# CHAPTER 5

# GRAZING SYSTEMS AND FEED SUPPLEMENTATION

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**Abstract.** Dairy farmers may choose one of four grazing management and feeding systems: unrestricted stocking, restricted stocking during the day, zero-grazing using fresh grass or zero-grazing using ensiled grass. In their choice, farmers may incorporate their opinion towards economics, animal welfare, society and environment. When fed on grass only, a maximum dry-matter intake of 110 to 120 g (kg body weight)$^{-0.75}$ can be expected. This will cover energy and protein requirements for maintenance and 22 to 28 kg of milk. For higher production levels, supplements are required. For well managed grasslands, supplements with a high proportion of rumen-available carbohydrates are preferred, such as maize silage and sugar-beet pulp. To control energy and protein intake, farmers can use restricted or zero-grazing. Thus the rise in productivity in dairy cattle has reduced the number of farmers that use unrestricted stocking. We expect this development to be continued in the next decade.
**Keywords**: grazing management; grass production; grass intake; supplement feeding; dairy cattle

## INTRODUCTION

In temperate regions such as northwestern Europe, New-Zealand or the southern part of Latin America, grass is the main feed for dairy cattle. Grass is fed either fresh – predominantly through grazing – or in a preserved form as silage or hay. Dry-matter intake (DMI) and hence energy and nutrient intake of grazing dairy cattle are limited. However, during the last decades, milk production of dairy cattle has increased considerably. For instance, in the four main milk-producing EU countries, collected milk increased between 800 (France) and 1500 (United Kingdom) kg cow$^{-1}$ yr$^{-1}$ in the last 10 years (Figure 1). The higher milk production requires a higher supply of energy and nutrients, to be achieved by a higher DMI or more concentrated DM or both. To ensure an adequate supply of energy and nutrients, different grazing systems have been developed. Four systems of grazing and feeding management can be distinguished:

1. unrestricted stocking (unrestricted)
2. restricted stocking, usually only during the day (restricted)
3. zero-grazing, ration of fresh grass (zero-fresh)



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4. zero-grazing, ration of ensiled grass (zero-ensiled)

Feed supplementation forms an important part of the systems restricted stocking and zero-grazing.

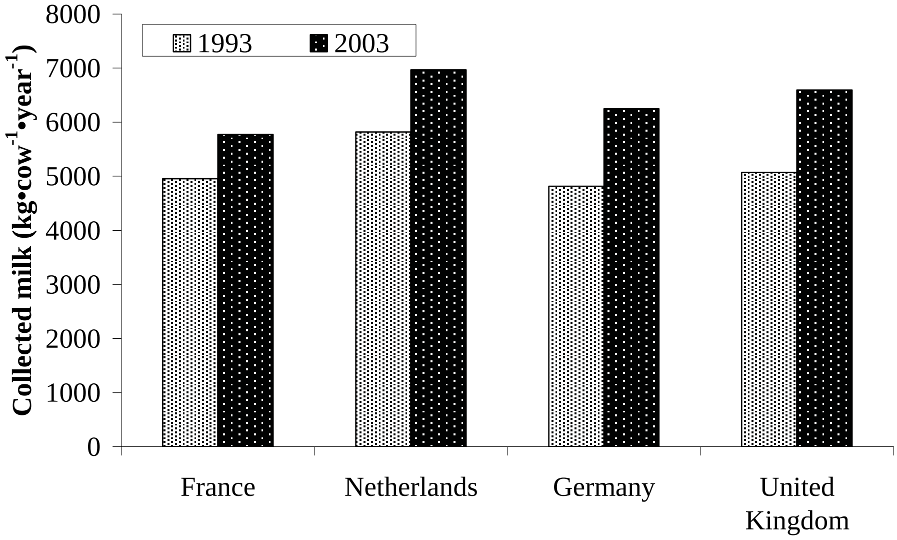


***Figure 1.*** *Amount of collected milk per cow per year in the four main milk-producing EU countries in 1993 and 2003 (adapted from EUROSTAT)*

This chapter describes the impact of different grazing systems on grassland productivity, chemical composition and nutritive value of grass. Furthermore, the required quantity and quality of feed supplementation are discussed. We show that farmers in northwestern Europe are increasingly eager to control the ration of their high-merit dairy cattle, thus inducing a trend towards less grazing.

## GRAZING IN NORTHWESTERN EUROPE

Long-term data of grazing in Europe are hardly available. However, experts indicate that zero-grazing is becoming more and more popular. In Denmark for example, zero-grazing increased from 16% of the dairy cows in 2001 to 30% in 2003 (Danish Agricultural Advisory Service, pers.comm.). In The Netherlands, zero-grazing increased from 6% in 1992 to 15% of all dairy cows in 2004 (Figure 2). In some regions of Germany and Austria almost every farm practices zero-grazing. If grazing is practised, the average number of grazing hours cow$^{-1}$ day$^{-1}$ has often decreased during the last decade. In The Netherlands for example, unrestricted stocking has become less favourable during the last five years (Figure 2).

The reasons for practising less grazing vary with the different types of farms that typically occur in different regions. Modern, large-scale farms with high-yielding dairy cattle, such as increasingly occur around Europe, may practice zero-grazing in order to control rations and optimize grassland utilization. On small-scale farms, such as for example in Austria and South Germany, usually cows are tied and this is often not combined with grazing. Other reasons for less grazing are increased herd size, scarcity of land in relation to herd size, increase of automatic milking, need to reduce mineral losses and labour efficiency.

## GRASSLAND PRODUCTIVITY AND UTILIZATION

The dry-matter (DM) production of grassland depends on soil factors, climatic factors, fertilization, species composition and grassland use. Moisture supply is an important influencing factor. Variation between fields, farms and regions is large. Typical net DM yield of grasslands used for dairy cattle in The Netherlands is 10.4 tonnes of DM $ha^{-1}$. The net DM yield varies from an average value of 9.6 for peat soils and 10.3 for clay soils to 10.4 for wet sandy soils and 11.5 for dry sandy soils (Schröder et al. 2005). Grasslands are utilized for mowing and grazing. There are different grazing systems, viz. continuous stocking, rotational grazing and strip-grazing.

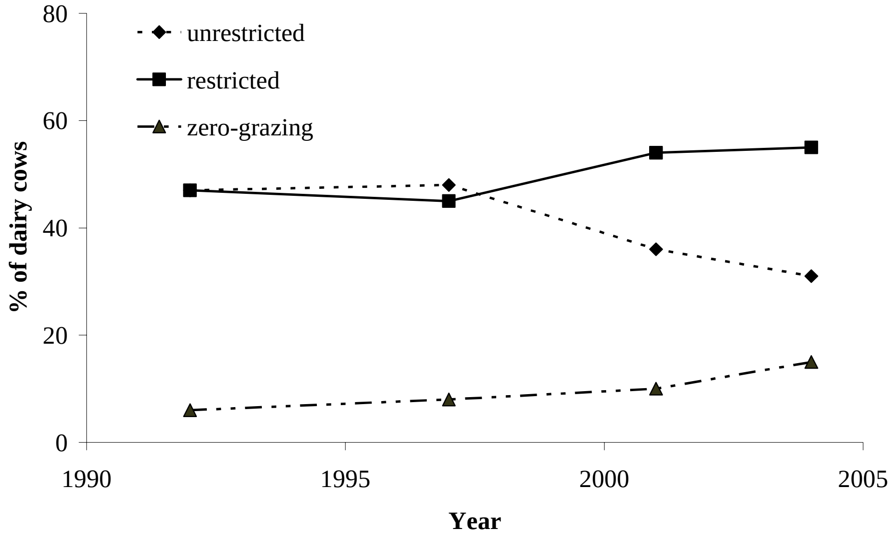


***Figure 2.*** *Grazing systems in The Netherlands in 1992 to 2004 (% dairy cows with unrestricted stocking, restricted stocking and zero-grazing) (CBS 2005)*

Grazing affects both grass yield and grass utilization. Grazing losses are positively related to the number of grazing hours just as the additional dairy-cow maintenance requirements for grazing. Zero-grazing gives harvest losses, preservation losses and feeding losses (Table 1). When grass is ensiled, the reduction in digestible organic matter (DOM) is relatively high compared to the reduction in dry matter. This explains the relatively high energy losses compared to dry-matter losses. Table 2 shows that grazing is inefficient compared to mowing. The figures in Table 2 are calculated using the losses given in Table 1. The relatively low gross DM production of grazing compared to mowing is a result of grass being harvested at a much younger stage. More regeneration periods are needed per year. The highest intake of net energy for lactation ($NE_L$) is found at zero-grazing with a ration of fresh grass. Unrestricted stocking results in the lowest $NE_L$ intake, corrected for additional maintenance, due to the combination of relatively low production and relatively large grazing losses.

***Table 1.****Effect of grazing and feeding system on relative losses of dry matter (DM) and energy ($NE_L$). Adapted from a desk study of Van den Pol-van Dasselaar et al. (2002) and CVB (2004)*

| Losses | Grazing system | | | |
|---|---|---|---|---|
| | Unrestricted | Restricted | Zero-fresh | Zero-ensiled |
| Grazing and harvesting (% of DM) | 20 | 14 | 7 | 5 |
| Preservation and feeding (% of DM) | 0 | 0 | 5 | 15 |
| Preservation and feeding (% of $NE_L$[1]) | 0 | 0 | 5 | 20 |
| Additional maintenance for grazing (% of $NE_L$) | 20 | 10 | 0 | 0 |

[1]$NE_L$: Net energy for lactation

***Table 2.****Effect of grazing management system on grass yield and grass utilization (dry matter and energy) relative to unrestricted stocking (= 100). Adapted from a desk study of Van den Pol-van Dasselaar et al. (2002) and CVB (2004)*

| | Grazing management system | | | |
|---|---|---|---|---|
| | Unrestricted | Restricted | Zero-fresh | Zero-ensiled |
| Gross DM production | 100 | 100 | 107 | 115 |
| Net DM production | 100 | 108 | 124 | 137 |
| Net DM intake | 100 | 108 | 118 | 116 |
| Total $NE_L$[1] production | 100 | 100 | 102 | 106 |
| $NE_L$ production corrected for grazing and harvest losses | 100 | 108 | 119 | 125 |
| $NE_L$ intake | 100 | 108 | 113 | 100 |
| $NE_L$ intake corrected for additional maintenance | 100 | 122 | 141 | 126 |

[1]$NE_L$: Net energy for lactation

## CHEMICAL COMPOSITION AND DEGRADABILITY OF GRASS

Weather conditions, maturity stage, fertilization and botanical composition cause variation in the chemical composition and nutritional value of grass.

The main influencing weather factors are light intensity, temperature and precipitation. The effect of weather conditions is reflected in changes in chemical composition throughout the growing season (Figure 3). The energy value ($NE_L$) is highest in April, but remains rather stable throughout the year. Highest crude protein concentrations are found in spring and autumn. The sugar concentration, which is related to light intensity, decreases throughout the season. The DOM remains rather constant during the season and varies between 80 and 85 %.

The effect of stage of maturity is illustrated in Figure 4. With an increasing length of the growing period, both $NE_L$ and crude-protein concentrations decrease, whereas concentrations of sugar and crude fibre increase.

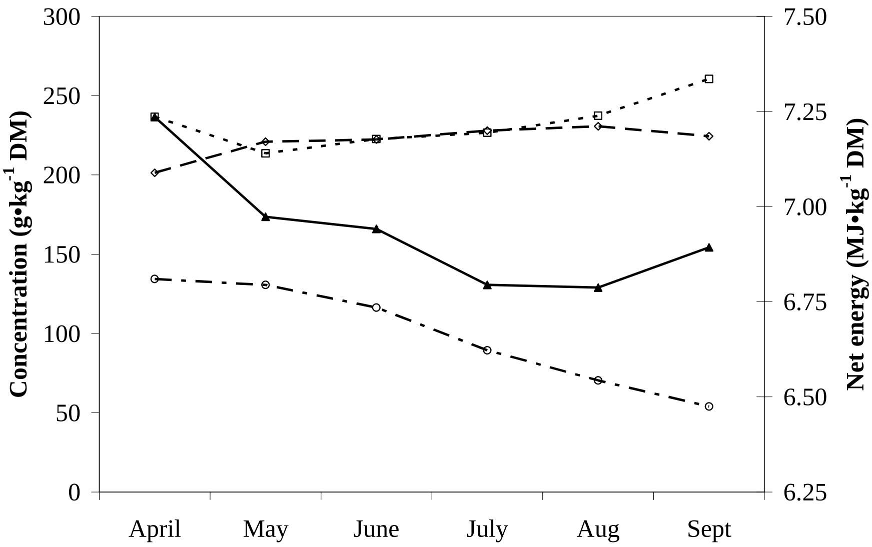


***Figure 3.****Seasonal variation in concentrations (g kg$^{-1}$ DM) of crude protein (□), crude fibre (◊) and sugar (o) and in energy value (▲; $NE_L$; MJ kg$^{-1}$ DM) of grass, based on analyses by BLGG (Oosterbeek, The Netherlands) from 1999 to 2001 (Van den Pol-van Dasselaar et al. 2002)*

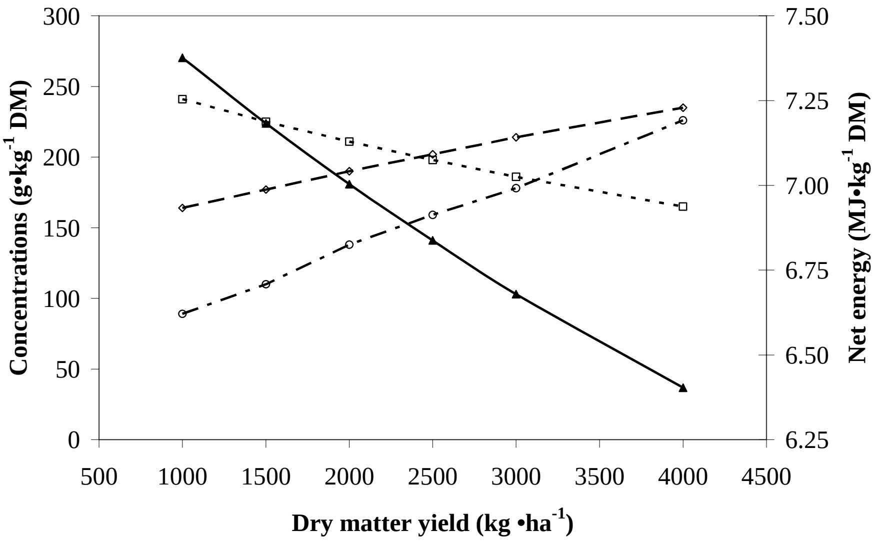


***Figure 4.****Effect of stage of maturity of the first cut on concentrations (g kg$^{-1}$ DM) of crude protein (□), crude fibre (◊) and water-soluble carbohydrates (o) and on energy value (▲; $NE_L$; MJ kg$^{-1}$ DM) in grass (Van den Pol-van Dasselaar et al. 2002)*

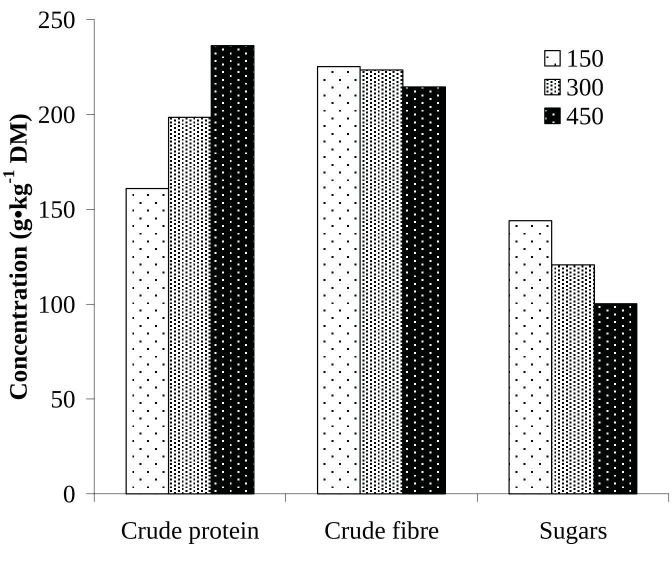


***Figure 5.****Effect of N application rate (150, 300 and 450 kg of N ha$^{-1}$ yr$^{-1}$) on the concentrations of crude protein, crude fibre and sugars and the net energy value of grass harvested at 1.5 to 2.0 tonnes of DM ha$^{-1}$ (after Valk et al. 2000)*

Nitrogen fertilization obviously increases DM yield. With increased application rates from 0 to 250 kg of N $ha^{-1}$ $yr^{-1}$, the DM yield under cutting increased from 6 to 12 tonnes of DM $ha^{-1}$ $yr^{-1}$ (Vellinga et al. 2001). Above rates of 250 kg of N $ha^{-1}$ $yr^{-1}$, the marginal response on DM yield was lower. When grass is sampled at a relatively young stage (1.5-2.0 tonnes of DM $ha^{-1}$), N application rate influences concentrations of crude protein and soluble carbohydrates but not crude fibre (Figure 5). In four experiments conducted over two years, Valk et al. (2000) observed an average reduction in $NE_L$ value of young fresh grass from 6.7 to 6.2 MJ $kg^{-1}$ DM, when reducing the N application rate from 450 to 150 kg of N $ha^{-1}$ $yr^{-1}$. In these experiments, grass fertilized at the lower N application level required only 1-7 extra growing days to reach a similar DM yield. Thus, it may be concluded that the impact of N application rate under grazing circumstances is relatively small, except for the crude-protein concentration.

***Table 3.****Potential milk production of grass-fed dairy cattle estimated from the energy and protein intake from grass (requirements calculated according to CVB 2004)*

| Parameter | Reference | | | | | |
|---|---|---|---|---|---|---|
| | Bruinenberg et al. (2002b) | | Tas (2005) | | Ribeiro-Filho et al. (2005)[a] | |
| | Min. | Max. | Min | Max. | Grass 20 | Grass 35 |
| DMI[b], kg·$day^{-1}$ | 14.6 | 18.1 | 15.6 | 18.4 | 13.9 | 16.6 |
| *Energy* | | | | | | |
| $NE_L$[b] value (MJ·$kg^{-1}$ DM) | 6.6 | 6.6 | 6.2 | 6.2 | 7.0 | 6.8 |
| $NE_L$ intake (MJ·$day^{-1}$) | 96 | 119 | 97 | 114 | 98 | 112 |
| Body weight (kg) | 623 | 623 | 538 | 538 | 593 | 593 |
| $NE_L$ maintenance[c] (MJ·$day^{-1}$) | 44 | 44 | 35 | 35 | 42 | 42 |
| $NE_L$ for milk (MJ·$day^{-1}$) | 53 | 76 | 58 | 75 | 56 | 70 |
| Potential FPCM[bd] (kg·$day^{-1}$) | 17 | 25 | 19 | 25 | 18 | 23 |
| *Protein* | | | | | | |
| DVE[b] value(g·$kg^{-1}$ DM) | 93 | 93 | 90 | 90 | 98 | 95 |
| DVE intake (g·$day^{-1}$) | 1358 | 1683 | 1408 | 1660 | 1363 | 1576 |
| DVE for maintenance[c] (g·$day^{-1}$) | 140 | 140 | 130 | 130 | 136 | 136 |
| DVE for milk (g·$day^{-1}$) | 1218 | 1543 | 1278 | 1531 | 1226 | 1440 |
| Potential FPCM[e] (kg·$day^{-1}$) | 23 | 29 | 24 | 29 | 23 | 27 |

[a]Herbage allowance 20 or 35 kg DM·$cow^{-1}$·$day^{-1}$

[b]$NE_L$: Net Energy of lactation; FPCM: Fat (40 g·$kg^{-1}$) and protein (33 g·$kg^{-1}$) corrected milk; DVE: Intestinal digestible protein

[c]Assuming 20% extra maintenance required for grazing

[d]Assuming a NEL requirement of 3.054 MJ·$kg^{-1}$ of FPCM (simplification, because NEL requirement for 1 kg of milk depends on production level)

[e]Assuming a DVE requirement of 53 g·$kg^{-1}$ of FPCM (simplification, because DVE requirement for 1 kg of milk depends on production level)

If less N fertilizer is applied under mowing circumstances and the growing period is not extended, nutritive value and chemical composition of the harvested grass are unaffected, although the DM production is lower. If the growing period is extended in order to obtain a similar DM production, the harvested grass will show the characteristics of ‘older’ grass.

Botanical composition is another cause of variation in chemical composition and nutritional value of grass. Differences between individual grass species were observed in the *in vitro* digestibility of the OM and crude-protein content (Korevaar 1986; Korevaar and Van der Wel 1997; Bruinenberg et al. 2002a). For example, throughout the growing season the DOM content of *Lolium perenne L*. was 2-6% higher than that of other grass species like *Poa trivialis*, *Holcus lanatus*, *Elymus repens* and *Agrosti*s species. The crude protein concentration of *Lolium perenne* was lower than that of the other grass species.

## ENERGY INTAKE

Energy intake of grazing dairy cattle depends on DMI and the energy value of the DM. Dry-matter intake of dairy cattle depends on herbage allowance, sward height, grass quality, stage of lactation – milk production – (Butler et al. 2003) and cattle breed (Crawford and Mayne 2002).

Although the energy value of grass is usually high, DMI from herbage is often insufficient to meet the energy requirements of high-yielding dairy cattle, even at adequate grassland management. Bruinenberg et al. (2002b) analysed the results of seven experiments in which 81 to 91 % of DMI was from fresh grass, offered under a zero-grazing system to dairy cattle with a mean body weight (BW) of 623 kg and producing between 20.4 and 28.3 kg of fat- and protein-corrected milk (FPCM) day$^{-1}$. In these experiments, the DMI from grass ranged between 14.6 and 18.1 kg day$^{-1}$ (Table 3). Tas et al. (2005) observed in grazing dairy cattle (mean BW 528 kg) a DMI between 15.6 and 18.4 kg day$^{-1}$ for different cultivars of perennial ryegrass. Ribeiro-Filho et al. (2005) observed in grazing cattle (mean BW 593 kg) a DMI between 13.9 and 16.6 kg day$^{-1}$ at an allowance of 20 and 35 kg of DM cow$^{-1}$ day$^{-1}$, respectively. Using the (average) energy values reported in these publications, it is calculated that the energy supply from grazing is sufficient to meet a maximum milk production of 17 to 25 kg day$^{-1}$.

In the seven experiments reviewed by Bruinenberg et al. (2002b), the OM intake kg$^{-1}$ metabolic weight (BW$^{0.75}$) ranged from 97 to 150 g day$^{-1}$. This value is similar to that reported by Meijs (1981), reviewing grass intake studies published between 1960 and 1981. In a recent review, Bargo et al. (2003) used data of seven studies to estimate the curvilinear relationship between DM allowance and DMI under grazing conditions. In six of these seven experiments, DM allowance was measured to ground level; in one experiment, DM allowance was measured above a stubble height of 5 cm. This relationship estimates a DMI of around 17 kg day$^{-1}$ at a DM allowance of 45 kg cow$^{-1}$. Extrapolation of the equation gives a maximum grass DMI of 21.9 kg day$^{-1}$, but at an unrealistic DM allowance of 110 kg cow$^{-1}$ day$^{-1}$. If we assume an OM intake between 110 and 120 g day$^{-1}$ kg BW$^{-0.75}$ for a 650-kg cow and an $NE_L$ value of 6.9 MJ $kg^{-1}$ grass DM, an $NE_L$ intake between 110 and 120 MJ $day^{-1}$ is estimated. This would meet the requirements of maintenance and 21 to 24 kg of milk.

## PROTEIN INTAKE

Usually, grass from well managed grassland contains high concentrations of crude protein (Figure 3). Consequently, the estimated available protein value is relatively high. In the studies of Bruinenberg et al. (2002b), Tas (2005) and Ribeiro-Filho et al. (2005), the supply of available protein was enough for a milk production that was 17 to 33 % higher than potential milk production estimated from the $NE_L$ supply. If we assume an OM intake between 110 and 120 g $day^{-1}$ kg $BW^{-0.75}$ for a 650-kg cow and a DVE value of 95 g $kg^{-1}$ grass DM, a DVE intake between 1.5 and 1.6 kg $day^{-1}$ is estimated. This DVE supply would meet the requirements of maintenance and 26 to 28 kg of milk, which again is 17 to 23 % higher than the potential milk yield from the energy supply.

## SUPPLEMENTATION

Since energy supply and protein supply from grazing are enough to meet the requirements of maintenance and only 22 to 26 kg of milk, cows with a higher milk production require supplementary feeding to meet their relatively high energy and protein requirements. Grazing cattle or grass-fed dairy cattle have been supplemented with various concentrate ingredients, concentrate mixtures and forages. Supplement feeding aims at improving the energy supply of the animals, or the protein supply, or both. Supplementation of energy can be in the form of fat, structural carbohydrates (fibre-rich feeds) or non-structural carbohydrates (starch-rich feeds). The protein supply of grazing animals can be improved by feeding rumen-available carbohydrates to enhance microbial protein synthesis in the rumen or by increasing the supply of rumen-undegradable feed protein.

The effects of supplementing grazing dairy cattle on digestion and animal performance have been comprehensively reviewed by Bargo et al. (2003). Therefore, in this chapter we will focus on some specific aspects of supplementing grazing dairy cows.

### *Substitution rate*

Supplement feeding usually results in a reduction in grass DMI. This reduction is expressed as ‘Substitution Rate’, which is calculated as the reduction in kg grass DM per kg of supplement DMI. Substitution rate in a grazing situation is affected by pasture (allowance, quality), animal (stage of lactation, production level) and type of supplement (Bargo et al. 2003). From the review of Bargo et al. (2003) it can be concluded that in general, the substitution rate increases with increasing pasture allowance. These authors did not find conclusive effects of the amount of supplementation (contradictory results) and type of concentrate (too few experiments) on the substitution rate. Bargo et al. (2003) also concluded that forage supplementation decreases pasture DMI more than concentrates (0.84 to 1.02 versus 0.11 to 0.50 kg of grass DM $kg^{-1}$ of supplement DM, respectively). Based on the index for satiety of different feeds, R. Zom (personal communication) estimated a substitution rate of 0.4 kg of grass DM $kg^{-1}$ of concentrate DM and 0.9 kg of grass DM $kg^{-1}$ of forage maize silage DM. However, Meijs (1986) observed a linear reduction in grass OM intake of 0.4 kg $kg^{-1}$ of forage maize silage OM when feeding up to 5.7 kg of forage maize silage OM $day^{-1}$ at a high herbage allowance and unrestricted stocking. In a restricted-stocking management, the substitution decreased to 0.3 kg of grass OM $kg^{-1}$ of forage maize silage OM. In an experiment with cows under unrestricted stocking, Valk (personal communication) measured a substitution rate of 0.5 kg of grass OM $kg^{-1}$ forage maize silage OM.

Thus, the effect of supplementation on herbage intake is higher at a high grass DM intake, realized either by a higher pasture allowance or by unrestricted stocking. This also implies that the effect of supplementation on total DMI is relatively low if grass intake is high.

*Fat supplementation*

Fat is a high-energy source, but fatty acids cannot be utilized as an energy source by rumen micro-organisms, and consequently no increase in microbial protein synthesis can be expected. Because energy supply is more limiting than protein supply in grass-fed dairy cows (Table 3), fat supplementation of approximately 0.6 kg $d^{-1}$ is required to compensate this Net Energy gap of approximately 15 MJ, being the requirement for 5 kg of extra milk. Bargo et al. (2003) found seven publications in which the effect of fat supplementation, ranging between 0.2 and 1.0 kg of fat $d^{-1}$, on DMI and milk production was studied. In those studies, fat supplementation had no effect on DMI when fat replaced other concentrate ingredients, or reduced DMI when fat was added to the diet. Fat supplementation significantly increased milk production by on average 1.43 kg $d^{-1}$. However, in none of these studies an average milk production above 27.2 kg was observed.

High levels of unsaturated fatty acids may have a negative effect on cell-wall digestion (Jenkins 1993). In this respect it should be noted that young, leafy grass from intensively managed grasslands may contain 20 g of linolenic acid per kg DM (Elgersma et al. 2003). The intake of linolenic acid from grass combined with an extra intake of unsaturated fatty acids by fat-rich supplements may reduce cell-wall degradation and may also result in linoleic isomers that inhibit milk fat synthesis (Bauman and Griinari 2003). In two of the seven studies reported by Bargo et al. (2003), in which fat sources were soybean oil or full-fat rapeseed, milk fat concentration was reduced.

*Carbohydrate supplementation*

Maize silage and concentrate ingredients rich in starch or fibre can be supplemented to increase the energy supply of grazing dairy cattle. Carbohydrates may also reduce the relatively high ratio between rumen-available crude protein and rumen-available organic matter as is often observed in young grass from highly fertilized grassland. Based on nylon-bag studies with various grass samples, which were cut to a particle length of approx. 1 to 2 cm and frozen before incubation, Van Vuuren et al. (1991) concluded that the major portion of rumen-degradable crude protein was in the form of insoluble, degradable protein. This is in contrast with grass silage, in which rumen-available protein is mainly soluble and instantly degradable. With an assumed rumen passage rate of 4.5% per hour, the insoluble degradable fraction contributes 60 to 70 % of the total rumen-degradable protein. This was confirmed by Valk et al. (1996), who sampled grass at a growing stage of 1.5 to 2.0 tonnes of DM $ha^{-1}$.They observed that the increase in crude-protein concentration with increasing level of N fertilizer was mainly an increase of rumen-degradable fractions (Figure 6).

In fresh, good-quality grass, the ratio between rumen-available nitrogen and rumen-available organic matter often exceeds 25 g of N $kg^{-1}$ of available organic matter, a ratio which is considered an optimum for microbial protein synthesis (Czerkawski 1986). From various studies it may be concluded that above a crude-protein concentration of 122 g $kg^{-1}$ dry matter, the ratio between rumen-available nitrogen and rumen-available organic matter is higher than 25 g $kg^{-1}$ (Figure 7).

Theoretically, energy (degradable carbohydrates) should be available to rumen micro-organisms in relation to available building blocks for macro-molecules like proteins and nucleic acids. This idea has led to the ‘synchronisation’ concept (Sinclair et al. 1993). In this concept the rate of release of energy and nitrogen is synchronized in such a way that per unit of time (e.g. hour), 25 g of N becomes available to the rumen microbes kg-1 of available organic matter. Based on their earlier results, Van Vuuren et al. (1990) concluded that supplements for grazing dairy cows should contain high levels of insoluble rumen-degradable carbohydrates, with a relatively high fractional rate of degradation (7 to 10 % h-1). In this respect, sugar-beet pulp, citrus pulp, maize meal, coconut expeller, rice and some specific potato starches seem appropriate. Other rapidly degradable carbohydrate sources, like wheat and tapioca may result in rumen acidosis due to a high fractional rate of starch degradation and are less appropriate. In their review, Bargo et al. (2003) compared fibre-rich concentrates with starch-rich concentrates. Although the number of studies in which both types of concentrates were included were too small to make decisive conclusions, fibre-rich concentrates tended to improve milk performance only when compared to starch sources that were rapidly degradable (like cassava, barley and wheat), or when the grass itself was high in fibre and consequently of lower quality.

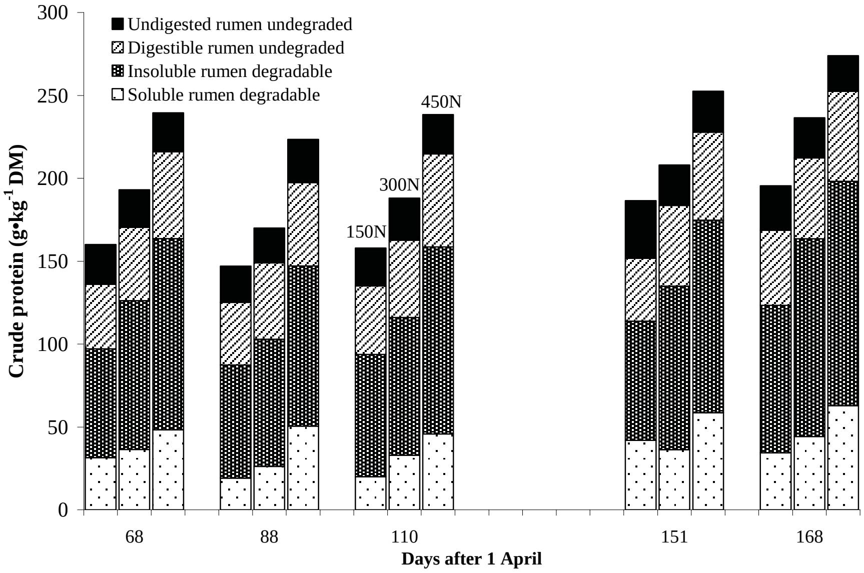


***Figure 6**. Effect of N fertilizer and date of harvesting on crude-protein characteristics of fresh grass, harvested at 1500 to 2000 kg of DM ha$^{-1}$ and fertilized at levels of 150, 300 and 450 kg N ha$^{-1}$ year$^{-1}$ (after Valk et al. (1996))*

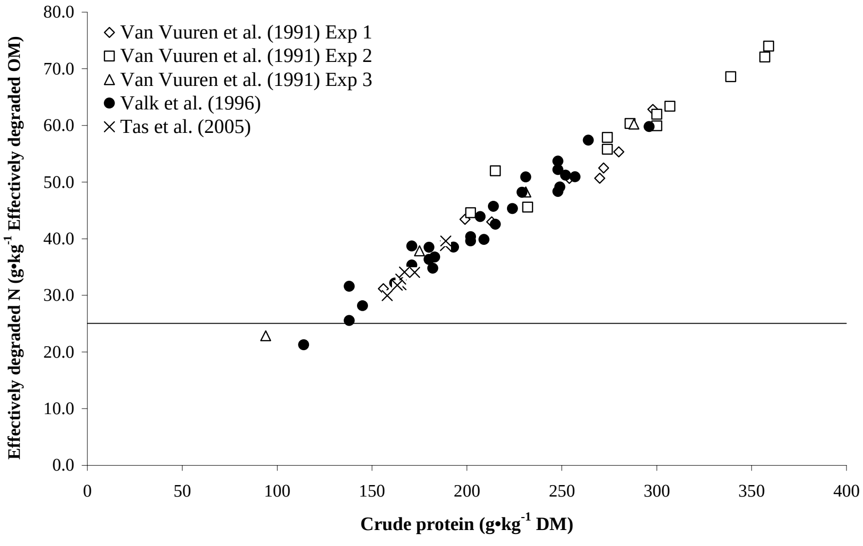


***Figure 7**.Relationship between crude-protein concentration of fresh grass and the ratio between effectively rumen-degradable nitrogen and effectively rumen-degradable organic matter OM, calculated from reported in situ data. The overall relationship was: $Y = 0.2037 \cdot x + 0.249$; $R^2 = 0.97$*

*Method of supplementation*

A more gradual delivery of supplements during the day is another method to realize a more stable and balanced rumen fermentation. Valk (1994) studied the effect of method of supplementing maize silage to dairy cattle in a zero-grazing system. Maize silage was offered – next to 3.6 kg of concentrate DM daily – either as a mixture with fresh grass or separately from grass. Separate feeding of maize silage was carried out either during night time (17:00 h to 5:00 h) or twice daily for 1.5 h after milking. Experiments were conducted over two years with different treatments, using the mixture of fresh grass and maize silage as the reference treatment. Cows that received maize silage and fresh grass as a mixture had a higher DMI and produced more FPCM than cows receiving fresh grass only (Table 4). Separate feeding of maize silage during night time resulted in a lower DMI and $NE_L$ intake, and consequently a lower FPCM production compared to mixed feeding. However, separate feeding of maize silage in two portions per day, 1.5 h after milking, resulted in DMI and FPCM productions similar to those observed for the mixture of forage maize silage and fresh grass.

In six experiments under a zero-grazing system and three under restricted stocking, Van Duinkerken et al. (2000; in press) fed maize silage and fresh grass separately, comparing two methods: maize silage fed during night time or fed in two 3-h periods directly after milking (‘siesta feeding’). Compared to night-time feeding of maize silage, ‘siesta feeding’ resulted in a small positive effect on energy intake and FPCM production of dairy cattle. In the three experiments under restricted stocking, Van Duinkerken et al. (2000) observed on average a 3 % increase in FPCM production with ‘siesta’ feeding compared to night-time feeding of maize silage.

## PROTEIN SUPPLEMENTATION

Due to the high rumen degradation of grass crude protein (Figure 6), only 20 to 30 % of the grass crude protein is available in the small intestine as rumen-undegraded protein. Thus, the protein supply from rumen-undegraded protein in grass-fed dairy cows is limited and a major proportion of intestinal digestible protein should come from microbial protein synthesized in the rumen. As mentioned previously, the ratio between rumen-available nitrogen and rumen-available organic matter in grass often exceeds 25 g of N $kg^{-1}$ of organic matter, a ratio which is considered an optimum for microbial protein synthesis (Czerkawski 1986). To incorporate this surplus of rumen-available nitrogen from grass requires supplementary energy sources, like rumen-available carbohydrates.

Nevertheless, some experiments have been carried out to study the response of exchanging rumen-degradable protein by rumen-undegradable protein in supplements for grazing dairy cows. Of the eight studies summarized by Bargo et al. (2003), only two reported a positive effect in milk yield with a higher amount of rumen- undegradable protein. The effect of extra rumen-undegradable protein depends mainly on the protein supply of the control diet. In that respect, the crude-protein content and the quality of the grass have a larger influence than the protein quality of the supplements (Bargo et al. 2003).

***Table 4.*** *Effect of method of feeding maize silage and grass on nutrient intake and milk production of dairy cattle.*

| Parameter | Reference | | | | | |
|---|---|---|---|---|---|---|
| | Valk (1994)[a] Maize silage feeding | | | | Van Duinkerken et al. (2000; in press)[b] | |
| | Mixed with grass | Night time | After milking | Grass only | After milking | Day time |
| | Proportion of maize (% of organic matter) | | | | Proportion of maize (% of dry matter) | |
| | 44% | 43% | 26% | - | 25% | 27% |
| | Absolute | *Relative to Mixed with grass, %* | | | Absolute | *Relative to After milking, %* |
| Dry-matter intake ($kg \cdot day^{-1}$) | 19.7 (0.5)[c] | *93* | *100* | *93* | 20.7 (0.2) | *102* |
| $NE_L$[d] intake ($MJ \cdot day^{-1}$) | 125 (2.8) | *93* | *102* | *100* | 135 (1.1) | *101* |
| DVE[d] intake ($kg \cdot day^{-1}$) | 1.3 (0.05) | *95* | *100* | *133* | 1.8 (0.03) | *102* |
| FPCM[d] ($kg \cdot day^{-1}$) | 30.7 (1.4) | *88* | *97* | *90* | 29.7 (0.4) | *102* |
| Feed N in milk (%) | 29.6 (2.0) | *92* | *91* | *67* | 30.0 (0.8) | *99* |

[a]Combined results of two experiments in which maize silage was mixed with fresh grass or fed separately during the night or during two times per day for 1.5 h after milking. Nine cows per treatment.
[b]Combined results of three experiments in which maize silage was fed during the day or during two times per day for 2 or 3 h after milking, Fourteen cows per treatment.
[c]Between parentheses: standard error of mean (average of the two and three experiments, respectively).
[d]$NE_L$: Net Energy of lactation; FPCM: Fat- (40 g $kg^{-1}$) and protein- (33 g $kg^{-1}$) corrected milk; DVE: Intestinal digestible protein.

## GRAZING MANAGEMENT AND SUPPLEMENTATION

Farmers have various reasons to choose a grazing-management system. In their choice they may incorporate the effect of grazing on grass yield and grass use, but also many other factors like economics, animal welfare, society and environment. The impact of grazing systems on all these aspects is summarized in Table 5. The value assigned to the various effects of grazing varies between individuals. For example, what is more important: acceptance of dairy farming by society or nitrate leaching? The relative scoring in Table 5 represents a personal view of the authors. For most aspects it holds that the more hours on the pasture, the greater the effect. It should be remembered that farm management is an important factor. An individual farmer can have an effect on most of the points via his or her management strategy and can thereby reduce or remove the negative effects of a certain grazing system. From Table 5 it appears that there is no single system with only disadvantages or only advantages. However, Table 5 also shows that restricted stocking scores well on most points. The future challenge is to obtain a balanced view per grazing system that weighs the various advantages and disadvantages to obtain an integrated view of the system.

Grassland management and realizing high milk production levels under unrestricted stocking demands a high competence of dairy farmers. Restricted stocking and feeding supplements facilitate an adequate energy and nutrient supply of high-yielding dairy cattle in the grazing period. Supplementation can be used as a buffer against the variation in grass DMI due to variations in pasture allowance caused by irregular weather conditions. Feeding maize or grass silages gives the animal the possibility to increase silage DMI to compensate for a reduction in grass DMI, occurring in a rotational-stocking system or in extreme weather conditions (drought; heavy rainfall).

***Table 5.*** *The effect of grazing on various aspects, from the viewpoints of society at large, the animal, the environment and economics. The scores indicate the relative value across systems (i.e., rows) for each characteristic. The score ranges from - - to ++, with ++ signifying that the system concerned scores positive for the point in question, e.g. high health, low losses. Adapted from review of Van den Pol-van Dasselaar (2005)*

| Viewpoint | Grazing management system | | | |
|---|---|---|---|---|
| | Unrestricted | Restricted | Zero-fresh | Zero-ensiled |
| Acceptance by society | ++ | + | - | - |
| Natural behaviour | ++ | ++ | + | + |
| Animal health | ++ | + | +/- | +/- |
| Grass yield and grass use | - | + | ++ | + |
| Adequate nutrient supply | - | +/- | + | ++ |
| Nitrate leaching, emission of $N_2O$, nitrogen losses | - | + | ++ | ++ |
| Phosphorus losses | - | +/- | + | + |
| Ammonia volatilization | ++ | + | - | +/- |
| Energy use, methane emission from enteric fermentation and manure | + | - | - - | - - |
| Labour | ++ | + | - | + |
| Economics | + | + | +/- | - |

## CONCLUSION

Productivity of dairy cattle is influenced by grass intake and by nutritive value of the grass. A problem in optimizing rations for grazing dairy cattle is the considerable variation between days in both grass intake and nutritive value of the grass. With a rising milk yield potential, the technical requirements of a properly balanced diet become increasingly important. Because pasturing produces relatively large fluctuations in the composition of the diet, the attractiveness of unrestricted stocking declines as the dietary requirements become more demanding.

Supplementary feeding of maize silage or concentrates rich in carbohydrates can alleviate the pressure from grassland management and can be used as a buffer for variations in grass allowance and grass quality. The choice of supplement depends on the quality of grass as well as other circumstances that the farmer needs or wants to take into account. These developments have already led to a decrease in the percentage of dairy cattle with unrestricted stocking in Western Europe. We expect this trend to continue.

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