CHAPTER 9

IMPROVING DRY-MATTER INTAKE OF PERENNIAL-RYEGRASS PASTURE BY DAIRY COWS

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Abstract. Dairy cows fed on perennial-ryegrass pasture produce higher-quality milk in terms of fatty-acid composition; however, they produce much less milk compared to dairy cows under other systems. The low dry-matter intake (DMI) has been identified as the main factor responsible for the lower milk production in pasture-based systems. To maximize milk production from those systems it is important to maximize DMI from pasture. Many interventions have been studied, such as: manipulating herbage allowance, feeding frequency, time of allocating the new pasture, pasture maturity, fertilization rate and the choice of perennial-ryegrass variety. The results have shown that pasture DMI increases in a curvilinear asymptotic manner as herbage allowance increases. However, increasing herbage allowance decreases milk production per hectare and increases production cost due to the increased need for pasture and land. More frequent allocation of pasture has shown no effect on pasture DMI. Allocating the new pasture after the evening milking has sometimes shown to increase pasture DMI without any negative effect in terms of productivity per hectare. Allocating a young and leafy grass has shown to increase DMI, but at the same time pasture holding capacity was reduced and milk production per hectare decreased. Using high-sugar grass was advocated as a way to improve DMI of dairy cows on pasture. Research findings with regard to the effect of high-sugar grass on DMI are very inconsistent. Some experiments reported a positive effect of high-sugar grass on DMI, but that was due to the confounded effect of high sugar and digestibility. Whereas, other experiments reported no effect, as in those experiments the high- and low-sugar grasses had a similar digestibility. This indicated that high sugar is not always associated with higher digestibility especially in young and leafy perennial ryegrass. It also indicated that grass digestibility exerts a stronger effect on DMI than its sugar content does. It was hypothesized that feeding grass that has a fast clearing or degrading fibre would improve DMI. The results of several experiments that screened different perennial-ryegrass varieties for their fibre clearance and degradation rates under grazing indicated that variation in these traits between perennial-ryegrass varieties is very limited under the chosen conditions. This suggested that choosing varieties with fast degrading fibre, as a means to improve pasture DMI, is very limited.
Keywords: dry-matter intake; perennial ryegrass; sugars; degradation rate

INTRODUCTION

Grazing and grass-feeding dairy production systems are regaining popularity and importance in the western world due to consumers’ demand and concern. Product

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quality, animal well-being and landscape improvements form the basis of these concerns. Consumers' perception is that keeping dairy cows year-round indoors may compromise their health and welfare, and in addition it contributes to the impoverishment of the landscape in the countryside. Moreover, it has been reported that milk produced by cows grazing grass pasture or fed on freshly cut grass contains higher concentrations of unsaturated fatty acids, viz., conjugated linoleic acids (CLA), than cows fed indoors on silage and concentrates (Elgersma et al. 2003). Unsaturated fatty acids in general are favourable against coronary heart disease, and CLA in particular are thought to have beneficial effects on human health (Banni et al. 2001; Turpeinen et al. 2002). Dairy cows fed mainly or only on grass pasture produce higher quality milk in terms of fatty-acid composition, but unless supplemented with sufficient amounts of concentrates, they produce much less milk compared to dairy cows under other systems. Research during the last decade has shown that energy supply of grazing and grass-fed dairy cows is insufficient to sustain milk production levels higher than 28 kg d^{-1} (Van Vuuren 1993). Daily energy supply for maintenance and milk production is the product of daily dry-matter intake (DMI) and energy density of the feed. Energy content of young and leafy perennial ryegrass has been shown to be high and fluctuates between 6.3 and 7.1 MJ NE_L kg^{-1} DM depending on grass genotype, season and management conditions (i.e. re-growth period, intensity of grazing and fertilization rate).The low DMI, rather than energy content of the grass has been identified as the main factor responsible for the lower total energy intake and milk production (Kolver and Muller 1998). Reported DMI of early lactating dairy cows grazing high-quality grass pasture or fed on freshly cut grass, rarely exceeds 19 kg d^{-1}, or 3.25 % of body weight (BW) (Bargo et al. 2003). At this level of pasture intake, energy input (135 MJ NE_L d^{-1}) will be sufficient for a 600-kg grazing cow to cover its maintenance requirements (0.393 MJ NE_L kg^{-1} $BW^{0.75}$) and produce no more than 28 kg of milk per day (3.2 MJ NE_L kg^{-1} milk). Kolver and Muller (1998) reported that cows grazing high-quality pasture in the spring consume 4.5 kg DM less than cows fed a nutritionally balanced total mixed ration (TMR). Furthermore, many other authors (Leaver 1985; McGilloway and Mayne 1996; Beever and Thorp 1997) identified the low grass pasture DMI as a major factor limiting energy intake and hence milk production of high-producing cows under grazing systems. The low DMI of perennial ryegrass is thought to be due to physical constraints, rate of removal from the rumen through degradation and passage, and water consumption associated with pasture (Beever and Thorp 1997).

To maximize milk production from pasture-based systems in a cost-effective manner while sustaining the health and welfare of the animals and the environment, it is important to maximize DMI of pasture grass. The main objective of this paper is to review and identify interventions that may lead to increased pasture DMI by high-producing dairy cows.

Many interventions to maximize perennial-ryegrass DMI have been proposed, studied and implemented with varied degrees of success. These interventions were mostly related to pasture and grazing management because these factors can be controlled effectively by the producer. Such interventions include manipulating herbage allowance, feeding frequency, pasture maturity, time of allocating the new pasture (under strip grazing systems) and time of cutting (under stall-feeding systems), fertilization rate and the choice of perennial-ryegrass variety. In the following sections of this paper we will briefly discuss and identify the pros and cons of each of those interventions with more emphasis on the choice of variety as a measure to improve DMI of pasture grass.

HERBAGE ALLOWANCE

Herbage allowance is the amount of pasture offered to the cow during one grazing day and is expressed in kg dry matter (DM) per cow per day. Herbage allowance was identified as one of the most important factors influencing pasture DMI by dairy cows (Hodgson and Brooks 1999). Research results unanimously showed that pasture DMI increased as herbage allowance increased, but at a progressively declining rate (Figure 1), indicating that the relationship between herbage allowance and pasture DMI is curvilinear asymptotic (Peyraud et al. 1996; Dalley et al. 1999; Bargo et al. 2002). In all those studies herbage allowance was manipulated by increasing the area of the offered pasture (the size of the paddock) rather than increasing the yield per hectare. However, research results are very variable and inconsistent with regard to the plateau value of herbage allowance at which no extra increase in DMI is expected. Peyraud et al. (1996) reported an increased DMI from 15.3 to 18.5 kg d^{-1} as herbage allowance increased from 20 to 54 kg DM d^{-1} per cow, with a plateau occurring at an allowance of 33 kg DM. Dalley et al. (1999) on the other hand reported an increased DMI from 11 to 19 kg d^{-1} as herbage allowance per cow increased from 20 to 70 kg DM d^{-1}, with a plateau occurring at an allowance of 55 kg DM, whilst Hodgson and Brookes (1999) reported an increased DMI as herbage allowance increased, with a plateau occurring at allowances per cow of 60 to 72 kg DM d^{-1}. Despite the fact that increasing herbage allowance increases DMI and hence milk production per animal, the level of increase at the highest herbage allowance did not reach the level needed to satisfy energy requirements of the high-producing dairy cow (4.2 % BW) to allow her to reach her genetic potential. In addition to that, increasing herbage allowance constitutes a waste of resources (Figure 1), decreases milk production per hectare and increases production cost due to the increased need for pasture and land. Therefore, when pasture availability is in excess, maximizing herbage allowance to increase DMI and milk production per animal seems to be an attractive option. However, when pasture availability is limited, this intervention seems to be much less attractive and the sensible objective would be to increase production per hectare.

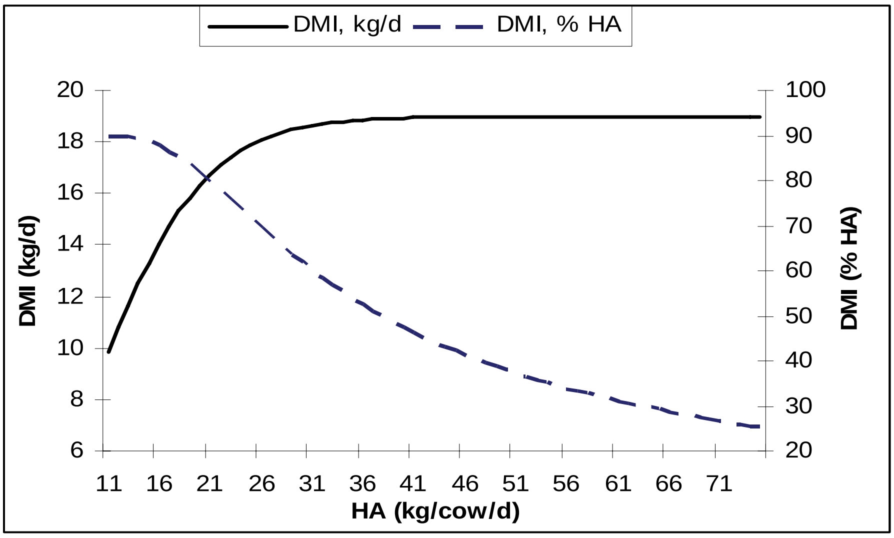

Figure 1. *Relationship between herbage allowance (HA) and DMI expressed either in kg/d (solid line, left-hand side y-axis), or in % of HA (broken line, right-hand side y-axis)*

FEEDING FREQUENCY

More frequent allocation of new pasture maintains fresher, taller and more palatable and erect pasture, and hence was suggested as a managerial measure to increase DMI of grazing dairy cows. However, Dalley et al. (2001) did not observe any differences in DMI and milk production between cows offered pasture once or six times a day at the same herbage allowance of 40, 50 and 65 kg DM cow^{-1} d^{-1}. In addition, more frequent allocation of new pasture is labour-intensive and results in increased labour and fencing costs and thus production costs, leading to a reduced profit margin for the producer. It also leads to more trampling and hence reduced grassland productivity in the subsequent months and grazing cycles.

PASTURE MATURITY

It is well documented that as pasture matures the content of cell wall in general and lignin in particular increases, leading to a decreased digestibility. Therefore, it is not surprising that allocating a young and leafy grass has shown to increase DMI when compared with older more mature grass. Parga et al. (2002) reported that at the same level of herbage allowance (18 kg $cow^{-1}d^{-1}$), dairy cows consumed 2 kg of DM more (14 vs. 16 kg DM), when offered 18-day-old compared to 38-day-old perennial ryegrass. The reduced intake on the mature-grass treatment (38-day-old) in this experiment can be related to the reduced space and increased social competition, in addition to changes in pasture structure and cell-wall content. Offering very young pasture at a high herbage allowance limits herbage accumulation and reduces the number of animals that can be sustained on pasture, and hence reduces milk production per hectare (Figure 2).

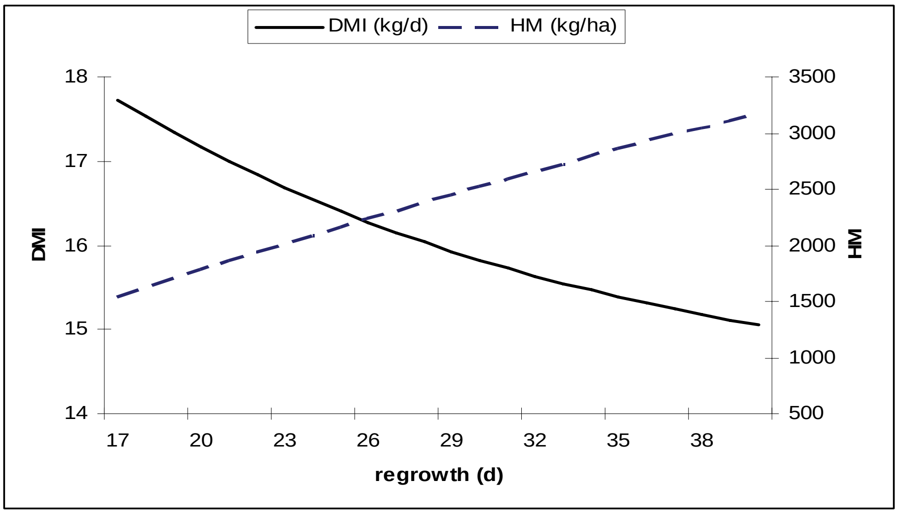

Figure 2*. Relationship between re-growth stage and DMI (solid line, left-hand side y-axis), and herbage mass (HM) (broken line, right-hand side y-axis)*

TIME OF ALLOCATING THE NEW PASTURE AND TIME OF CUTTING

Changing the time at which the new pasture is allocated was also suggested as a measure to improve DMI by dairy cows. Under strip-grazing systems, allocating the new pasture after the evening milking when DM and water-soluble carbohydrate (WSC) contents are at their maximal level, was suggested to be advantageous for increasing pasture DMI. Orr et al. (2001) reported a non-significant increase in DMI from 17 to 18 kg/d when allocated the new pasture after the evening milking as compared to after the morning milking, and they attributed the non-significant level to the low number of replicates in their study. Under a cut-and-carry system, cutting time was suggested as a measure to increase DMI. Lee et al. (2002) and Mayland et al. (1998) reported a significantly higher DMI by cattle offered forage cut in the afternoon rather than in the morning. This intervention is easy to implement, does not influence production cost or the short-term grassland productivity, and therefore is very attractive compared to other interventions. However, its effect on the long-term grassland productivity is yet to be determined.

FERTILIZATION RATE

Altering the N fertilization rate of grass pasture has been shown to be one of the managerial measures that can be used to influence DMI of dairy cows. On the one hand, reducing N fertilization is known to reduce crude-protein (CP) content and elevate DM and WSC contents of the grass, which may lead to a higher DMI due to the lower uptake of water within the grass. However, on the other hand, reducing N fertilization is known to reduce plant growth and the green-leaf mass per unit of land, which has a major influence on pasture DMI under grazing, either continuous stocking or rotational (Hodgson 1986; Peyraud et al. 1996). Therefore, under stall-feeding management systems lowering N fertilization seemed to be advantageous in increasing DMI, as Van Vuuren et al. (1992) reported an increase in DMI for stall-fed dairy cows with grass fertilized at a low rate (250 kg N/ha/year) compared to a high rate (500 kg N/ha/year). They attributed this increase in DMI to the difference in DM content between the two grasses, as the low-fertilized grass had a higher DM % compared to the high-fertilized grass (22 vs. 14 %). In contrast, under grazing management systems, lowering N fertilization seemed to reduce DMI, as Delagarde et al. (1997) reported that at the same level of herbage allowance, dairy cows consumed less DM when grazed unfertilized pasture compared to fertilized pasture (60 kg N per ha per grazing cycle); they attributed that to the lower green-leaf mass of the unfertilized pasture. Although the effect of N fertilization on grass growth (and probably quality) varies with soil, weather conditions, time of the year etc., extremely lowering N fertilization results in reduced grassland productivity through a reduction in the growth rate, reduced milk production per hectare, increased demand for pasture land and thus increased production cost.

THE CHOICE OF VARIETY

In ruminant animals, DMI is a function of the balance between eating motivation, which is strongly related to palatability, on the one hand and rumen capacity on the other. Therefore, increasing DMI could be achieved by either improving palatability or increasing rumen capacity or both. Palatability is mainly a function of flavour and taste, which arise from certain compounds in the grass, especially WSC (see section below). Rumen capacity is related to the rate of clearance (kcl) of material from the rumen, which is the summation of both rates of degradation (kd) and passage (kp). This section investigated the possibility of improving perennial-ryegrass DMI by dairy cows through manipulating both palatability and clearance or degradation characteristics of perennial-ryegrass varieties.

High-sugar grass

Palatability is a major determinant of what and how much a healthy non-starved animal will eat of a given feed. Palatability includes all of the oral, pharyngeal and olfactory sensations arising from the feed such as flavour, taste, smell and texture, but does not include any of its post-ingestive effects. Flavour and taste provide the primary information for food preference, tolerance or rejection, while visual and olfactory messages function as secondary reinforcers (Chiy and Phillips 1998). Cattle have been shown to be sensitive to the same principal flavours (sweet, sour, salt and bitter) as humans, but they have different sensation thresholds (Phillips 1993). Foods with strong bitter, salty and sour flavours were avoided by cattle

(Nombekela et al. 1994) or had reduced intakes (Frederick et al. 1988), indicating that these flavours negatively influence the palatability of the food. In contrast, sweeteners have the potential to enhance palatability at high concentrations and thus increase DMI. Numerous authors have reported the relation between sweet foods and increased intake (Chiy and Phillips 1998; Siever-Kelly et al. 1999). Therefore, producing perennial-ryegrass pastures that have a higher concentration of WSC and sugars, to a level that can be sensed by dairy cows, may further improve their palatability and hence improve DMI. High-sugar grass may also have a lower fibre content, as the increased sugar content has to be at the expense of other components. This may lead to a faster DM degradation and better digestibility and hence improved DMI and milk production. Although high sugar content in the grass seems to be advantageous in improving palatability on the one hand, one must not forget or neglect the fact that on the other hand high-sugar grass may increase the acid load in the rumen and reduce pH to a level that is not optimal for cell-wall-degrading bacteria, counterbalancing the advantages of increased palatability on DMI. A low rumen pH severely reduces the activity of cell-wall-degrading bacteria, leading to a lower clearance rate of fibre and particles and hence a decreased throughput and DMI. A lower fibre degradability induced by a low pH may also lead to milk fat depression.

There are two ways to produce high-sugar grass: firstly, by manipulating N fertilization rate, and secondly by selection and breeding. It has been shown that reducing N fertilization rate will elevate WSC content in the grass at the expense of crude protein (Peyraud et al. 1997). It has also been shown that WSC content in the grass is a heritable trait that can be passed from parents to offspring (Humphreys 1989). This allowed grass breeders to select for it using molecular markers, and this led to the successful production of several high-sugar ryegrass varieties. Many studies evaluated the effect of feeding high-sugar grass, produced either by breeding (Miller et al. 2001; Lee et al. 2002; Taweel et al. 2005a) or by manipulating N fertilization (Peyraud et al. 1997), on DMI, milk production and composition, and nutrients utilization efficiency. The results of these studies are summarized and discussed below.

Three of the studies (Peyraud et al. 1997; Miller et al. 2001; Taweel et al. 2005a) were conducted with dairy cows, whereas the fourth study (Lee et al. 2002) was conducted with steers. In these studies the difference in WSC between the grasses ranged from 31 to 83 g/kg DM. All the studies showed that high-sugar grass is characterized by a lower CP and neutral detergent fibre (NDF) content, indicating that the high sugar content is at the expense of both CP and NDF (Table 1). In the studies of Miller et al. (2001) and Lee et al. (2002), the high-sugar grass had a much higher dry-matter digestibility than the low-sugar grass (Table 1). Therefore, caution should be taken when interpreting the results of those two studies, because the effects of digestibility and sugar content are confounded and cannot be separated. In the other two studies (Peyraud et al. 1997; Taweel et al. 2005a), despite the difference in sugar content the two grasses had a similar organic-matter digestibility. Both Miller et al. (2001) and Lee et al. (2002) observed an increased DMI and digestible DMI by cattle fed high-sugar grass, whereas Peyraud et al. (1997) and Taweel et al. (2005a) did not observe any difference in DMI (Table 1). This could mainly be related to the large difference in digestibility between the two grasses in the studies of Miller et al. (2001) and Lee et al. (2002). This may indicate that high sugar is not always associated with higher digestibility, especially in young and leafy perennial ryegrass. It may also indicate that grass digestibility exerts a stronger effect on DMI than its sugar content does.

All the studies showed that rumen pH was not influenced and was similar for animals consuming the high- and low-sugar grasses (Table 1). It is well known that pH in the rumen is related to VFA production and absorption rates in addition to salivation rate. It was expected that feeding high-sugar grass would lead to a higher sugar input and might lower rumen pH due to the rapid degradation of sugars in the rumen. However, in animals fed fresh grass, ingestion rate and the rate of release of sugars from the cells in addition to salivation rate seemed to have prevented a drop in the pH. Therefore, it is safe to assume that feeding high-sugar grass does not influence the activity of cell-wall-degrading bacteria and does not reduce fibre degradation in the rumen.

Two of the studies (Lee et al. 2002; Peyraud et al. 1997) showed a shift in rumen fermentation toward higher proportions of propionate and butyrate when animals were fed the high-sugar grass, whereas Taweel et al. (2005a) did not observe any differences in VFA production or molar proportions. This may be due to the much smaller differential magnitude in sugar content between the grasses in the study of Taweel et al. (2005a) (Table 1). The shift of rumen fermentation to propionate is believed to be valuable in improving energy status of the animal and in reducing energy waste in methane form. However, it remains to be seen whether feeding high-sugar grass reduces methane emission by ruminants.

Feeding high-sugar grass did not lead to increased milk production in the studies of Peyraud et al. (1997) and Taweel et al. (2005a), which was probably due to the absence of an effect on DMI. Whereas, in the study of Miller et al. (2001) cows eating the high-sugar grass produced 2.5 kg more milk than those eating the low-sugar grass. This is believed to be mainly due to the large difference in digestibility between the two grasses, which led to a higher digestible DMI on the high-sugar grass (Table 1). Moreover, in this study, the grass was fertilized at a low N fertilization rate and cut at a late stage of re-growth (6 weeks) leading to a low protein content in both varieties (Table 1). Therefore, the improvement in milk yield when feeding high-sugar grass in Miller at al. (2001) was exacerbated by the fact that they fed a poorly digestible pasture that contained low crude protein to producing cows. This does not mean that high-sugar grass will improve production under all circumstances. An increase in WSC content in grasses is only likely to improve production in situations where protein that can be metabolized, but not rumen-degradable protein, is lacking, because of the resulting increase in microbial protein production and consequent increase in the supply of protein that can be metabolized.

***Table 1**. The effect of feeding high-sugar (HS) versus low-sugar (LS) grass on intake, rumen parameters and production in cattle*

	Study							
	Peyraud al. 1997		Miller al. 2001		Lee al. 2002		Taweel al. 2005a	
	HS	LS	HS	LS	HS	LS	HS	LS
Grass data								
CP (g/kg)	106	150	92	106	100	104	151	158
WSC (g/kg)	246	180	165	126	243	161	180	149
NDF (g/kg)	496	528	544	589	480	563	414	430
Residue (g/kg)	152	142	199	179	177	172	255	263
Dig.[1] (%)	79 [a]	81 [a]	71	64	61	56	82 [a]	81 [a]
Intake								
DMI (kg/d)	15.1	15.3	11.6	10.7	9.3	6.7	16.2	17.1
Rumen data								
Rumen pH	6.2	6.2	NR	NR	6.4	6.3	5.8	5.8
Acetate [2]	61.2	64.7	NR	NR	62	65	65	66
Propionate [2]	21.1	20.2	NR	NR	23	20	19	19
Butyrate [2]	14.5	11.9	NR	NR	12	11	13	12
NH_3-N (mg/L)	12.6	81.2	NR	NR	14	26.4	108	125
Milk data								
Milk (kg)	NR	NR	15.3	12.6	NA	NA	25.1	26.6
Fat (%)	NR	NR	4.82	4.82	NA	NA	4.18	4.02
Protein (%)	NR	NR	3.45	3.45	NA	NA	3.35	3.37
Lactose (%)	NR	NR	4.48	4.36	NA	NA	4.57	4.57
Urea (mg/dL)	NR	NR	16 [b]	22 [b]	NA	NA	16.7	19.9

[1] Dig. is digestibility of dry matter
[2] expressed as a percentage of total VFA concentration in the rumen
NA is not available
NR is not reported
[a] organic-matter digestibility
[b] non-protein nitrogen content in milk (mg/dL)

All the studies showed that feeding high-sugar grass leads to a better N utilization by cattle, as it increases the proportion of N appearing in product and reduces that excreted in urine. Moreover, all the studies showed that feeding high-sugar grass lowers ammonia concentration in the rumen (Table 1). Moreover, in the study of Taweel et al. (2005a) milk urea content was reduced due to feeding high-sugar grass.

Grass with fast clearing and/or degrading fibre

Assuming perfect herbage allowance, environmental and management conditions and a good palatability, feed intake in ruminants is most likely controlled by both physical and physiological factors. Physical factors include the cow's rumen holding capacity (rumen fill) for DM or fibre. Physiological factors include end products of rumen fermentation and intestinal digestion, rumen pH and osmolality, hormones secreted by the endocrine system, such as insulin and glucagons, or secreted by the gastrointestinal tract, such as gastrin and cholecystokinin (Grovum 1981). It is generally believed that, as energy density in the ration increases and fibre content decreases, physical factors pose less of a constraint on feed intake and physiological factors become more important in regulating feed intake. Therefore, one may tentatively conclude that the intake of low- to medium-quality forage may be limited mainly by distension and fill of the rumen, but that when high-quality forage is fed, additional factors, mainly physiological, may become important in signalling satiety and consequently limit intake. Within this framework, many factors related to rumen function could influence (not control) DMI. Anything that increases the rate of breakdown of the plant material in the rumen would be expected to increase the throughput and hence the intake that can be attained at a given distension level which would signal satiety (Grovum 1984). Moreover, anything that contributes to the dilution of fermentation end products in the rumen would also be expected to increase intake at a given concentration level that would signal satiety. Improving microbial activity in the rumen, loosening plant cell-wall structure, increasing saliva flow to the rumen and increasing the frequency and strength of rumen contractions would all be expected to influence DMI positively.

Altering the chemical, physical and mechanical characteristics that contribute to the low DMI of perennial-ryegrass pasture through breeding, selection and the choice of variety may be a way forward in trying to maximize its DMI. Modifying characteristics that contribute to physical limitations such as fibre content, degradation rate by microbes in the rumen or rate of clearance of fibre from the rumen may lead to a considerable improvement in DMI. Choosing varieties that have fast fibre clearance and/or degradation rates may reduce the residence time of material in the rumen, allow more space for extra material to be ingested, and increase DMI and hence milk production. To be able to choose and select grass for fast clearing or degrading fibre, perennial ryegrass varieties should differ in their fibre clearance or degradation rates. Therefore, the first step was to evaluate and screen different varieties of perennial ryegrass for these characteristics (fibre clearance and degradation rates) and define the available ranges for selection and choice.

Taweel et al. (2005b) evaluated the degradation and clearance characteristics of eight varieties of perennial ryegrass in two consecutive years using the rumen evacuation technique. These experiments showed that perennial-ryegrass varieties do not differ significantly in their fractional NDF clearance rates (kcl_{NDF}) or in their fractional NDF degradation rates (kd_{NDF}) and characteristics (Figure 3). Moreover, these experiments showed that the difference in fractional degradation rate between the variety with the fastest degrading fibre and the one with the slowest degrading fibre is less than 1 %/h.

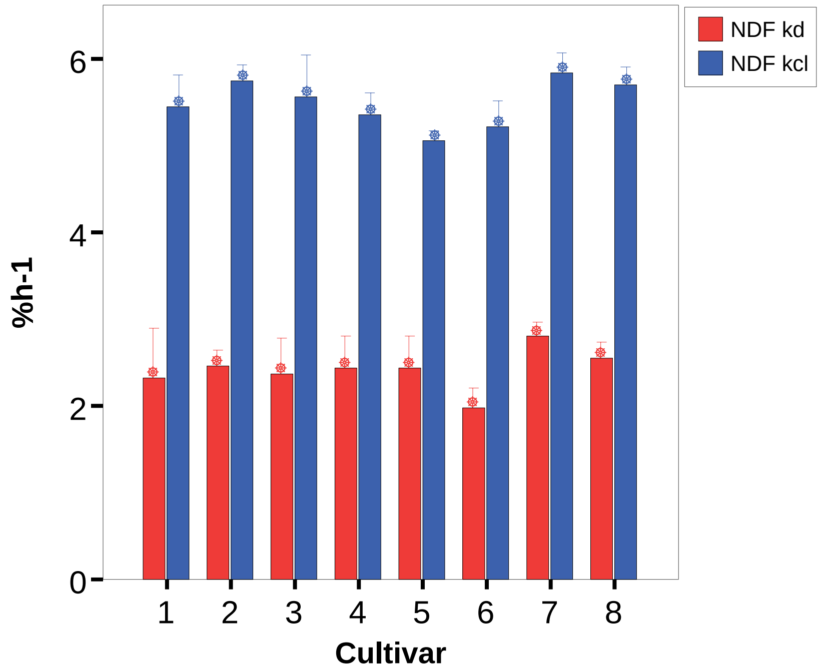

***Figure 3**. Fractional clearance (empty bars) and degradation (filled bars) rates of six perennial-ryegrass varieties*

Nevertheless, because these experiments stretched over most of the grazing season in The Netherlands (June to September) and the measurements were performed once every two weeks, a data set with a good range in fractional clearance and degradation rates, DMI and rumen parameters was generated (Taweel 2004, p. 110). This range allowed studying the effect of varying NDF fractional clearance and degradation rates on DMI of dairy cows. The data set was divided based on NDF fractional clearance rate (kcl_{NDF}) into three categories: slow clearing (kcl_{NDF} from 3.77 to 5.14), moderate clearing (kcl_{NDF} from 5.15 to 6.51) and fast clearing (kcl_{NDF} from 6.52 to 7.87). On average the kcl_{NDF} of the slow, moderate-and fast-clearing categories were 4.7, 5.8 and 7.1 %/h, respectively, and the kd_{NDF} were 2.4, 2.4 and 3.3 %/h, respectively (Table 2). Contrary to expectations, grass DMI was not different among the three categories and averaged around 15.7 kg/d (Table 2). Animals in the slow kcl_{NDF} category seemed to compensate by having a larger rumen size as illustrated by the bigger ($P < 0.05$) rumen DM, OM, NDF pools of these animals. The relationship between clearance rate and rumen pool size is illustrated in Figure 4. It can be seen that as the clearance rate increases the rumen pool size decreases in a cubic fashion. The results of these experiments clearly indicate that variation in NDF degradation and clearance characteristics and rates between perennial-ryegrass varieties is very limited. This suggests that choosing varieties with fast degrading fibre, as a means to improve pasture DMI, is also of very limited use. It also implies that breeding grasses for fast degrading and/or clearing fibre as a measure to improve pasture DMI seems to be unattainable at this stage, at least under the pasture management conditions presently applied in The Netherlands on most dairy farms.

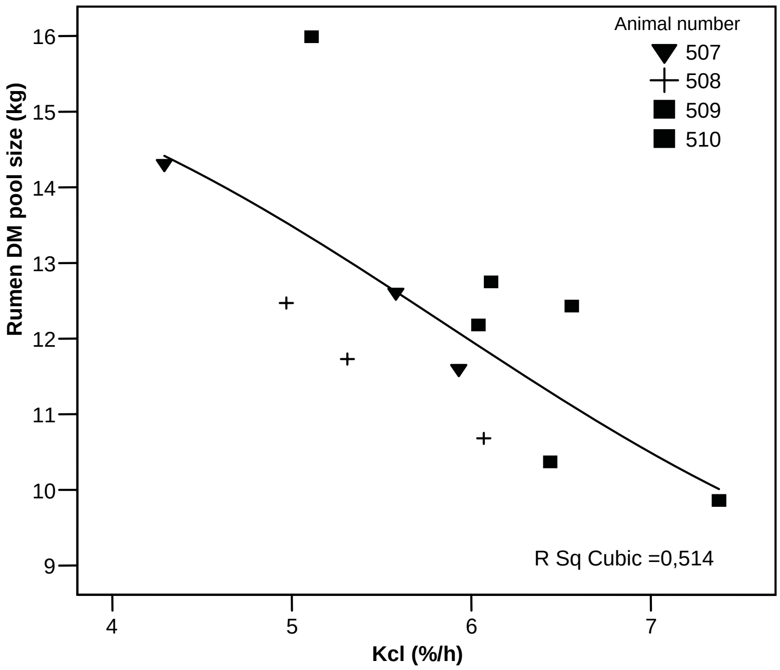

***Figure 4**. The relationship between clearance rate (Kcl) and rumen pool size*

***Table 2**. The effect of varying NDF clearance rate (kcl_{NDF}) on DMI and rumen function in dairy cows*

	NDF clearance rate category			
Variable	Slow	Moderate	Fast	SD[1]
		Grass data		
Re-growth (days)	24	24	24	2
Height (cm)	20	20	20	2
DM yield (kg/ha)	2093	2254	2158	384
WSC (g/kg DM)	131	123	124	29
CP (g/kg DM)	173	179	182	23
NDF (g/kg DM)	441	443	438	32
		Intake data		
Days in milk	142	140	154	55
Grass DMI (kg)	15.7	15.7	15.6	1.4
Total DMI (kg)	19.1	18.8	18.5	1.8
		Rumen data		
DM pool (kg)	13.7 [a]	11.8 [b]	11.1 [b]	2.1
OM pool (kg)	12.0 [a]	10.4 [b]	9.8 [b]	1.8
NDF pool (kg)	6.2 [a]	5.4 [b]	5.0 [b]	1.1
ADL pool, kg	0.54 [a]	0.48 [b]	0.42 [b]	0.10
kcl_{NDF} (%/h)	**4.69 [a]**	**5.79 [b]**	**7.06 [c]**	**0.90**
kcl_{ADL} (%/h)	2.33 [a]	3.40 [b]	3.81 [b]	0.99
kd_{NDF} (%/h)	2.36 [a]	2.39 [a]	3.26 [b]	0.85
VFA (mM)	119	112	110	17
Acetate (%)	66	66	65	2
Propionate (%)	20	20	21	2
Butyrate (%)	12	12	12	1
NH_3-N (mg/L)	172	180	184	69
pH	5.80 [a]	5.98 [b]	6.01 [b]	0.24

[1] SD is the standard deviation; Kcl_{ADL} is the clearance rate of acid detergent lignin; kd_{NDF} is the degradation rate of NDF

CONCLUSIONS

The main conclusions of this paper are the following:

1. Pasture DMI by dairy cows can be increased by increasing herbage allowance, allocating young and leafy pasture, allocating the new pasture in the evening and using highly digestible varieties.
2. Although effective in increasing DMI, increasing herbage allowance and allocating young and leafy pasture lead to a reduced pasture holding capacity and reduced productivity per hectare. Therefore, finding the ideal balance is

essential.

3. Allocating the new pasture in the evening has been shown to be effective in increasing DMI. In addition, it does not reduce pasture holding capacity or productivity per hectare. However, its effect on the long-term grassland productivity is yet to be determined.
4. High-sugar grass is not always associated with higher dry-matter or organic-matter digestibility and may not improve DMI and milk production from pasture-based systems at all times.
5. Grass organic-matter digestibility appears to exert a much stronger effect on DMI than its sugar content does.
6. Variation in NDF degradation and clearance rates between well managed perennial-ryegrass varieties is very limited. Therefore, choosing varieties with fast degrading fibre, as a means to improve pasture DMI, is not a possibility at the present stage of grassland management.

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