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The effect of degree of competition for feeding space on the silage dry matter intake and feeding behaviour of dairy cows

Efecto del grado de competencia por espacio de comedero en el consumo de materia seca y comportamiento del consumo de vacas lecheras

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RESUMEN

Veinticinco vacas lecheras fueron asignadas a cinco tratamientos con 1, 3, 5, 7 ó 9 vacas por espacio de comedero. Cada comedero consistió en un alimentador electrónico que permitía el acceso del animal a ensilaje dispuesto sobre una balanza. El comportamiento de consumo fue monitoreado con collares electrónicos que permitían la identificación individual de cada animal mientras consumía ensilaje. Los animales tuvieron acceso al ensilaje durante todo el día, el que fue ofrecido diariamente a las 9:30 h. No se utilizó concentrado. Las vacas fueron asignadas a un diseño de Cuadrado Greco-Latino con cinco períodos. Cada período consistió en 14 días, y para cada período se registró el comportamiento de consumo de una vaca por tratamiento con el resto de las vacas utilizadas para lograr el nivel de competencia asignado. Se observó un incremento lineal ($P < 0,001$) en el número de comidas por día y la tasa de ingestión, a medida que se incrementaba la competencia. Un aumento en la competencia resultó en una reducción lineal ($P < 0,01$) en el tiempo total de consumo, tiempo de consumo por cada comida y tamaño de cada comida. El consumo total disminuyó, tanto bajo la ausencia de competencia, como a altos niveles de competencia, observándose una tendencia cuadrática ($P < 0,05$) al incrementar los niveles de competencia. Se concluye que a niveles bajos de competencia las vacas consumen pocas comidas de mayor tamaño, pero en la medida que aumenta la competencia, éstas consumen el ensilaje en un gran número de pequeñas comidas. A niveles intermedios de competencia, las vacas mantienen su nivel de consumo como resultado de marcados cambios en su comportamiento ingestivo.

Key words: dairy cows, competition, intake, behaviour.

Palabras clave: vacas lecheras, competencia, consumo, comportamiento.

INTRODUCTION

In group housing situations, the role of spacing during feeding is important since it has implications both for production, as related to food intake, and for housing design (Ferris *et al* 2006). Dairy system designers need to pay close attention to the needs of cows and all aspects of the animal area when developing designs and recommendations (Mc Farland 2003). For example, Friend *et al* (1977) examined the effect of feed manger space per cow (0.1, 0.2, 0.3, 0.4 or 0.5 m/cow) on time spent eating and voluntary food intake. They found that when the length of manger was reduced below 0.2 m per cow, eating time and voluntary food intake were reduced. It has been suggested that with trough feeding, competition for food will occur if all cows cannot eat at the same time (Albright 1993, Tolkamp *et al* 1998). However, there is little experimental data on the critical length of manger/cow for easy-feed systems, below which eating behaviour, intake and performance may be adversely affected. Work reported by DeVries *et al* (2004), indicated that when access to food for 24 Holstein

cows was increased from 0.5 to 1.0 m of feeding space per animal, daily feeding activity increased by 14% and aggressive behaviour between animals decreased.

The aim of the present study was to evaluate the effect of competition between animals on dry matter intake and eating behaviour of late lactation dairy cows offered grass silage, using equipment which facilitates the automatic monitoring of food intake and feeding behaviour of individual animals kept in a group housed situation.

MATERIAL AND METHODS

TREATMENTS AND ANIMALS

Twenty five Friesian dairy cows in late lactation (average milk yield 7.4 kg/day) were allocated to 5 treatments with 1, 3, 5, 7 or 9 cows per feeding space. Each feeding space consisted of a Calan gate with access to grass silage blocks placed on a load platform, as described by Forbes *et al* (1986). All animals were accustomed to the building and the feeding during the preceding winter feeding period. Animals were offered medium-quality grass silage *ad libitum* for a seven day standardisation period prior to the start of the experiment.

Cows were then allocated to a five period Graeco-Latin square design, in which the 5 treatments were grouped into replicates in three different ways with the consequence that the effects of three different sources of variation (i.e. gates, periods and competing animals) were equalized for all treatments (Cochran and Cox 1957). Each period consisted of 14 days, with the last five days of each period being the main recording period during which one cow per treatment was recorded for each period, with additional cows used to obtain the required level of competition. Recorded and non-recorded cows were rotated across treatments and gates over periods, as shown in table 1.

The silage offered in this experiment was harvested from a primary growth of a perennial ryegrass sward, using a double-chop harvester. An inoculant (Ecosyl®), was applied at the rate of 2.50 litres per tonne of fresh grass. The grass was ensiled in walled silos, thoroughly compacted and covered with polythene sheeting weighted with rubber tyres. During feeding, the silage was removed from the silo using a block cutter, in blocks as required. Silage was offered to each treatment in sufficient quantities to allow a refusal of 50 g/kg intake. Water was freely available at all times, from drinking troughs. No concentrates were offered.

All animals were housed as a single group in cubicle accommodation with access to the silage controlled by 5 Calan gates. Treatment changeovers were made abruptly on the first day of each period. Cows were milked daily at 06:00 and 16:00 h with milk yields recorded at each milking.

DRY MATTER INTAKE AND FEEDING BEHAVIOUR

Each feeding space consisted of a Calan gate with access to grass silage blocks placed on a load platform. These load platforms consisted of four compressions type load cells, the output of which was input via a signal conditioner to a microcomputer. Cows had continuous access to the silage on the load platforms via a feed barrier with one access point (Calan gate) per platform. Each access point was fitted with an aerial loop which energized an active transponder and transmitted the identity of the cow to the microcomputer. Signals were stored on a microcomputer programmed to continuously record the weight on each weight platform to the nearest 100 g and the time. Information on timing and size of meals for individual cows for each day was then transferred to the mainframe computer for sorting and statistical analysis. Each day's data file was sorted according to cow using the mainframe computer. In order to determine which consecutive meals should be merged according to a minimum intermeal interval criteria, an appropriate intermeal interval was then determined, using the method proposed by Forbes *et al* (1986). This involved plotting the frequency distribution of intervals between visits with the change in slope indicating the boundary between within-meal pauses and true between meal intervals. The sorted data was then scanned by means of a program in which the intermeal interval criteria were specified when activating the program. The data for dry matter content of the silage was also input onto the program at this stage.

Table 1. Allocation of cows to treatments.
Asignación de las vacas a los tratamientos.

	Gate N°				
	1	2	3	4	5
Period I	A1	A2 B C	A3 D E F G	A4 H I J K L M	A5 N O P Q R S T U
Cows/gate	1	3	5	7	9
Period II	A3 B C	A4 D E F G	A5 H I J K L M	A1 N O P A R S T U	A2
Cows/gate	3	5	7	9	1
Period III	A5 D E F G	A1 H I J K L M	A2 N O P Q R S T U	A3	A4 B C
Cows/gate	5	7	5	1	3
Period IV	A4 N O P Q R S T U	A5	A1 B C	A2 D E F G	A3 H I J K L M
Cows/gate	9	1	3	5	7
Period V	A2 H I J K L M	A3 N O P Q R S T U	A4	A5 B C	A1 D E F G
Cows/gate	7	9	1	3	5

Treatment cows: A1 A2 A3 A4 A5.

Additional cows: B D E F G H I J K L M N O P Q R S T U.

This program then calculated information regarding : number of meals per day ; amount eaten per meal (kg DM); mean daily eating rate (g DM/min); eating rate for the first meal during the day (g DM/min) and daily total silage intake (kg DM/day). The pattern of feed consumption throughout the day was also recorded using the mainframe computer, programmed to give the weight of feed consumed per cow continuously from 0 to 24 hours after feeding. Fresh silage was offered daily at 09:30 h. Daily samples of the silage were taken from each block of silage as loaded on the weigh platforms to give a bulked sample which was retained for determination of oven dry matter content. Once per week a sample of fresh silage (bulked across blocks) was analysed for toluene DM, ammonia - N, pH, volatile fatty acids, lactic acid, and ethanol, as described by MAFF (1981). Total N was determined by the macro - Kjeldahl method, using fresh samples of forage. Oven-dried samples were also analysed for MAD fibre (Clancy and Wilson 1966). Ash and GE concentrations were analyzed as described by British Standard Institutions (1967). Daily silage dry matter intake and feeding behaviour were calculated on an oven dry matter basis. This was converted to a toluene dry matter basis, ethanol corrected.

LIVE WEIGHT AND MILK YIELDS

Live weights were recorded once per week during the experimental period. All animals were weighed to the nearest 0.5 kg on a 1500 kg capacity weighbridge, with weighing being carried out after pm milking. Individual milk yields were recorded at each milking to the nearest 0.1 kg.

STATISTICAL ANALYSIS

All data recorded during the last five days of each period i.e. milk yields, live weights, forage intake and feeding behaviour parameters were analyzed as 5 cows x 5 gates x 5 periods, Graeco-Latin square design with 5 treatments. Each of the 5 observations per treatment was used in deriving equations of response lines for increasing levels of competition, using the regression procedure of Genstat 5 Committee (1988).

RESULTS

SILAGE COMPOSITION

The chemical composition of the silage offered is given in table 2. Each value is the mean of ten observations. The silage was well preserved, as indicated by its low pH value and low concentration of ammonia-N and butyric acid.

FEEDING BEHAVIOUR AND SILAGE DRY MATTER INTAKE

Sequences of visits alternating with short intervals were assumed to be part of the same meal. In order to

reduce the data to a more manageable form, a minimum intervisit - interval of 6 minutes was used.

Data on feeding behaviour and silage dry matter intake are presented in Table 3. There was a linear trend ($P < 0.001$) towards a higher number of meals per 24 h as the number of animals allocated per feed box increased. However, the amount eaten per meal decreased linearly ($P < 0.01$) with increasing number of animals per feeding space. Total feeding time per 24 h and feeding time per meal showed a similar trend, with linear reductions ($P < 0.001$) with increasing competition per feeding space. Mean daily eating rates increased markedly with increasing competition per feeding space ($P < 0.001$). A similar trend was found with eating rate during the first meal of the day, increasing linearly ($P < 0.001$) with increasing number of animals per feeding space.

Overall, total silage dry matter intake tended to be lower with the lowest and the highest levels of competition resulting in a quadratic trend ($P < 0.05$) with increasing competition per feeding space.

Data on the percentage occupancy of individual feeding spaces is also presented in table 3. There was a tendency towards increasing occupancy rate with increasing competition per feeding space, up to 7 cows per feeding space. Above 7 cows per gate, occupancy rate appeared to decrease.

PATTERN OF INTAKE DURING THE DAY

Treatment effects on silage dry matter intake at two hour intervals after offering fresh silage are presented in table 4 with the cumulative dry matter consumption over a 24 h period presented in figure 1. During the first two hours

Table 2. Chemical composition of silage as removed from the silo (g/kg toluene DM, ethanol corrected, unless otherwise stated).

Composición química del ensilaje, tal como removido del silo (g/kg MS al tolueno, corregida por etanol, a menos que se señale de otra manera).

		s.d.
Dry matter	222	± 19.1
pH	3.68	± 0.12
<i>Composition of DM</i>		
Crude protein	137	± 10.5
Ammonia N (g/kg TN)	72	± 10.8
Acetic acid	22.8	± 4.2
Propionic acid	0.72	± 0.45
Butyric acid	1.02	± 0.55
Lactic acid	136	± 16.0
Ash	74	± 9.9
MAD-fibre	353	± 8.7
Ethanol	6.83	± 2.5

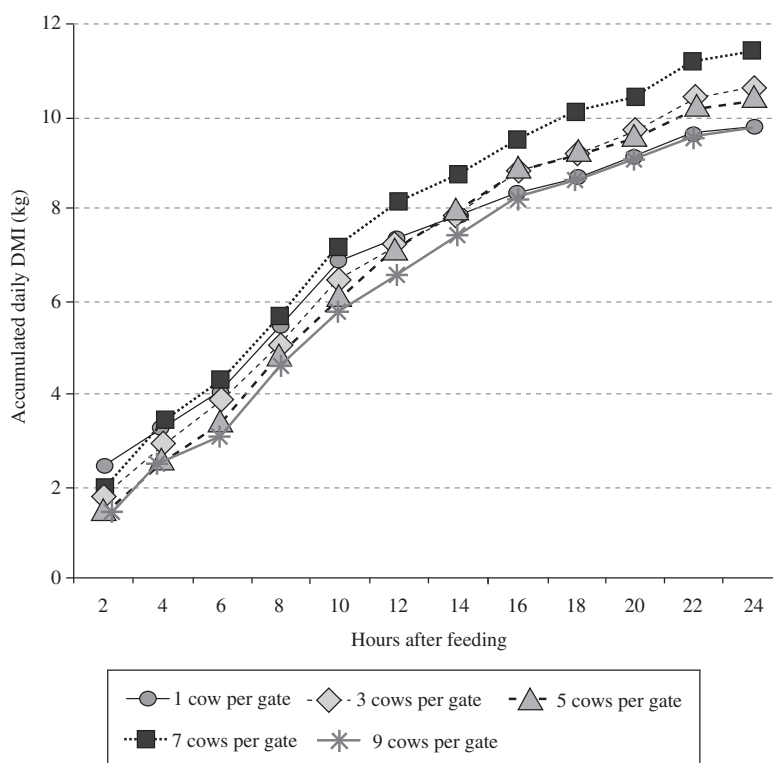
Table 3. Effect of level of competition on feeding behaviour, dry matter intake, percentage occupancy of individual feed spaces and animal performance.

Efecto del grado de competencia en el comportamiento del consumo, consumo de materia seca, porcentaje de utilización de los espacios individuales de comedero y la respuesta productiva animal.

	Treatment						Linear trend	Quadratic trend
	1	2	5	7	9	s.e.		
Number of meals per day	11.0	13.2	15.0	15.4	16.9	0.80	**	***
Amount eaten per meal (min)	0.90	0.80	0.69	0.74	0.57	0.06	*	NS
Feeding time per meal (min)	30.9	19.1	11.3	11.3	5.9	2.60	***	*
Total feeding time (min/day)	339	253	170	174	100	12.5	***	*
Mean daily eating rate (g DM/min)	29.0	42.1	60.8	65.3	96.3	6.31	***	NS
Eating rate during the first main meal (g DM/min)	30.6	51.4	97.6	96.3	153.9	8.92	NS	NS
Silage dry matter intake (kgDM/day)	9.8	10.6	10.4	9.6	9.6	0.37	NS	*
Percentage occupancy of individual feed spaces (%)	24	53	59	85	63	NA	NA	NA
<i>Animal data</i>								
Mean live weight (kg)	561	567	554	549	541	3.5	***	NS
Milk yield (kg/day)	8.0	7.5	6.9	7.4	7.3	0.33	NS	NS

NA: Not applicable.

NS: Not significant.

**Figure 1.** Effect of number of cows allocated per feeding space on the cumulative silage dry matter consumption over a 24 h period.

Efecto del número de vacas asignadas por espacio de comedero en el consumo acumulado de materia seca de ensilaje en un período de 24 horas.

Table 4. Effect of level of competition for feeding space on silage dry matter intake (kg) at two hour intervals after feeding initiation.
Efecto del nivel de competencia por espacio de comedero en el consumo de materia seca de ensilaje (kg), cada dos horas luego de ofrecido.

Time intervals (hours after feeding)	Level of competition (cows per gate)					Significance #
	1	3	5	7	9	
0-2	2.43 ^b	1.71 ^{ab}	1.44 ^b	1.94 ^b	1.38 ^a	***
2-4	0.99	1.17	1.27	1.25	1.16	NS
4-6	0.93	0.86	0.68	0.73	0.60	NS
6-8	1.09 ^a	1.30 ^{ab}	1.42 ^{ab}	1.77 ^b	1.45 ^{ab}	**
8-10	1.45	1.47	1.26	1.50	1.18	NS
10-12	0.39 ^a	0.86 ^{ab}	1.13 ^b	0.96 ^b	0.76 ^{ab}	**
12-14	0.55	0.58	0.65	0.56	0.87	NS
14-16	0.54	0.86	0.54	0.79	0.82	NS
16-18	0.25 ^a	0.39 ^{ab}	0.83 ^b	0.60 ^{ab}	0.43 ^{ab}	*
18-20	0.36	0.45	0.27	0.33	0.48	NS
20-22	0.61	0.74	0.68	0.74	0.35	NS
22-24	0.16	0.19	0.13	0.23	0.22	NS

Means with the same superscripts, within rows, are not significantly different ($P > 0.05$).

SED in all comparisons was 0.179.

after feeding, silage dry matter intake was significantly higher ($P < 0.001$) with 1 and 7 cows per feeding space than when 5 or 9 cows were allocated per feeding space. Between 6-8 h after feeding, silage dry matter intake was significantly lower ($P < 0.01$) with 1 cow compared to 7 cows per feeding space, with the rest of the treatments being intermediate. By 10-12 h after feeding, animals on treatments with 5 or 7 cows per feeding space consumed significantly ($P < 0.01$) more silage dry matter, than when 1 cow was allocated per feeding space, with the remaining treatments being in an intermediate position. Between 16-18 h after feeding, silage dry matter intake was significantly higher ($P < 0.05$) with 5 cows than with 1 cow allocated per feeding space, with the rest of the treatments being intermediate and not differing significantly ($P > 0.05$) from each other. Increasing the number of cows allocated per feeding space had no significant effect ($P > 0.05$) on silage dry matter intake in the remaining time intervals.

LIVE WEIGHT AND MILK YIELD

Data on animal live weight and milk yield are presented in table 3. Animal live weight declined linearly ($P < 0.001$) with increasing number of animals per feeding space. At the same time, milk yields were not significantly ($P > 0.05$) affected by increasing level of competition.

DISCUSSION

Increasing the level of competition for silage between animals by increasing the number of cows allocated per

feeding space had a marked effect on feeding behaviour. In general, as the degree of competition increased, an increase in both number of meals per day and eating rate was observed, accompanied by reductions in total feeding time, feeding time per meal and average meal size. Hence, at low levels of competition, cows ate relatively few large meals, but as competition increased cows consumed silage in a larger number of small meals.

In the present study, overall silage dry matter intake was lower with no competition or with the highest level of competition, with a significant quadratic trend ($P < 0.05$). At intermediate levels of competition, cows tended to maintain their dry matter intake as a result of marked changes in eating behaviour. In the absence of competition, animals consumed large meals over a longer feeding time resulting in a lower total dry matter intake.

As intake per meal declined, there was a concomitant increase in eating rate. For example, the data presented in table 3 indicate a marked linear increase in rate of eating with increasing competition, reflecting the remarkable flexibility of the dairy cow to maintain dry matter intake (Grant 2006). However, the beneficial effect of a higher eating rate with increasing competition was insufficient to compensate for the large reduction in meal size at the highest level of competition, and a reduction in dry matter intake occurred.

These results are in general agreement with most of the available data reported in the literature. For example, early studies reported by Harb *et al* (1985) suggested that eating rates were increased when cows were group fed compared to when they were individually fed (57 vs.

43 g/min, respectively) and that feeding rate was further increased (71 g/min) if the number of trough spaces available to the group was reduced from 10 to 5. Later, Longenbach *et al* (1999), when restricting the manger space of dairy heifers from 47 to 31 and 15 cm, found that animals with restricted bunk space, ate faster in smaller meals to prevent a reduction in feed intake.

Work reported by Olofsson (1999) and Olofsson and Wiktorsson (2001), indicated that the average feed consumption tended to increase when the number of cows per feeding station was changed from 1 to 4. The most common explanation for this phenomenon is an increased maintenance activity factor in the group-fed animals, due to additional energy expenditure such as stress during competition for manger space (Coppock *et al* 1972). In the current trial, cows without competition (1 cow per feeding space) ate on average 6.6% less dry matter than those with increased levels of competition.

A number of studies reported in the literature suggest that group-fed animals eat more than isolated animals (Albright 1993, Nielsen 1999). Further, it has been noted that social stress increases food intake and body mass in hamsters (Foster *et al* 2006). However, there is little information regarding the effect of social factors on the dry matter intake of individual cows when offered feed in a group. It has been suggested that social facilitation (Ingrand *et al* 2000, Grant and Albright 2001), can result in enhanced intake in cows.

In the present study, all cows were fed as a group and higher feeding times were observed with one cow per feeding space. However, the low eating rates accompanied with fewer meals per day, i.e. larger intermeal intervals, suggest that a lack of competition may result in a reduction in dry matter intake due to a decrease in the rate of eating.

On the other hand, it is likely that the depression in intake observed at the higher level of competition (9 cows per Calan gate) might be due to stress of competition, i.e. more interaction between cows behind the feed barrier. As a result of this extremely high level of competition, the proportion of time during which feeding spaces were occupied was reduced at the highest level of competition (table 3). It has been stated that restricting feed access may cause subclinical acidosis and an overall reduction in mean intake (Schwartzkopf-Genswein 2003). This may account for the reduction in dry matter intake observed at the highest level of competition. Furthermore, the mean daily eating rate at 9 cows per gate is high (96 g DM/min). It has been reported that a high eating rate may lead to a reduction in plasma volume and a rise in systolic blood pressure (Blair-West and Brook 1969). This may result in a temporary dehydration and consequently feeding inhibition (Cole 2000). The tendency for lower silage dry matter intakes with individually fed animals has major implications for animal production research studies. For example the results of the present work, taken in conjunction with those previously published in the literature (Phipps *et al* 1983, Phipps 1986) suggest

that intake of individually fed animals is between 6-9% lower than that of group fed animals subject to a degree of competition during feeding.

Consequently, the use of feed intake recording equipment such as that described by Forbes *et al* (1986), which enables automatic monitoring of food intake with group-fed animals under varying degrees of competition, may simulate more closely the on-farm situation, where there is normally a degree of competition during feeding.

PATTERNS OF CONSUMPTION

In general within a 24 h period, the majority of the dry matter intake and also most of the significant differences in intake tended to occur during daylight hours. For example, Tolkamp *et al* (2002) reported that loose-housed, lactating dairy cows offered grass silage *ad libitum* and concentrates, consumed most of the feed during daylight hours, with peaks and troughs in intake per hour of the feeding cycle just after noon and just after midnight, respectively. In the current trial, cows consumed on average 62% of their total daily silage dry matter intake between 9:30 am and 7:30 pm. For all treatments, a high proportion of the daily intake was consumed during the first 2 h after feeding. Studies have shown that the delivery of feed has great effect in terms of stimulating feeding activity in group-housed dairy cattle and is the primary influence in determining their daily feeding patterns (DeVries *et al* 2005, Mäntysaari *et al* 2006). This effect tended to be more pronounced at low levels of competition. Therefore, a more uniform pattern of consumption was observed with increasing competition, reflecting higher activity throughout the day. The relatively low levels of initial intake observed at high levels of competition, tended to be compensated later during the day between 6-8, 10-12 and 16-18 h after feeding, with cows consuming relatively more dry matter at this time.

It has been accepted that dairy cattle exhibit a diurnal feeding pattern where most of the feeding activity occurs during daylight hours. For example, Shabi *et al* (2005) observed that under dry lot, loose-housing, lactating dairy cows exhibit a distinct diurnal pattern in feeding activity; they were most active near sunrise and again near sunset. It is worth noting that in the present study, even at one cow per feeding space, some dry matter consumption was recorded 16-20 h after feeding, suggesting some circadian pattern of consumption (Takahashi and Zatz 1982).

LIVE WEIGHT AND MILK YIELD

Animal live weight tended to decrease linearly ($P < 0.001$) with increasing level of competition (table 3), probably as a result of an increase in the maintenance energy requirements with increased competition per feeding space, as suggested by Ellis *et al* (2006). It may be of interest to note, however, that animal live weight tended

to be lower with one cow per feeding space compared to three cows per feeding space, although this may reflect gut fill effects resulting from reduced dry matter intake.

When Olofsson (1999) compared 1 or 4 mid lactation dairy cows per feeding station with a total mixed diet fed for *ad libitum* intake, he found no differences in milk production. In the current study, mean milk yields were not markedly affected ($P > 0.05$) by increasing competition. However, the lack of effect of increasing competition on milk yield in the present study may reflect the fact that animals in this study were in late lactation, with the result that treatment effects on dry matter intake tended to be reflected in live weight change.

It can be concluded that increasing the degree of competition per feed space had a marked effect on feeding behaviour. At low levels of competition, cows consumed relatively few, large meals but as the degree of competition increased, cows consumed silage in a large number of small meals. Total silage dry matter intake was reduced by 6.6% in the absence of competition, with a further reduction in intake at high levels of competition. Overall there was a significant quadratic relationship between degree of competition and total silage dry matter intake. The practical implication of these results is that provision of sufficient feeding space to enable all animals to consume forage simultaneously may reduce total forage intake in comparison to the situation where a moderate degree of competition is imposed at the feed barriers.

SUMMARY

Twenty five late lactation dairy cows were allocated to 5 treatments with either 1, 3, 5, 7 or 9 cows per feeding space. Each feeding space consisted of a Calan gate with access to silage blocks placed on a load platform. Eating behaviour was monitored by identifying cows using collar borne transponders. Animals had access to silage throughout the day, with fresh silage being offered daily at 09:30 h. No concentrates were offered during the experiment. Cows were allocated to a Graeco-Latin square design with 5 periods. Each period consisted of 14 days, and one cow per treatment was recorded for each period, with additional cows used to reach the required level of competition. All cows were rotated across treatments and gates over periods. As the degree of competition increased, animals modified their feeding behaviour, with a linear increase ($P < 0.001$) in both number of meals per day and eating rate. Increasing level of competition resulted in linear reductions ($P < 0.01$) in total feeding time, feeding time per meal and average meal size. Total dry matter intake was reduced both by the absence of competition and at high levels of competition, showing a quadratic trend ($P < 0.05$) with increasing competition. It is concluded that at low levels of competition, cows ate relatively few, large meals, but as competition increased cows consumed silage in a large number of small meals. At moderate levels of competition (3-7 cows/feeding space) cows maintained their intake as a result of marked changes in feeding behaviour.

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