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Adaptation of dairy cows to change in a computer-controlled concentrates feeding routine*

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ABSTRACT

Adaptation of cows to a new regime of concentrate allocation *via* computerised feeders was studied in an Israeli commercial corral-type dairy (about 50 cows in milk). A new fixed-time routine with six equal diurnal feeding cycles was introduced, replacing a long-used former routine with four equal diurnal cycles. The adaptation process was investigated for changes in cows' visit timing and intensity during 1-5-day intervals for 3 months.

The daily concentrates allowance was consumed from the first day of change. Within a few days, the cows started to consume newly timed feed portions in the same cycle it became available – with the exception of night hours. However, adaptation of self-feeders visiting behaviour was a prolonged multistage process comprising changes in both visits' timing and intensity. Initially there was spontaneous activity rise, reaching a maximum after 5 d. After 3 months, the mean number of visits to feeders after non-attendance periods from 0.5 to 4 h was 1.5 times greater than under the previous feeding routine – the rise proportional to the increase in diurnal number of feeding cycles. The increase in visits frequency alone, does not explain the cows adaptation to new feeding routine. The adaptation consists of a gradual acquaintance to new timing on one hand and abandoning old visits timing on the other. Stable visiting patterns, including visits timing and intensity, may be the appropriate criterion of cows' adaptation to new feeding environment on top of consuming the daily ration.

KEY WORDS: dairy cows, feeding behaviour, computerized self-feeders

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INTRODUCTION

Computerised feeders create a specific feeding environment. Without visual evidence of the presence of feed, and with limited access to only a small number of feeders, cows have to choose feeding/visiting strategies which will enable them a daily feed allowance made available by a particular feeding program.

Although the number and timing of feeding opportunities available for programming in the system may vary widely, the feeding practice is usually reduced to two approaches. The first is to make feed available in small portions through the day and hence allow cows a large number of feeding opportunities. In essence, such a "redundant" approach rewards any strategy – from the frequent consumption of small feed portions to the consumption of the daily allowance in a few "accumulated" lots. The second approach is to supply the daily allowance in a few discrete parts. Usually, this is achieved by a fixed-time feeding routine: a fixed part of the individual daily allowance becomes available for all cows at fixed times of the day, so that feeding intervals (feeding windows, FW) are the same for all cows in the herd. This approach encourages the cows' cyclic feeding, both directly – by not rewarding unduly frequent visits to feeders, and indirectly – by triggering mechanisms of group behaviour (Wierenga and Hopster, 1991b; Livshin et al., 1995). Under a cyclic feeding routine, similar feeding results may be achieved under different visiting patterns. For example, FW regular attendance may be either the result of "fine tuning" visiting behaviour to the number and times of feeding opportunities, or it may be the consequence of a sufficiently high number of visits. Indeed, if the cows visit the feeders sufficiently often, the regular usage of feeding opportunities can be achieved under almost any feeding routine. In fact, this was the conclusion reached about cows' feeding strategies under cycled routines with different times of feed availability (Wierenga and Hopster, 1991b).

The existing findings on cows behavioural adaptation to computerised concentrate feeding relates mostly to inexperienced cows adjusting to usage of computerised feeders. The consumption of daily allowances and the regular visiting were used as adaptation criteria. It was established that, after a few days experience, cows generally visit computerised feeders regularly and consume almost completely their daily allowances under any type of feeding routine proposed (e.g., Collis, 1980; Cassel et al., 1982; Maltz et al., 1991; Wierenga and Hopster, 1991a; Pirkelmann, 1992). It is known also, that cows are willing to consume the available concentrate portions in one meal (for the studied feed quantities – which were up to 4 kg), and to do so immediately after feed becomes available (Wierenga and Hopster, 1991a,b; Livshin et al., 1995).

The data on the adaptation of cows' visiting behaviour to change in a particular feeding routine are limited. It has been established that the larger the number of feeding opportunities, the higher the level of visiting activity, as measured by the

mean number of visits to feeders. Under comparable experimental conditions, this has been demonstrated through a comparison of (a) feeding routines with very large numbers of feeding opportunities versus cyclic routines (Wierenga and Hopster, 1991a), and (b) two cyclic routines with different numbers of diurnal feeding windows (Livshin et al., 1995). In the latter work it was also found that utilization of all programmed cyclic feeding opportunities by cows may be very high (96-99%).

The cows' behavioural adaptation as a process was not investigated. There is a tendency to equate the regular consumption of feed allowances with visiting behaviour adaptation; so measurements of visiting behaviour in comparative experiments are usually conducted after a short period of adaptation, when the regular usage of feed is achieved (e.g., Wierenga and Hopster, 1991a). However, there is some evidence of prolonged visiting behaviour adaptation. In an experiment devoted to cows adjusting to computerised concentrates feeders, in each subsequent observation within a 3-months period the cows' visiting activity was significantly lower than in previous observations (Collis, 1980).

One reason for the incomplete understanding of cows' behavioural responses to feeding routines may be methodological. The literature on visiting behaviour describes behaviour mainly in terms of the mean number of visits to feeders per cow per 24 h or during particular hours of the day. This measure does not necessarily reflect the complex structure of the cows' visiting patterns, particularly under cycled feeding through computerised concentrate feeders. In this paper a set of parameters was used for more adequate presentation of changes in the timing and intensity of visits. In particular, visiting behaviour is considered as alternation of periods of feeder's attendance and non-attendance. This approach is based on a description of cows' behavioural pattern as a consequence of uninterrupted spells (bouts) of feeding, rumination and other activities (Metz, 1975).

This work examines the process of dairy cows' feeding and visiting behaviour adaptation to a new cyclic fixed-time feeding routine. The routine deserves attention for a number of reasons. The adaptation to "cyclic" feeding requires a more complex and structured response from the cows. More natural criteria for adaptation may be proposed with this routine (e.g., cows either use or do not use each or any of the proposed feeding opportunities). The cyclic routine is convenient for studying the cows' visiting behaviour, which often does not coincide with feeding as such. Last but not least, the study of cows' adaptation to proposed feeding cycles has an applied significance for ensuring regular attendance at automatic milking station (Devir et al., 1993; Livshin et al., 1995).

Because of large differences in the visiting patterns and feeding strategies of individual cows, we did not intend in this paper to describe individual patterns, but remained mostly in the framework of averaged herd data. The data on individual cows are used generally to highlight the changes in timing of individual cows' visits.

MATERIAL AND METHODS

Animals and management

The trials were performed during January-May, on a commercial farm with approximately 50 (from 49 to 55 in different observation periods) Israeli Holstein cows (average milk yield, 28 kg/d). The cows were milked twice daily, at 05.00 to 05.30 h and at 17.00 to 17.30 h. At about 07.15 h, hay (lucerne and vetch) was distributed, and the cows were locked at the feeding bunk for veterinary inspection until about 08.00 h (except for period V in trial 2). At about 14.00 and 21.30 h, maize silage was distributed. The rectangular (12 x 25 m) corral-type shed has a feeding manger along one of the larger fenced sides. The concentrate feeding station was located at the centre of the feeding area, 5 m from the manger, and included three feeders with minimal (100 mm) partition between feeding stalls. Concentrates were fed only through the feeding station. The average allowance was approximately 10 kg/d per cow and ranged from 3 to 18 kg/d according to milk production. Concentrates were delivered at a rate of 300 g/min.

Treatments

The concentrate feeders dispensed the daily ration in four equal 6-h FW (opened at 24.00, 06.00, 12.00, and 18.00 h) as a standard routine for 2 years. Daily allowances were distributed equally between FW, and non-consumed feed was transferred to the following FW. After a series of measurements within this routine (Trial 1), the feeding routine was changed to six equal 4-h FW (opened at 24.00, 04.00, 08.00, 12.00, 16.00, and 20.00 h), with no routine-related changes in the daily allowance of concentrates (Trial 2). In the FW 04.00-08.00 h the new feed allotments were 15% of the daily allowances, and in all others FW – 17% of the daily allowances. There was no attempt to prolong light hours artificially.

Measurements

The self-feeders (Fulwood; Ellesmere, Shropshire, England) were served by software (S. A.E. Afikim, Kibbutz Afikim, Israel) used to monitor visiting behaviour. This software are supplying the primary data on visiting behaviour – time, duration, and allotment of concentrates of each cow's visit to each self-feeder. The duration of the visit was defined as feeding stall occupancy time. It was recorded as the period when the cow rear leg with identification tag was in the stall. Hence, the "in" was recorded only when the cow was completely in the stall.

Variables investigated

To highlight the changes in cows' feeding and visiting patterns in the process of adaptation to the new feeding routine, we used an expanded set of behaviour adaptation criteria that characterised feeding/visiting timing and intensity. All of the criteria were computed on the basis of primary data supplied by the software used.

(a) Variables describing the timing of feeding/visiting events:

1. FW attendance by individual cows,
2. completeness of FW allowance consumption by the herd,
3. herd feeding density within FW. The feeding density was defined as cumulative feed consumption by cows for a given time from the FW start,
4. number of different cows that attended the concentrate feeding station at particular hours of day. The intention was to determine cows' adaptation to the starting time of new FW and to feed non-availability in the starting time of abolished FW. For this purpose, the 1 h intervals studied were 16.00-17.00 h and 18.00-19.00 h – the first hour of the new 4 h FW 16.00-20.00 in Trial 2, and the first hour of the 6 h FW 18.00-24.00 in Trial 1.

(b) Variables describing the visiting behaviour intensity:

1. general number of visits. A visit was defined as a cow's attendance at one of concentrate feeders; several recorded visits of the same cow to the same feeder were counted as one visit if (i) the interval between recorded visits was less than 5 min, (ii) the cow did not visit any other feeder between the recorded visits to this feeder, and (iii) there were no visits by other cows at the same feeder between this cow's recorded visits,
2. vector measure the alternation of attendance and non-attendance periods. The choice of this measure was based on the proposition that visiting patterns may be described more adequately as alternation of feeding station attendance and non-attendance periods of different length. Therefore, as measures of visits' intensity were used mean diurnal number of individual cows' visits to the concentrate feeding station after different periods of feeding station non-attendance by the same cows. This measure may also be interpreted as the mean diurnal number of different intervals of concentrate feeding station non-attendance by the individual cows. The non-attendance periods were classified as repeated feeding attempts (<0.5 h), intermediate non-attendance (for 0.5-4 h), and prolonged non-attendance for more than 4 h (which was the FW duration in Trial 2).

Observation periods

The following series of measurements were taken:

Trial 1: seven 24 h measurements within 30 d.

Trial 2:

period I: Day 1 (24 h)
period II: Days 5-6 (48 h)
period III: Days 11-13 (72 h)
period IV: Days 19-23 (120 h)
period V: Days 89-93 (120 h).

For technical reasons, complete diurnal data for periods IV and V were available for only 3 d in each period. The mean values for separate FW in Trial 2 periods IV and V were counted on the basis of all data available, which were: FW1 – 3 d data for period, FW2 – 4 d data for period,; FW 3 to 5 – 5 d data for period, and FW6 – 4 d data in period IV and 5d data in period V.

Because of the routine changes in the herd during the 5-months study, the data on visiting activity were analysed and compared for 32 lactating cows that were present in Trial 1 and at all observation periods of Trial 2. From these cows, 12 were in the first lactation, 11 in the second and 9 in the third or later lactation. For the self-feeders workload analysis, all cows present in the barn were included.

The proportion of "constant" cows in the herd was between 60 and 70% in the different observation periods (Table 1).

The differences between averages were evaluated by a paired t-test.

RESULTS

Feed consumption

On the herd level, concentrates' consumption within all FW excluding one was in accord with the programmed distribution from the first day of introducing the new feeding routine: the underfeeding did not exceed several percentage units. The exception was the new FW 04.00-08.00 h, where the consumption became satisfactory (underfeeding less than 5% from allotments) after 20 d, and complete consumption of feed allotted was registered only after 90 d. The amount of concentrates not consumed in one FW of the new routine was consumed in the following ones. As a result, the concentrates allocation was consumed daily by all cows from the first day after the new feeding routine was introduced, and on the same level as that of the old routine.

Visiting behaviour intensity

On the most aggregated (and conventional) level of analysis, the cows' visiting activity, as reflected by mean diurnal number of all visits (rewarded and non-re-

TABLE 1

Average concentrates consumption (CC) per animal, and self-feeders usage per kg concentrates consumed in different observation periods

Trial/ Period[1]	32 constant cows			Others cows			Herd total		
	Group size, % of herd	CC, kg/cow per day	Time in SF, min:sec per kg	Group size, % of herd	CC, kg/cow per day	Time in SF min:sec per kg	Cows number	CC, kg/cow per day	Time in SF, min:sec per kg
Trial 1	59.3	11.7	05:16	40.7	8.5	05:37	54	10.4	05:23
Trial 2/I	65.3	11.9	05:44	34.7	8.6	06:07	49	10.8	05:50
Trial 2/II	65.3	12.2	05:42	34.7	9.4	05:26	49	11.2	05:38
Trial 2/III	65.3	11.9	05:46	34.7	8.7	05:25	49	10.8	05:38
Trial 2/IV	59.3	11.9	05:55	40.7	8.4	05:15	54	10.5	05:42
Trial 2/V	58.2	10.7	05:33	41.8	13.1	04:45	55	11.7	05:11

[1] Trial 2 observation periods: I – first day of feeding routine change; II – after 5 d, III – after 10 d, IV – after 20 d, and V – after 90 d of feeding routine change

warded), increased by 29.7% in relation to the level of Trial 1 on the very first day the new feeding routine was introduced. The peak activity was observed in period II (after 5 d): a rise of 50% compared to the level of Trial 1, i.e., strictly proportional to the increase in the diurnal number of feeding opportunities. Later, the total number of visits was reduced consistently and after 90 d it was 119% of that in Trial 1.

There was a drastic increase in the number of short-interval successive visits, and a substantial decrease in number of long-interval successive visits. The mean diurnal number of repeated feeding attempts after non-attendance for less than 0.5 h initially increased 1.8 times in relation to Trial 1, but towards the last observation period was only non -significantly higher than with 6 h FW in Trial 1 (Figure 1). When calculated per FW, the number of such visits in Trial 2 decreased consistently from the peak value (119% of the mean value of Trial 1) 5 d after routine change – to the lowest value (76%) in the last observation period.

The total number of visits after non-attendance between 0.5 and 4 h increased approximately 60% immediately after introduction of the 4 h FW, and remained quite stable thereafter (Figure 1). However, the more detailed comparisons showed that this stability was a result of a stepped change in visiting intensity within this interval. Up to 10 d after routine change, there were (i) a further increase in the number of visit intervals of 0.5-2 h and (ii) substantial decreases in the number of visit intervals

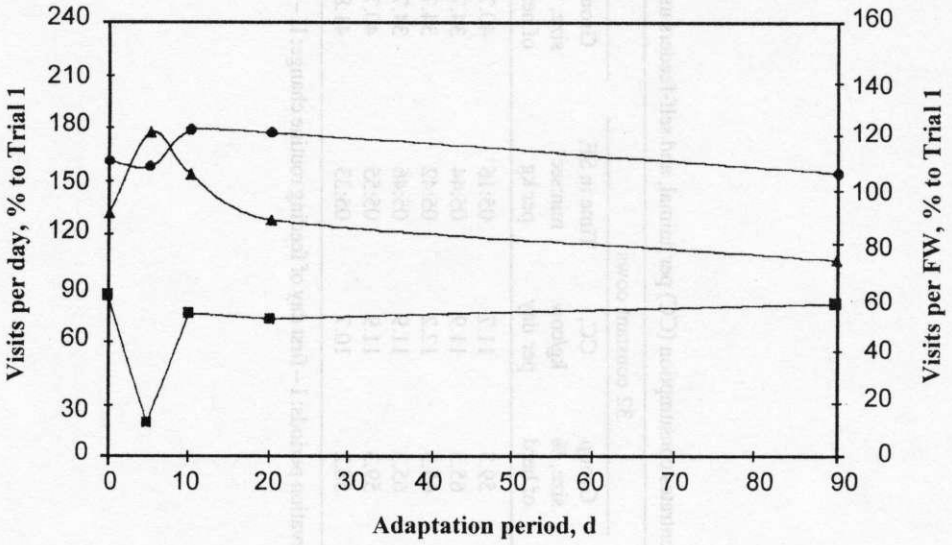

Figure 1. The diurnal number of visits (mean per cow) after different periods of non-attendance to concentrate feeders under six diurnal 4 h feeding windows (FW) (Trial 2) as percent of that recorded under four diurnal 6 h FW (Trial 1). Data for the same 32 cows in both trials. Non-attendance periods: ▲ – <0.5 h, ● – 0.5-4 h, and ■ – more than 4 h

of 2-4 h. After that, the number of visits (all intervals) reached the common point of ~ 160% of the Trial 1 level. Accordingly, per FW, the differences did not exceed 10% of Trial 1 level. It indicates also that the proportion between the number of visits after non-attendance intervals of 0.5-1 h, 1-2 h, 2-3 h and 3-4 h was rather steady between Trial 1 and after a 3-months adaptation in Trial 2 (1:1.5:1.5:1, respectively).

To analyse the effects of previous feed availability timing on the adaptation to a new routine, the visiting behaviour intensity of all six new FW in Trial 2 was compared with that in the same 4 h intervals in Trial 1. For the first 10 days after routine change, in all six new FW the cows demonstrated a fluctuating overshoot of visiting intensity in comparison with that of the corresponding duration of Trial 1. Between periods IV and V the differences in visiting intensity were small. In all FW, period V visiting intensity reached a level equal to or higher than that of the corresponding duration of Trial 1.

Timing of visits

Feeding windows' attendance. The maximal level (7%) of diurnal non-attendance for a 4 h FW was in period I (first 24 h of feeding routine change). In this period, highest non-attendance (almost 20% of the cows) was recorded in FW 04.00-08.00 (Table 2), after which it decreased gradually to a minimal value of 2.5% in period IV; in period V, the non-attendance level was almost double compared to period IV.

TABLE 2

Percent of non-attended cows under the feeding routines with 6-h (Trial 1) and 4-h (Trial 2) feeding windows. Data for the same 32 cows in both trials

Trial 1		Trial 2					
FW		FW	Observation period[2, 3]				
			I	II	III	IV	V
n[1]	7		1	2	3	3-5	3-5
00.00-06.00	2.15	00.00-04.00	0.00	1.61^{a}	4.30^{a}	2.15^{a}	7.61^{b}
06.00-12.00	3.23	04.00-08.00	19.40	11.30^{a}	12.90^{ab}	7.53^{ac}	6.52^{ac}
12.00-18.00	0.00	08.00-12.00	12.90	8.06^{a}	2.15^{b}	0.00^{c}	3.26^{ab}
18.00-24.00	2.15	12.00-16.00	3.23	0.00^{a}	3.23^{b}	2.15^{b}	5.43^{c}
		16.00-20.00	6.45	1.61^{a}	2.15^{a}	3.23^{a}	2.17^{a}
		20.00-24.00	0.00	8.06^{a}	4.30^{b}	2.15^{b}	2.17^{b}
24-h total	1.88		6.99	5.11^{a}	4.84^{b}	2.87^{b}	4.53^{b}

[1] n – number of observation (days)

[2] Trial 2 observation periods: I – first day of feeding routine change; II – after 5 d, III – after 10 d, IV – after 20 d, and V – after 90 d of feeding routine change

[3] significant differences between observation periods marked with different superscripts ($P<0.10$; paired t-test)

Feeding density

In the FW without milking, there was basically the same feeding pattern in all observation periods from the first day of new routine introduction. The cows consumed 36.7±1.5 percent of the total FW amount in the first FW hour, another 31.1±1.7 percent in the second and about 21.8±1.7 percent in the third hour. So, about 90 percent of feed was usually consumed within first three hours of 4 h FW. In the FW that had the same starting time as in Trial 1, the adaptation was more rapid than that recorded in the FW that did not include a previous routine's timing. There was a strong influence of milking time on concentrates consumption in the two FW that were interrupted by milking. Nevertheless, in the 16.00 FW the adaptation pattern until milking was very similar to that of all other FW. The 04.00 FW was the exception (because of the hour it opened; Livshin et al., 1995) although signs of similarity with the other FW adaptation patterns could be observed here too.

The feeding density patterns in FW of Trial 2 with the same starting time as in Trial 1 were similar to those of Trial 1, with the difference of lower consumption during the last hour of the 4 h interval. This was probably due to the fact that the concentrates allotment of each 4 h (new) FW was smaller than that of the 6 h FW of Trial 1.

The FW where visiting intensity developed a consistent pattern soon after change, i.e. the FW starting at midnight, noon, 16.00 h and 20.00 h, were also those in which regularity in concentrates consumption was achieved earlier after a change in routine.

Attendance at feeders at the start of new FW

Table 3 compares the number of different cows attending the concentrates feeding station in the first and third hours of the new FW 16.00-20.00 h, in Trial 2. In Trial 1 these 1 h intervals were the fifth hour of the 6 h FW 12.00-18.00 h and the first hour of the 6 h FW 18.00-24.00 h, respectively. In the interval 16.00-17.00 h, the average number of cows that attended a concentrates feeding station was about the same in both trials; however, whereas in Trial 1 only 14% of the cows were rewarded, all of them were rewarded in Trial 2. There were no non-rewarded cows during 18.00-19.00 h in Trial 1, whereas in Trial 2 the number of non-rewarded visits reached a peak in period III and declined toward period V (Table 3). Self-feeders idle time in 18.00-19.00 h, increased from period II through IV. The decline in idle time in period V was the result of the increased number of cows in the group between period IV and V (Table 3). Analysis on the individual cows level shows the drastic changes in regularity of attendance at feeders (Figure 2). For 5 d in Trial 1, 12 cows (37.5%) did not visit the feeders in this time interval or visited it only once, and five cows (15.6%) visited it 4 or 5 times (Figure 2A). For 5 d in the

TABLE 3

Mean number of different cows attended the concentrate feeding station and feeding station idle time in one hour intervals 16.00-17.00 and 18.00-19.00 under four 6-h (Trial 1) and six 4-h (Trial 2) diurnal feeding windows. Attendance data are for the same 32 cows in both trials

		Trial 1	Trial 2				
			Observation period[2]				
			I	II	III	IV	V
16.00-17.00	n[1]	7	1	2	3	5	5
Attended cows							
– total		15.5	16	14.5	16.7	17.2	19
– non-rewarded		13.8	0	0	0	0	0
Feeding station idle time, %		50.8	14.3	7.5	5.6	8.2	7.7
18.00-19.00	n[1]	7	1	2	3	5	5
Attended cows							
– total		11.7	13.0	21.0	23.7	18.0	18.3
– non-rewarded		0	8.0	14.0	16.7	12.2	11.3
Feeding station idle time, %		4.7	42.1	9.7	27.8	32.1	15.1

[1] n – number of observation days

[2] Trial 2 observation periods: I – first day of feeding routine change; II – after 5 d, III – after 10 d, IV – after 20 d, and V – after 90 d of feeding routine change

last period of Trial 2, seven cows (22%) made no more than one attendance and 14 cows (44%) attended feeders very regularly. This situation evolved through a stage (period IV) when 50% of the cows had 2-3 attendances in 5 d and only 31% of the cows visited the feeders very regularly during this hour.

To study the "dominance" factor, which seems very relevant for an analysis of visits to feeders in the first hour of an FW, when access is more difficult than at the end of a FW, the cows were divided into two groups. The first group consisted of 15 cows, which had rewarded visits in 16.00-17.00 h in Trial 1. Such cows can be considered as less dominant, under the assumption that a reward visit in the fifth hour of 6 h FW means that the cow did not compete previously in this FW for access to feeders or that its attempts were rebuffed. After excluding these cows, the changing attendance level for the rest of the cows was expressed more clearly: in Trial 1 only one such cow attended the feeders in this time interval very regularly (on 4 or all 5 days of a 5 d observation period), whereas in Trial 2 after 20 d adaptation there were eight such cows (47%), and after 90 d – 11 cows (65% of the group) (Figure 2B).

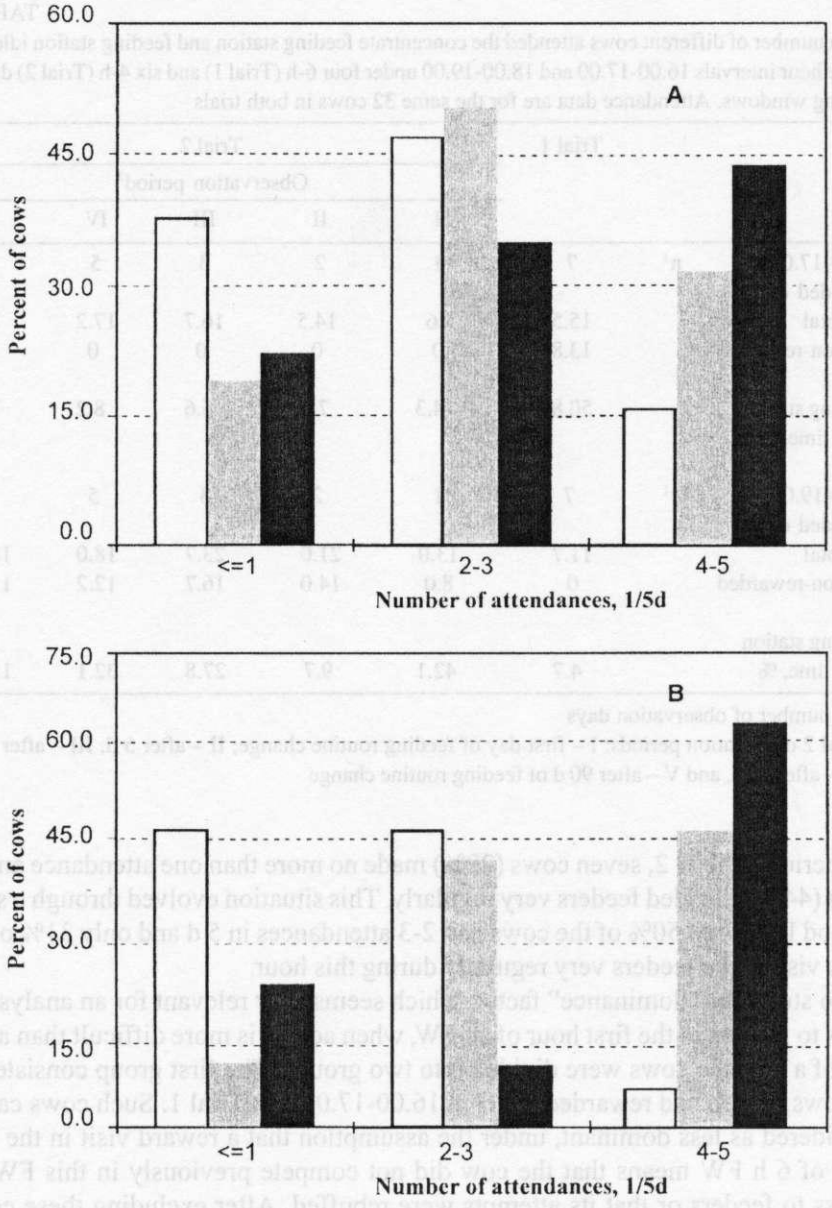

Figure 2. Attendance at feeders by cows during a 1 h interval (16.00-17.00 h) on 5 days under four diurnal 6 h feeding windows (FW) (Trial 1 – empty bars) and each of two last observation periods under six diurnal 4-h FW of Trial 2 (grey bars – 20 days after change; black bars – 90 days after change). This 1-h interval was the fifth hour of FW 12.00-18.00 in Trial 1 and the first hour of FW 16.00-20.00 in Trial 2. Data for the same 32 cows in both trials (A), and for 17 cows which in Trial 1 had no rewarded visits during this hour (B)

Adaptation process: Case study

Figure 3 illustrates the adaptation process of an individual cow, which in Trial 1 had consumed concentrate most often immediately after feed became available at the beginning of each FW. Number and starting times of visits to feeders after non-attendance for 30 min or more describes the cow's visiting pattern. In other words, repeated visits with intervals less than 30 min were combined with previous visits.

In Trial 1, the main features of this particular visiting pattern were (Figure 3A):

- feedings started very close to the time of feed availability, very often – immediately after FW start, and
- there were few non-rewarded visits (on average, less then one visit daily), most of which were prefeeding visits related to the FW starting at 12.00, when this cow tended to wait in the vicinity of feeders.

After 10 d of new feeding routine introduction (Figure 3B), the visiting patterns remained still unchanged in relation to previous time of FW starts, i.e., midnight, 06.00, 12.00 and 18.00 h. From the four new FW starts (04.00, 08.00, 16.00 and 20.00), the cow was reacting typically only to feeding opportunity at the 16.00 FW (on two from three observation days, she consumed the concentrates strictly after this FW starts).The feed allocations that were available at 04.00 h were consumed twice at 06.00 h – this cow usual feeding time in Trial 1. The allotments available at 08.00 and 20.00 were consumed after 1 h or more of availability. Nevertheless, all FW allotments were consumed within the same FW when they were available. There was a sharp increase in visiting activity in relation to Trial 1: besides the 50% rise in number of rewarded visits – related to the programmed increase in number of feeding opportunities from four to six daily, there were 11 non-rewarded visits within 3 d, a rise of 4.3-times in relation to Trial 1 per day, or of 2.5-times per FW.

After 90 d of adaptation (Figure 3C), this cow feeding behaviour pattern returned to that of Trial 1 – consumption of feed as soon as it became available at all diurnal feeding cycles, including new FW starting at 04.00, 08.00, 16.00 and 20.00 h. Visits to feeders around 06.00 and 18.00 h ceased, but the number of non-rewarded visits remained rather high.

DISCUSSION

Our observations and analysis were conducted under conditions of animals movement through the herd because of drying off and calving, which is the normal routine in this (and any other) dairy. Besides, because lactation is a physiologically dynamic process, cows "changed" along it. Therefore, our results are liable to be criticized on the grounds of "the lack of standard conditions". However, feeding in general, and concentrates consumption by dairy cows in particular, have a strong

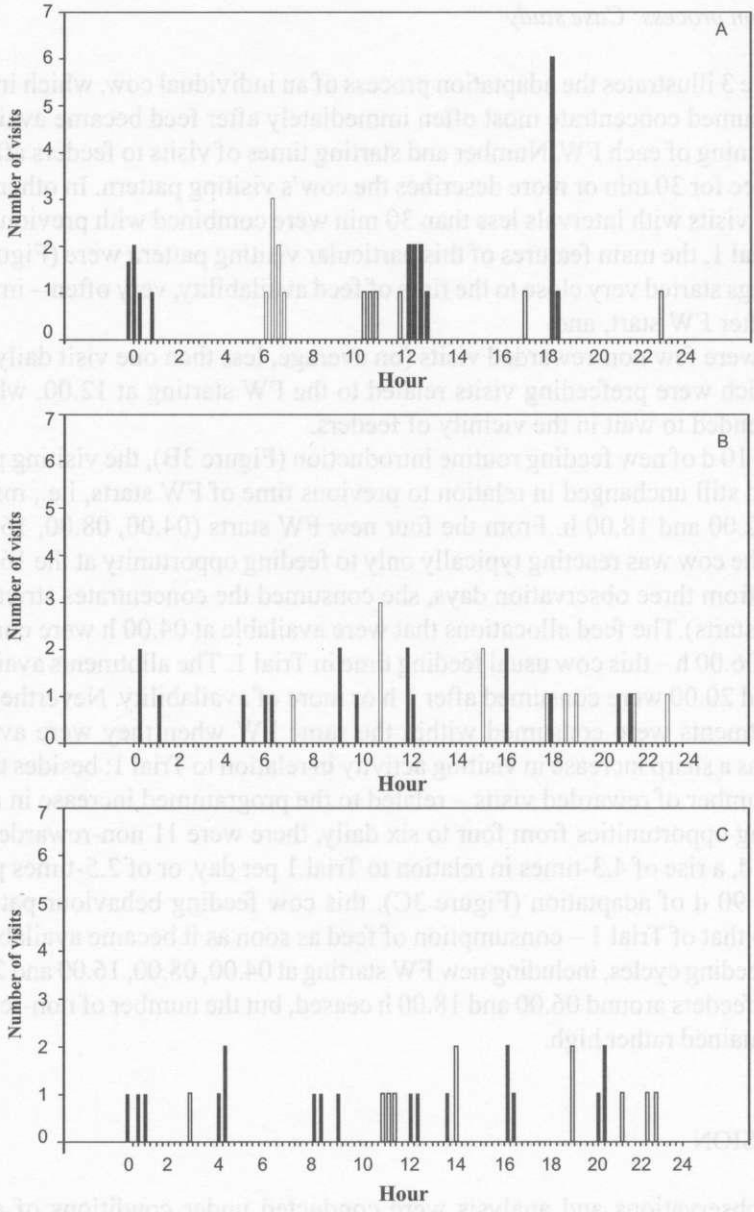

Figure 3. Case illustration. Cow #77 visiting patterns under four 6 h (Trial 1) and six 4 h (Trial 2) diurnal feeding windows. The cow's visiting pattern is described by number and starting times of visits to feeders. Data on repeated visits after non-attendance of less than 30 min were combined with previous visits. A – 7 d data for Trial 1; B – 3 d data for Trial 2, period II (after 10 d adaptation); and C – 3 d data for Trial 2, period V (after 90 d adaptation). Filled bars – rewarded visits; empty bars – non-rewarded visits

enough driving force to assume persistency even when the cow undergoes natural physiological and social changes. In any case long time observations and trials in lactating dairy cows at different stages of lactation involves cows drying off hence reducing the number of cows in the group. One should always consider, under these circumstances, the effect of reduced number animals in the group in comparison of maintaining the group size by replacing cows. The new cows that entered the herd during the experiment were familiar only with the current feeding routine. It can be assumed that they were balancing rather then disturbing agents.

The cows' adaptation studied can be viewed as a process with two main stages. The first stage is of increasing the intensity of visits while figuring out the new routine. The sharp rise of visiting activity was observed from the very first day of change, including FW with old starting times. On this stage, observing rewarded attempts of exploration by other cows is likely to be the main factor in timing the cows' visits to newly timed feeding opportunities. Continuous herd feeding after the start of different- timed FW during periods I and II of Trial 2 (up to 5 d) are the outcome of this kind of events.

On the second stage, cows are abandoning the old routine visits and reducing the probative ones, whereas the visits properly timed to the new routine become regular.

The data suggest that this is a one-way adaptation process if the new routine remains stable and undisturbed for a long time. At the end of Trial 2, the cows adapted mostly the same type of visiting behaviour as in Trial 1: the visiting pattern in each FW of the six-FW routine was similar to that of each FW in the four-FW routine, allowing for night time FW. This gradual process is expressed in both herd data and individual cows data. All this is relevant for conditions under which cows can identify the cyclic character of the routine. We assume that a smaller number of feeders would impose conditions under which cows would not be able to identify the timing of FW.

The first stage of adaptation was completed after ~ 20 d of the new routine; the second stage lasts much longer. The prolonged adaptation indicates that observation periods used in studies of dairy cows' visiting behaviour, should not be too short, as it sometimes occurs (e.g., 3-week data for each of different feeding routine in Wierenga and Hopster (1991a,b) or 1-month data in Livshin et al. (1995).

Milking is a significant factor in affecting cows' visiting behaviour to self-feeders. Cows feed after milking (Morita et al., 1996) and will try the self-feeders after leaving the milking parlour. Our results suggest that FW opening time should be related to milking time, since after milking cows will feed in the common bunk if the self-feeders are occupied, and seize the opportunity to consume concentrates once feeders become vacant. It may be better to start diurnal FW cycles from end of milking time rather then at midnight. When milking thrice daily it may be beneficial to sacrifice the FW duration evenness for FW opening time following milking. This

way cows will be able to accomplish feeding in a manner that may leave more time for laying and ruminating.

Robot milking is now a reality. Efficient utilization of this technology depends on "convincing" each cow in the group to visit the milking station in a desired frequency that may exceed the traditional twice or thrice daily. The cows are motivated to visit the milking station by the concentrates provided during milking and in the feeding area after passing the milking station when forced traffic is implied (Halachmi et al., 2000). Milking six times a day at transition time will effect lactation throughout (Bar Peled et al., 1995). Our findings show that cows can get accustomed to this frequency of visiting the feeding station. This was achieved when milking in the conventional milking parlor imposed a limited flexibility for FW design. When milking by robot this limitation is removed, and it is logic to assume that adaptability to FW timetable may be improved. We suggest that under milking robot condition the FW timetable will be dictated by the highest desired milking frequency. In this case only cows that have to be milked at highest milking frequency will be milked each FW visited. All the others, with lower milking frequency will be allowed to consume concentrates (either in the milking station or pass it in the feeding area) in each FW, but milked only in those that correspond with predetermined milking frequency.

The cows' adaptation process to the new feeding routine did not affect diurnal feed consumption from the first day it was imposed. The cows used every feeding opportunity proposed with the exception of the new FW 04.00-08.00 where satisfactory consumption of feed allotted was reached only after 20 d of adaptation. This FW is open at a time when feeder visiting is less intensive (Livshin et al., 1995; Morita et al., 1996), and adaptation proceeds more slowly (Wierenga and Hopster, 1987). The rise in number of feeding opportunities by reducing the duration of FW increases the possibility of missing a FW. Indeed, the number of cows that missed a FW increased, but still remained very low. Since non-consumed concentrates in a FW can be consumed in the successive ones (see Material and Methods), missing a FW will not necessarily affect daily consumption. Hence, the stable visiting patterns (in regard to visits timing and intensity), and not the consumption of the daily ration, may be the appropriate criterion of a cow's adaptation to a new feeding environment.

Our working hypotheses were that cows: (i) have high motivation to consume the available concentrates immediately (Wierenga and Hopster, 1991a), and (ii) are capable to learn the exact timing of feed availability or can establish it by observing results of other cows' visits (Livshin et al., 1995). So, it could be expected that cows will rebuild gradually their visiting patterns in accordance with new times of feed availability, and that their adaptation would be an one-way process, i.e. regularity of the feeding opportunities' usage would increase in the process of adaptation. From this point of view, the cow's initial response to an increase in the diurnal

number of allotments (for the same daily allowances) seems to be too enthusiastic – in relation to its spontaneity, and the size of increase in the visiting activity. The establishing a more "rational" level of visiting activity at the end of 3-month period was also accompanied by a reduction in the feeding opportunities usage and in the feeding station workload after FW start, and by an increase in the number of prolonged feeders non-attendances by individual cows.

It seems as if the cows initially have a more strong motivation to interact with concentrate self-feeders, which becomes weaker with time. Similar observations were made in investigation of inexperienced cows adjusting to computerised concentrate feeders under the "redundant" feeding routine: the frequency of visits reduced in time; the feeders initially causing strong competition, but, over a periods of weeks, the cows were increasingly willing to back out of the feeder even when concentrate was being dispensed (Collis, 1980). The most probable explanation may be that concentrate self-feeders are capable to satisfy not only the animals feeding drive, but other general needs, such as investigative behaviour and manipulation drive (Harlow et al., 1950). Some authors have argued that one of the problem facing animals in intensive housing system is "simple boredom" because there is little with which to interact (Tennessen, 1989). The concentrate self-feeders may thus be seen as a means for enrichment of cow house environments. From this point of view, an increase in the number of diurnal feeding opportunities may be simply an additional stimulus for cows in stimuli-barren environments. Such an interpretation explains the dynamics of observed visiting patterns.

The role of concentrate self-feeders for enrichment of cow house environments needs further investigations. Currently, behavioural aspects of computerised concentrate feeding are discussed mainly in relation to assuring satisfactory consumption of allotted feed by cows (Prichard and Estridge, 1988), or prevention of possible negative consequences, such as cows crowding or excessive visits (Pirkelmann, 1992). It seems that relevant consideration may be also the role of such systems as means for creation appropriate level of environmental complexity to prevent harmful deprivation and boredom, or aversive stimulation and fear (Hurnik, 1992). The highlighting of cows' behaviour under different design of such system may be helpful to improve animal wellbeing in the modern dairy.

CONCLUSIONS

Cows' behavioural adjustment to a new feeding routine with computerised self-feeders is a rather prolonged multistage process comprising changes in both the timing and intensity of visits. Initially, the emergence of additional feeding opportunities (introduction of more short feeding windows) creates an immediate response with an excessive level of feeding attempts. Gradually, the visiting activity stabilises

on a more "natural" (for this feeding environment) level, corresponding to the number and timing of feeding opportunities.

Stable visiting patterns, in regard to visits timing and intensity, may be the appropriate criterion of a cow's adaptation to a new feeding environment, in addition to consumption of the daily ration.

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STRESZCZENIE

Przystosowanie się krów mlecznych do zmian w komputerowo sterowanym systemie podawania paszy treściwej

Badano przystosowanie się krów do nowego sposobu dawkowania paszy treściwej przez skomputeryzowane karmidła w oborze przemysłowej typu zagrodowego w Izraelu. Wprowadzono nową zasadę podawania paszy w sześciu jednakowych dziennych cyklach, zamiast stosowanych uprzednio przez długi okres czterech dziennych cykli. Proces przystosowawczy badano przez 3 miesiące; dotyczył on czasu podchodzenia do żłobu i czasu pobierania paszy w 1 do 5-cio dniowych odstępach.

Dzienna dawka paszy treściwej była wyjadana od pierwszego dnia wprowadzonej zmiany. W ciągu kilku dni krowy rozpoczynały pobieranie paszy w nowo zastosowanym systemie – z wyjątkiem godzin nocnych. Jednak proces przystosowywania się do samoczynnych karmideł, na co składa się zarówno częstotliwość podchodzenia do karmideł, jak i czas pobierania paszy, przedłużał się. Początkowo aktywność zwierząt wzrastała, osiągając maksimum po 5 dniach. Po 3 miesiącach średnia liczba podchodzenia krów do karmideł po okresie ich zamknięcia od 0,5 do 4 godzin była 1,5 raza większa niż w poprzednim systemie żywienia – wzrost był proporcjonalny do zwiększenia dziennych cykli odpasów. Zwiększeniem tylko częstotliwości podchodzenia do karmidła nie wyjaśnia adaptacja krów do nowego systemu żywienia. Adaptacja polega z jednej strony na stopniowym zapoznaniu się z nowym czasem odpasu, z drugiej – zaniechaniem uprzednich nawyków.

Stały układ, obejmujący czas podchodzenia do karmideł i długość przebywania przy żłobie i pobierania dziennej dawki paszy, mogą być właściwym kryterium przystosowania się krów do nowych warunków żywienia.