	10.0	12.5	15.34	5.60	20.94	6.39	13.7
average									
3,000	50.0	35.0	15.0	0.0	13.87	0.42	14.29	5.62	11.9
4,000	50.0	35.0	15.0	0.0	14.04	0.92	14.95	5.70	12.0
5,000	45.0	30.0	15.0	10.0	13.83	1.77	15.60	5.88	12.3
6,000	43.8	30.0	15.0	11.3	13.77	2.78	16.55	6.03	12.7
7,000	37.5	35.0	15.0	12.5	14.33	3.34	17.67	6.10	12.9
8,000	31.3	40.0	15.0	13.8	14.22	4.42	18.64	6.25	13.2
9,000	25.0	45.0	15.0	15.0	14.13	5.49	19.61	6.39	13.6
10,000	18.8	50.0	15.0	16.3	14.03	6.54	20.57	6.51	13.9

1) Milk yield: 3000, 4000, 5000, 6000 kg: Simmental, 700 kg live weight, 4.18 % milk fat, 3.44 % milk protein
2) Milk yield: 7000, 8000, 9000, 10000 kg: Holstein Friesian, 640 kg live weight, 4.15 % milk fat, 3.28 % milk protein
3) 3000 and 4000 kg milk yield represents suckler and nurse cows, respectively
(ZAR, 2003)

a consequence of variable nutrient outputs (milk and foetus). In the present model, the calculations were performed for every week of lactation and dry period. The results presented in Tables 1 and 2 are therefore means of 52 weeks.

In Figures 4 and 5 two examples (Simmental – 6,000 kg milk, Holstein Friesian – 10,000 kg milk) are given to illustrate how feed intake, concentrate level and the respective protein content of the ration are reduced during progress of lactation. For example with 10,000 kg milk (HF) the daily milk yield decreases from 45 to 20 kg per day and the corresponding protein content from 16.5 to 13.5 % CP, the mean CP concentration being only 13.9 %.

Based on these assumptions the mean calculated N excretions of cows per year are presented in Table 2, dependent on milk yield. The N intake via the diet increases from 99 to 168 kg per year and the corresponding N output via products (mainly milk) rises from 18 to 53 kg. This results in N excretions of 81 to 114 kg and – when gaseous losses from buildings and manure storage of 15 % are considered – in values of N in manure of 69 to 97 kg per cow and year.

These N excretion figures are higher than reported in the paper of GRUBER and STEINWIDDER (1996), based on the excretion equations of KIRCHGESSNER et al. (1991). There are several reasons for this discrepancy. Although the model assumptions are similar they are not identical. The nutrient requirements were updated by the Society of Nutrition Physiology in the meantime (GEH, 1986 versus GfE, 2001), leading to slightly different protein concentrations of the ration. The main reason, however, is that the present data are based on model assumptions being very close to practical farming conditions in Austria (forage composition and quality, in particular the total lactation cycle), whereas the equation of KIRCHGESSNER et al. (1991) only considers the protein content of the ration und the level of milk yield. This apparently results in underestimating the N excretion, especially at low levels of milk production. These excretion data are lower than assumed in several EC member states (FUNAKI and PARRIS, 2005). One main reason is the low protein content of grassland forage ranging from 12 to 14 % due to the relatively extensive grassland management, as shown by the data of PÖTSCH (2005).

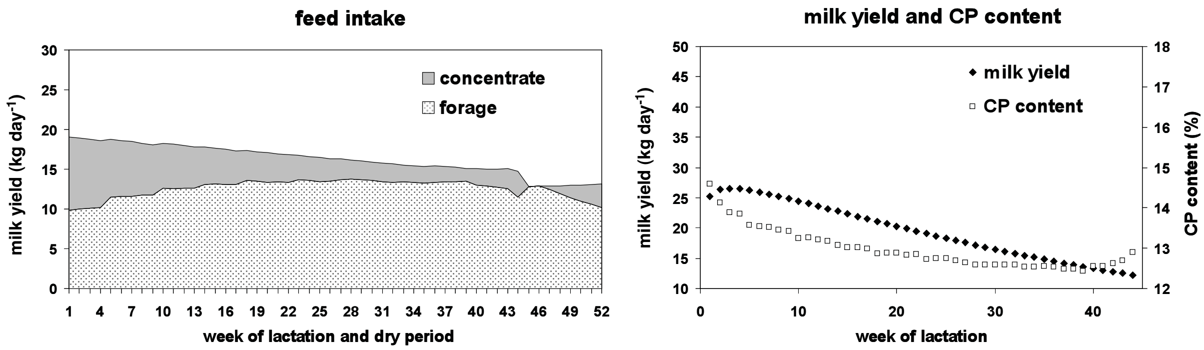


Figure 4: Production data for Simmental cows (6,000 kg milk yield)
Abbildung 4: Produktionsdaten für Fleckviehkühe (6.000 kg Milchleistung)

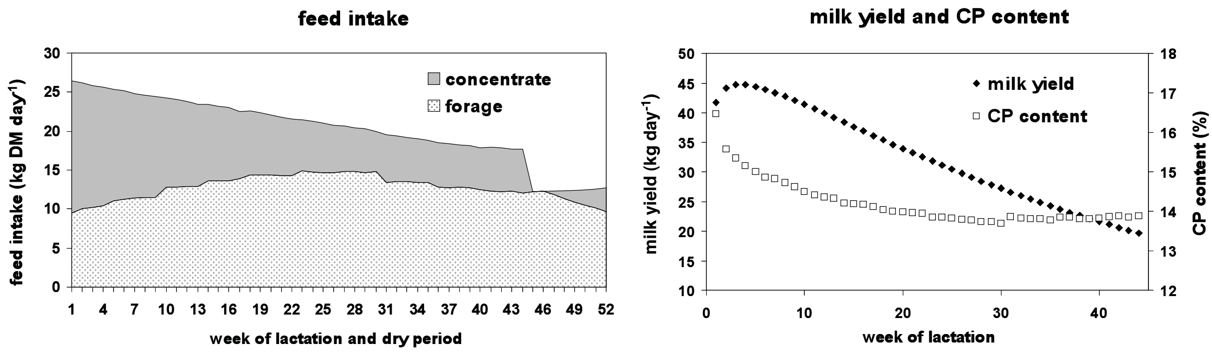


Figure 5: Production data for Holstein Friesian cows (10,000 kg milk yield)
Abbildung 5: Produktionsdaten für Holstein Friesian Kühe (10.000 kg Milchleistung)

Table 2: Calculation of N excretion of the cows (kg per year)
Tabelle 2: Kalkulation der N-Ausscheidung von Milchkühen (kg pro Jahr)

yield per lactation	DM intake	N diet	N milk	N calf	N weight gain cow	N products	N excretion	N gaseous losses	N manure
3,000 [1), 3)]	5,216	98.9	16.2	0.9	1.1	18.2	80.8	12.1	68.7
4,000 [1), 3)]	5,457	104.4	21.5	0.9	1.1	23.5	80.8	12.1	68.7
5,000 [1)]	5,694	112.5	26.9	0.9	1.1	28.9	83.6	12.5	71.1
6,000 [1)]	6,039	123.1	32.3	0.9	1.1	34.3	88.8	13.3	75.5
7,000 [2)]	6,448	133.0	35.9	0.9	1.0	37.8	95.2	14.3	80.9
8,000 [2)]	6,804	143.6	41.1	0.9	1.0	43.0	100.7	15.1	85.6
9,000 [2)]	7,158	155.7	46.2	0.9	1.0	48.1	107.6	16.1	91.5
10,000 [2)]	7,506	167.5	51.3	0.9	1.0	53.2	114.3	17.1	97,2

1) Milk yield: 3000, 4000, 5000, 6000 kg: Simmental, 700 kg live weight, 4.18 % milk fat, 3.44 % milk protein
2) Milk yield: 7000, 8000, 9000, 10000 kg: Holstein Friesian, 640 kg live weight, 4.15 % milk fat, 3.28 % milk protein
3) 3000 and 4000 kg milk yield represents suckler and nurse cows, respectively
(ZAR, 2003)

The other very important reason for the low N excretion is the low milk yield level of Austrian dairy cows, as shown in Figure 6. Then mean milk production in Austria is 5,432 kg per cow and year which is much lower compared to the milk production in Scandinavian and Western European countries (EUROSTAT, 2004). As described in Table 1, protein content and hence N excretion are considerably low at this level of milk production. The milk production level is further confirmed by the distribution of milk yield classes (AMA, 2003) showing that farms of 5,000–7,000 kg are most frequent (80 % of cows are Simmental, a dual purpose breed).

In Figure 7 the relationship between milk urea content and ruminal N balance is presented (STEINWIDDER and GRUBER, 2000), pointing out that milk urea content can be used as an indicator of the ruminal N balance and hence the protein content of the diet (KIRCHGESSNER et al., 1986; VERITE et al., 1995). The value of 20.8 mg milk urea has turned out to correspond to an optimal CP content of the ration, i.e. a ruminal N balance of zero (STEINWIDDER and GRUBER, 1999). The statistical evaluation of the official milk recording and breeding organisation in Austria (ZAR, 2004) indicates that the average milk urea content is around 20–22 mg/100 ml in the relevant milk yield classes (3,000–7,000 kg milk).

Conclusions

Forage from permanent grassland is the main feed ration component for cows in Austria. Its relatively low N content, which is in strong contrast to data from intensively used

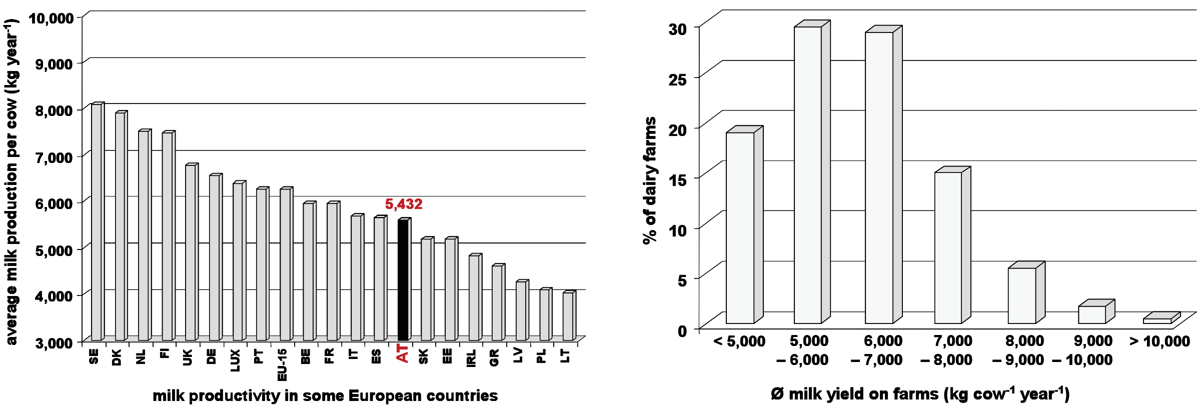


Figure 6: Milk production level in Europe and Austria (EUROSTAT, 2004; AMA, 2003)
Abbildung 6: Milchproduktionsdaten für Europa und Österreich (EUROSTAT, 2004; AMA, 2003)

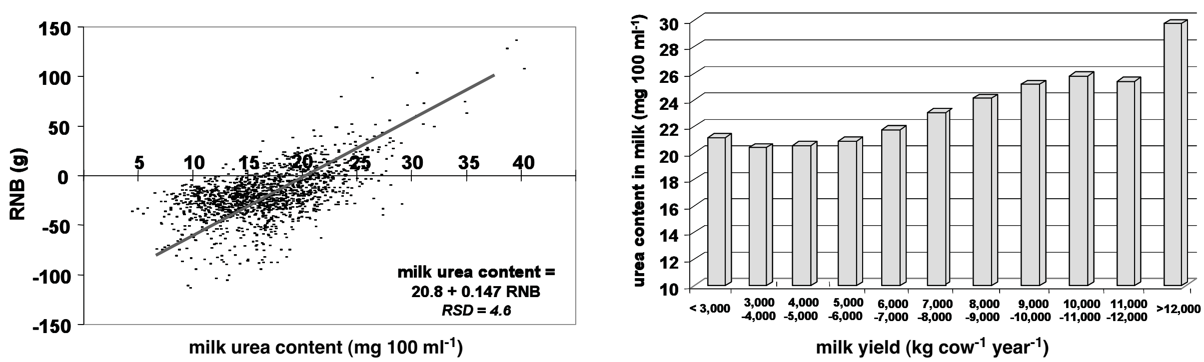


Figure 7: Relationship between milk urea content and ruminal N balance (STEINWIDDER and GRUBER, 1999) and milk urea content in practical farms (ZAR, 2004)

Abbildung 7: Zusammenhang zwischen Milchharnstoffgehalt und ruminaler N-Bilanz (STEINWIDDER und GRUBER, 1999) sowie Milchharnstoffwerte in Praxisbetrieben (ZAR, 2004)

grassland regions in Europe, is a consequence of low input and sustainable grassland management as well as of unfavourable growing conditions.

The N input represents the crucial factor determining the N excretion of dairy cows. Further, it is well established that the protein requirement of dairy cows increases with rising milk yield (GfE, 2001). The milk production level in Austria is quite low compared to most of the European countries (5,400 kg per lactation) which, following the actual nutrition requirements, results in a low protein content of the dairy cow rations. But even at higher production levels the protein content of the ration has to be adapted to the lower milk yield at the end of lactation and to the lower protein requirements in the dry period.

The assumptions as well as the results of the present model calculations are well confirmed by the milk urea data of the official milk recording and breeding organisation in Austria (ZAR, 2004). The average milk urea content is around 20–22 mg/100 ml and the value of 20.8 mg milk urea has turned out to correspond to an optimal CP content of the ration, i.e. a ruminal N balance of zero (STEINWIDDER and GRUBER, 1999).

Up to now the N excretion of dairy cows in Austria was calculated on the basis of 4,500 kg milk per year, which is about 1,000 kg lower than the actual average amount (BMLFUW, 1999). According to the "Austrian Action Program 2003" from 2007 onwards, different production levels, ranging from 3,000 kg (suckler cows) to 10,000 kg milk per cow and year will be taken into account, considering their strong impact on N excretion. This will ensure an efficient use of nutrients at each milk production level and effects both providing the animals according to their requirements and minimizing nutrient excretion. Aiming at the reduction of N excretion to avoid negative impact on the environment, the compliance of actual energy and protein requirements has to be seen as a key point.

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