BEHAVIOUR OF DAIRY COWS UNDER MODERN HOUSING AND MANAGEMENT

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STELLINGEN

1. De functie en de wijze van functioneren van sociale dominantie bij dieren zijn divers; dit leidt tot misverstanden bij onderzoekers en leken.
   (o.a. Bernstein, Behavioural and Brain Sciences, 4: 419-457)

2. Het regelmatig wisselen van dieren tussen groepen en het aanbrengen van afscheidingen - met name tussen eet- en ligplaatsen - in de ligboxenstal, hebben als nuttig neveneffect dat ze leiden tot een verhoging van de kansen van elk dier.
   (dit proefschrift)

3. Voor een optimaal gebruik van automatische systemen voor voeren en melken is - vergelijkbaar met de nu bestaande communicatie van de veehouder met zijn koeien - een goede communicatie van het systeem met de koeien van groot belang.

4. Beoordeling van het welzijn van dieren impliceert een beoordeling van de aanpassing van die dieren aan de wijze waarop ze gehouden worden. Daarbij dient naast het succes van die aanpassing ook de ten behoeve van die aanpassing geleverde inspanning betrokken te worden.
   (dit proefschrift)

5. De verzorger speelt een essentiële rol bij het welzijn van het gehouden dier; toch zou het dier het directe contact met die verzorger kunnen missen als kiespijn.

6. Iedere vorm van houden van dieren resulteert in een aantasting van hun welzijn; bij melkkoeien lijkt deze aantasting echter - gegeven het doel waarvoor de dieren worden gehouden - alleszins aanvaardbaar.

7. Door veelvuldige discussies heeft het begrip "welzijn" voor de diverse betrokken partijen een bepaalde betekenis gekregen welke gebruikt wordt bij de beslissing of een vorm van houden van dieren aanvaardbaar is of niet; discussies over de aanvaardbaarheid van houderijsystemen behoeven echter een betere ethisch-maatschappelijke basis.

8. De eisen die de consument stelt aan het welzijn van de dieren zijn zeker voor de individuele veehouder moeilijk vast te stellen. Een verbetering van de informatie-uitwisseling tussen producent en consument is daarom nodig.

9. Mede vanwege - ogenschijnlijke - verschillen tussen individuele en collectieve belangen van de veehouders, is een adequate regelgeving aangaande het welzijn van de dieren - op te zetten door bedrijfsleven dan wel overheid - noodzakelijk.

10. Onderzoek en beleid op het terrein van het welzijn van dieren dienen een economisch belang en zijn derhalve niet in strijd met de belangen van de veehouder.

11. Eventuele nadelige gevolgen van intensieve dierlijke produktie behoeven een fundamentele - op preventie gerichte - oplossing, teneinde een duurzame, veilige en concurrerende landbouw te kunnen ontwikkelen.

12. Door de toegenomen welvaart is de consument in de gelegenheid meer eisen te stellen aan de kwaliteit van produkten. Het welzijn van de dieren is zo'n kwaliteitsaspect. Bij een eventuele afname van de welvaart kan de aandacht voor het welzijn van de dieren weer afnemen.

13. Volgens het Nieuw Burgerlijk Wetboek staat het dier juridisch nog steeds gelijk aan een "niet levend stoffelijk object". In aansluiting op een eventuele aanvaarding van de Gezondheids- en Welzijnswet voor dieren zou dan tevens wettelijk vastgelegd moeten worden dat een dier iets anders is dan een ding.

14. Een goede organisatie - van welke aard dan ook - besteedt niet alleen aandacht aan de externe public relations doch ook aan de "interne p.r."; een organisatie functioneert eerst goed als ook de interne communicatie goed is.

15. De huidige snelle en wereldwijde informatievoorziening heeft als bezwaar dat de variatie in humane leefgewoontes afneemt en dat de kans kleiner wordt dat zich in korte tijd lokaal een nieuwe cultuur ontwikkelt; snelle informatievoorziening beperkt de culturele evolutie.

16. De ontwikkelingen op het terrein van de genetische modificatie maken het des te belangrijker dat een organisatie als de "Stichting Zeldzame Huisdierrassen" zich inzet voor het behoud van bestaande huisdierrassen.

Stellingen behorende bij het proefschrift van H.K. Wierenga, "Behaviour of dairy cows under modern housing and management", Wageningen, 14 juni 1991.

H.K. Wierenga

Behaviour of dairy cows under modern housing and management

Proefschrift
ter verkrijging van de graad van doctor
in de landbouw- en milieuwetenschappen,
op gezag van de rector magnificus,
dr. H.C. van der Plas
in het openbaar te verdedigen
op vrijdag 14 juni 1991
des namiddags te vier uur in de Aula
van de Landbouwuniversiteit te Wageningen

cover design: Ole Kortzau (DK) and Henk de Vries (NL); many thanks to Wil Rutten

Wierenga, H.K., 1991. Behaviour of dairy cows under modern housing and management. Thesis, Agricultural University, Wageningen. Also published as Report B-366 of the Research Institute for Animal Production "Schoonoord", Zeist.

The results of behavioural studies of dairy cows' behaviour under some modern housing and management conditions are presented. Social dominance in dairy cows is studied and methods to describe social dominance are discussed. The lying behaviour of dairy cows is studied under various conditions, including over- and undercrowding. In particular the significance of the cubicles for resting and for hiding is discussed. The behaviour of dairy cows when fed concentrates with an automatic concentrates feeding system is investigated. The cows' adaptation to such systems and the cows' strategy of timing of their visits to the feeding station is analysed. Finally, the costs and success of adaptation of the cows to their environment are presented and also discussed with respect to their welfare.

The work for this thesis was accomplished at:
Research Institute for Animal Production "Schoonoord", P.O. Box 501, 3700 AM Zeist, The Netherlands.

EEN WOORD VAN DANK

Dit proefschrift vormt een samenvatting van mijn gedragsonderzoek aan melkkoeien, wat ik in de periode 1977 - 1990 op het Instituut voor Veeteeltkundig Onderzoek "Schoonoord" heb verricht. Gedurende deze gehele periode hebben veel verschillende personen een onmisbare bijdrage aan dit onderzoek geleverd.

Graag wil ik de directie van het IVO, de leden van de Werkgroep Huisvesting en Verzorging, de medewerkers van het proefbedrijf "De Bunzing", maar ook alle andere IVO-medewerkers dankzeggen voor de steun die ze op enigerlei wijze - direct of indirect - hebben geleverd aan dit onderzoek.

Verder wil ik als eerste met name Hans Hopster persoonlijk dankzeggen voor zijn bijdrage aan dit onderzoek. Zijn wetenschappelijke inzicht, zijn (computer-)technische vaardigheden, zijn grote inzet en loyaliteit hebben een evidente invloed gehad op de kwaliteit van het in dit proefschrift beschreven onderzoek. De proefopzet van de diverse experimenten en ook de verwerking van de gegevens kwam steeds tot stand na uitvoerig overleg met statistici. Ir. A.A.M. Jansen, drs. B. Engel, mw.ir. M.S.T. Stapel en W. Buist hebben zodoende een belangrijke bijdrage geleverd aan het onderzoek. De in dit proefschrift beschreven resultaten zijn gebaseerd op een zeer omvangrijke hoeveelheid gedragsgegevens. Bij de verzameling, maar ook bij de verwerking van deze gegevens zijn IVO-medewerkers, met name van het proefbedrijf "De Bunzing", en vele studenten - van diverse Agrarische Hogescholen, Landbouwuniversiteit, Universiteit Leiden - betrokken. Nadrukkelijk wil ik allen bedanken, die op deze wijze een onmisbare bijdrage aan het onderzoek hebben geleverd. In aansluiting hierop wil ik ook graag Jos Metz danken voor zijn bijdragen aan het beschreven onderzoek. Onze regelmatige contacten leidden tot diverse gezamenlijke activiteiten. Het resultaat van één daarvan is in dit proefschrift opgenomen.

Pas in een laat stadium vatte ik het plan op om het gedragsonderzoek aan melkkoeien ook in de vorm van een proefschrift vast te leggen. Een belangrijk motief voor mij was dat ik behoefte had aan een intensieve, gedegen wetenschappelijke discussie met een deskundige. Ik ben Piet Wiepkema erg dankbaar dat hij instemde met mijn verzoek om als promotor te willen fungeren. Als een strenge en veeleisende promotor was hij ten alle tijde bereid om een concept uitvoerig te bespreken en van suggesties voor verbetering te voorzien. Deze discussies hebben een onmiskenbare invloed op het eindresultaat gehad.

Aangeland in het stadium van het op deze wijze publiceren van het onderzoek, heb ik een onmisbare hulp van Elly Kroeze gekregen. Haar grote inzet en haar snelle en zeer betrouwbare wijze van werken betekenden telkens opnieuw een grote steun. Jackie Senior zorgde daarbij telkens voor een zeer nauwgezette correctie van de Engelse teksten. Alle figuren zijn van de hand van Henk de Vries.

Tenslotte wil ik nog graag mijn vrouw en kinderen - Annegreet, Elien en Roeli - danken voor hun bijdragen. Hun stimulering en ondersteuning op velerlei vlakken en op willekeuirige tijdstippen of dagen maakten dat ik daadwerkelijk als onderzoeker kon functioneren.

CONTENTS

1. INTRODUCTION

INTRODUCTION

When new systems for the housing or management of farm animals are developed, several criteria have to be considered. Roughly these could be divided into producers' and consumers' criteria (the consumers' criteria of course are also very relevant to the producer!). The producers' criteria include costs of equipment, labour costs, etc., but also, for example, the current state of technology and the animals' potential production in a system are essential. The consumers' criteria include, for example, the demand for a certain product and - increasingly - the quality of that product. Quality encompasses not only the sensoric quality (flavour) of the product but also the conditions under which the animals are kept. In recent years this latter aspect of quality - the animals' welfare - has become more and more important. Thus, it is important for both the producers and the consumers to have information about the animal: are they able to adapt to their housing and management so that they produce and feel well?

Traditional examples of information about the animal are its production level, its feed intake and its health. More recently, information about the behaviour of the animal is also being collected. The science of farm animal ethology has grown rapidly since the 1970s. Knowledge about the behaviour of farm animals was at first mainly gathered and used to discuss the animals' welfare. Studies of farm animal behaviour have played an essential role in the development of totally new - "alternative" - systems for housing and management with less welfare problems. Examples of alternative housing systems for laying hens, dry sows and veal calves were presented in De Wilt and Wierenga (1989). Gradually behavioural studies have now become an integral part of investigations into the development of new systems (one example is the development of automatic milking, see Ipema et al., 1988).

In this thesis the behaviour of dairy cows kept under modern housing and management conditions is studied. Several aspects of the cows' behaviour are discussed. Firstly, social dominance in dairy cows is analysed. Because dairy cows in a cubicle house are kept in a relatively small area - with lying places as well as eating places close to each other - social dominance could play an important role in, for instance, lying and eating behaviour. In particular, the influence of housing and management on social dominance is discussed. Secondly, the lying behaviour of dairy cows is analysed in detail. Dairy cows kept indoors lie down for about half of the 24-h period, which indicates that it is relevant to have information about this behaviour and about the influences of housing and management on it. The significance of cubicles for the cows is discussed in general, with special attention to the consequences of reduction in the number of available cubicles. Thirdly, the behaviour of dairy cows when fed with automatic concentrates feeding systems is investigated. These systems are relatively new and it is important (for both the producers and the consumers) to know how the cows adapt to such systems. Such information is also important in view of another new development: the milking robot. Because of similarities between systems for automatic concentrates feeding and for milking, the results of studies on concentrates feeding systems can also be used in the development of automatic milking systems.

Mainly the interaction between housing and management and the cows' behaviour will be discussed. However, the results of these investigations will also be discussed in terms of the dairy cows' welfare and can be used in the further development of housing and management. No attempt is made to translate the results into new conditions of housing and management which would fulfill both producers' and consumers' demands. This would need further research into the consequences of such modifications on the cost of equipment, labour demand, production, the animals' welfare and also into the response of the consumer.

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2. SOCIAL DOMINANCE IN DAIRY CATTLE AND THE INFLUENCES OF HOUSING AND MANAGEMENT

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Published in Applied Animal Behaviour Science 27(1990): 201-229.
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SOCIAL DOMINANCE IN DAIRY CATTLE AND THE INFLUENCES OF HOUSING AND MANAGEMENT

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ABSTRACT

Although there is much information available on social dominance in dairy cattle the concept is still regularly discussed. The results of four experiments with dairy cows, together with the relevant literature are used to discuss the influence of housing and management on social dominance. In total, seven groups of dairy cows kept in cubicle houses were studied.

Stable dominance relationships appeared to exist, but in 41.1 % of all pairs both members displaced each other. It is argued that the housing system (feeding rack and cubicles) and the management (crowding) greatly influence the occurrence of successful displacements by a subordinate cow ("contradictory displacements") and of other "aberrant" interactions.

The role of social dominance in the daily life of the dairy cow is discussed. The chances of a cow obtaining resources (e.g. food or a lying place) can only be predicted to a limited degree from her dominance value. Various "disturbing factors" (e.g. aberrant interactions, triangular relationships, individual variation in frequency and "direction" of interactions) affect such a prediction. These disturbing factors are the result of the housing and the management at the dairy farm. It is concluded that the described dominance value is the best available because possible alternatives are more difficult to obtain and no more useful.

INTRODUCTION

There is considerable information available on social dominance in dairy cattle. Brantas (1968), Sambraus (1969, 1975), Reinhardt (1973), Reinhardt and Reinhardt (1975) and Beilharz and Zeeb (1982) collected data under practical conditions. Bouissou (review: 1981) collected data under experimental conditions. Some years ago, the concept of dominance in dairy cows was discussed anew. The method for measuring social dominance and the interpretation of the results of Beilharz and Zeeb (1982) were challenged by Syme and Syme (1982/1983). Syme and Syme discussed the concept of social dominance and the methods used to determine the social position of an animal. They suggested that more detailed studies were needed.

The concept of social dominance was first proposed by Schelderup-Ebbe (1922). It seems surprising that there is still much discussion and some confusion about social dominance. The discussion may be partly due to the great variation in the social systems of different species and partly to the variation in the ways social dominance is measured (Hand, 1986). Often the method used for measuring social dominance is only described superficially. Furthermore, researchers seem to have different expectations of the role of social dominance in the lives of the animals. Bernstein (1981) summarized the existing views and tried to reduce the confusion. He proposed that dominance relationships between animals and the dominance order in a group of animals should be seen as two different concepts. For each animal in a group it is important to know its dominance relationships with each of the other members of the group. Bernstein (1981) suggested that the animals may have no knowledge about the relationships between other pairs in the group. This means that the animals have no overall "picture" of the dominance order within the group. Furthermore, Bernstein suggested basing the dominance relationships primarily on the aggressive interactions between the animals and not on the priority of access to certain incentives (e.g. water, food or a sexual partner), which are often assessed under experimental conditions.

The opinions of Bernstein (1981), Beilharz and Zeeb (1982) and Syme and Syme (1982/1983) need to be verified with detailed information. During experiments on the space requirements of dairy cattle, information was collected on the aggressive interactions between cows. These data permitted the analysis of dominance relationships and gave insight into the dominance structure and its relation with aggressive interactions in different groups of dairy cows. Both this information and information available from the literature will be used to discuss the concept of social dominance in dairy cattle.

MATERIALS AND METHODS

The animals and their housing and feeding

The investigation comprised four experiments carried out during four consecutive years. In the first three experiments two groups of dairy cows were available, in the fourth experiment data were collected on only one group. The groups varied between 15 and 20 animals (Figure 1). Some cows took part in all four experiments, others in three, two or only one of the experiments. The groups were formed at least one week before the start of observations. All the experimental animals originated from one large group. Between the experimental periods the cows may have been changed one or more times between different groups. During each experimental period all the cows were lactating and all were at about the same stage of lactation. The age-composition resembled a situation at a commercial farm; within each group the animals varied between 2 years (heifers) and 10 years old. The cows had been dehorned.

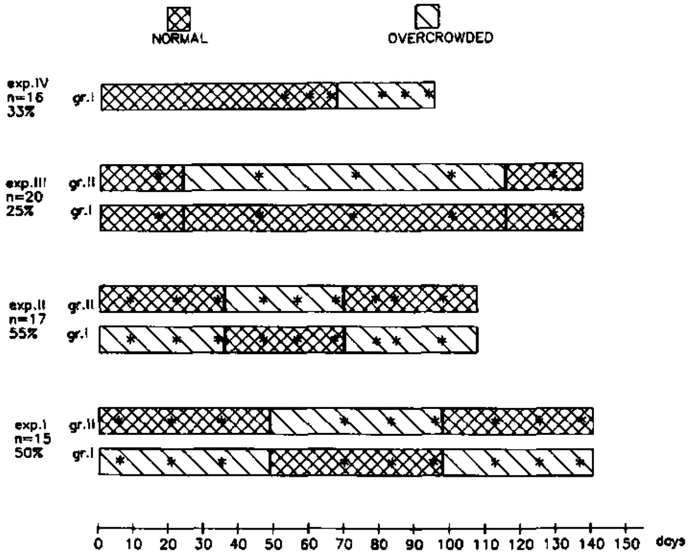

Figure 1. Experimental design. The duration (days) of the whole experiment and of each separate round is presented for each experiment (I, II, III, IV) and for each group (I, II). The day when a 24-h behavioural observation was carried out is also presented (* = 24-h observation, n = number of animals per group, % = level of overcrowding tested).

The animals were kept in cubicle houses, each comprising a row of cubicles, a feeding rack and a walking area with a concrete slatted floor. The animals were milked twice daily and fed roughage and concentrates comparable to normal dairy practice. Slight variations between the experiments, in particular in the feeding regime (ratio maize silage: grass silage: concentrates), will be neglected here since they are not relevant to the main topic of this paper.

Experimental design

The cows were kept both in normal and in overcrowded conditions. In normal conditions, there were feeding and lying places available for each cow in the group. In the overcrowded conditions, the number of feeding and lying places was reduced (at the same rate) and the surface area for walking was decreased in proportion to the reduction in the number of places.

In Experiments I and II two groups were kept alternately, during three successive periods, in normal and in overcrowded conditions (Fig. 1). In Experiment I an overcrowding of 50 % was applied; i.e. for 15 cows only 10 places were available. In the overcrowded conditions of Experiment II, 11 places were available for the 17 cows of each group (55 % overcrowding). In

Experiment III one group was kept permanently in normal conditions, while the other group was kept in normal conditions only for short periods at the beginning and end of the experiment. In the middle of the experimental period, there were 16 feeding and 16 lying places available for the 20 animals of this latter group (25 % overcrowding). In Experiment IV 16 cows were at first kept in normal conditions and then in overcrowded conditions, in which 12 places were available (33.3 % overcrowding).

Behavioural observations

aggressive interactions

Because this paper focuses on social dominance, only the collection and analysis of aggressive interactions is described in detail. Most of the data about aggressive interactions were collected by direct observations during 24-h periods. Supplementary observations were made during part of the day (= between morning milking and afternoon milking), during part of the night (= the last four hours before morning milking) and during a period of two hours directly after feeding of roughage. In the first three experiments, each group was studied by an observer; the observations of both groups were performed simultaneously, making a direct comparison between the two groups possible. In the four experiments, totals of 9, 9, 5 and 6 24-h observations were made respectively. The other observations were also distributed evenly over the experiments. In total, behavioural observations were carried out for 2014 h (2 x 385.5, 2 x 322.5, 2 x 202.5 and 1 x 193.0 h, respectively, for the four experiments).

The groups were always observed continuously. Every observed aggressive interaction was noted. For each interaction, both the cows involved (actor - the cow provoking the interaction - and reactor - the cow subjected to the provocation) were noted. Three different types of aggressive interactions were distinguished. (1) An aggressive interaction could be a displacement, i.e. a withdrawal (change of position) of the reactor caused by an approach, a threat or a butt by the actor. A displacement was only noted as such, when there was no doubt that the reactor responded to the actor. Possible spontaneous withdrawals by the reactors were neglected. (2) An unsuccessful butting was recorded when a butt was not followed by withdrawal of the reactor. (3) Penetration was noted when an animal forced its way between two cows at the feeding rack or alongside a cow which was standing in a cubicle. Unsuccessful butting and penetration are not analysed separately, but are considered together with contradictory displacements (see Results). About 40 % of the total observation time was spent during the first two hours after feeding, because feeding often results in an increased level of aggression. Thus, most of the recorded aggressive interactions took place at and around the feeding rack.

general activities

During the 24-h observations in each experiment the general activities of the cows were also recorded. At 10-min intervals each cow was recorded as eating, standing in the walking area or standing or lying in a cubicle. In this paper only data about time spent in the cubicles is presented, and its correlation with social dominance is analysed.

Analysis of data

The dominance relationship could be analysed for each pair of cows based on the recorded displacements. This was done separately for each experimental period and each group. For this analysis, displacements observed in both normal and in overcrowded conditions were considered together, since dominance relationships tend to be stable for a long period and are not readily influenced by the level of crowding applied in the present experiments (see Results). By using all the known dominance relationships within a group, a dominance value for each animal was calculated and the dominance structure of the group was determined.

The correlation (Pearson's correlation coefficient) between the dominance position and the number of aggressive interactions of an animal was also calculated. For this analysis, data collected in normal and in overcrowded conditions were treated separately and corrected for variations in total observation time. Thereby, a possible interaction between dominance, aggressive interactions and competition for an eating or a lying place (overcrowding) could be analysed. When the same experimental group was kept twice in the same conditions, all interactions recorded in these conditions were treated together. In this analysis, no distinction was made between the various levels of overcrowding; thus all "overcrowding" was compared with "normal".

The data and results of all the experimental groups were comparable in many respects and, therefore, the analysis is sometimes illustrated with the data from only one representative group (group 1, Experiment II).

Terminology

A brief description follows of the terms and definitions used in this paper.

A dominance relationship exists when, within a pair of animals, one animal (= the subordinate) defers to the other (= the dominant). Whether one animal defers to another can be defined in different ways; this is discussed later. In the present experiments dominance relationships are based on the observed displacements.

The dominance value of an animal in a certain group is the ratio of the number of subordinate animals to the total number of known dominance relationships of that animal.

The dominance structure summarizes all the (known) dominance relationships within a group in one diagram.

The dominance position of an animal describes roughly how many group-mates are dominated; an animal which dominates many group-mates has a high dominance position (= high-ranking animal), an animal which dominates only a few group-mates has a low dominance position (= low-ranking animal).

Social dominance is a general term used to express the phenomenon of the existence of (stable) dominance relationships within a group of animals.

RESULTS

Number of aggressive interactions and the distribution of displacements among the animals

In total, in the four experiments, 18,939 displacements, 934 unsuccessful buttings and 500 penetrations were observed. The number of displacements per experimental group - with a mean of 2705.6 - varied between 1875 and 3411. This variation was presumably due to variation in group size, variation between animals, to the level and duration of overcrowding, and to variations in observation time. For the analysis of dominance relationships, this variation in the total number of displacements does not matter, because the absolute number of displacements is not significant.

The displacements were used to determine the dominance relationships for all the pairs of animals within the same experimental group. Firstly the distribution of displacements for the pairs of animals within each group was analysed. Table 1 shows the distribution for group 1 of Experiment II. All the animals initiated displacing, but the displacements were not distributed evenly among all the animals. A comparable picture was found in the other groups.

For a group of 17 cows the displacements can theoretically be distributed over 17 x (17-1) = 272 different cells of a dominance-matrix, assuming that each member of a pair can both displace and be displaced by the other cow. If the observed displacements were divided at random over all the available cells, then 0.37 % of all the observed displacements would be expected in each cell. If, however, unilateral dominance relationships exist (one member of a pair performs all displacements and is never displaced by the other member) half of the available 272 cells should be empty. When the distribution of the displacements occurs evenly over the remaining 136 cells, one can expect 0.74 % of all observed displacements in each of those cells. Displacements were found in more cells than expected (assuming that

Table 1. Dominance matrix for group 1 of Experiment II. Horizontal: the number of times that a cow has displaced another cow (wins) and vertical: the number of times that a cow has been displaced by another cow (loses).

		Reactor (= loses)																	
		112	271	306	320	401	407	504	511	520	613	616	618	619	621	719	801	803	total
Actor	112	/	14	21	10	11	9	13	24	15	7	27	22	17	22	4	11	6	233
(=wins)	271	1	/	0	24	2	0	25	0	2	19	19	2	0	35	26	25	14	194
	306	0	32	/	17	0	1	40	25	36	0	22	42	27	38	25	23	14	342
	320	0	1	0	/	0	14	37	7	5	0	22	2	14	3	25	25	12	167
	401	2	17	15	18	/	12	14	19	0	0	10	14	13	18	3	8	6	169
	407	1	17	45	2	2	/	27	2	1	1	25	1	22	22	0	23	8	199
	504	1	3	1	3	3	1	/	0	4	18	44	6	35	50	25	39	16	249
	511	2	12	0	6	0	5	33	/	3	2	14	26	10	22	5	15	10	165
	520	5	15	0	11	10	14	28	19	/	0	12	4	14	28	15	17	6	198
	613	2	0	39	29	34	31	3	26	21	/	21	37	16	29	25	19	1	333
	616	0	1	0	5	0	0	1	1	0	1	/	52	12	1	1	18	12	105
	618	0	44	0	31	4	42	80	1	50	2	1	/	8	5	19	21	14	322
	619	0	30	0	1	0	0	3	0	1	0	2	15	/	30	19	11	9	121
	621	0	1	0	26	0	0	0	2	3	0	76	84	4	/	52	55	21	324
	719	1	0	0	0	0	9	0	1	0	1	7	0	0	2	/	11	0	32
	801	0	1	0	0	1	0	0	1	0	0	1	0	1	1	2	/	0	8
	803	1	0	0	0	0	0	0	1	0	8	0	0	1	1	1	10	/	23
Column total		16	188	121	183	67	138	304	129	141	59	303	307	194	307	247	331	149	3184

unilateral dominance relationships exist) in all the experimental groups. On average for the seven experimental groups displacements were found in 42.1 % more cells (varying from 30.0 % in Exp. III, group 1 to 51.5 % in Exp. II, group 1) than expected. This implies that not all dominance relationships are unilateral. The variation in the number of observed displacements per cell was small: the largest number of displacements of one animal provoked by an individual cow was 3.9 % of the total number of performed displacements recorded for that group (Exp. I, group 2). The large number of observed displacements provided data for all but 3 of the 982 possible pairs (no displacements were collected for one pair in Exp. I, group 1 and two pairs in Exp. III, group 2).

These results show that for almost every pair and for every group sufficient information about displacements is available. The collected data thus appear to be suitable for an adequate analysis of the dominance relationships between animals.

Dominance relationships, dominance value and dominance structure

dominance relationships are often not unilateral

It was shown above that in many pairs both members displaced each other. In total this occurred in 404 (41.1 %) of the 982 pairs. In 399 of these pairs the number of times that both animals had displaced each other differed (i.e. one animal had provoked at least one more displacement than the other); in 5 pairs both members displaced each other equally. Pairs in which both members displaced each other are called pairs with contradictory displacements, because these interactions are contrary to expectations, assuming unilateral relationships. All those pairs in which both members displaced each other needed to be examined in more detail to determine the dominance relationship. The distribution of the observed displacements for both members was analysed for each of these pairs. Both the difference in the number of displacements between the pair-members, and the total number of displacements are relevant. Information from these data are presented separately, but not combined because it is difficult to present the latter information in a condensed way. The chosen way of presentation of the data will prove to be sufficient. The information for all pairs (with or without contradictory displacements) and for only the pairs with contradictory displacements is given separately. Those pairs in which there was no difference in the number of displacements between both members were excluded from the analysis; 974 pairs (with and without contradictory displacements) and 399 pairs (with contradictory displacements) respectively, were analysed. The results are presented in Figure 2, which gives the mean of the seven experimental groups. This figure shows a difference of one in the

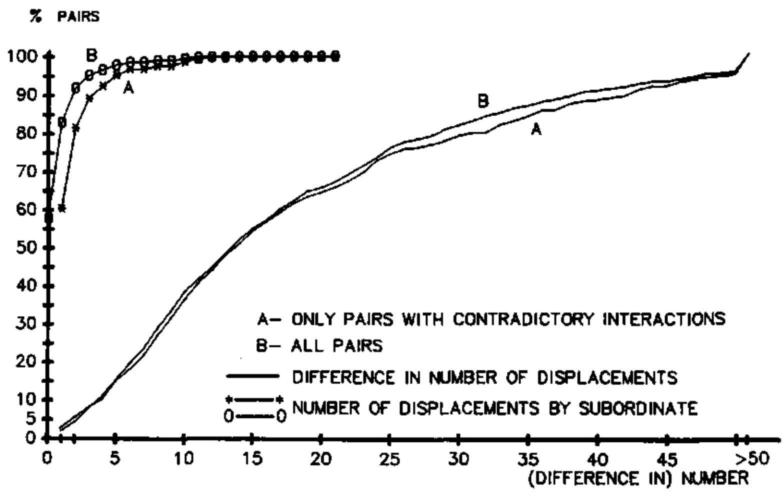

Figure 2. Cumulative frequency (% pairs) of the difference in number of displacements between both members of each pair of cows and of the number of displacements by the subordinate member of each pair. The mean for all seven experimental groups is presented. Both values are presented for a) only those pairs in which contradictory displacements have been observed, and b) for all pairs (including pairs without contradictory displacements).

number of displacements provoked by the pair-members for 2.1 % of all pairs and for 3.0 % of the pairs with contradictory displacements. A difference of two or less is shown for 4.5 % and 5.7 % of the pairs, respectively. A difference of three or more displacements thus occurs in 95.5 % and 94.3 % of the pairs, respectively. The curve rises rapidly showing that the difference in the number of displacements between pair-members is much larger than three in most pairs.

Figure 2 also shows the number of displacements provoked by the pair-member credited with fewer displacements (probably the subordinate animal). In 60.4 % of the pairs with contradictory displacements, this member provoked only one displacement and one or two displacements in 81.6 % of the pairs. In 95.2 % of these pairs this member provoked a maximum of five displacements. When all pairs (with and without contradictory displacements) are considered, the pair-member with fewer displacements provoked no displacements at all in 58.0 % of the pairs, and less than four displacements in 95.3 % of the pairs.

The similarity of the results for all pairs and for only those pairs with contradictory displacements is striking. For the distribution of the displacements, this implies that the pairs with contradictory displacements are not very different to the pairs without any contradictory displacements. Although contradictory displacements were observed in many pairs (41.1 % of all pairs), the total number of contradictory displacements actually recorded was not large (only 3.9 % of all recorded displacements).

To summarize: one pair-member generally provoked a considerably higher number of displacements while the other pair-member provoked few or none. In 95.5 % of all pairs the difference in the number of displacements between pair-members was three or more, and in only 4.7 % of all pairs did the subordinate member provoke four or more displacements. It seems most likely that the pair-member who provoked the higher number of displacements is the dominant animal. In most of the pairs the dominant animal provoked at least three more displacements than the subordinate animal. If the subordinate animal provoked any displacements at all, this was generally limited to one or two such contradictory displacements in most of the pairs.

It is possible that in those pairs in which both members displaced each other several times, the dominance relationship was changing during the course of the experiment. To check this theory, those pairs in which each member displaced the other at least four times during one experimental period (an arbitrarily chosen selection parameter) were examined. Only 43 such pairs were found in the experimental groups. The occurrence of all their displacements was traced and, thus, the order in which the displacements were observed during the experimental period. A dominance relationship was classed as changed when at least four displacements were provoked by one pair-member at the start of the experimental period and without interruption by a displacement by the other member. Thus, the displacements provoked by the previously subordinate member were observed towards the end of the period. Examples are given in Table 2 of the order of observation of displacements for some pairs. Only 3 out of the 43 pairs met the criteria for a changed dominance relationship (see Table 2). For the other 40 pairs there was no indication that the dominance relationship had changed during the course of the experiment. For 3 pairs out of the 40 it was still difficult to decide which pair-member was the dominant one, either because there was only a slight difference in the number of times that both cows displaced each other, or because both animals displaced each other throughout the experiment. In these 3 pairs a relatively low number of displacements was observed (12, 13 and 14 displacements, respectively, during the whole experimental period). In 37 pairs (86.0 %) there was no evidence that a change in the dominance relationship had taken place, although the subordinate member had displaced the dominant member several times.

Thus, for pairs with contradictory displacements it is generally not difficult to decide which is the dominant pair-member, even when the pairs perform a relatively high number of contradictory displacements. In the following analysis it is assumed that, within each pair, the animal with most displacements is always the dominant animal. Of course, such an assumption will sometimes be wrong. In particular, for those pairs in which the difference in the number of displacements between both members is only one or two, one could argue that the evaluation of which animal is dominant

Table 2. Some examples of pairs in which the dominance relationship has probably changed during the experiment or has obviously not changed, although both members displaced each other several times. Only the displacing animal (= actor) is given. All the observed displacements for the pair are presented; they are given in the original order of observation, irrespective of the elapsed time between them.

dominance relationship probably changed			dominance relationship unchanged		
pair: 607x614 (Exp.III, gr.1)	pair: 609x914 (Exp.IV, gr.1)	pair: 511x813 (Exp.IV, gr.1)	pair: 611x615 (Exp.I, gr.1)	pair: 320x616 (Exp.II, gr.1)	pair: 914x613 (Exp.IV, gr.1)
607	609	511	615	320	613
607	609	511	615	320	914
614	609	511	611	616	914
607	609	511	611	320	914
607	914	813	615	320	914
607	609	813	615	320	914
607	609	511	615	320	613
607	609	511	611	320	613
607	609	511	611	616	914
607	914	511	611	320	914
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614	609	813	611	320	914
614	914	813	611	320	914
614	609	813	611	320	914
614	609	813	611	616	914
614	609	813	611	320	914
614	914		615	320	
614	914		615	320	
614	914		611		
614	914		611		
			611		

and which subordinate, is doubtful. Because such pairs are uncommon (less than about 4.5 %), a wrong evaluation will have little effect on the following analysis.

stability of the relationships

In total 106 pairs of cows took part in the experiments more than once. It was therefore possible to analyse how often dominance relationships remained constant over a longer period. The experiments took place over a period of four years. Possible changes in dominance relationships can thus be determined over an interval of one, two, or a maximum of three years. It is not known exactly what happened to the cows in these intervals but, at least for short periods, the cows were kept in different groups. For some pairs, dominance relationships are known for each of these three intervals; for many pairs, information for only one or two of these intervals is available. It appeared that within an interval of 1 year, a change in dominance relationship was found in only 6.8 % of all the pairs. Within an interval of 2 or 3 years, a change in dominance relationship was found in 26.1 % and 23.8 % of the pairs, respectively. It can be concluded that most of the dominance relationships stayed constant not only within one experimental period but also over longer periods. Because detailed information is lacking (for instance about events between experimental periods or about the age of the animals) it is difficult to speculate about the factors which may have influenced the changes in each interval.

dominance value

Information about the dominance relationships between animals in a group gives insight into the position of each animal in that group. A matrix as presented in Table 1 is rather complex, so alternative methods have been developed to more easily describe the position of each animal in a group. One method which is often applied is to calculate a dominance value (d.v.). For dairy cows, Sambraus (1975) has suggested the following procedure:

$$d.v._{\text{cow A}} = \frac{\text{number of cows subordinate to cow A}}{\text{number of known dominance relationships of cow A within the group}}$$

This dominance value is used in this paper. It represents the (relative) number of animals which are subordinate to that animal. The value gives no information about the number of displacements that an animal takes part in, because only the "final result" of all displacements performed by both members of each pair is used.

In the preceeding discussion about dominance relationships, the question was raised if, for those pairs in which the difference in the number of displacements between both members was only one or two, a mistake could be made in evaluating which animal is dominant and which animal subordinate.

The possible consequences of incorporating such "doubtful" dominance relationships in the dominance value was tested. Dominance values were calculated: (1) with all the known data (only pairs in which both members displaced each other an equal number of times were excluded), and (2) with only those dominance relationships in which the dominant animal displaced the subordinate one at least 3 times. This was done for each animal in each experimental group. It was found that within each group the correlation between both types of dominance values was always high ($r_{d.v.}$ varied between 0.94 and 1.00), which means that - as expected - the dominance value hardly changed when all known relationships were considered compared to the dominance value based only on the "obvious" relationships. It was therefore decided to use a dominance value based on all the relationships.

In a previous paragraph it was shown that changes in the dominance relationship were rare during the course of the experiments. The dominance value was therefore calculated on the basis of all the displacements recorded, irrespective of the experimental rounds in which they occurred. Thus the records did not take into account whether the conditions were normal or overcrowded. To check whether it is justifiable to analyse all the recorded displacements together and ignore the variation in overcrowding, for Experiments I and II, which had the highest levels of overcrowding, a dominance value was calculated per cow, for each experimental round and for each group. It appeared that within each group the correlation between the dominance values in the subsequent experimental rounds always was high. The correlation coefficients (r) varied between 0.95 and 0.99. Thus, this analysis shows that the level of overcrowding did not affect the dominance relationships.

Because some of the animals took part in several experiments, it was possible to examine changes in their dominance value with time. For those animals which took part in the experiments for more than two successive years, Figure 3 shows how their dominance values changed with time. Since the age of a cow may be an important factor influencing changes in her dominance value, this figure shows the dominance value plotted against the age of the cow. In general, the dominance value of a cow increased during subsequent experiments, i.e. as the animal grew older. For some animals this increase of dominance value was evident, but there were other animals whose dominance value decreased over the years. Heifers did not always have a low dominance value. One heifer even had a dominance value of 0.714.

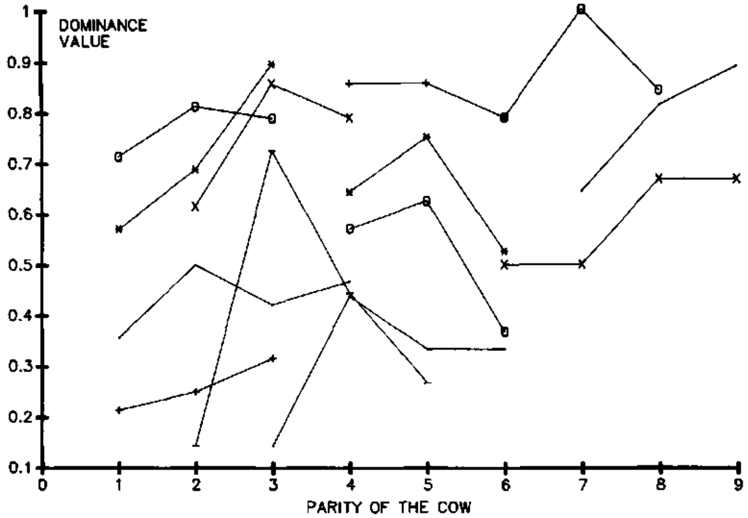

Figure 3. The changes in dominance value with time (represented as the parity of the animal) of 13 different cows which were observed during at least three experiments. Each line represents one cow.

dominance structure

Another method for summarizing the dominance relationships within a group is to construct a dominance structure. On the one hand, if one animal dominates all the other animals in a group and the second animal is only dominated by that α-animal etc., a simple picture can be drawn with the highest ranking animal on top and the lowest ranking animal at the bottom (linear rank order). On the other hand, theoretically, each animal of the group could dominate half of the group and be subordinate to the other half. This would result in a very complicated picture. An example of a dominance structure observed in the present groups is given in Figure 4. It shows a picture which falls in between the two extremes described. Apparently there are many cows which dominate a "higher-ranking" animal. Comparable results were found in the other six experimental groups. Only one cow was found who was not dominated by any of the other members of the group (a "true" α-animal); in all the other groups, each animal was dominated by at least one animal. Only one cow was found who had no subordinate (a "true" Ω-animal).

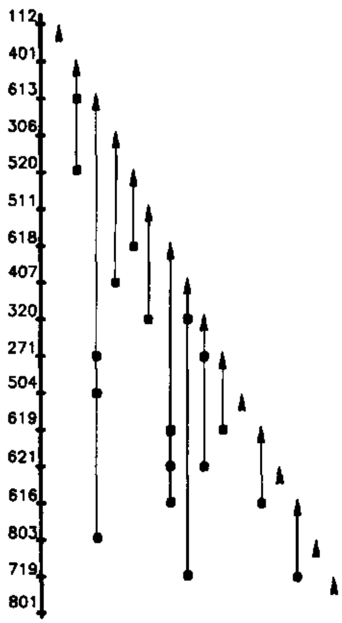

Figure 4. The dominance structure of group 1 of Experiment II. The cow numbers are given in the column, in order according to their dominance value. The vertical lines illustrate by which low-ranking animal(s) (dots) a certain animal (arrow) is dominated.

The relations between dominance value and the number and type of aggressive interactions

The dominance value of an animal, calculated as described, is based on the number of animals dominated and not on the absolute number of displacements performed. Because data on aggressive interactions were collected so that, within each experimental group, all the animals were observed for the same length of time, it was possible to analyse the relation between the social position of an animal and the number of displacements. In addition, the relation between social position and the cows' other interactions will be analysed. With the information about the dominance relationships, it was possible to determine for each aggressive interaction observed whether the animal which initiated the interaction ("actor") was dominant or subordinate to the other animal ("reactor"). In displacements, one would usually expect the displacing animal to be the dominant one and the displaced animal, the subordinate one. However, it has been shown that a subordinate cow sometimes displaces a dominant one. This has been called a contradictory displacement. Unsuccessful buttings can also be separated into interactions in which the butting animal is dominant and those in which the butting animal is subordinate. In both types, the subordinate animal behaves contrary to the dominance relation: in the first, the subordinate cow ought to yield to the dominant one and in the second, she should not have taken the initiative to butt a dominant animal. The third type of aggressive interaction is a penetration. It is assumed that a penetration occurs when a cow finds she cannot displace the other animal(s) by butting. Penetrations, unsuccessful buttings and contradictory displacements all seem to be unexpected. Table 3 shows that these types of behaviour do not occur often in normal conditions but that they do occur more in overcrowded

Table 3. Frequency of aberrant interactions per cow per 24 h in a normal (N) and in an overcrowded (O) situation. The average for all experiments is presented.

	N	O
contradictory displacements	0.297	0.473
unsuccessful buttings	0.257	0.696
penetrations	0.075	0.429
all aberrant interactions	0.629	1.598

conditions. These types of interaction are called aberrant interactions and they have been analysed together. Correlations between dominance value, displacements and aberrant interactions were calculated for each group, in normal and overcrowded conditions.

Firstly, the correlation between dominance value and number of displacements and number of times of being displaced was calculated (Table 4). Both in normal and in overcrowded conditions, a positive - and in 10 out of the 13 cases significant - correlation was found between dominance value and number of displacements. In both situations a negative correlation - always significant - was found between dominance value and number of times of being displaced. The correlation between number of displacements and number of times of being displaced was always poor and only in 2 out of the 13 cases was it statistically significant. Examples of the relations between dominance value and number of displacements and number of times of being displaced are given in Figure 5.

Table 4. Correlation between the dominance value, the number of displacements and the number of times of being displaced of each cow, calculated for each experimental group, and for normal and overcrowded conditions. Only correlation coefficients (Pearson's) which are statistically significant (P < 0.05) are presented (n.s. = not significant).

	exp. group	Normal: displacements	Normal: being displaced	Overcrowded: displacements	Overcrowded: being displaced
Dominance value	I.1	0.61	-0.74	0.53	-0.81
	I.2	n.s.	-0.82	0.45	-0.72
	II.1	0.66	-0.87	0.63	-0.67
	II.2	0.55	-0.75	0.48	-0.75
	III.1	0.50	-0.86	-	-
	III.2	n.s.	-0.86	n.s.	-0.75
	IV.1	0.76	-0.84	0.71	-0.90
Being displaced	I.1	n.s.		n.s.	
	I.2	n.s.		n.s.	
	II.1	0.45		n.s.	
	II.2	n.s.		n.s.	
	III.1	n.s.		-	
	III.2	n.s.		n.s.	
	IV.1	n.s.		0.49	

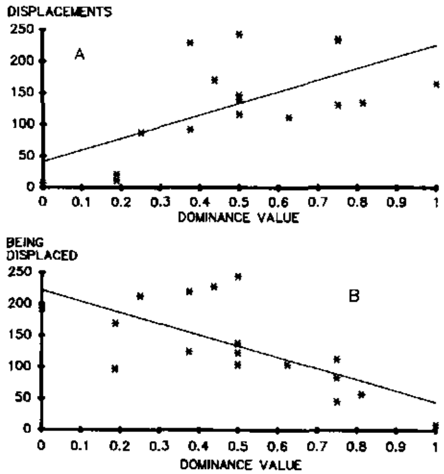

Figure 5. Relations between dominance value and displacements and being displaced, illustrated for group 1 of Experiment II for overcrowded (55 %) conditions. Each cross represents the recorded result of one animal.

The correlations between aberrant interactions and dominance value, displacements and being displaced - again calculated for each experimental group and for both conditions separately - are given in Table 5. In normal conditions almost no significant correlations were found. In overcrowded conditions aberrant interactions correlated significantly - negatively - with dominance value for four out of six groups. Thus, in overcrowded conditions the low-ranking animals performed aberrant interactions more often

Table 5. Correlation between the number of aberrant interactions and the dominance value, the number of displacements, and the number of times of being displaced of each cow, calculated for each experimental group both for normal and for overcrowded conditions. Only correlation coefficients (Pearson's) which are statistically significant ($P \leq 0.05$) are presented.

	Normal			Overcrowded		
exp. group	dom. value	displ.	being displ.	dom. value	displ.	being displ.
I. 1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
I. 2	n.s.	0.59	0.52	n.s.	n.s.	0.44
II. 1	n.s.	n.s.	n.s.	-0.48	n.s.	0.74
II. 2	n.s.	n.s.	n.s.	-0.75	n.s.	0.70
III. 1	n.s.	0.64	n.s.	-	-	-
III. 2	n.s.	n.s.	n.s.	-0.62	n.s.	0.63
IV. 1	n.s.	n.s.	n.s.	-0.50	n.s.	0.51

than high-ranking animals. No significant correlation with the number of displacements was found. In overcrowded conditions, the number of times of being displaced, in five out of the six cases, correlated significantly with the number of aberrant interactions. These correlations were all positive, indicating that animals which were displaced more often, performed a higher number of aberrant interactions. Examples of these relations are presented in Figure 6.

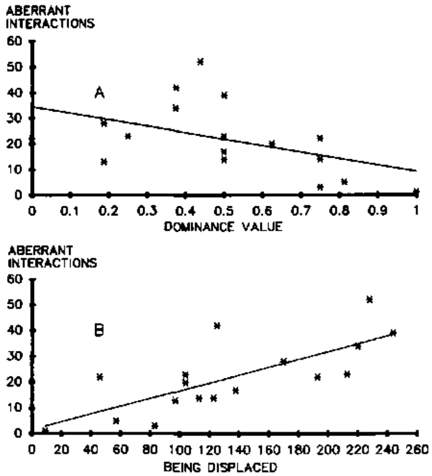

Figure 6. Relations between dominance value and being displaced and aberrant interactions, illustrated for group 1 of Experiment II, for *overcrowded (55 %)* conditions. Each cross represents the recorded result of one animal.

The relation between dominance value and time spent in the cubicles

The main aim of this experiment was to analyse social dominance in dairy cows. To obtain information about a possible connection between social position and the cow's chances of access to important resources, for experiment II the time spent lying per cow per 24 h in both the normal and overcrowded conditions was compared with the cow's dominance value. The results are presented in Figure 7. In normal conditions there was no significant correlation between dominance value and time spent in the cubicles ($r = 0.04$; $P > 0.05$). However, there was a significant correlation ($r = 0.60$; $P \leq 0.001$) between dominance value and time spent in the cubicles in overcrowded (55 %) conditions. Thus, the dominance position only affects the time spent in the cubicles in overcrowded conditions (i.e. when there is competition for the resources).

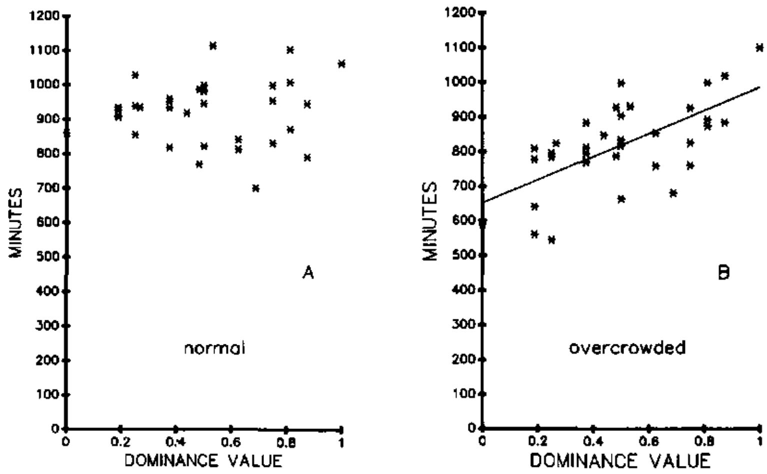

Figure 7. Relations between dominance value and total time spent (min) in the cubicles per 24 h for normal and overcrowded (55 %) conditions. Results of group 1 and group 2 in Experiment II; each cross represents one animal.

DISCUSSION

The aim of this paper is to discuss social dominance in dairy cattle based on both the new information which was collected in the described experiments, as well as the available literature. Firstly the new information from our experiments concerning contradictory displacements, and the relation between social dominance and (aberrant) interactions is discussed. Secondly, social dominance in dairy cattle, including dominance structure and dominance value, is discussed more generally.

The consequences of housing and management on aggressive interactions

aggressive interactions and dominance relationships

The experiments showed that in 41.1 % of all pairs both members displaced each other. Because the existence of unilateral dominance relationships forms the main part of the original concept of social dominance, the occurrence of contradictory displacements in dairy cows needs to be considered first. Based on our results it was assumed that even in those pairs in which both members displaced each other, dominance relationships existed. This implies that contradictory displacements - and aberrant interactions in general - should be accepted as an element of social dominance in dairy cows. Some other authors also accept the existence of contradictory displacements (e.g. Wagnon, 1965; Sambraus, 1969; Reinhardt and Reinhardt, 1975). However, Beilharz and Zeeb (1982) did not accept contradictory as "normal". They considered these displacements to be observational mistakes and they suggested a method to correct the calculation of the dominance value. One could argue that relationships in which contradictory displacements occur are not dominance relationships in the original sense. However, the results of this investigation show that the contradictory displacements observed are not so disturbing that the existence of dominance relationships becomes unlikely. Firstly, it was found - despite the contradictory displacements - that many dominance relationships stay the same for some years. This strongly suggests that the distribution of aggressive interactions between the members of a pair is not random. Stable dominance relationships in dairy cows have also been observed in other investigations (e.g. Wagnon, 1965; Sambraus and Osterkorn, 1974; Bouissou, 1981). Secondly, it is important to stress that, compared with "normal" displacements, contradictory ones occurred infrequently (3.9 % of all displacements). Other investigations on cattle also reported a low frequency of contradictory displacements, varying between 1.4 % (Sambraus, 1969) and 3.9 % (Wagnon, 1965). Thirdly, it was found that in most pairs (95.3 % of all pairs) the subordinate animal performed few displacements (less than 4), and the dominant animal performed many more displacements than the subordinate one (in 95.5 % of the pairs at least 3 displacements more). Again this suggests that the distribution of aggressive interactions between the members of a pair is not random. Jackson (1988) reviewed the literature and concluded that in many species the subordinate animal sometimes displaces the dominant one, but that the dominants are typically responsible for more than 90 % of all aggressive acts initiated.

It seems possible that some, or most, contradictory displacements - and in general aberrant interactions - are due to the housing system and are thus artificial. This point needs an explanation. In a cubicle house the cows have to put their heads through a feeding rack to reach their food. The feeding rack creates feeding places which are separated by vertical bars. Directly after food delivery, most of the cows proceed to the feeding rack and start eating. During a certain period many cows are standing at the feeding rack, close together and all with their heads through the barrier. A comparable situation can be found in the resting area. Here the farmer has constructed partitions to make individual lying places. These partitions force the cows to stand or lie with their head forwards, away from the walking area. The designs of the feeding rack and lying area mean that an animal which is standing at the feeding rack, or standing or lying in a cubicle, cannot (easily) be threatened from in front. While busy at the feeding rack, only the hind-part of an animal can be reached. Thus, because the cow is relatively "safe", she may not always yield when she is butted by a dominant animal (= unsuccessful butting). Alternatively, the cow may feel unsafe in this position because she is unable to defend herself. This may be the reason why she sometimes yields even when she is butted by a subordinate animal (= contradictory displacement). The effect of separations between animals on displacements has been investigated by Bouissou (1970a, 1971). She showed that the chances of the subordinate animal obtaining food increase with increasing protection from constructed separations between two animals. Wagnon et al. (1966) also suggested that it can be difficult for a dominant animal to displace a subordinate one that can only be butted on the rear quarters. So it does seem possible that the design of the housing system affects the occurrence of aberrant interactions. More support is provided by Hall (1986), who found that few contradictory displacements occurred in Chillingham cattle kept outside, and Rutberg (1986), who found few contradictory displacements in American bisons kept under extensive conditions. It was shown in this paper that the number of contradictory displacements, and also the number of unsuccessful buttings and penetrations, increased with overcrowding. Thus, increased competition as well as housing conditions can influence the occurrence of aberrant interactions. It is interesting that overcrowding caused no changes in the dominance relationships or dominance values.

Assuming that housing and management may affect the occurrence of aberrant interactions implies that the performance of these interactions by the subordinate cow is not primarily seen as a challenge to the dominance position of the other animal. The same view was presented by Keiper (1988) for aggressive acts by Przewalski mares towards the dominant stallion of the herd.

amount of aggressive interactions

Some remarks can be made about the factors which play a role in the occurrence of aggressive interactions. In particular, the variations between animals in the frequency of displacing, being displaced and of aberrant interactions are discussed.

The number of performed displacements correlated positively with the dominance value of an animal. This correlation between dominance position and aggression has already been described (e.g. Wagnon, 1965; Reinhardt and Reinhardt, 1975; Reinhardt, 1980). Such a positive correlation may be expected, since an animal with a high dominance value dominates many animals and thus will displace many animals. This could imply that a cow regularly displaces a subordinate simply because she wants to assert herself. However, this is questionable. Most of the displacements seem to be directly caused by competition for a resource, e.g. a place at the feeding rack or a lying place. Thus, displacements may be performed only to obtain a resource and a high-ranking cow should not need to perform many displacements: once she has obtained a feeding place she can stay there for a long time because there is little chance of her being displaced. If this hypothesis is true, the recorded number of displacements of the high-ranking animals is higher than would be expected. What explanation can be given for such an observation? For the high-ranking animals there are few obstructions to performing a displacement. When cows are eating at the feeding rack, they regularly change feeding places before all the food at the previous place is consumed. Even when many cows are eating, high-ranking animals still can behave in this way, e.g. just by displacing their neighbour. Also a cow sometimes displaces one or more cows at the feed manger, not to obtain another eating place but, for example, "simply" to get some space to be able to turn and walk to the water bowl (see also Wagnon, 1965). It seems likely that this kind of displacement is performed more often by high-ranking animals. It does not imply that high-ranking animals regularly want to assert their dominance, or that they are more aggressive, but that they make use of their possibilities to behave as they would do under more natural or less crowded circumstances. In the literature, dominance and aggression are also considered as two different concepts (Bouissou, 1981; Beilharz and Zeeb, 1982) and dominant animals are not necessarily the most aggressive (e.g.: Reinhardt, 1973; Clutton-Brock et al., 1976; Reinhardt, 1980).

In general a significant (positive) correlation was found between aberrant interactions and being displaced. Since it is particularly those animals that (probably) have the most difficulty with obtaining and retaining resources which tend to perform aberrant interactions, it seems plausible that these aberrant interactions are used to increase their chances of obtaining important resources - one could call them "tricks". It could be that the performance of aberrant interactions is the result of an animal's strategy to gain food or a lying place, for instance. The occurrence of all types of interactions is enhanced by a concentrated (in space and time) presentation of food and lying places. Thus, the occurrence of aberrant interactions is induced by the housing system (as stated earlier), and increases when the competition between the animals (further) increases.

The role of social dominance in the life of the dairy cow

Stable dominance relationships in cattle do not only exist when the animals are kept indoors. Studies of Benham (1984) with suckler cows, of Clutton-Brock et al. (1976) with Highland cattle, of Reinhardt (1980) with Zebu, and of Rutberg (1986) with American bison, have all shown that in herds of cattle kept under less intensive conditions, stable dominance relationships between the animals also exist. However, as already discussed, housing and management can affect the relationships between animals and hence the role of social dominance when the animals are kept indoors. Gartlan (1968) even suggested that social dominance may be seen as an artifact of captivity. The function of dominance relationships, the dominance structure and the value of the concept of social dominance for dairy cows kept indoors are discussed next, based on the data and ideas presented here and on discussions in the literature (e.g. Syme and Syme, 1982/1983; Beilharz, 1983/1984; Bernstein, 1981). Whether it is relevant to consider other methods of measuring dominance relationships, for instance, a competitive order as discussed by Syme (1974), is also looked at.

dominance relationships and priority to incentives

Stable dominance relationships enable the animals to predict the outcome of any aggressive interaction in which they are involved. This seems to be advantageous to both the dominant and the subordinate animals (Bernstein, 1981). One can imagine that this effect of social dominance is important enough for the animals to develop and maintain a system of stable relationships.

Another important function of a dominance relationship is that it regulates the distribution of resources between the two members of a pair. The dominance value of an animal kept in a group, thus indicates the chances of that animal to obtain resources. The results of the present experiments were used to test this prediction. It was shown, that only in the overcrowded situation did the dominance value explain some of the variation between the animals in the time spent in the cubicles. In another experiment Hopster and Wierenga (1985) showed that the dominance position had little influence on the food intake of each individual, even in an overcrowded situation when the amount of food was restricted. Thus, social dominance may only play a limited role in the distribution of such resources as a lying place or food. This could suggest that, for dairy cows, social dominance is primarily of importance to make the outcome of interactions predictable. Such a conclusion also fits with the suggestion that in dairy cattle (Beilharz and Zeeb, 1982), and also in other animals (Bernstein, 1981), a dominance relationship between two animals often seems to be settled not by strength, but by "accidental" factors like age, familiarity in the group, etc.

There are three aspects of social dominance in dairy cows kept indoors, which may make the dominance value unreliable in predicting the chances of an animal obtaining resources, even when competition is high. Firstly, the prediction of the outcome of an encounter between two cows on the basis of their known dominance relationship, and thus also the prediction of a cow obtaining a certain amount of food or a certain total lying time, sometimes fails because of the occurrence of aberrant interactions. The possibility that a cow will sometimes not react to the butting of a dominant animal, or that she will sometimes displace a dominant animal, does of course affect her chances of obtaining a certain resource. Secondly, the many triangular dominance relationships can also affect the chances of an animal obtaining resources. In these triangular relationships, a low-ranking animal can dominate a high-ranking animal. An animal which can displace a high-ranking cow, may have more chance of obtaining resources than a low-ranking animal which "only" dominates other low-ranking animals. Similarly, an animal which is dominated by high-ranking animals may have fewer chances than an animal which is only dominated by low-ranking cows. Thus, one dominance relationship may be "worth" more than another. Thirdly, one animal may displace other animals more easily than a herdmate with a comparable dominance position; one animal may also be more easily displaced than another. In the first two experiments for instance, cow 607 performed 423 (Exp. I, group 2) and 910 (Exp. II, group 2) displacements respectively (21.7 % and 26.7 %, respectively, of all displacements in the group). Cow 313 had a comparable dominance position in group 1 of Experiment I and cow 401 had a comparable position in group 1 of Experiment II. These cows performed only 127 and 169 displacements (5.5 % and 5.3 %, respectively, of all displacements). This shows how large the differences in the number of displacements between cows can be. Not only the number of aggressive interactions but also the "direction" of these interactions varied. It was observed that some animals direct most of their interactions towards only one animal in the group (see Table I). Experiences during rearing (e.g. Bouissou and Hövels, 1976a, 1976b; Bouissou and Andrieu, 1977; also Broom and Leaver, 1978) but also at a later age will have caused such variation in the performance of aggressive interactions. Variation between individual cows in aggressive behaviour has also been described by other authors (Wagnon, 1965; Wagnon et al., 1966; Sambraus, 1969; Reinhardt, 1973, 1980). It seems evident that this variation in frequency and "direction" of aggressive interactions can reduce or increase the "worth" of the dominance value of an animal - for both the actor and the reactor.

complex dominance structure

It was shown that the dominance structure in the observed groups of cows was very complex. Comparable findings have been described by e.g. Sambraus (1964), Reinhardt (1973) and Beilharz and Zeeb (1982). Next, it will be discussed how dominance relationships are established and maintained, resulting in a certain dominance structure. The detailed work of Bouissou (1965, 1974a, 1974b, 1975), and Bouissou and Andrieu (1977) indicated the factors which influence the establishment of dominance relationships between two cows. Some remarks can be made about the maintenance - or dynamics - of such relationships. Sambraus (1969) suggested that normally there is a strong correlation between the dominance position of a certain animal and its age. Young animals (heifers) which enter the herd, start at a low position and gradually rise as new heifers join the herd and older cows leave. Eventually each animal can gain a high dominance position. Our experiments have shown that heifers tend to have a low dominance value and that with time the dominance value of an animal gradually increases. However, there were many exceptions. Futhermore, it needs to be noted again that a linear rank order was not found in these experimental groups.

If a relationship between age and dominance position is to be expected, why is it so often not found? Management at the dairy farm may play a role in the "disturbance" of the relationship between age and dominance position and it may enhance the occurrence of many triangular relationships within a herd. In the present experiments this "disturbance" may be caused by the practice at the experimental farm, of regularly splitting up the animals into different (experimental) groups between which the animals are interchanged. This changing of animals between groups also occurs regularly on commercial farms (Sambraus, 1969). Schein and Forman (1955) found that when animals were placed in a group which was unfamiliar to them they acquired a relatively low rank. Sambraus (1969) also described how new cows obtained a lower rank than one might have expected on the basis of age, weight and previous rank. A similar effect of group-changing was described for primates by Southwick (1966), and for hens by Guhl and Allee (1944). So normally, a relatively old cow will dominate a heifer. But when she is put in another group, she may become subordinate to a heifer with a low dominant position whom she meets for the first time. This results in a low correlation between age and dominance position. Because the cow will remain dominant over many other cows with whom she has previously made up a group, triangular relationships will occur. Thus, by regularly changing animals between groups many triangular relationships may develop. These triangular relationships will persist because dominance relationships tend to be stable for many years. Unfortunately, in the described experiments it was impossible to trace how the groups were formed, or when individual cows were added to the experimental groups. Nor was information available about changes at times when the animals were not taking part in the described experiments. However, if such management practice is one of the causes of triangular relationships, one should find a more linear rank order in herds which are less influenced by man. Hall (1986) found an almost linear rank order in female Chillingham cattle. Benham (1984) observed only a few triangular relationships in his herd of free-ranging suckler cows, while Rutberg (1986) found an almost linear rank order in a group of American bison cows. Reinhardt (1980) concluded that in a group of loose-housed dairy cows almost three times more changes in relationships occurred than in a herd of Zebu cattle kept under extensive conditions. Therefore, as Sambraus (1969) suggested, under natural conditions a clear relation between age and dominance position and a linear rank order may be expected, whereas the management at the farm may disturb this relation and cause many triangular relationships.

dominance value

Theoretically, the formula used for calculating the dominance value cannot be justified. The number of subordinate cows should not be divided by the number of <u>known</u> dominance relationships of a particular cow but by the total possible number of relationships of that cow within the group. In the experiments described in this paper, the dominance relationship was not known for only 8 pairs out of a total of 982 pairs. For one animal, two relationships were not known; the remaining 6 pairs concerned different animals, of which only one relationship each was not known. So in these experiments the number of unknown dominance relationships is negligible, but it could be suggested that publications should always state the number of unknown dominance relationships.

The function of the dominance value is that it summarizes the position of an animal in a group as a single parameter. This enables other calculations, for example, correlations between the dominance position and the number of aggressive interactions or the time spent lying in the cubicles. The dominance value is particularly helpful when the dominance structure is complex. However, when the dominance position or dominance value - as was shown in this paper - has only a limited predictive value, it seems worthwhile to look for possible alternatives. One solution could be to calculate a dominance value corrected for the three disturbing factors which have been mentioned. However, this is complicated and is, in fact, an investigation in its own right. For those investigations in which social dominance is used "as a tool" to explain variations between individuals, such a solution is not attractive.

Alternative statistical procedures have been proposed for calculating a dominance value based on aggressive interactions. The application of a BLUP-method, as proposed by Friend and Polan (1978), has been criticized by Beilharz (1979) and Syme and Syme (1982/1983). It is also doubtful if a transformation, as applied by Beilharz and Zeeb (1982), is useful. Such a transformation corrects for possible non-linear relationships between dominance value and certain other variables, but it is not even certain that such corrections are necessary. Anyhow, it is important to test the effect of such a correction before it is applied. Furthermore, a correction would also be needed for the "disturbing factors" mentioned.

As an alternative method for summarizing social relationships within a herd, Syme (1974) discussed the use of a "competitive order", which is "..... defined in terms of the demonstration of priority of access to an approach situation (e.g. food, water) or away from an avoidance situation (e.g. electric shock) which one animal has over another. Generally, these priorities have been measured by artificially limiting the amount of reward available or by ensuring that two animals cannot be rewarded simultaneously". A competitive order can correlate perfectly with a dominance order (e.g. Tyler, 1972; Bouissou, 1970b; Sereni and Bouissou, 1978). However, Banks et al. (1979) found a high correlation between competitive and dominance orders for domestic fowl when the animals competed for food, but not when they competed for water. Craig (1986) suggested that some animals could become so frustrated after a deprivation that in the competition test they did no longer behave according to their dominance relationship. Both

Craig (1986) and Rushen (1983/84) concluded that a competitive order did not always reflect the dominance relationships in a herd. Bernstein (1981) suggested basing dominance relationships primarily on aggressive interactions between the animals.

Attempts to better predict the chances of an animal obtaining a certain resource suggest that it ought to be possible to find one index which is an exact predictor of the animal's chances. However, it is doubtful whether a more reliable index than the dominance value can be found. It seems more realistic to view social dominance not as a static concept, but as a more dynamic concept with a limited value as a predictor for chances of obtaining resources (Syme and Syme, 1982/1983). Beilharz and Zeeb (1982) also warned of expecting too much. It can be concluded that a simple dominance value, calculated as suggested in this paper, is a useful parameter which can be assessed quickly. However, partly due to the effects of housing and management, it may give unreliable predictions when certain resources are only available in restricted amounts.

CONCLUSIONS

Stable dominance relationships exist between dairy cows but sometimes a subordinate cow will displace or try to displace a dominant cow, or will not yield to a dominant animal. The occurrence of these aberrant interactions is probably induced and enhanced by the housing and the management systems. In particular, under crowded conditions social dominance may affect an animal's chances of obtaining resources.

The dominance order constructed on the basis of known dominance relationships is always complex. The calculation of a dominance value is a useful method of summarizing the relationships existing in a group. Due to the various effects of housing and management systems, the dominance position and dominance value are not always adequate predictors of priority of access to resources.

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3. MEASURING SOCIAL DOMINANCE IN DAIRY COWS

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Submitted for publication in Applied Animal Behaviour Science.

MEASURING SOCIAL DOMINANCE IN DAIRY COWS

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ABSTRACT

Social dominance is often used to explain differences in behaviour of animals living in a group. The collection of aggressive displacements - which are needed to analyse dominance relationships - demands much observation time. This paper investigates the minimum number of displacements needed in order to obtain representative information about social dominance in a group of dairy cows.

Detailed information obtained with relatively small sets of displacements (200, 400, 600, 800, 1400) and with large sets of displacements (between 1875 and 3411) was compared. The information included known dominance relationships, dominance values, dominance positions and dominance groups. Data was available from four different experiments, with a total of seven different groups of lactating dairy cows kept in cubicle houses. The groups varied in size between 15 and 20 animals.

The analysis showed that at least 2000 - 3500 displacements need to be recorded if all the dominance relationships need to be known for a group of 15 - 20 cows.

When social dominance is used to explain variations in the animals' chances of obtaining resources, less detailed information is needed. When between 5 % and 10 % of the cows may have a large deviation from the "true" dominance value (> ± 0.10) or dominance position (> ± 2), about 90 % of the dominance relationships need to be known. This means that for a group of 15 - 20 cows, about 800 displacements have to be collected to obtain reliable enough information about social dominance.

When social dominance is used in presentations, the number of known dominance relationships should always be stated, to indicate the levels of confidence in the data.

INTRODUCTION

Studies of dairy cows often use social dominance to explain some of the differences in behaviour between animals (Baehr, 1984; Potter and Broom, 1987; Metz and Mekking, 1984; Wierenga and Hopster, 1990). Wierenga (1990) discussed social dominance in dairy cows. He concluded that dominance relationships should be established based on aggressive interactions and that social dominance in a group could be described best with the dominance value of each animal. This analysis left open the question of how much information is necessary to provide reliable information on dominance in a group of dairy cows. The collection of aggressive interactions takes much observation time. It is, therefore, understandable that there is a tendency to limit the number of aggressive interactions on which social dominance is based. Thus it is important to know the minimum number of aggressive interactions needed to assess dominance parameters. In answering such a question not only the total number of displacements is relevant, but also the distribution over the animals (or: pairs of cows).

The aim of this paper is to assess how many displacements are necessary to provide sufficiently detailed information to determine social dominance in a group of dairy cows.

MATERIALS AND METHODS

Experimental design

Data collected during experiments described by Wierenga (1990) and Wierenga and Hopster (1990) were used in this analysis. Briefly, during four different experiments, a total of seven different experimental groups of lactating dairy cows kept in cubicle houses were studied (Table 1). Of these groups of cows, six were kept in both normal (as many lying and eating places as cows in the groups) and overcrowded (reduced number of available lying and eating places) conditions. One group was kept only under normal conditions (group 1, Experiment III; Table 1). During the experiments, which lasted between 3 and 5 months each, aggressive interactions were recorded. The observed displacements (= a withdrawal or change of position of one animal caused by another animal) were used to assess dominance relationships (Wierenga, 1990).

Table 1. Number of animals, number of pairs of cows, recorded number of displacements and displacements per pair, presented per group within each experiment.

exp.	group	number of animals	number of pairs	number of displacements	displacements per pair
I	1	15	105	2167	20.6
I	2	15	105	1875	17.9
II	1	17	136	3184	23.4
II	2	17	136	3411	25.1
III	1	20	190	2328	12.3
III	2	20	190	2565	13.5
IV	1	16	120	3409	28.4

Dominance relationships, dominance values, dominance positions, dominance groups

Firstly, the dominance relationship was analysed for all the pairs of cows based on the observed displacements. A dominance relationship was classed as "known" when one animal of a pair had displaced the other at least once more than the reverse. In a second analysis, a relationship was classed as known only when one animal of the pair had displaced the other at least two times more than the reverse (see also Wierenga, 1990). These two classes are called respectively known-1 and known-2 dominance relationships.

Based on both the known-1 and the known-2 dominance relationships, a dominance value (d.v.-1, respectively d.v.-2) was calculated for each animal (Wierenga, 1990):

$$\text{d.v.} = \frac{\text{number of subordinate cows}}{\text{number of known dominance relationships}}$$

Next, the animals were ranked in a dominance order according to their dominance value. The cow with the lowest dominance value received dominance position 1 and the cow with the highest dominance value received dominance position 15, 16, 17 or 20 - depending on the group size. When two or more cows in a group had the same dominance value, their dominance relationships were investigated further. If the relationships were known, the most subordinate animal received the lowest dominance position, etc. If the dominance relationships appeared to be unknown, all the animals concerned were given the same dominance position (= mean of the two or more positions involved).

Finally, the animals of each group were divided into three dominance groups. The "high-ranking" group consisted of the five animals with the highest dominance positions. The five animals with the lowest dominance positions were the "low-ranking" group. The remaining animals (5, 7, 10 and 6 in Exp. I, II, III and IV respectively) were classed as "middle-ranking" animals.

Analysis of data

Analysis of the known-1 and known-2 dominance relationships with the total number of observed displacements showed that, on average, 99.2 % and 97.1 % respectively, of all these relationships were known for the experimental groups (Table 2). The dominance value, the dominance position and the dominance group of each animal of each experimental group, obtained when all the observed displacements were analysed, were considered to be the "true" value, position and dominance group respectively. To determine the minimum number of displacements needed to provide reliable information, the results of analyses based on smaller numbers of displacements were compared with results based on all the observed displacements. Several relatively small sets of displacements (200, 400, 600, 800) and a larger set of displacements (1400) were compared with the maximum number available per

Table 2. Percentage of known-1 and known-2 dominance relationships (known relationships/possible relationships x 100 %) in the experimental groups. Results of analysis of all observed displacements.

exp.	group	known-1	known-2
I	1	97.1	94.3
I	2	100.0	98.1
II	1	100.0	98.5
II	2	99.3	97.8
III	1	99.5	95.8
III	2	98.4	95.3
IV	1	100.0	100.0
mean		99.2	97.1

group (varying between 1875 and 3411). For each experimental group, the sets of displacements (200, 400, 600, 800, 1400) were generated by repeated sampling with replacement from the total set of displacements available for that group. For each set, 1000 samples were generated on a micro VAX with the random number generator implemented in Fortran 77. For each of the samples, dominance relationships, dominance values, and dominance positions (including dominance groups) of the animals were estimated. The estimates were compared with the corresponding "true" values obtained from the full set of interactions (only calculated once). Percentages of known dominance relationships and Pearson's correlation coefficients between "true" and estimated dominance value were calculated. Furthermore, differences between "true" and estimated values were summarized in statistics, such as the percentage of animals with a wrong dominance value or position and the percentage of animals in the wrong dominance group. Results are presented as the means of these statistics with a corresponding standard error over all the experimental groups. A mean, say m, of the seven experimental groups can be interpreted as an estimate for a population mean when the seven groups are assumed to be representative for a whole population of groups. The standard error, say s, reflects both variation within groups and between groups. Because 1000 samples were generated for each set, the component of variation within a group was relatively small. The 95 %-confidence interval for the population mean is $m \pm 2s$.

RESULTS

Dominance relationships

The mean percentages of known-1 and known-2 dominance relationships for the different sets of displacements are presented in Figure 1. For known-1

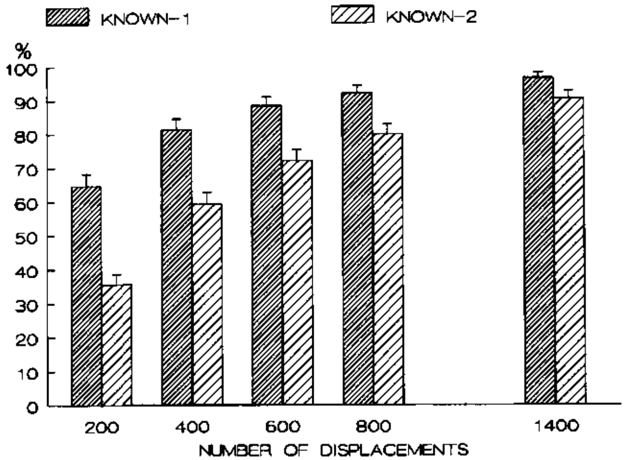

Figure 1. Mean percentage (including upper bound of the 95 % confidence interval) of known-1 and known-2 dominance relationships for the different sets of displacements.

relationships, only 64.7 % of all possible relationships were known with 200 displacements. With larger samples of displacements, more relationships gradually became known. With 1400 displacements, 96.3 % of the relationships were known. The difference between the set of 1400 displacements and the full set of displacements, with 99.2 % known relationships (Table 2), was small. For known-2 dominance relationships, only 35.6 % of all possible relationships were known with 200 displacements. This is a much smaller percentage than the results of known-1 relationships. Again, as more displacements were used, more relationships gradually were known. With 1400 displacements, 90.2 % of the relationships were known compared to 97.1 % when all available displacements were used (Table 2). With increasing sample size, the difference in percentages of known-1 and known-2 dominance relationships gradually became smaller.

Dominance values

Pearson's correlation coefficients were calculated between the estimated and the "true" dominance values. Table 3 presents the mean correlation co-

Table 3. Mean correlation coefficients (standard error between brackets) between dominance values based on small sets of displacements and on the full set of displacements. Results for known-1 and known-2 relationships are presented.

sets	known-1 relationships	known-2 relationships
200	0.89 (0.01)	0.69 (0.04)
400	0.94 (0.01)	0.87 (0.02)
600	0.97 (0.01)	0.93 (0.01)
800	0.98 (0.00)	0.96 (0.01)
1400	0.99 (0.00)	0.98 (0.00)

efficients. For all sets of displacements, the dominance values correlated significantly with the "true" dominance values. For known-1 and known-2 relationships, the correlation coefficient was larger than 0.95, when more than 600 or 800 displacements were used respectively.

It was analysed how many dominance values were calculated wrongly in each sample. Four classes of wrong dominance values were distinguished. First, the dominance value was classed as wrong when it was not exactly the same as the "true" dominance value. Further, the dominance value was classed as wrong, when it differed by more than 0.05, more than 0.10, and more than 0.15, respectively, from the "true" dominance value. These three values were felt to be relevant degrees of deviation from the "true" dominance value. They are not based on, for instance, available information about the variation which may be expected around the "true" dominance value. Because for each animal the "true" value is only measured once, such information about variation is not available. The analysis was carried out for both known-1 and known-2 dominance relationships. This analysis showed that for many animals the dominance value was classed as wrong when it was not exactly the same as the "true" dominance value: even with 1400 displacements for known-1 and known-2 dominance relationships, on average 46.3 % and 63.0 %, respectively, of the animals were given a wrong dominance value. The results for the other three classes of wrong dominance values are presented in Figure 2. With 1400 displacements for known-1 and known-2 relationships, 16.7 % and 18.5 %, respectively, of the animals still had a dominance value which differed by more than 0.05 from the "true" dominance value. When a difference of $\leq$ 0.10 is accepted, with 1400 displacements only 2.9 % and 4.1 %, respectively, of the animals were given a wrong dominance value. With 800 displacements 6.4 % and 13.2 %, respectively, of the animals had a wrong dominance value. When the dominance values were only classed as wrong when they differed by more than 0.15 from the "true" dominance values, the percentage of animals wrongly classed was further reduced. For instance, with 600 displacements only 3.3 % and 9.7 %, respectively, of the animals were given a wrong dominance value - based on known-1 and known-2 relationships.

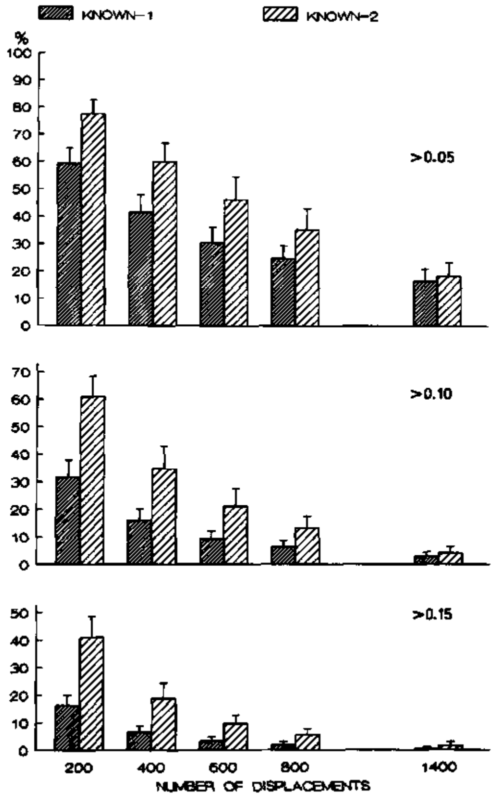

Figure 2. Mean percentage (including upper bound of the 95 % confidence interval) of animals with a wrong dominance value (deviation from "true" value > 0.05, > 0.10 and > 0.15; for explanation see text), calculated for the different sets of displacements, both for known-1 and known-2 dominance relationships.

Dominance positions

For the dominance positions based on the different sets of displacements, correlation coefficients were calculated between estimated and "true" positions. The results presented in Table 4 show that high correlation coefficients were again found. For known-1 and known-2 relationships, correlation coefficients larger than 0.95 were found when more than 600 or 1400 displacements, respectively, were used.

Table 4. Mean correlation coefficients (standard error between brackets) between dominance positions based on small sets of displacements and on the full set of displacements. Results for known-1 and known-2 relationships are presented.

sets	known-1 relationships	known-2 relationships
200	0.87 (0.02)	0.69 (0.04)
400	0.93 (0.01)	0.86 (0.02)
600	0.95 (0.01)	0.91 (0.02)
800	0.96 (0.01)	0.94 (0.01)
1400	0.98 (0.01)	0.97 (0.01)

Using a similar procedure to that followed for the dominance values, it was calculated how many animals were given the wrong position based on the different sets of displacements. First, a wrong dominance position was classed as such when a cow was not given the "true" position exactly. Next, dominance positions were classed as wrong when they differed by more than 1, more than 2, or more than 3 from the "true" dominance position. Comparable to the deviations from the "true" dominance value also these deviations from the "true" dominance position are based on the assumption that they are relevant degrees of deviation from the "true" value and not based on information about variation around this "true" value. As with the analysis of dominance values, this analysis also showed that few animals were given their "true" dominance position. With 1400 displacements, for the known-1 and known-2 dominance relationships respectively, 41.3 % and 49.1 % of the animals got the wrong dominance position on average. The results for the other three classes of wrong dominance positions are presented in Figure 3. When a difference of only one dominance position is accepted for known-1 and known-2 relationships, 12.3 % and 16.3 %, respectively, of the cows still received the wrong position with 1400 displacements. When a difference in dominance position of no more than 2 is accepted, the percentages of animals with the wrong position were 4.5 % and 5.4 %, respectively, with 1400 displacements. With 800 displacements, they were 7.7 % and 13.3 %. When a difference of 3 was accepted, 4.6 % and 9.8 % of the animals were given the wrong dominance position for known-1 and known-2 relationships with 600 displacements.

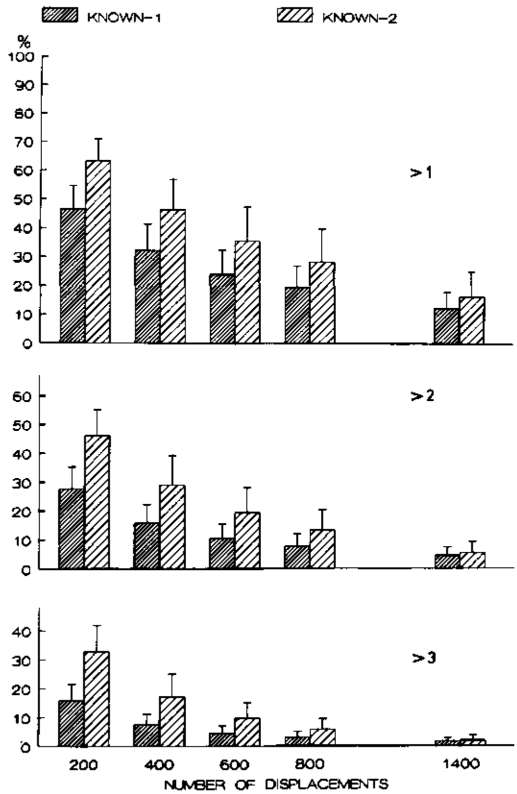

Figure 3. Mean percentage (including upper bound of the 95 %-confidence interval) of animals with a wrong dominance position (deviation from "true" position > 1, > 2 and > 3; for explanation see text), calculated for the different sets of displacements, both for known-1 and known-2 dominance relationships.

Dominance subgroups

A rough estimate of the dominance position of each animal was obtained when the cows were divided into so-called dominance groups. The distribution of the animals between the different dominance groups, based on the different sets of displacements, was compared with the ("true") distribution based on all the observed displacements. The animals were mostly assigned to the right subgroup (Fig. 4). With 600 displacements for known-1 and known-2 relationships, 12.6 % and 17.5 %, respectively, of the cows were placed in a wrong dominance group. With 800 displacements, 10.7 % and 13.3 % of the cows were assigned to the wrong dominance group.

In a separate analysis, it was calculated how often an animal was shifted just one group (from high- to middle-ranking, or from middle- to low-ranking) and how often an animal was shifted two groups (from high- to low-ranking). This analysis showed that, for known-1 relationships, a shift from high- to low-ranking was recorded only with the smallest sets of 200 displacements (on average 0.3 % of the cows). For known-2 relationships, such a shift occurred with sets of 200, 400 and 600 displacements (on average 2.5 %, 0.4 % and 0.1 %, respectively, of the cows).

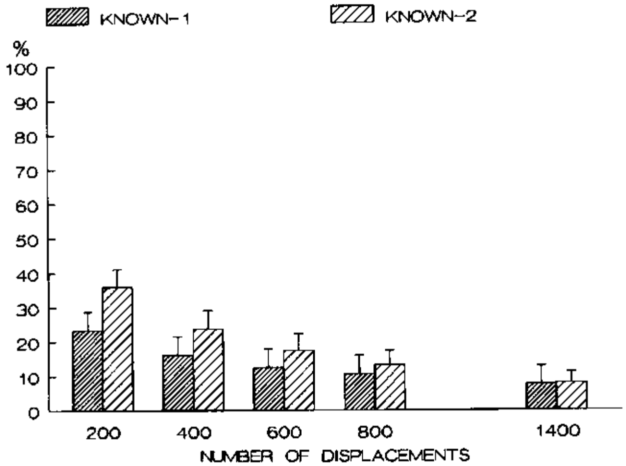

Figure 4. Mean percentage (including upper bound of the 95 %-confidence interval) of animals assigned to the wrong dominance group, calculated for the different sets of displacements, both for known-1 and known-2 dominance relationships.

DISCUSSION

Introduction

The aim of the analysis presented, was to determine the minimum number of displacements needed to obtain sufficiently detailed information about social dominance in a group of dairy cows.

It needs to be stressed that these data were obtained from dairy cows kept in relatively small groups (15 - 20 cows) and kept partly in overcrowded and partly in normal conditions. It is not possible to judge how larger groups would affect the results. In the groups investigated, nearly all the possible pairs of cows were seen to have had aggressive interactions. In larger groups certain animals might never interact with each other or interactions might not be recorded. Furthermore, to translate our information to larger group sizes, it would be better to discuss the number (or percentage) of known dominance relationships rather than the number of displacements needed. This is preferred, since a certain number of displacements per pair will be necessary, and with increasing group size the number of pairs is increasing fast. For instance, with 600 displacements for a group of 20 animals (190 pairs) there are 3.2 displacements per pair, but for a group of 40 animals (780 pairs) there are only 0.8 displacements per pair. Nevertheless, in this paper a varying number of displacements was analysed, because our group sizes did not vary much, and because sampling a certain number of known relationships from the full set of displacements would have asked for considerably more computer time. However, both the number of displacements and the corresponding percentages of known relationships (Fig. 1) will be used in discussing the results.

The influence of different treatments between the groups (level of overcrowding) on social dominance will be neglected. First, because there was little variation between the groups (small standard error), which suggests that the consequences of different treatments were also small. Secondly, it is impossible to analyse and discuss these influences because with the present data they cannot be distinguished from differences between groups. Thirdly, Wierenga (1990) showed - with the full set of displacements - that overcrowding did not affect social dominance.

There was a difference in the results of known-1 and known-2 relationships. The analyses showed that a larger sample of displacements was needed to obtain information with the same degree of accuracy (e.g. high correlation with "true" dominance value or position, low percentage of animals with wrong dominance value or position) for known-2 dominance relationships compared to known-1 relationships. However, the same general trend was found: both with known-1 and known-2 relationships the accuracy of the information increased with an increasing number of displacements. The difference in accuracy between known-1 and known-2 relationships was largest with 200 displacements and decreased with increasing sample size. When the full set of displacements was used, Wierenga (1990) recorded a high (significant) correlation between dominance values based on known-1 and known-2 relationships and decided to base further analyses only on known-1 relationships. In the present analysis with 1400 displacements for known-1 and known-2 relationships, a high correlation between estimated and "true" dominance value and position was also found (varying between 0.97 and 0.99). Therefore - and supported by the conclusion that there was only a difference in level of accuracy - further discussion and interpretation of these results will be based mainly on the results of the known-1 relationships.

Amount of information required for determination of dominance value, dominance position and dominance group

The results have shown that with the group sizes investigated, more than 1400 displacements are necessary to obtain information about all the dominance relationships. Even with the maximum available number of displacements some dominance relationships were still unknown. How can the available information be used to determine the minimum number of displacements or percentage of known relationships required? The answers will depend on the questions asked in the research.

Firstly, it is possible that for a certain investigation information is required about dominance relationships between animals to explain other interactions, or the animals' other behaviour. For such purposes, 100 % of the relationships may need to be known, which means that for a group size of 15 - 20 cows at least 2000 - 3500 displacements need to be collected. If the collection of so many displacements is too time consuming, alternative methods of assessing dominance relationships could be considered (e.g. Bouissou, 1970), although several authors have argued that such methods have restrictions (Rushen, 1983/84; Craig, 1986; Wierenga, 1990).

Secondly, social dominance is often used to predict the animals' chances of obtaining resources (e.g. food, lying place). Wierenga (1990) discussed several reasons why a cow's chances of obtaining resources can only be predicted to a limited degree from her dominance value. Thus, for some research aims it seems unnecessary that all the relationships are known which means that some deviation from the true values might be acceptable. It could be argued that just a dominance value or position is required which correlates significantly with the "true" value or position. However, a correlation coefficient is a simple and thus a rather crude measure. The presented analysis was carried out to obtain more precise information about deviation from the "true" values. Based on the available data it is possible to determine more precisely the number of animals with a wrong dominance value, position or dominance group. But the question remains, how many animals may have a wrong dominance value or position and what deviation from the "true" value or position is acceptable. A reasonable starting point is to allow wrong information for a maximum of 5 % or 10 % of the animals in the group (in the groups studied this means one or two cows). It is more difficult to decide about the deviation from the true value or position which is acceptable. What is "wrong information"? It is not possible to base this on information about the variation around that "true" value, because such information is not available. It is felt, that a deviation of at most 0.10 from the "true" dominance value or at most 2 from the "true" dominance position could prove acceptable.

Combining these two conditions - between 5 % and 10 % of the animals may have a wrong dominance value or position or be assigned to a wrong dominance group and the dominance value or position should not differ more than 0.10 or 2 from the "true" value or position respectively - it is possible to determine the number of displacements or known relationships required. For the dominance value and dominance position, Table 5 summarizes the number of displacements or known relationships which would be needed under these conditions (derived from the results presented in Figs. 2 and 3). The results of the analysis of dominance value and of dominance position will be discussed together, because comparable results were obtained. A

Table 5. Number of displacements (dis.) and percentage of known dominance relationships (rel.) needed, when ≤ 5 % or ≤ 10 % of the animals of a group are accepted with a wrong dominance value or dominance position and when the deviation from the "true" dominance value (d.v.) and dominance position (d.p.) is not more than 0.10 and 2, respectively. Only results concerning known-1 relationships are presented.

deviation from "true" value or position	≤ 5 % cows wrong		≤ 10 % cows wrong	
	dis.	rel.	dis.	rel.
d.v. ≤ 0.10; d.p. ≤ 2	≥1400	≥96.3%	≥ 600	≥88.3%

difference in dominance value of 0.10 appears to be more or less comparable to a difference of 2 in dominance position. When maximum deviation of 0.10 and 2 from the "true" dominance value and position are allowed, 1400 displacements are sufficient if 5 % of the cows may have a wrong value and 600 displacements if 10 % of the cows may have a wrong value. In discussing the number of displacements needed to obtain reliable information about the distribution of the cows into dominance groups, a slightly higher percentage of animals in the wrong group might be acceptable. This is because a swop between dominance groups will involve at least two animals (when one animal is assigned to the wrong dominance group, automatically another animal is also assigned to the wrong group). When instead of 5 % and 10 %, 10 % and 15 % cows in wrong dominance groups is accepted, minimally 1400 (7.7 % cows wrong), 800 (10.7 % wrong) or 600 (12.6 % wrong) displacements are needed (Fig. 4).

Based on these results presented, it can be concluded, that at least 800 displacements need to be collected, or 90 % of the dominance relationships need to be known, to provide a reliable impression of social dominance in groups of 15 - 20 cows. With that number of displacements the described conditions are fulfilled: only between 5 % and 10 % of the cows would have a dominance value or position which differs more than 0.10 or 2 from the "true" value or position, respectively, only slightly more than 10 % of the animals would be assigned to the wrong dominance group. With 800 displacements correlation coefficients higher than 0.95 could be expected with the "true" dominance value or position. For known-2 relationships similar results would be obtained with between 800 - 1400 displacements.

The type of research determines how many displacements need to be collected to obtain sufficient information on the social dominance in a group of dairy cows. But even for investigations where little detailed information on social dominance is needed, a rather high number of displacements or of known dominance relationships is still needed. Reports of investigations in which social dominance is studied, should explain how the social dominance was determined and state the number of displacements recorded and the number of dominance relationships known, to indicate the levels of confidence in the data.

THE SIGNIFICANCE OF CUBICLES FOR THE BEHAVIOUR OF DAIRY COWS

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ABSTRACT

For dairy cows, a large variation is observed in daily time spent lying down. Individual variations and differences connected with housing or management are known to affect the actual time spent lying. A series of experiments with dairy cows kept in cubicle houses was carried out. We investigated the consequences of some details of the cubicle house and of overcrowding on the time spent standing and lying in the cubicles. The aim of the experiments was to obtain information about the significance of cubicles for resting and for hiding.

Four experiments were carried out with a total of seven different groups of dairy cows. In the first experiment, the cows were kept in a so-called old cubicle house, which differed in various ways from a so-called new cubicle house in which the other three experiments were performed. In each experiment, a normal situation - with as many feeding and lying places as animals in the group - was compared with an overcrowded situation in which both the number of feeding and lying places was reduced. In the four experiments, overcrowding levels of 50, 55, 25 and 33.3 % were tested. To measure the time spent eating, standing and lying, detailed observations were carried out for 24-h periods.

Under normal conditions, the cows spent ~ 13 h lying and 2.5 h standing per 24 h. In the old cubicle house, under normal conditions, the time spent in the cubicles was lower than in the new cubicle house. This is probably due to two factors: (1) the cubicles were smaller and less comfortable; (2) in the old cubicle house the cows could hide from confrontations with group mates at the feeding rack with its separations between the feeding places as well as in the cubicles.

Overcrowding resulted in a reduction in time spent lying in the cubicles and also in a reduced time spent standing in the cubicles in the new cubicle house. It is concluded that under overcrowded conditions, lying is more important than standing in the cubicles.

Based on these experiments and on the available literature, it is concluded that lying is important for the cows. This means that cubicles are important for the cows; however, the minimum time that the cows need to lie or stand in a cubicle is not yet known. Various factors are suggested wich may affect how long the cows need to lie down.

INTRODUCTION

For dairy cows, lying is generally seen as an important behaviour (Metz et al., 1986; Krohn and Konggaard, 1987), as it enables the cows to rest. Süss and Andreae (1984) summarised the available literature and found that dairy cows lie down for ~ 9 - 12 h daily. This variation in the time spent lying is probably partly due to individual variations between cows - caused by various factors - and partly due to the housing and management of the animals.

In this paper, we first briefly describe the various factors which affect the lying time according to the available literature. Thereafter, some experiments are described which have provided additional information about factors affecting the time spent in cubicles. Finally, we discuss the significance of cubicles for the cows.

VARIOUS FACTORS AFFECTING THE TIME SPENT IN THE CUBICLE

Individual variation

A primary factor which causes variation between individuals is their age. Various authors have found that older cows generally lie down longer than younger cows (Reinbrecht, 1969; Sambraus, 1971; Pollock and Hurnik, 1979; Baehr, 1984). Variation in the lying time between individuals can also be caused by differences in their stage of lactation. However, there is little information about this factor. Roussev (1982) and Wierenga (1984) found that lying time was lowest at the beginning of lactation, which Baehr (1984), however, could not confirm. Oestrus is a factor which for a short period can substantially reduce the time spent lying (Sambraus, 1971; Pollock and Hurnik, 1979).

Social factors also cause variations in lying time between individuals. An example of the consequences of social interactions is given by Oester (1977). He found that after the dehorning of cows which were kept in a loose housing system with straw bedding, the number of displacements of lying animals decreased, resulting in an increased lying time. Dominance relationships can also influence the lying position which an animal chooses. Friend and Polan (1974) suggested that animals tend not to lie down near dominant animals. Arave and Walters (1980) observed that cows tend to avoid facing one another where there are two rows of cubicles. Jakob et al. (1988) found that high-ranking cows more often lie in the most popular cubicles than low-ranking cows. However, such effects of social dominance do not necessarily result in reduced lying times for the low-ranking animals. Both Sambraus (1971) and Baehr (1984) reported that, under normal practical conditions, there was no difference in lying times for high- and low-ranking animals.

Another social factor which influences lying is the synchronisation of behaviour. For instance, it is well known that at pasture dairy cows tend to synchronise their grazing and lying (Atkeson et al., 1942; Sambraus, 1973). Indoors, such synchronisation is often less pronounced (O'Connell et al., 1987a), but there is a difference in the level of synchronisation between types of housing. Schmisseur et al. (1966) noted a more pronounced synchronisation in a loose housing system with straw bedding housing with cubicles. Synchronisation primarily affects th which the cows lie down and stand up but, like social dominance, necessarily affect the total lying time.

Andreae et al. (1982) and Wierenga et al. (1985) have suggested that the cubicles can also serve as a safe area where the animals can hide from confrontations with their group mates. Thus, a cubicle is probably not important to the cow only for resting. Some evidence is available to support this idea. For instance, Metz and Mekking (1984) found that low-ranking animals spend less time in the walking area than high-ranking animals, which suggests that the low-ranking animals try to avoid confrontations by staying in the cubicles. Potter and Broom (1987) reported that low-ranking animals spend three times longer standing with only their head and front legs in the cubicles than other animals, which also suggests that low-ranking animals use cubicles to hide from dominant animals. How important the cubicles are as a hiding place for the cows probably depends on the lay-out of the cubicle house. When the cows have other possibilities for avoiding a confrontation with a group mate, one may expect the cubicles to be used less in which to "hide".

Housing

The housing systems which are generally used for dairy cows are a tether system and a loose housing system. In the latter, cubicles are mostly used, but when the system was first developed, straw bedding (without cubicles) was also used. The lying times found in such housing systems (tied or loose) and at pasture may differ (Phillips and Leaver, 1986), or be equal to each other (Meyer-Ötting, 1974). This suggests that the way the cows are kept is not the only influence on their lying time; other details in the housing or management also influence the time spent lying.

For all housing systems, the bedding material, the size of the lying place and the partitions (at the front and the sides) significantly influence the lying time of the animals. Firstly, the importance of the bedding is discussed. It has been shown that cows prefer soft bedding to harder bedding material (Wander, 1976; Kovalcik et al., 1978; Maton et al., 1981; Gebremedhin et al., 1985). This preference may result in reduced lying time when only cubicles with hard bedding are available. Stottmeister and Lamprecht (1966) found an average lying time of 504 min per 24 h when the cows had to lie down on concrete, but a lying time of 656 min when the cows had cubicles with sawdust. Secondly, the size of the lying place affects lying time. Wander (1976) noted an increased lying time when the width of the cubicles was increased from 105 to 120 cm, and also when the length of the cubicles was increased from 210 to 250 cm. A comparable increase in lying time was reported by Maton et al. (1978) when the width of the standings in a tether system was increased. Tschirch and Sommer (1970) also reported an increased lying time when the length of the standings in a tether system was increased. Thirdly, the partitions of the lying places (both at the front and the sides) affect lying behaviour. Kämmer and Schnitzer (1975) observed that cows need some extra space at the front and at the sides when they stand up or lie down. Therefore, the partitions at the front and the sides of the lying place should be such that the cows are not hindered when they lie down or stand up. Cows clearly prefer those cubicles which present few problems with standing up or lying down, and which also offer more comfort when they are lying (O'Connell et al., 1987b; Jakob et al., 1988). In a tether system, the cows are probably hindered when they stand up or lie down. However, Tschirch and Sommer (1970) found no difference in the lying times between cows kept in a cubicle house or in a tether system.

From the cow's point of view, loose housing with straw bedding appears to be the most comfortable system. Experiments by Irps (1985), Schmisseur et al. (1966) and Crowd and Albright (1965) showed that the cows prefer this type of housing to a loose housing system with cubicles. Even when the area with straw bedding was gradually decreased, the animals at first preferred to lie down closer to each other before choosing to use the available cubicles (Irps, 1985).

In a cubicle house, the lay-out, in particular the way the cubicles are arranged, can also affect the lying behaviour of cows. Various authors have described how some of the available cubicles are used less often by the cows, particularly the cubicles at the end of a row (Tschirch and Sommer, 1970; Keys et al., 1976; Daelemans et al., 1981; Baehr, 1984; Wierenga, 1984; Jakob et al., 1988). Factors like disturbance (owing to cow traffic, vicinity of a water trough, etc.) or an unfavourable microclimate (draught) may be responsible for the lower popularity of some cubicles.

Management

Atkeson et al. (1942) described how lying time increased when, owing to a better quality of pasture, grazing time decreased. A similar relation between grazing and lying time has been described by Castle and Halley (1953) and Könekamp (1953). Thus, the time necessary for the intake of food is one of the factors which can influence lying time. For cows kept indoors, no information is available about the effect of the time necessary for the intake of roughage on lying time. There is, however, some information about the relation with time spent eating concentrates. By comparing various programmes for the distribution of concentrates, Wierenga and Hopster (1988) noted a significant decrease in lying time in the evening, when a new concentrates feeding period was started in that period of the day. However, Andreae and Smidt (1983) compared feeding concentrates in a feeding station (using a so-called variable-time system) with feeding concentrates in the milking parlour and did not find any difference in lying time. So, under certain circumstances, feeding concentrates may affect the time spent lying.

Metz et al. (1987) investigated the consequences of automatic roughage feeding and of continuous milking. They compared the behaviour of three different groups of cows. Firstly, they tested a feeding group where the animals received concentrates and roughage via an automatic feeding system. Secondly, in the test milking group, the cows were also fed automatically and were milked in a milking box, which was continuously available. Thirdly, in a control group, the cows were fed concentrates with an automatic feeding system; roughage was fed at the feeding rack. In this experiment, the cows of the control group spent more time in the cubicles than the cows of the other two experimental groups, showing that automatic feeding and milking may result in a reduced lying time.

Another management factor that clearly affects lying behaviour is overcrowding. Various authors have described how a reduction in the number of cubicles resulted in a reduction in lying time. This was noted particularly for low-ranking animals (Friend et al., 1977; Wierenga, 1983, 1984; Krohn and Konggaard, 1987).

More detailed information about the possible influence of the management of the farm on the time spent lying is not available. One can imagine, however, that lying time will be affected by more factors than only the feeding regime or overcrowding. For instance, depending on how the farmer works, the total time that the cows are not in the cubicle house during milking will vary. This may affect the lying time of the cows. Furthermore, during the day the farmer may carry out other activities, such as the cleaning of cubicles, walking area, etc., which may disturb lying.

Further experiments

This review of the available literature has shown that both individual variations and differences connected with housing or management may affect the time spent lying and standing in the cubicles. In the following, we describe a series of experiments with dairy cows that focus on the consequences of overcrowding for the time spent in the cubicles. Based on our results and on the available literature, the significance of cubicles for both lying and for hiding will be discussed.

MATERIALS AND METHODS

Materials

Four experiments were carried out (Experiments I, II, III and IV) with small groups of Holstein Friesian x Dutch Friesian as well as Dutch Red and

White dairy cows. In Experiments I, II and III, two groups of 15, 17 and 20 cows, respectively, were available. Experiment IV was carried out with one group of 16 cows. All the animals were lactating and they were at about the same stage of lactation. The age composition resembled a practical situation: within each group the age of the animals varied between 2 years (heifers) and a maximum of 10 years.

The experiments were performed in a cubicle house with a feeding rack, a walking area and a row of cubicles. In the cubicle houses, daylight and also additional artificial light were available during the day; during evening and night, the lighting was reduced such that behavioural observations of the cows were still possible. The animals were kept in: (1) a cubicle system with as many lying and eating places as the number of animals in the group ("normal situation"); (2) in a cubicle system with a reduced number of lying and eating places ("overcrowded situation"). The first experiment was performed in a cubicle house which differed in various ways from that in which the other three experiments were carried out. This so-called old cubicle house (Fig. 1) had a row of cubicles on one side of the building and on the other side there were another three cubicles and the feeding rack. The wooden feeding rack was supported by wooden balks between each feeding place. These were set from the top of the feeding rack at 1.20 m height, at an angle to the floor, and extended ~ 1 m into the walking area. Thus, each feeding place was separated from the neighbouring one by a partition of ~ 1 m. The width of each feeding place was 74 cm. The walking area, with a slatted floor, was 2.40 m wide (excluding the space at the feeding rack). The cubicles were only 1.08 m wide and 1.93 m long, with a wooden floor sparsely covered with sawdust. The building was separated into two parts for the experiment. In the right part, 15 lying and 15 eating places were available, and in the left part there were 10 lying and 10 eating places.

The other three experiments were carried out in the so-called new cubicle house (Fig. 1). In this building, on either side of the central feeding passage were successively the feeding rack, the walking area and a row of cubicles. Here a metal feeding rack without partitions extending into the walking area was used. The width of each feeding place was 65 cm. The walking area, with a slatted floor, was 2.70 m wide. The cubicles were 1.15 m wide and 2.20 m long. They had a concrete floor with a thick (~ 5 cm) layer of sawdust as bedding. For Experiments II and III, parts of both sides of the central feeding passage were available. In Experiment II, on the right side 17 lying and 17 feeding places were available, and on the left side 11 lying and 11 feeding places. In Experiment III, on the left side alternately 20 or 16 places were available, and on the right side 20 places were available. In the last experiment (Experiment IV), on the left side of the cubicle house only, there were at first 16 lying and 16 feeding places available, and later 12 places. In all experiments, that part of the cubicle house directly adjacent to the entrance was used.

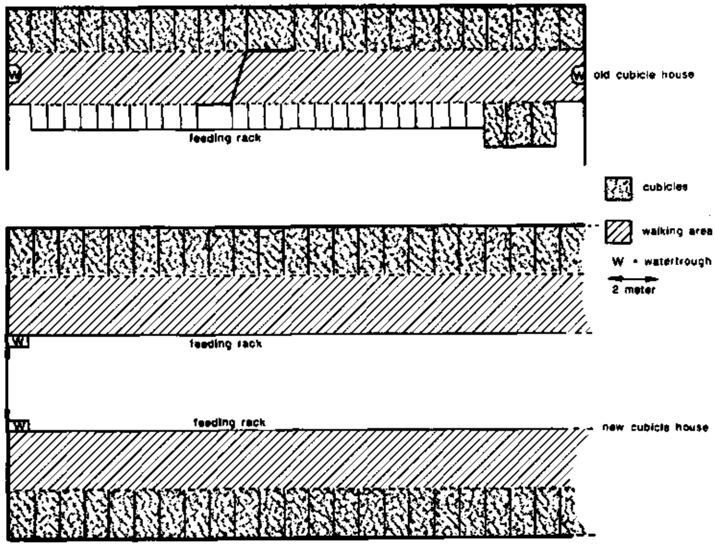


Figure 1. Plan of the two experimental cubicle houses.

The animals received a restricted amount of maize silage mixed with a small amount of concentrates. They also received ad libitum grass silage which was fed once or twice daily. In Experiments I, III and IV, roughage was delivered twice daily. Directly after morning milking (at 06.00 h), the animals received the maize silage and directly after the afternoon milking (at 15.30 h) the grass silage was distributed. In Experiment II, grass silage was also given at 10.30 h and in Experiment IV the animals received an additional amount of concentrates at 11.30 h. These slight variations between the experiments in feeding management may have affected the general activity of the cows and thus also the time spent in the cubicles. Such possible (interfering) consequences will be discussed only briefly, because the effect of overcrowding was always analysed within each experiment.

Experimental design and behavioural observations

In the first two experiments, both groups of cows were kept alternately, during three rounds, in the normal and overcrowded part of the cubicle house (Fig. 2). When overcrowded, there were 10 and 11 feeding and lying places available for the 15 and 17 cows of each group, respectively. Thus, the overcrowding was 50 and 55 %, respectively. In Experiment III, possible long-term consequences of overcrowding were also investigated. One group was therefore kept permanently in normal conditions (Fig. 2) on the right side of the cubicle house. The other group was kept on the left side; for a short round in normal conditions at the beginning and at the end of the ex-

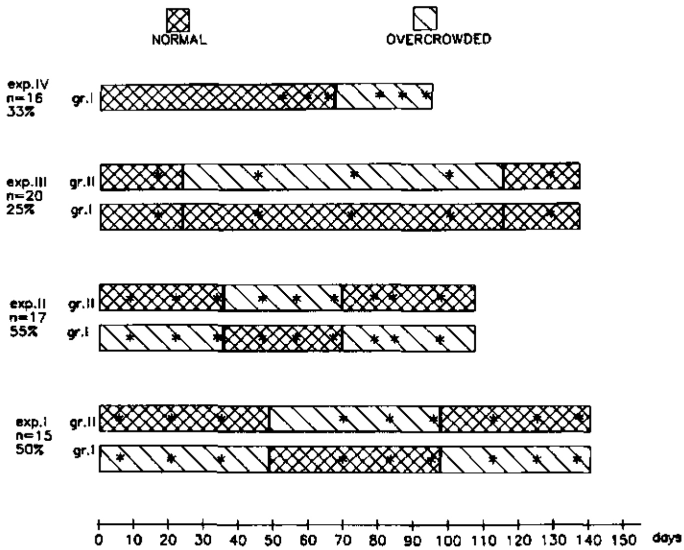


__Figure 2__. Experimental design. The duration (days) of the whole experiment and of each round is presented for each experiment (I, II, III and IV) and for each group (I and II). The day when a 24-h behavioural observation was carried out is also presented (* = 24-h observation, n = number of animals per group, % = level of overcrowding tested).

periment, and in the middle round, the 20 animals of this group had 16 lying and feeding places available (25 % overcrowding). In Experiment IV (Fig. 2), the 16 cows were first kept under normal conditions and then under overcrowded conditions (33.3 %; 12 places for 16 cows) on the same (left) side of the cubicle house.

To measure "general activity" (eating, standing, lying), detailed observations were carried out for a 24-h period. Generally, in each experimental round three 24-h observations were carried out (Fig. 2). These observations were made mostly 2 weeks after a change of conditions to make sure that data were collected when the cows had adapted to the new situation. Thus, the adaptation of the cows to a new situation was not investigated. At 10-min intervals, we noted whether each cow was eating, standing or lying, and also her position (feeding rack, walking area or cubicle), according to the following rules. A cow was recorded as eating when she had her head through the feeding rack and was actually engaged in consuming food. A cow was standing at the feeding rack when she had her head through the feeding rack, but was not busy with the food. In the old cubicle house, a cow was also recorded as standing at the feeding rack when she had her forefeet between the partitions of the feeding rack without having her head through the feeding rack. A cow was recorded as standing in the cubicle when she had her two forelegs or all four legs in the cubicle. A cow lying in the cubicle was noted as such. In the remaining cases, the cow was in the walking area. Both standing and walking cows were noted as standing in the walking area. Finally, lying down in the walking area was noted as such.

For information about the dominance position of each animal, aggressive interactions were recorded during the 24-h observations and also during separate 2-h observations directly after feeding (see Wierenga, 1990).

Analysis of data

The results of the 10-min interval observations were used both to describe the daily rhythm for the observed activities and to calculate the time spent on the various activities (time budget). The total time spent on the various activities was calculated per 24-h period, but also separately for the period between morning and afternoon milking ("day"; lasting ~ 8.5 h), for the last 4 h before morning milking ("night"; 4 h) and for the period between afternoon milking and the "night" ("evening"; ~ 10 h).

Differences in the time spent on the various activities between the four experiments separately, and between the old (Experiment I) and the new (mean of Experiments II, III and IV) cubicle houses were analysed with a *t*-test.

Differences in the time spent on the various activities caused by overcrowding were analysed within each separate experiment. In Experiments I and II, the consequences of overcrowding were analysed with an analysis of variance (univariance mixed model; Searle, 1971). Groups of cows per experimental round were used as an experimental unit (Hoekstra and Jansen, 1986). With this model, the effects of the factors treatment (crowding), group, round and day on the time spent on the various activities were analysed. Treatment and round were considered as fixed effects; day within round, group and the interaction group x round were considered as stochastic effects. For the calculations, the programme REML (Robinson, 1987) was used. In Experiments III and IV, only one group of cows was tested both in normal and in overcrowded conditions; in both experiments the consequences of overcrowding were analysed with a *t*-test.

On the basis of the dominance values (Wierenga, 1990), a subgroup of high-ranking animals (the 5 animals with the highest dominance values) and a subgroup of low-ranking animals (the animals with the lowest dominance values) were distinguished. For these two subgroups, the consequences of overcrowding for the mean time spent in the cubicles were also tested with an analysis of variance (Experiments I and II) or a *t*-test (Experiments III and IV).

RESULTS

General description of daily rhythm and time budget

We first give a general description of both the daily rhythm and time budget of the cows. A more detailed analysis, including statistics, is presented later. To illustrate the consequences of overcrowding, the most extreme overcrowding (55 %; tested in Experiment II) was chosen. Therefore the results obtained from Experiment II under normal conditions will also be presented. To describe the daily rhythm, the results of one representative day (again from Experiment II) were selected.

The daily rhythm which was recorded in the normal situation in Experiment II is presented in Figure 3. The percentage of animals at the feeding rack or in the cubicles varied considerably. During the day, there were two periods (at about 07.00 and 11.00 h) with many cows at the feeding rack. The animals were fed at these times. In the evening, we did not record so many animals eating at the same moment. Until about midnight, a fairly constant number of cows was found at the feeding rack. In the night (between 02.00 and 06.00 h) hardly any cow was seen to eat. In between and after the two "eating" peaks in the day, there was a large number of cows in the cubicles. After the afternoon milking, the number of cows in the cubicles increased rapidly and subsequently varied roughly between 50 and 80 %. During the night, very often ≥ 90 % of the cows were found in the cubicles. The number of animals in the walking area was fairly low all the time. A

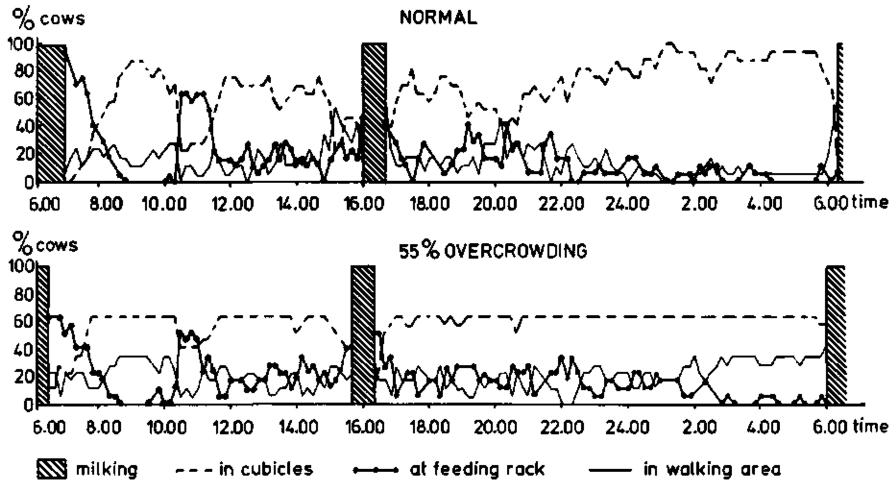


Figure 3. Activity pattern (per 10 min the percentage of cows at the feeding rack, in the walking area or in the cubicles) observed during a 24-h observation in a normal and in an overcrowded situation (third observation in the third round of Experiment II; group II and group I, respectively).

representative picture of the daily rhythm observed in the overcrowded conditions in Experiment II is also given in Figure 3. With 55 % overcrowding, not more than 64.7 % of the animals could stay at the feeding rack or in the cubicles simultaneously. This reduction of feeding places apparently had almost no consequences on the eating pattern. However, the maximum possible number of lying cows is observed almost constantly, except during the two "eating" peaks in the morning and directly after the afternoon milking. In the overcrowded situation, the number of animals which stayed in the walking area was higher than in the normal situation. This is particularly evident in the night period (between 02.00 and 06.00 h). In the other experiments, roughly the same daily rhythm was found, both in normal and overcrowded conditions. Differences were mainly observed in the number and timing of the eating peaks, caused by the variation in feeding times between the experiments.

The total time per cow per 24 h spent on the different activities in normal conditions (Experiment II) is presented in Figure 4. On average, the

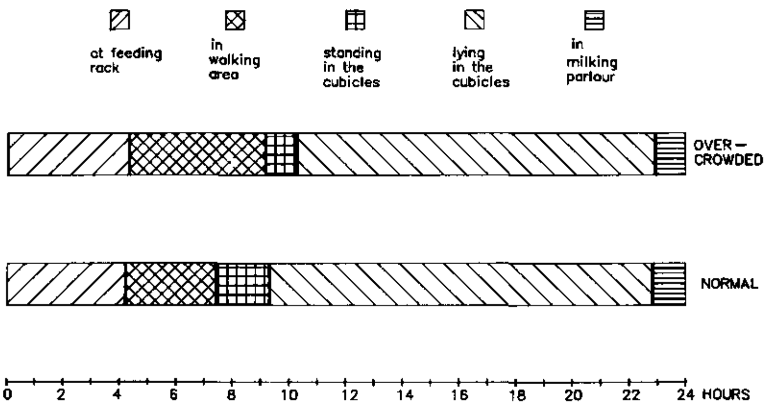
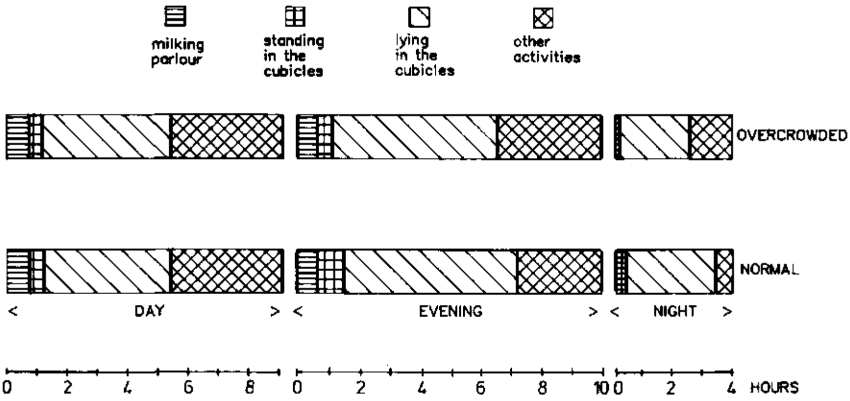


Figure 4. Time spent per 24 h at the feeding rack, in the walking area, standing or lying in the cubicles and in the milking parlour, for the normal and overcrowded situations in Experiment II (mean of all 24-h observations of both groups).

cows spent > 4 h at the feeding rack and ~ 3 h in the walking area. The animals spent > 15 h in the cubicles, during which they lay down for > 13 h. The remaining time (~ 1.5 h) was spent in and around the milking parlour. In overcrowded conditions, both the time spent standing and the time spent lying in the cubicles were much lower than in the normal situation. The time spent in the walking area was increased in the overcrowded cubicle house. With respect to time spent in the cubicles, the "time budgets" are presented for each separate part of the 24-h period in Figure 5. Under nor-



<u>Figure 5</u>. Time spent standing or lying in the cubicles during the day, the evening or the night of the 24-h period, for the normal and the overcrowded situations in Experiment II (mean of all 24-h observations of both groups).

mal conditions, during the day, slightly more than half of the available time was spent in the cubicles; of this time, the cows stood in the cubicles for about half an hour. In the evening, about two-thirds of the available time was spent in the cubicles; about 1 h of this time was spent standing in the cubicles. During most of the night period the cows were found in the cubicles; they only spent about half an hour standing in the cubicles. In the overcrowded situation a more or less comparable pattern was found. However, in particular in the evening and the night the time spent in the cubicles (both standing and lying) was reduced.

Analysis of the time budget under normal conditions

For each experiment separately, for the normal condition, the mean time spent at the feeding rack, in the walking area and in the cubicles is given in Table 1. The results of the analysis for differences in results between each of the four experiments are also presented in this table. Furthermore, the difference in time spent on the various activities between the old (Experiment I) and the new cubicle houses (mean of Experiments II, III and IV) is presented. The analysis of the various experiments separately shows that the eating time in Experiment IV was significantly higher than in the other three experiments. The high eating time in this experiment also caused the difference in eating time between the old and the new cubicle houses (20.3 min) to become significant. Time spent standing at the feeding rack was significantly higher in Experiment I compared with the other three experiments. Thus, a significant difference (28.7 min) between the old and the new cubicle houses was found. The time spent standing in the

Table 1. Time budget (min per 24 h) found under normal conditions in the four different experiments, in the old and in the new cubicle houses. When the time spent on a certain activity differed significantly ($P \leq 0.05$) between the experiments, they are marked with a different superscript (a, b or c). The difference between the results in the old (Experiment I) and new cubicle houses (mean of Experiments II, III and IV) is also given.

	I (old)	II (new)	III (new)	IV (new)	Difference (old - new)
Feeding rack					
Eating	235.8^{a}	244.6^{a}	248.4^{a}	276.1^{b}	-20.3 $P \leq 0.003$
Standing	34.2^{a}	7.1^{b}	8.9^{b}	0.4^{b}	+28.7 $P \leq 0.00$
Walking area	242.1^{a}	194.5^{b}	163.9^{bc}	131.7^{c}	+78.9 $P \leq 0.00$
Cubicles					
Standing	181.0^{a}	108.6^{b}	163.6^{a}	115.0^{b}	+52.0 $P \leq 0.00$
Lying	664.8^{a}	807.2^{b}	759.5^{c}	816.9^{b}	-129.0 $P \leq 0.00$

walking area varied considerably between the experiments. The highest level (and significantly different from each of the other three experiments) was found in Experiment I. The difference in time spent standing in the walking area between the old and the new cubicle houses (78.9 min) was significant. The time spent standing in the cubicles also varied between the experiments. In Experiments I and III, this standing time was significantly higher compared with Experiments II and IV. The difference between the old and the new houses (52.0 min) was significant. Finally, a variation in the time spent lying in the cubicles was also found between the four experiments. The lowest lying time (differing significantly from each of the other three experiments) was recorded in Experiment I. Thus, the difference in lying time between the old and the new cubicle houses (129.0 min) was found to be statistically significant.

Analysis of the time budget under overcrowded conditions

The consequences of overcrowding are presented for each experiment as the difference between the overcrowded and normal conditions in the time spent on the various activities (Table 2). None of the experiments revealed a significant change in the time spent eating. Only in the experiment held in the old cubicle house was the time spent standing at the feeding rack found to be significantly higher (15.8 min) in the overcrowded situation.

Table 2. Difference (overcrowding minus normal; min per 24 h) between the normal and the overcrowded conditions for the various general activities in the four experiments (I, in the old cubicle house; II, III and IV, in the new cubicle house). Significant differences (within one experiment) between the normal and overcrowded situations are marked.

	25 % (III-new)	33.3 % (IV-new)	55 % (II-new)	50 % (I-old)
Feeding rack				
Eating	9.0	-12.5	2.7	1.3
Standing	- 1.1	0.2	2.1	15.8*
Walking area				
Standing	53.8**	70.0***	89.7***	62.8***
Lying	0.0	0.0	8.0	0.0
Cubicles				
Standing	-43.8**	-28.7*	-46.8***	13.2
Lying	0.4	-15.6	-54.7**	-93.7*

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.

In all four experiments, the time spent standing in the walking area was significantly higher in the overcrowded conditions. The increase was highest (89.7 min) when 55 % overcrowding was applied and lowest with 25 % overcrowding (53.8 min). Relatively, the increase was not so high in the overcrowded situation in the old cubicle house (62.8 min). Lying in the walking area was recorded only for 55 % overcrowding. This increase was not statistically significant because the lying was performed by only two (low-ranking) cows. The time spent standing in the cubicles was affected significantly only in those experiments carried out in the new cubicle house. In these experiments, the time spent standing was reduced (varying between 28.7 and 46.8 min) in the overcrowded conditions. The time spent lying in the cubicles was not affected significantly by 25 and 33.3 % overcrowding. With 50 and 55 % overcrowding a significant reduction in lying time was found. In the old cubicle house, the lying time was reduced much more (93.7 min) than in the new cubicle house (54.7 min).

Consequences of overcrowding for time spent in the cubicles: A more detailed analysis

Next, the consequences of the different levels of overcrowding will be compared for all the animals, and for the low- and high-ranking animals both for the 24-h period and for the different parts of it. The aim was to look for possible trends that might be associated with different levels of overcrowding. The results of Experiment I in the old cubicle house will not be discussed for the moment because the consequences of overcrowding in the old and in the new cubicle houses were so different. A possible explanation for this difference will be discussed later. The results, presented in Table 2, showed a decrease in time spent in the cubicles (lying and/or standing) and an increase in time spent in the walking area. The latter may be the result of the decrease in time spent in the cubicles. In any case, the consequences are interdependent: the cows would have had difficulty in obtaining a cubicle owing to the reduction in the number of cubicles, resulting in an increase in time spent elsewhere. Because it seems plausible that time spent in the cubicles is the activity primarily affected by overcrowding, this particular activity has been analysed in more detail.

In Figure 6, the consequences of overcrowding for time spent in the cubicles - again presented as the difference between the overcrowded and the normal conditions - are given for the 24-h period as a whole and also for each separate part of it. At all three levels of overcrowding, the time spent standing per 24 h was reduced significantly. A reduction (but not always significant) was found during the day as well as during the evening and the night. The time spent lying per 24 h was reduced significantly only with 55 % overcrowding. Such a reduction was not observed during the day. In the evening, a significant reduction of lying was only found with 55 % overcrowding. At an overcrowding level of 33.3 % in the evening, an increase in time spent lying down (22.7 min; not statistically significant) was even measured, which could be a compensation for deprived lying time during the night. In the night period, the time spent lying was significantly reduced when 33.3 and 55 % overcrowding was applied (by 34.7 and 40.4 min, respectively). The total (standing and lying) time per 24 h spent in the cubicles was decreased significantly at all three levels of overcrowding. This reduction was highest for overcrowding of 55 %. In the evening with 55 % overcrowding only, and in the night at all three levels of overcrowding, a significant reduction in the total time spent in the cubicles was found.

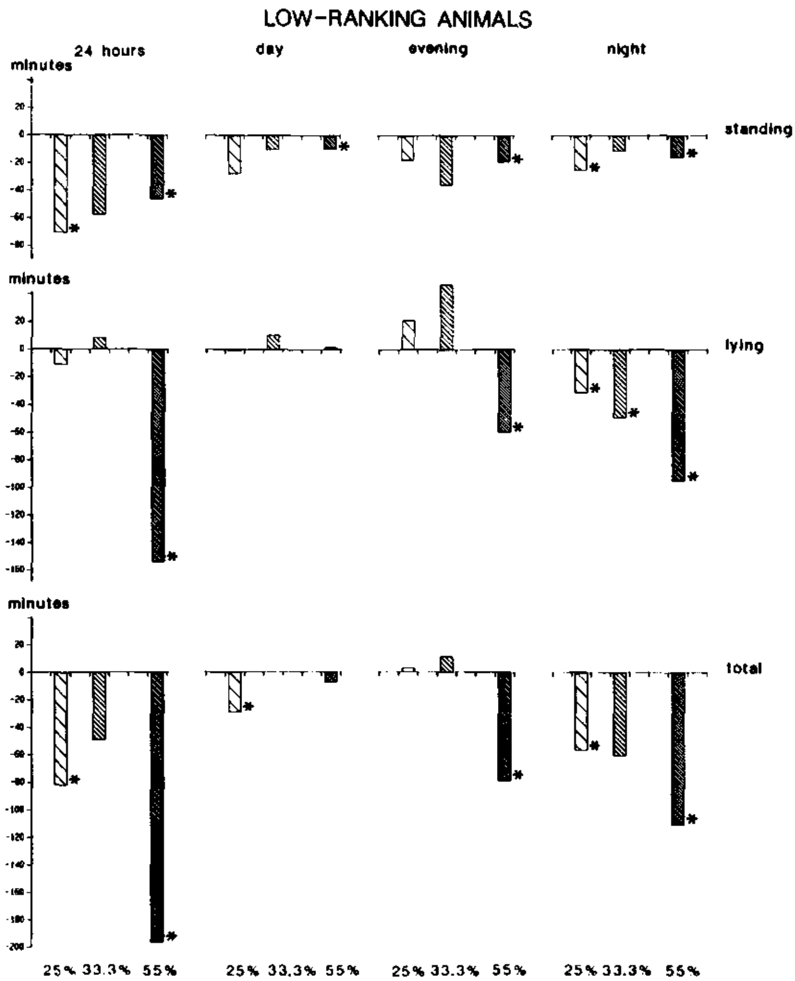
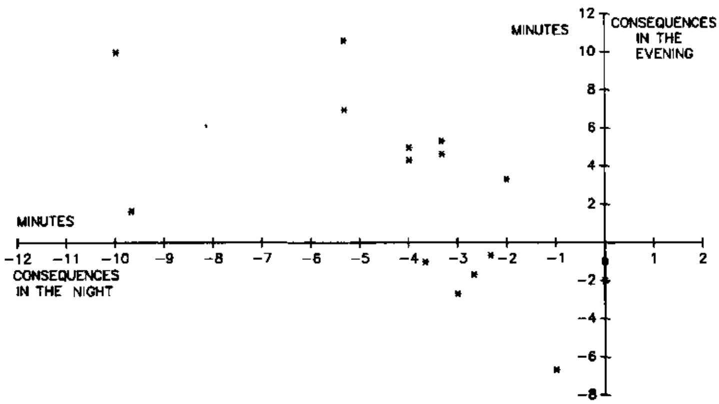


Figure 8. Consequences (overcowding minus normal) of overcrowding on time spent in the cubicles for the low-ranking animals. For further explanation, see Fig. 6.

- reduction during the night and compensation during the evening - was found with 33.3 % overcrowding. When 55 % overcrowding was applied, a significant reduction in lying time was found, both in the evening and in the night (by 60.0 and 94.9 min, respectively). Thus, the total time spent standing and lying in the cubicles was reduced considerably (varying between 49.3 and 196.2 min per 24 h) for the low-ranking animals.

A comparison of lying times in the evening and the night leads to the suggestion that sometimes a reduction of lying in the night is compensated for by an increased lying time in the evening. For 25 % overcrowding, this was not observed for all animals. Apparently 25 % overcrowding resulted in a reduction in lying time only for the small group of low-ranking animals. For 33.3 % overcrowding, not only for the low-ranking animals but also for the mean of all animals, a signficant reduction of lying time in the night period is compensated for sufficiently (in the evening) such that for the whole 24-h period only a very small, and not significant, reduction of lying was recorded. A level of overcrowding of 55 % resulted in a reduced lying time, not only in the night but also in the evening (for the mean of all animals and for low-ranking animals). Apparently this level of overcrowding is so high that a compensation during the evening for lying time lost in the night is not possible. The results suggest that 33.3 % overcrowding was so high that on the one hand for many animals lying time was reduced during the night, but on the other hand these animals were able to compensate during the evening for this reduction. If indeed such a compensation took place, it might be expected that those cows which experienced a high reduction in the night would show a high increase during the evening, whereas cows which were hardly affected by overcrowding would not show an increased lying time in the evening. To test this hypothesis, the relationship between the consequences of overcrowding on lying time in the night and in the evening was analysed for each cow. A significant correlation (Pearson's correlation; $r = -0.62$, $P \leq 0.01$) was indeed found (Fig. 9): those animals with the highest reduction in lying time during the night showed the highest increase in lying time during the evening.



<u>Figure 9</u>. Relation between the consequences (overcrowding minus normal) of 33.3 % overcrowding on time (min) spent lying in the night and in the evening. Each point represents one animal.

DISCUSSION

Daily rhythm and time budget under normal conditions

Eating and lying were performed by the cows in a clear and constant daily pattern. In this investigation we found that the cows spent > 60 % of their time in the cubicles. Under normal conditions, ~ 13 h were spent lying and 2.5 h were spent standing in the cubicles. In particular during the evening and night, the cows spent a lot of time lying. During the last 4 h of the night, the cows spent as much as 75 % of the available time lying in the cubicles. These results are comparable with data presented in the literature (e.g. Tschirch and Sommer, 1970; Sambraus, 1971; Süss and Andreae, 1984).

Significant differences between the experiments were often found in the time spent on the various activities. These differences may partly be because different groups of cows have been observed in different years, or because there were slight differences in the feeding management. The experimental design does not permit us to judge the importance of these different factors. An additional difference between Experiment I and Experiments II, III and IV is the change from the old to the new cubicle house. A significant difference was always found between the results obtained in the old and in the new cubicle house. Again these differences will have been caused partly by differences in groups of cows or in feeding management. However, concerning standing at the feeding rack, standing in the walking area and lying in the cubicles, a significant difference was observed between the results of the experiment in the old cubicle house and the results of each of the three experiments in the new cubicle house. This suggests that, in particular, the time spent on these activities was affected by the housing system. The differences between the old and the new cubicle house will be discussed first.

Differences between the old and new cubicle houses

under normal conditions

In the old cubicle house, the cows spent less time in the cubicles than in the new cubicle house. Differences between groups and between feeding management will have partly caused this. However, the lower lying time can also partly be explained by the smaller cubicles and by the less comfortable bedding offered in the old cubicle house. As has been mentioned, various investigations have shown that the time spent lying decreases with decreasing size and comfort of the cubicles (Wander, 1976; Maton et al., 1981; Gebremedhin et al., 1985). So some reduction in time spent in the cubicles in the old cubicle house may be expected. However, because the observed reduction is so large, other factors may also have played a role. As mentioned earlier, there is evidence that cubicles are not only used for resting, but also as a safe area which the cows use to avoid confrontations with group mates (Andreae et al., 1982; Wierenga et al., 1985; Potter and Broom, 1987). In the old cubicle house, the cubicles may be less necessary for this purpose because the feeding rack, with separations between the eating places, could also be used as a place to withdraw from group mates. Such a function of the old-style feeding rack could explain both the longer time spent just standing at the feeding rack and the reduced time spent in the cubicles. Furthermore, in the old cubicle house the total available space was slightly larger so that the cows probably would have had to leave the walking area less often to avoid a confrontation with a group mate.

under overcrowded conditions

The difference in the consequences of overcrowding found between the old and the new cubicle houses also needs to be discussed. We discovered that in the old cubicle house the time spent standing in the cubicles (which was already higher than in the new building) did not decrease, as in the new cubicle house, when overcrowding was applied. Thus, in the old building, the cows did not reduce their standing time to attain their desired lying time. It is thought that in the new cubicle house the time spent standing in the cubicles is reduced because the cows, owing to the overcrowding, try to lie down more quickly when they have succeeded in obtaining a cubicle. It is possible that in the old cubicle house the cows have problems with lying down quickly. This could be explained by the lower "quality" of the cubicles. It has been argued that the bedding and also the smaller size of cubicles resulted in lower lying times and in higher standing times in the old cubicle house. In overcrowded conditions, the smaller cubicle size could have an even greater effect. In an overcrowded situation, there is a higher chance that either one or both of the neighbouring cubicles will already be occupied by a lying cow, which reduces the actual size of the empty cubicle further. Lying cows may occupy part of a neighbouring cubicle with their legs or with their head or back, and thus hinder a standing cow from lying down in the empty cubicle. In the new cubicle house, Wierenga et al. (1985) have described how, when there are several empty cubicles, cows tend not to lie down immediately next to a lying cow, but to skip one cubicle. It was hypothesized that not only social aspects, but also "physical" aspects, determined this tendency. So it seems likely that with overcrowding, the standing time in the old cubicle house increased even more owing to the lower quality of the cubicles. One advantage of the old cubicle house is that the cows can partly withdraw by standing between the partitions at the feeding rack. They did this more in the overcrowded situation.

Consequences of overcrowding for time spent in the cubicles in the new cubicle house

Overcrowding particularly affected the time spent in the cubicles (lower) and thereby the time spent in the walking area (higher). Eating time, and also food intake (Wierenga and Hopster, 1986), were affected to a smaller extent. Such a difference in the consequences of overcrowding between the time spent at the feeding rack and in the cubicles seems plausible, as the cows in these experiments normally spent > 15 h in the cubicles and only ~ 4 h at the feeding rack. Thus, it will be much easier for a cow to compensate for changes in the opportunities for eating than for changes in the opportunities for lying or standing in the cubicles.

Overcrowding resulted in a significant decrease in time spent in the cubicles. An experiment under practical conditions with a group of 55 cows kept under an overcrowding level of 30 % revealed comparable results (Wierenga, 1984; Wierenga and Van Geneijgen, 1985). Combining the results of these experiments with other experiments at commercial farms (Wierenga and Hopster, 1982) has lead to the conclusion that even at a rather low level of overcrowding, less time is spent in the cubicles.

The detailed analysis of the consequences of overcrowding found in the new cubicle house revealed interesting results. For the mean of all animals, at all three levels of overcrowding, we observed the same reduction per 24 h in time spent standing in the cubicles. Some degree of reduction in time spent standing in the cubicles, was observed in all three parts of the 24-h period (day, evening and night). On the other hand, for the mean of all animals a significant reduction in lying time was observed only with 55 % overcrowding and in particular at night. The difference between the consequences of overcrowding for standing and for lying time is remarkable, and can probably be explained as follows. In the normal situation, time spent standing in the cubicles did not vary much between the three parts of the 24-h period (in Experiment II ~ 35, 55 and 20 min during the day, the evening and the night, respectively; Fig. 5). Part of this standing time occurs in the period just before the cows lie down, part of it is an interruption of lying, part will occur at the end of a lying bout. One can imagine that the cows, as a reaction to the increased competition for the cubicles, lie down more quickly once they have succeeded in obtaining a cubicle, resulting in a reduced standing time. Furthermore, it was the observers' impression that cows standing in a cubicle were more often displaced than cows lying in a cubicle. Under overcrowded conditions, this may mean that cows which stand up after a period of lying may be displaced quickly, resulting in a reduced standing time. Because standing time in the normal situation did not differ very much between day, evening and night, it can be understood that the reduction in standing is also comparable for the three periods.

Unlike time spent standing, lying time is not so evenly distributed over the three separate parts of the 24-h period. During the night, for instance, the cows lie down for ~ 75 % of the available time (Fig. 5), so that overcrowding in this period results in a large reduction of available lying time per cow. During the day and the evening, the cows spent ~ 50 and 60 %, respectively, of the available time lying down (Fig. 5); so in these periods overcrowding may have fewer consequences. With low levels of overcrowding, a compensation for the reduction in lying time experienced in the night may then occur. With 25 % overcrowding, a significant decrease in lying time was not observed for the mean of all animals in any part of the 24-h period. Apparently, the reduction in time spent standing was enough to prevent a reduction in lying time. With 33.3 % overcrowding, a significant decrease in lying time was found for the mean of all animals during the night. To a great extent, this reduction was compensated for by an increased lying time during the evening. This compensation, together with a reduction in time spent standing, meant that for the whole 24-h period no significant decrease in lying time was found. With 55 % overcrowding, the reduction in available cubicles was apparently so high that not only in the night but also in the evening a significant decrease in lying time was found for the mean of all animals. Thus, in this situation the decrease in standing time only prevents the lying time being even further reduced.

For the high- and low-ranking animals, large differences in the consequences of overcrowding were found. The high-ranking cows suffered little from the overcrowding. However, the lying time of the low-ranking animals was reduced by 154.0 min per 24 h when 55 % overcrowding was applied. With 25 and 33.3 % overcrowding, these animals showed a significant decrease in lying time in the night, but this reduction was compensated for more or less completely during the evening. These results thus show that, with increasing competition, at first the low-ranking animals experience the consequences, while the high-ranking animals are hardly affected.

Interestingly, the compensation for reduced lying time in the night is only found during the evening and not during the day, although under normal conditions during the day ~ 50 %, and during the evening ~ 60 %, of the available time spent lying, suggesting that during the day there should be more possibilities to compensate for lost lying time. An explanation could be that during the day the tendency to compensate for deprived lying time may be lower than during the evening.

The experiments have shown that for many animals overcrowding results in a reduction in the total time spent in the cubicles. The explanations given for the observed consequences of overcrowding imply that we think that the cows actively try to minimise the consequences for lying time. This implies that for dairy cows lying is important. It also implies that, under overcrowded conditions, lying in the cubicles is more important than standing in the cubicles.

Importance of the cubicles for the cows

Both from a scientific and from a practical point of view, it is relevant to have information about the importance of the cubicles (both for lying and for standing) for the cows. Such information is needed to be able to judge, from a cow's point of view, current systems, and also to anticipate the consequences of new developments in the housing and/or management of dairy cows.

Both the results of our own experiments and the literature cited have shown that the time spent in the cubicles (lying and standing) can vary considerably. Some causes of this variation are known. For instance, individual factors like age, stage of lactation and position in the social dominance order are known to affect the time spent in the cubicles. Furthermore, the housing system (bedding, size and partitions of the lying place; lay-out of the house) and also the management (feeding system, overcrowding) appear to have an effect on the time spent in the cubicles. It is not clear how much of the variation in time spent in the cubicles can be explained by all these factors. Moreover, such information does not answer the question what minimum lying time is needed. Sambraus (1971) suggested, based on the large variation found, that probably at least part of the time spent lying in cubicles is luxury, which means that the cows do not necessarily need to have the total time in the cubicles which they normally obtain. In discussing the minimum time needed in the cubicles, it is important to differentiate between the two functions which a cubicle can have: a place to rest and a place to hide.

cubicles for resting

From the overcrowding experiments, it can be concluded that, in particular, lying in the cubicles is important for the cows. As soon as the available number of cubicles is reduced, the cows react by reducing the time spent standing. Such a reaction is also found for the high-ranking animals, even at a low level of overcrowding. It shows that lying is important for the cows (and that standing in cubicles is of lesser importance). However, it is not justifiable to conclude that the time during which the cow lies down in the cubicle in the normal situation is the minimum lying time required. If that were so, probably less variation would be found under normal conditions. It could be that the described reaction of the cows only shows that the cows prefer to lie down for a certain amount of time, but that this lying time is not necessary from a "physical" point of view. In any case, an experiment with 30 % overcrowding did not reveal any consequences for health or for milk production (Snoek, 1988). Friend et al. (1979) also recorded no reduction in milk production, although lying time was decreased and glucocorticoid concentrations in the blood increased with increasing level of overcrowding.

In experiments in which conditions other than overcrowding were investigated, Krohn and Konggaard (1982) and Metz and Wierenga (1984) also showed the importance of lying for cows. Krohn and Konggaard (1982) showed that blood cortisol levels became more than twice as high compared with normal levels when the lying time of the cows was reduced from 667 to 167 min per 24 h. This shows that such a decrease to 25 % of the normal lying time is stressful to the animals. Metz and Wierenga (1984) performed experiments in which cows were deprived of lying for periods of 3 or 6 h; in part of the experiments the cows were also deprived of food. The cows gradually adapted their daily rhythm to compensate for the deprived lying time (Wierenga and Metz, 1986). The cows always compensated completely, sometimes even more than that, for the deprived lying time during the remaining part of the day and night. Sometimes the cows gave a higher priority to lying than eating. This again shows the importance of lying for the cows. However, these experiments were not detailed enough to give information about the minimum lying time necessary "from the cow's point of view".

The various experiments have shown that the dairy cow is flexible in the actual time spent in the cubicles. This suggests that the minimum required time will be somewhat lower that the time recorded in most of the experiments. It could be that the cow's need for lying depends on the circumstances. There are two possibilities. Firstly, it may make a difference how the cows obtain their lying time. For example, four lying bouts of 3 h each may fulfill the needs of the cow better than two bouts of 6 h each, although in both situations a total lying time of 12 h is achieved. One explanation of the total and partly "over"-compensation of the deprived lying time found by Metz and Wierenga (1984) could be that the cows in that experiment were forced to stand in a small area so that they did not have much opportunity for moving about. In our overcrowding experiments, the cows did have room to walk around. The physical load in this situation could thus be lower than in the deprivation experiments, and could result in a different need for lying. Secondly, one can imagine that the need to lie down is not constant throughout the whole 24-h period. From the deprivation experiments (Wierenga and Metz, 1986) and also from an experiment into the consequences of undercrowding (23 cubicles for 12 cows; Wierenga et al., 1985), we suggest that lying could be more important for the cows in the night period than during other parts of the 24 h. This fits with the observations that lying down on the slatted floor of the walking area in our experiments mostly occurred in the night period and also with the observation that during the day the cows did not compensate for deprived lying time. Furthermore, in experiments in which acoustic signals announced the availability of food, Hammell and Hurnik (1987) found that cows reacted less to the signal during the night than during other parts of the 24 h. In further investigations into the minimum time needed for lying by dairy cows, these various interactions need to be taken into account as well as the individual variations.

cubicles for hiding

The comparison of the results obtained in the new and old cubicle houses, together with comments in the literature, led to the suggestion that cubicles are not only important for the cows as a resting place, but also as a hiding place to avoid confrontations with group mates. The importance of this "safety" function will be lower when the animals have alternative possibilities of avoiding confrontations in the cubicle house. The comparison between the old and new cubicle houses suggests that in the old cubicle house the feeding rack served as a "safe area". Of course, in constructing a cubicle house other solutions can be found to provide the cows with enough possibilities to avoid confrontations. At present, it is not possible to judge how important it is for cows to have such a place to hide.

CONCLUSIONS

There is considerable variation, both within and between individuals, in the actual time spent standing and lying in the cubicles. Cubicles are important for the cows primarily because they provide the opportunity to rest, and also because they can be used to hide to avoid confrontations.

Lying is an important behaviour for the cows; cows react to changes in the environment which cause a decrease in lying time. The minimum time which the cows need to lie and/or stand in a cubicle is not yet known.

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5. THE EFFECT OF EXTRA SPACE ON THE BEHAVIOUR OF DAIRY COWS KEPT IN A CUBICLE HOUSE

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Published in: R. Zayan (Editor), Social Space for Domestic Animals. Martinus Nijhoff, Dordrecht, pp. 160-170 (1985).

THE EFFECT OF EXTRA SPACE ON THE BEHAVIOUR OF DAIRY COWS KEPT IN A CUBICLE HOUSE

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ABSTRACT

To study the need for physical and social space in dairy cows, two groups of cows were kept alternately in a "normal" cubicle house (as many places as cows) and in an "undercrowded" cubicle house (almost twice as many places as cows). The effect of extra space on lying behaviour in particular was studied.

It appeared that the time spent lying was slightly increased in the undercrowded condition. This increase was found especiallly in those parts of the day during which the cows were mainly lying. In the cubicle house with extra space, the cows were often standing or lying alone or in groups of two or three animals, and they adopted more comfortable lying postures.

The effects of extra space are interpreted as a reaction to extra physical space as well as to extra social space. Probably the most important effect of extra space in a cubicle house is that the cows have more freedom to determine where and when they want to lie down or to eat.

INTRODUCTION

In general it is found that dairy cows - like so many other animals - tend to keep some distance between each other (Sambraus, 1973; Kimstedt, 1974). The function of this spacing behaviour may be to control access to resources like food, water and a resting place (McBride, 1971). Often the animals tend to reserve more space than they require physically for carrying out a certain type of behaviour. This phenomenon is described by the term "social space" and it can be distinguished from "physical space".

Social spacing is mostly studied by observing the interactions between animals and by describing the spacing patterns which are the result of these interactions (e.g. Archer, 1970). However, the study of the consequences of this spacing for behavioural functions like food or water intake or resting is equally essential. Especially for dairy cows kept in a cubicle house, such an indirect approach to spacing phenomenon can be considered as suitable. As a consequence of the lay-out of the cubicle house, dairy cows perform different types of behaviour in different parts of the house. The cows therefore have extra possibilities to regulate the distance to other cows by changing their activities. To what extent the cows have to make use of this spacing mechanism will depend on the amount of available space. Analysis of the changes in performance and synchronization of the behaviour as a result of changes in the amount of available space, can give insight into possible space problems of dairy cows which are kept in a cubicle house. The consequences of a reduction of the amount of space in a cubicle house have already been studied (Wierenga, 1983). The present experiment compares the behaviour of cows in a cubicle house with extra space with the behaviour in a cubicle house with the standard amount of space.

MATERIALS AND METHODS

The animals, their housing and feeding

For the experiment, two groups of 12 lactating dairy cows were used. All the cows were in the second half of their lactation period. Within each group the age of the animals varied between 3 and 9 years. Both groups were formed about one month before the start of the experiment.

The cows were kept in a cubicle house with a row of cubicles at each side of the central feeding passage. The area between the cubicles and the feed manger - the walking area - was 2.5 m wide. On one side of the feeding passage was a housing unit with 12 cubicles and 12 eating places; this was called the "normal situation". On the other side, a unit with 23 cubicles and 23 eating places was available; this was called the "undercrowded situation".

The animals were milked at 06.00 h and at 15.30 h. For milking, both groups left and returned to the cubicle house simultaneously. The animals received grass silage (about 10 kg/cow) after morning milking, and hay (about 8.5 kg/cow) after the afternoon milking. After milking each animal received 1.5 kg concentrates from an automatic feeder. The concentrates had to be consumed within 2 h. According to her milk production level each cow received an additional amount of concentrates in the milking parlour.

Experimental design, behavioural observations

Both groups of cows were kept alternately in normal and in undercrowded conditions, each time for a period of about ten days (min 9, max 14 days). Altogether each group was kept for three periods in normal and for three periods in undercrowded conditions. At the end of each experimental period one 24-h observation was carried out. During this observation each animal's activity was recorded at 10-min intervals: eating, standing (at the feed manger, in the concentrates feeder, in the walking area or in a cubicle), or lying. From one group, all the aggressive interactions (displacements) that occurred were recorded also.

During the night (00.00 h - 06.00 h) of the last four 24-h observations, the lying postures (fore- and hindlegs near the body or stretched) adopted by two cows of one group were recorded continuously.

At the end of the experiment, one of the two experimental groups was kept indoors for another month. The animals now had 46 cubicles available. In this extra-undercrowded situation only the dispersion of the cows over the cubicles was recorded. This kind of information had also been collected in the normal and the undercrowded situation. For this purpose we recorded twice a day (in the afternoon and in the beginning of the night) which cubicles were occupied by a cow. For the final analysis, only those observations were taken into account during which ten or more cows were seen in the cubicles. In this way, nine observations could be used for each of the three experimental conditions. From the data of each observation it was determined how many cows were lying or standing in a "lying group", defined as a row of cows standing or lying adjacent to each other, without any empty cubicles between them.

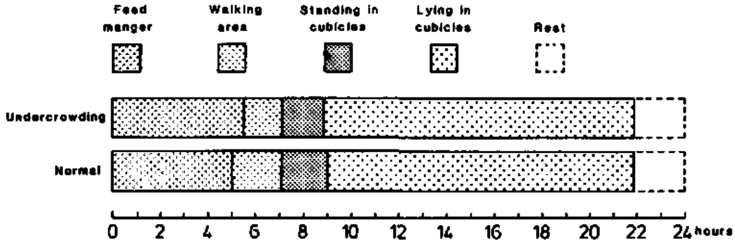
Statistical analysis

Data on the effect of undercrowding on the time budget of the animals was analysed by means of an analysis of variance model. Because observations on animals within the same group are dependent, the twelve group means - corresponding to the twelve observations - were analysed. Treatment, group and observation date were the factors which were entered into the model. Sometimes a significant influence of observation date or a significant difference between the two experimental groups was found. Because these effects did not change the interpretation of the effects of extra space, they will not be mentioned in detail. The effect of undercrowding on the number of displacements, only measured for one group, has been tested for significance with a t-test. The differences in the adopted lying postures (only known for two animals) and in the dispersion of the animals over the cubicles could not be tested statistically.

RESULTS

Time budget

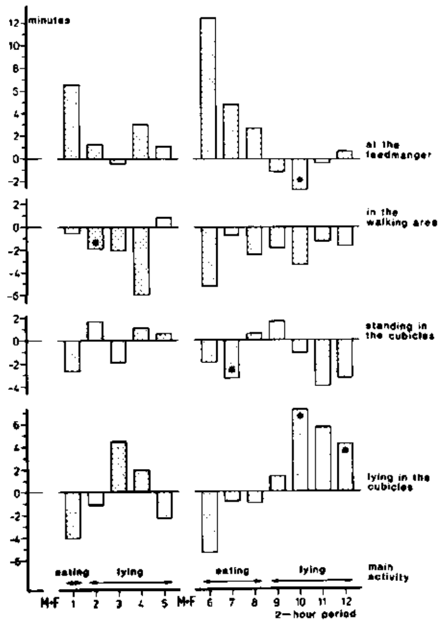
Figure 1 shows that the differences between the normal and the undercrowded conditions in time spent at the manger, in the walking area, and standing and lying in the cubicles are small. In the undercrowded condition the animals spent about half an hour more at the manger and half an hour less in the walking area ($P < 0.05$, in both cases). The slight decrease in time spent standing and the increase in time spent lying in the cubicles



<u>Figure 1</u>. The mean time per 24 h spent at the manger, in the walking area and standing or lying in the cubicles for the normal and for the undercrowded conditions. The remaining time ("Rest") is spent in the concentrates feeder and in the milking parlour.

were not significant (P > 0.05).

Figure 2 shows the mean difference between the undercrowded and the normal conditions for each 2-h period of the 24-h period. The figure also shows the main eating periods (periods during which more than 50 % of the cows are eating) and the main lying periods (more than 50 % of the cows are



<u>Figure 2</u>. The effect of undercrowding on the time per 2-h period spent at the manger, in the walking area and in the cubicles. For each 2-h period the difference (in min) between the undercrowded and normal conditions is given (*; the difference is statistically significant, P < 0.05). Also shown is during which parts of the day most of the cows are eating or lying. Periods 1 to 6 form the day, periods 5 to 12 the evening and night. Periods 5 and 9 are respectively much and slightly shorter than 2 h. M + F: milking and feeding of the animals.

lying). It can be seen that, in the morning as well as in the evening, during the main eating periods the cows spent more time eating in the undercrowded cubicle house ($0.05 < P < 0.10$). This is correlated with a decrease in time spent standing in the walking area and in the cubicles. In the lying periods an increase in time spent lying in the cubicles was found. This was especially the case in the night ($P < 0.05$), but also during some parts of the day. This increase is associated with a decrease in time spent standing in the walking area and in the cubicles. In the night the time spent eating was also shorter.

In summary, the more detailed analysis of the effects of undercrowding reveals: 1) the increase in eating time occurred during the main eating periods; 2) the decrease in time spent in the walking area is not related directly to the increase in eating time, because it was spread over the 24 h; 3) the small increase in time spent lying is the result of a small decrease during the eating periods and a larger increase during the main lying periods.

Dispersion over the cubicles

Not only the time spent in the cubicles but also the dispersion of the individuals over the available cubicles gives useful information about the

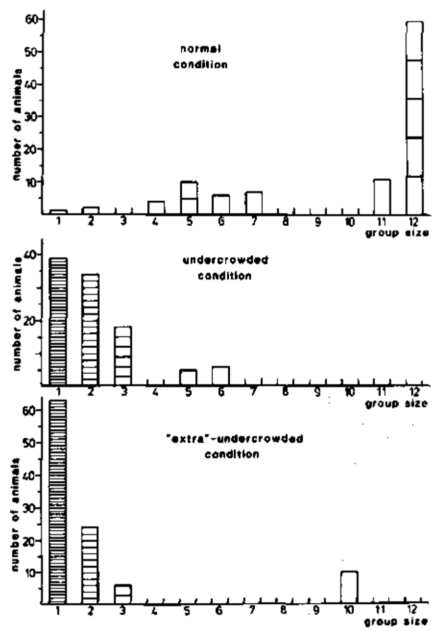


Figure 3. Frequency distribution showing for each of the three housing conditions how many animals made up part of a lying group of a certain size (total frequency over the 9 selected observations).

reaction of the cows to the extra space. In Figure 3 it can be seen that in normal conditions the cows formed large lying groups most of the time; only once an animal was observed lying alone. On the other hand, in undercrowded conditions the cows were mostly solitary or formed groups of two or three animals. In the situation in which the group of twelve cows had 46 cubicles - the extra-undercrowded condition - solitary cows were seen even more often. But strikingly, in this situation it was once seen that ten animals were lying adjacent to each other.

Lying postures

The two cows observed for lying postures during the night, stretched their hindlegs more often in the undercrowded situation (Table 1). For one cow an increase of the percentage of time spent lying with the forelegs stretched was also found.

Table 1. The influence of the housing condition on lying posture. The percentage of the total lying time spent with the forelegs or with the hindlegs stretched, for normal (N) and for undercrowded (U) conditions is presented for the two cows which were observed during the night.

	cow 507		cow 109	
	N	U	N	U
forelegs stretched	19.5 %	35.2 %	6.8 %	3.5 %
hindlegs stretched	43.3 %	63.3 %	10.4 %	28.6 %

Aggressive interactions

No significant difference between the two experimental conditions was found in the total number of aggressive interactions per 24 h (Table 2). When the interactions are differentiated according to the part of the cubicle house where they took place, it appears that in the undercrowded condi-

Table 2. The mean number of aggressive interactions per cow per 24 h observed in the normal and in the undercrowded cubicle house. The interactions are differentiated according to the position of the attacked animal. None of the differences between the normal and undercrowded conditions are statistically significant ($P > 0.10$).

	feed manger	walking area	cubicles	total
normal conditions	6.4	3.6	1.3	11.3
undercrowded conditions	8.5	3.7	0.6	12.8
difference	2.1	0.1	-0.7	1.5

tions the number of interactions at the manger increased slightly, whereas displacements out of the cubicles slightly decreased.

DISCUSSION

Effects of undercrowding

In general it appeared that in the undercrowded conditions eating was more restricted to the periods directly after milking and feeding - the main eating periods - and lying occurred more during the rest of the day and night, in the lying periods. This means that eating and lying were more synchronized. The results concerning the lying behaviour and the use of the cubicles will be discussed in more detail.

The decrease in time spent lying, which was found in the periods directly after milking and feeding, was correlated with the increase in time spent eating. It is assumed that mainly the increased space at the manger caused an increase in eating time. As a secondary effect this may have caused a reduction in the time spent lying in those eating periods. Therefore, for this experiment the specific consequences of extra cubicles on the lying behaviour of the cows should be measured outside the eating periods. It was shown (Fig. 2) that during the non-feeding periods, generally an increase in time spent lying (in total 21.5 min) was found. This leads to the conclusion that extra space in the lying area results in an increase in time spent lying.

This increase in lying time found in the undercrowded situation can have different causes. Firstly, a higher degree of dispersion of the cows over the available cubicles was found in the undercrowded situation. One effect of this dispersion is that the cows had more space for lying, because an adjacent cubicle was more often empty. The two observed cows more often stretched their (hind)legs when they were lying in the undercrowded situation. This suggests that the cows made use of the extra space which was available, by adopting more comfortable lying positions. Wander (1976) showed that lying time increases when the cubicles are larger. So it seems plausible that the extra "physical space" for lying in the undercrowded cubicle house lead to an increase in time spent lying. The higher degree of dispersion may also have influenced the lying time in another way. It is likely that the cows in undercrowded conditions are less often obliged to lie down next to an animal which they dislike or of which they are afraid. This means that the animals also have more "social space". It is possible that this greater "social space" in undercrowded conditions has also caused an increase in time spent lying.

Metz and Mekking (1984) showed that low-ranking animals spent less time in the walking area when it was occupied by many cows. It is possible that cows, in general, will tend not to stay too long in the walking area, because they run some risk of negative confrontations with group mates there. In the undercrowded conditions the cows are probably able to leave the walking area sooner, because the cubicles are more accessible. So a possible tendency to shorten the time spent in the walking area may be a second cause for the increased lying time in the undercrowded cubicle system.

The slight decrease in the number of displacements out of the cubicles which was found in the undercrowded cubicle house may be the third factor responsible for the increased lying time. This reduction implies that the competition for the cubicles is lower. It means that in the undercrowded conditions the cow is not only more free to enter a cubicle, but the chance that she can stay in that cubicle is also higher.

In summary, it seems likely that the possibility to disperse more over the cubicles increases the time spent lying in the undercrowded conditions. Some possible explanations are given for the way this dispersion may have influenced the behaviour of the cows. With the available data it is not possible, however, to decide how important each of these explanations is. The effect of undercrowding on the behaviour of the cows can be interpreted as a reaction to extra physical space as well as to extra social space.

Requirements for lying space

This undercrowding experiment was carried out to gain more insight into the need for lying space of dairy cows kept in a cubicle house. For the same purpose, experiments have been done in which the behaviour of dairy cows kept in a normal and in an "overcrowded" cubicle house (fewer places than cows) was studied (Wierenga, 1983). The overcrowding experiments have shown that a reduction in the lying space results in a decrease of the lying time and in an increase of the number of displacements out of the cubicles. The decrease in lying time is in conflict with the basic needs of the cows (Metz and Wierenga, 1984) and thus can be interpreted as a negative consequence of overcrowding.

The effects of undercrowding on the time spent lying and on the number of displacements are small in comparison to the effects of overcrowding. However, they can be interpreted as positive from the animal's point of view. The effect on the dispersion over the cubicles is notable, but it must be realized that in the undercrowded situation the cows sometimes also formed rather large "lying groups" (as in normal conditions). Apparently undercrowding does not greatly improve the living conditions of the cows. On this basis we conclude that a cubicle house with as many cubicles as cows (normal conditions) meets the requirements of dairy cows for social and physical space for lying to a good degree.

It seems plausible that the partitions between the lying places play an important role in the apparently low need for extra space for lying in a normal cubicle house. Because of these partitions there are two possibilities for a cow which would like to lie down: 1) lie down in a cubicle of about 1.10 m width or 2) remain in the walking area. Obviously most cows prefer lying down in a cubicle. The partitions probably prevent many aggressive interactions between cows which might be meant to create some extra space for lying (see also Bouissou, 1970). The farmer thus anticipated the tendency of dairy cows to reserve some extra space for lying by placing these partitions. This enables him to minimize the amount of lying space in the cubicle house. The demand for extra space still exists for the cow, but in a cubicle house the expression of this demand, in general, does not help the animal.

CONCLUSIONS

It can be concluded, that extra space in a cubicle house gives the cows effectively more freedom to choose their eating and lying times. They synchronize their activities more and they lie more comfortably. The differences however are not so large that the extra space should be seen as a necessity for the animals. The effects are rather small compared to the consequences of overcrowding.

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6. BEHAVIOUR OF DAIRY COWS WHEN FED CONCENTRATES WITH AN AUTOMATIC CONCENTRATES FEEDING SYSTEM

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Published in Applied Animal Behaviour Science 30(1991): 223-246.

BEHAVIOUR OF DAIRY COWS WHEN FED CONCENTRATES WITH AN AUTOMATIC FEEDING SYSTEM

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ABSTRACT

On Dutch commercial farms automatic systems for feeding concentrates in a feeding station are increasingly being used. Various systems have been developed, which differ in the timing and amount of concentrates made available to the cows over a 24-h period. Three types of a fixed-time system and one variable-time system are compared to a traditional system. The fixed-time systems provided a ration of concentrates every 12 h. The starting time of these 12-h cycles varied, hence the fixed-7-time system started at 07.00 and 19.00 h; the fixed-11-time system cycles started at 11.00 and 23.00 h; and the fixed-3-time system cycles started at 15.00 and 03.00 h. The variable-time system continuously added small amounts of concentrates to the available ration per cow, throughout a 24-h cycle. The traditional system provided concentrates mixed with maize silage at the feeding rack. The aim of the investigation was to describe the pattern of intake of concentrates, and the possible consequences of the various feeding systems on the cows' general activities such as eating, standing and lying down.

Three experiments were carried out, each with a group of 20 lactating dairy cows kept in a cubicle house with a single concentrates feeding station. In each of the experiments, feeding systems were tested during 3-week experimental periods. Behaviour was observed during three 24-h periods in each experimental period.

It was found that each of the five feeding systems tested evoked a typical pattern of visits to the feeding station. The number, the duration and the timing of rewarded and unrewarded visits differed between the various systems. The cows adapted to each feeding system, eating all their rations of concentrates as soon as they were made available.

Adaptation to the feeding system affected several of the general activities, in particular the time spent at the feeding rack and the time spent lying in the cubicles. With the fixed-11-time system, new feeding cycles started at times when many cows were lying down. Under these conditions the low-ranking cows sometimes had to wait a long time before they could enter the station, which resulted in a reduced lying time for them.

INTRODUCTION

The use of a programmed distribution of concentrates has increased greatly on Dutch dairy farms during recent years. With such systems cows can be identified individually in a feeding station and they can receive concentrates if they have not already consumed their total allotted ration. There are various systems for the programmed distribution of concentrates on the market. These can roughly be divided into two main types: fixed-time and variable-time feeding systems. Investigations (Spiegelberg, 1980; Collis, 1980; Baehr, 1984; Wierenga and Folkerts, 1986; Wierenga and Van der Burg, 1989) have shown that each system evokes a typical pattern of visits to the feeding station.

Several aspects of these automatic feeding systems make it worthwhile to investigate the interactions between the system and the cows. Firstly, these systems do not provide the cows with any information about the availability of concentrates. Whereas cows kept indoors and fed manually will learn to relate certain of the farmer's activities with new supplies of food, no comparable information is given by the automatic feeding systems. It is interesting to discover what pattern of intake the cows develop with such feeding systems and whether the pattern depends on the type of feeding system. A second aspect of the automatic concentrates feeding systems is that they create an intake of concentrates which is more or less evenly distributed throughout the 24 h. From a physiological point of view, this is important because it helps to prevent possible disturbance of the rumen function from a high intake of concentrates at any one time. However, such an even distribution of food over the 24 h could interfere with the normal daily rhythm of the dairy cows, which is characterized by long periods of rest in the afternoon and during the night (Wierenga and Hopster, 1990). A third aspect of the automatic feeding systems is that, generally, on commercial farms only one feeding station is available for about 25 cows (Van der Burg et al., 1989). Thus, the cows are forced to eat one at a time, which means that there is competition for the feeding station. Besides a variation between individuals in timing of the visits, this competition could result in a variation in the number of visits and could probably also affect the cows' general activities.

This paper first describes the pattern of visits to the feeding station, depending on the feeding system used. Secondly, the possible consequences of the various systems for the general activities of the cows are analysed, and the differences compared to a "normal" practical situation, i.e. feeding concentrates at the feeding rack. In particular, the consequences of automated feeding on the cows' lying behaviour (total time and daily rhythm) were investigated. Thirdly, the consequences of possible competition for the feeding station are looked at by considering the pattern of concentrates intake and of lying down for both high- and low-ranking animals.

MATERIAL AND METHODS

Animals, housing and feeding

The investigation comprised three experiments (Experiments I, II and III), which were performed with three different groups of 20 lactating dairy cows each. Different cows were used in the three experiments as much as possible. One cow took part in Experiment I and also participated in Experiment III, and five of the cows which took part in Experiment II also participated in Experiment III. In Experiment III, there were three cows which, during part of the experimental period, had serious lameness problems, affecting their visits to the feeding station and their general activity. These three cows were not included in the analysis of the data. At the start of the experiments the cows were in about their third month of lactation. The age of the animals in each group varied between two and ten years. All cows were black-and-white; a mix of the Dutch Friesian and the Holstein Friesian breeds.

The cows were kept in a cubicle house (Fig. 1) with one row of 19 cubicles, a feeding rack with 16 places, and a walking area 2.60 m wide with a slatted floor. The concentrates feeding station was placed in the cubicle row.

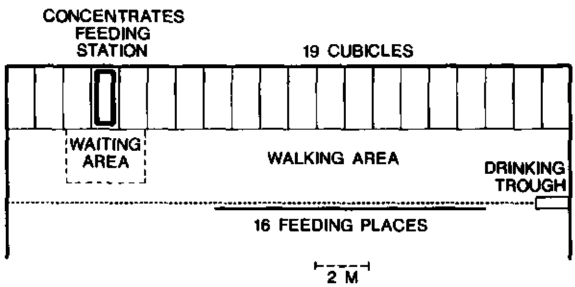

Figure 1. Plan of experimental cubicle house.

In Experiments I and II the cows were milked in a milking parlour at 07.00 h and 16.30 h. In Experiment III they were milked at 06.00 h and 15.30 h. In the three experiments the cows received maize silage (5.0, 5.0 and 4.0 kg dry matter respectively per cow) immediately after morning milking. In the first two experiments the cows received hay ad lib., of which part was given at 13.30 h and the rest immediately after evening milking. The total intakes of hay in Experiments I and II were 5.0 and 4.7 kg dry matter per cow respectively. In the third experiment the cows received grass silage; the intake was 5.7 kg dry matter per cow.

Concentrates were fed partly in the feeding station and partly in the milking parlour. In Experiment II during two experimental periods, providing concentrates at the feeding rack - instead of the feeding station - was also tested. In Experiment I each cow received 12 kg of concentrates per 24 h; in Experiments II and III, 11 kg of concentrates per cow were given. With automatic feeding 9 kg of the total ration was always given via the feeding station and the remainder was given in the milking parlour. When the concentrates were given at the feeding rack (Experiment II), the cows received only 5 kg of concentrates each, mixed with maize silage, directly after morning milking (an additional 4 kg of concentrates was given in the milking parlour). The amount given at the feeding rack had to be reduced compared to distribution via the feeding station, because the cows in this situation simply did not eat such large amounts. Although the level of milk production varied between the cows, within each group all the cows received the same amount of concentrates. The amount of concentrates given was fairly high, which means that - compared with their level of milk production - none of the cows would have received too little, but some cows will have received too much. All cows received the same amount of concentrates to minimize variation in the number of visits to the feeding station. The difference between the total amount of concentrates fed in Experiment I and the amount fed in Experiments II and III correlated with a difference in the milk production of these groups.

When concentrates were fed in the feeding station, the cows did not receive a large portion all at once, but they were given a portion of 100 g every 20 seconds. As soon as the cow was no longer recognized by the system, the delivery of concentrates was stopped. When a cow left the feeding station, the feeding trough was emptied automatically, to make sure that the next cow could not eat any leftover concentrates.

Four different systems for the automatic feeding of concentrates were investigated: three fixed-time systems and one variable-time system. In the fixed-time systems a 24-h period was divided into two cycles of 12 h. In each 12-h cycle, 4.5 kg of concentrates was available for each cow. At the start of each cycle the allotted ration for each cow was set at 3.0 kg. After a period of 4 h, 1.5 kg was added to the available ration. If a cow had not eaten any concentrates in the first four hours, her balance then became 4.5 kg. In the last 4-h period of a cycle the balance was not increased again, but those cows who had eaten only part or nothing of their concentrates were rewarded at a visit to the feeding station. Any (mostly very small) portion of concentrates not eaten by the end of a 12-h cycle was discarded. In the first of the three fixed-time systems tested, the 12-h cycles started at 07.00 h and 19.00 h (this system was called the "fixed-7-time system"). In the second system (the "fixed-11-time system") the 12-h cycles started at 11.00 h and 23.00 hr, and in the third system (the "fixed-3-time system"), the 12-h cycles started at 03.00 h and 15.00 h. These three variants of the fixed-time system were chosen to investigate the possible consequences of different starting times of the 12-h cycles. The fixed-7-time system started in a period following milking and roughage feeding. The fixed-11-time system started at a time when the cows could be expected to be lying down in the cubicles rather than eating. The fixed-3-time system started even later in the cows' resting period.

The fourth automatic feeding system tested was a variable-time system. This system had a 24-h cycle. Every day, each cow started at 19.00 h with a balance of 0.2 kg and every 14 min 0.1 kg was added to this balance. For instance, when a cow visited the feeding station for the first time 140 min after the start of the period, she could receive a maximum of 1.2 kg of concentrates. If she consumed all her 1.2 kg ration, her balance built up gradually again, starting from zero. The balance could grow to a maximum of 3.0 kg. When the maximum was reached, the cow first had to visit the station and eat all or part of the concentrates before the procedure of increasing the balance was started again. When a cow visited the feeding station regularly to eat concentrates, the maximum amount of 9 kg of concentrates was normally allocated after a period of about 21 h (i.e. by about 16.00 h). One might expect that with this system the intake of concentrates would be distributed more evenly over the 24 h than with a fixed-time system with two starting times.

Experimental design

The experimental design is given in Table 1. In Experiment I three automatic feeding systems were used; one, the fixed-7-time system, was repeated. In Experiment II, feeding concentrates at the feeding rack was

Table 1. Design of the experiments with three different groups of cows, fed concentrates with five different systems (see text for further explanation).

Experimental period	Experiment I	Experiment II	Experiment III
1	Fixed-7-time system	Feeding rack	Fixed-7-time system
2	Variable-time system	Fixed-11-time system	Variable-time system
3	Fixed-7-time system	Feeding rack	Fixed-7-time system
4	Fixed-11-time system	-	Fixed-3-time system
5	-	-	Variable-time system
6	-	-	Fixed-3-time system

tested twice, interrupted for an experimental period when the fixed-11-time system was introduced. In Experiment III only automatic feeding systems (fixed-7-time, fixed-3-time and variable-time) were investigated; all the systems were tested twice. It has been considered testing the fixed-11-time system again, but finally it was decided to test another type of a fixed-time system (fixed-3-) instead. This provided insight into the consequences of a third variant, although the fixed-11-time system was not tested in an "ideal design". All the experimental periods for testing a system lasted for three weeks.

In the experiments, the automatic feeding systems received most attention. Visits to the feeding station will only be discussed for the automatic feeding systems. General activities will be compared between the feeding-rack system and the different automatic feeding systems.

Because not all the feeding systems were tested in one experiment, information about differences between some of the systems can only be obtained by comparing the results obtained in different experiments. This is only done in a descriptive way and with reservation, because possible differences between the systems may have been partly due to differences in the groups of cows. Some information about such group effects can be obtained by comparing tests of the same system from two experiments.

Collection and analysis of data

To obtain information about visits to the feeding station, the time-budget and daily rhythm, the cows were observed during three 24-h periods in each 3-week experimental period. These observations took place during the last 10 days of the experimental period. Two successive 24-h observations were normally interrupted by at least one day without observations (except once in the third experimental period of Experiment I, when two 24-h observations immediately followed each other). The observations started at 07.00 h in the morning and finished at 07.00 h the next day. Visits to the feeding station were recorded continuously. Based on information from the feed computer, these visits could later be divided into rewarded (concentrates received) and unrewarded (no concentrates received) visits. Every 5 min the general activity of each cow was recorded. The following five activities were distinguished: standing (including eating) at the feeding rack, standing (including eating) in the concentrates feeding station, standing in the walking area, standing in a cubicle, lying in a cubicle. In Experiments II and III a separate note was made when a cow in the walking area was standing or walking close to the feeding station. This "waiting area" was defined as the square 1 m to either side of the feeding station and 2 m in front of it (see Fig. 1). Based on the 5-min interval observations, the total time spent on each of the observed activities could be estimated for each cow over a certain period. The number and duration of "cubicle bouts" were also analysed based on these observations. A cubicle bout was defined as a period during which the cow stayed standing or lying in a cubicle without interruption.

The intake of roughage (of the whole group) and of concentrates (per cow) was recorded daily.

To obtain information about the dominance relationships in the groups, aggressive displacements were recorded during the 24-h observations, and also during extra observations, which were mostly done during feeding, when many displacements could be observed. Based on these displacements a dominance value for each animal was calculated (see Wierenga, 1990). The five animals with the highest dominance value were called "high-ranking animals", the five animals with the lowest dominance value, "low-ranking animals". The remaining ten (seven in Experiment III) animals were called "middle-ranking animals". In Experiments I, II and III totals of 2058, 857 and 876 displacements were recorded, respectively. Generally, for each cow more than two thirds of all the possible dominance relationships with the other 19 animals was known. In Experiment III, fewer than two-thirds of the possible relationships were known for three cows. For one animal 63.2 % of the possible relationships was known, and for the other two animals only 52.6 %. One of these animals was classed as high-ranking, one as middle-ranking and one as low-ranking.

The collected data were analysed with analysis of variance. The time factor was accounted for in this model, i.e. observations were corrected for possible time effects. Data for both the whole 24-h period as well as for part of the 24-h period were analysed. For the latter analysis the 24-h period was divided into 4-h periods which coincided with those of the fixed-time systems. The results were analysed for the whole group, but also for the high-, middle-, and low-ranking animals separately. Because possible group effects could not be estimated reliably, each experiment was analysed separately.

RESULTS

Visits to the feeding station

To analyse the pattern of visits to the feeding station, information about the number and duration of visits, and also about the intake of concentrates were used. Both totals per 24 h and the variation during a 24-h period were analysed. A statistical analysis was mainly performed on the totals per 24 h; most data about variations over the 24-h period will only be described generally.

number and duration of visits

The mean number of visits to the concentrates feeding station varied for the three fixed-time systems between 7.64 and 9.86 per cow per 24 h (Table 2). Only in Experiment III a significant difference was found between the fixed-time systems tested. With the fixed-time systems the number of unrewarded visits varied between 3.18 and 5.36 per cow per 24 h. Thus, with such a system, about half of the visits were unrewarded. With a variable-time system the total number of visits per cow per 24 h was significantly higher than with the fixed-time systems (Table 2). Relatively few visits went unrewarded (2.55 and 1.31).

Table 2. Number of visits to the concentrates feeding station and time (min) spent in the feeding station per cow per 24 h. All visits and unrewarded visits only are presented separately. Mean of each group of cows (20, 20 and 17 cows, respectively for each experiment). Results of the four tested systems of feeding concentrates are given for each different experiment (n = number of 24-h observations). Significant differences within one experiment ($P < 0.05$, analysis of variance) are marked with a different character (a, b or c). Results of unrewarded visits of Experiment I were not tested statistically due to technical problems (data for some days was missing).

	Experiment I			Experiment II	Experiment III		
	fixed-7-time (n=6)	fixed-11-time (n=3)	variable time (n=3)	fixed-11-time (n=3)	fixed-7-time (n=6)	fixed-3-time (n=6)	variable time (n=6)
number of visits							
total	8.29^{a}	8.97^{a}	15.14^{b}	9.86	7.64^{a}	9.66^{b}	12.62^{c}
unrewarded	3.20	3.75	2.55	5.36	3.18^{a}	4.84^{b}	1.31^{c}
time (min)							
all visits	41.3^{a}	46.3^{b}	52.4^{c}	50.3	46.0^{a}	47.5^{a}	54.4^{b}
unrewarded	6.0	5.4	3.5	8.0	4.9^{a}	7.6^{b}	2.1^{c}
duration (min) per visit							
unrewarded	1.9	1.5	1.4	1.5	1.5	1.6	1.5

The mean time spent in the feeding station varied between 41.3 and 50.3 min per cow per 24 h for the fixed-time systems, and was slightly (but significantly) higher for the variable-time system (varying between 52.4 and 54.4 min; Table 2). The total time spent on unrewarded visits was rather low (varying between 2.1 and 8.0 min per 24 h); each unrewarded visit itself was very short, only between 1.4 and 1.9 min.

The daily pattern of number and duration of the visits is presented in Figures 2 and 3. To illustrate the influence of the feeding system on these patterns independent of the time of the day, the time scales on the x-axes start according to the starting time of the cycles. For all automatic feeding systems the total number of visits appeared to be distributed more or less evenly over the 24-h period (Fig. 2). With the fixed-time systems, the number of visits to the feeding station was between 1 and 2 per 4-h period (Fig. 2). With the variable-time system, the number of visits per 4-h period varied between 2 and 3. Thus, the higher total number of visits per

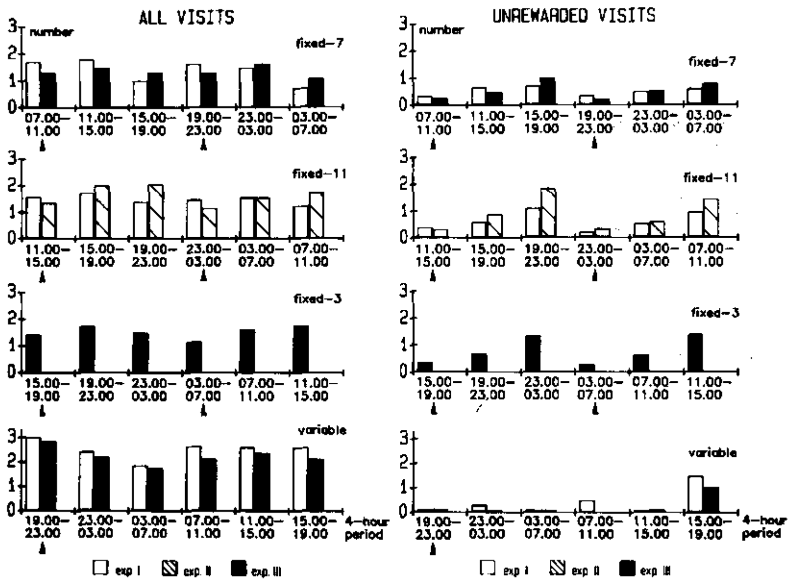

Figure 2. Variation over the 24-h period in the total number of visits and in the number of unrewarded visits to the concentrates feeding station. Data are presented for each concentrates feeding system and each experiment separately, as the mean per cow of each 4-h period. The arrow (▲) indicates in which period a 12-h or a 24-h cycle started.

24 h with a variable-time system is achieved by more visits within each of the 4-h periods.

The variation in the number of unrewarded visits over the 24-h period is also shown in Figure 2. It appears that, with the fixed-time systems, the number of unrewarded visits increased rapidly after the start of a new 12-h cycle. Thus, although the total number of visits was fairly constant, at the end of each 12-h cycle a high number of unrewarded visits was often found, which means that only a few visits were rewarded then. With the variable-time system almost no unrewarded visits were observed in the first five 4-h periods of the 24-h cycle, whereas in the sixth 4-h period (at the end of the 24-h cycle) a relatively high number of unrewarded visits was observed.

In the time spent in the feeding station much more variation is found over the 24-h period than in the total number of visits per 4-h period (Fig. 3). With the fixed-time systems, in the first 4-h period after the start of each 12-h cycle, the cows spent about 10 min each in the feeding station. In the second 4-h period of each 12-h cycle, the cows spent between 5 and 10 min in the feeding station. Finally, in the third 4-h period, the cows always spent less than 5 min in the station. These results clearly show that, for the fixed-time systems, the variations in time spent

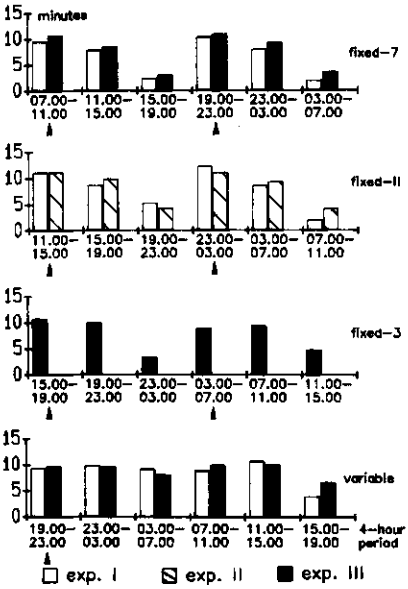

Figure 3. Variation over the 24-h period in the time spent in the feeding station (min per cow per 4-h period). Further explanation: see Figure 2.

in the feeding station were related to the amount of concentrates available per 4-h period and to the starting time of a new 12-h cycle. With the variable-time system, during the first five 4-h periods after the start of the 24-h cycle, less variation was found in the time spent in the feeding station. During these periods the cows spent about 8 - 11 min each in the station. In the last 4-h period (15.00 - 19.00 h) an occupation time of about 5 min was found.

Intake of concentrates

The mean intake of concentrates per cow per 24 h with the automatic feeding systems varied only between 8.6 and 8.9 kg and no significant differences between the systems were found ($P > 0.05$). The variation in the intake of concentrates over the 24-h period (Fig. 4) is comparable to the variation found for the different systems in the time spent in the feeding station. With the fixed-time systems, the highest intake was always found in the first 4-h period after the start of each 12-h cycle. In this period, generally about 2.5 kg of the allotted 3.0 kg of concentrates was eaten. In the second 4-h period an additional amount of 1.5 kg was allotted. In all three fixed-time systems the cows often ate more than 1.5 kg, because some of their available ration of concentrates was left uneaten from the first 4-h period. Although in the third period no extra concentrates were added to the available ration, some concentrates were always eaten. This was the remainder of the total allotted ration of concentrates. The variable-time system showed a different pattern of intake (Fig. 4), as expected from the variation in time spent in the feeding station over the 24-h period. During the first five 4-h periods the intake was fairly constant, varying between 1.3 and 1.8 kg. Clearly, the intake was lowest in the last 4-h period of the 24-h cycle.

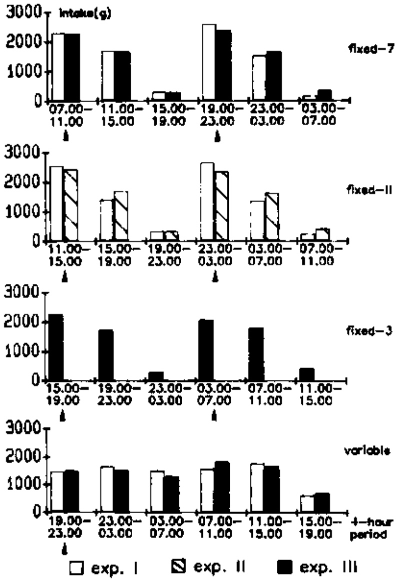

Figure 4. Variation over the 24-h period in the intake of concentrates (g per cow per 4-h period). Further explanation: see Figure 2.

General activities

Besides the pattern of visits to the feeding station, the consequences of automatic feeding on the cows' general activities were also analysed. Both the differences between the feeding-rack system and the automatic feeding systems, as well as the differences between the automatic feeding systems will be described.

time-budget

Some variation in time spent at the feeding rack was found between the experiments (Table 3). However, a significant difference was only found in Experiment II between the fixed-11-time system and feeding concentrates at

Table 3. Time budget (min per cow per 24 h) observed for the various systems for feeding concentrates in the three experiments. Further explanation: see Table 2.

	Experiment I			Experiment II		Experiment III		
	fixed-7-time (n=6)	fixed-11-time (n=3)	variable time (n=3)	fixed-11-time (n=3)	feeding rack (n=6)	fixed-7-time (n=6)	fixed-3-time (n=6)	variable time (n=6)
at feeding rack	186.2	183.4	192.3	232.4[a]	292.3[b]	196.0	198.5	201.6
in feeding station	41.3[a]	46.3[b]	52.4[c]	50.3[a]	0.3[b]	46.0[a]	47.5[a]	54.4[b]
in waiting area	*	*	*	62.1[a]	1.3[b]	43.5	45.0	37.1
in walking area	209.8[a]	259.1[b]	198.0[a]	230.8[a]	185.0[b]	207.5	243.1	219.2
cubicles, standing	232.0[a]	242.0[a]	188.0[b]	228.0	262.0	228.3	188.5	227.1
cubicles, lying	707.0[a]	646.0[b]	746.0[c]	652.0	653.0	686.7	692.3	670.8
cubicles, total	939.2[a]	887.8[b]	933.9[a]	879.4[a]	915.1[b]	914.9	880.7	897.9

* not noted

the feeding rack. The total time spent at the feeding rack increased by about 60 min when concentrates were fed at the feeding rack. This increase is more or less equivalent to the time which the cows spent in the feeding station (41.3 - 54.4 min) with the automatic feeding systems. Statistically significant differences between the automatic feeding systems were sometimes found with respect to the times spent in the feeding station (Table 3). In particular, with the variable-time system, the cows spent slightly (but significantly) more time in the feeding station. In Experiment I, the cows spent significantly more time in the feeding station with the fixed-11-time system compared to the fixed-7-time system. Information about time spent in the direct neighbourhood of the feeding station - the waiting area - was only available from Experiments II and III. The results of Experiment II showed that the waiting area was not attractive to the cows when they received concentrates at the feeding rack. In Experiment III no differences were found in the time spent in the waiting area for the three systems tested. In Experiment I, the cows spent about an hour longer in the walking area with the fixed-11-time system compared to the other two systems. In Experiment II the total time spent in the walking area (230.8 min) was again rather high with the fixed-11-time system. In Experiment III no significant differences were found, but with the fixed-3-time system the total time spent in the walking area (243.1 min) was rather high.

Significant differences in the time spent standing in the cubicles were only found in Experiment I: with the variable-time system this standing time was significantly less. However, this reduction in standing time found with the variable-time system was not observed in Experiment III. A comparison with the time spent lying in the cubicles shows that with the variable-time system in Experiment I, a relatively high lying time was found. So the total time spent in the cubicles with the variable-time system was more or less the same in both experiments and comparable to the results with the feeding-rack system, the fixed-7-time and the fixed-3-time systems. In Experiment I the lying time and total time spent in the cubicles was significantly lower with the fixed-11-time system compared to the other two systems. The lying times found with the fixed-11-time system in Experiment I (646.0 min) and in Experiment II (652.0 min) were comparable. The lying time when the cows were fed concentrates at the feeding rack was also similar (653.0 min). By comparing the results of the three experiments, it can be concluded that the lying times found with the fixed-11-time and the feeding-rack systems (646.0, 652.0 and 653.0 min per 24 h) were considerably less than those found with the other three automatic feeding systems.

daily rhythm

Table 3 showed that significant differences were found between the systems, particularly, in the time spent at the feeding rack, in the walking area and lying in the cubicles. Variations in the times spent in the walking area and lying in the cubicles seem to be negatively correlated: when the cows spent more time in the walking area, less time was left for lying down. Because of this relation, only the times spent at the feeding rack and lying in the cubicles will be analysed in more detail. The daily rhythm of the times spent at the feeding rack and lying in the cubicle is presented in Figure 5. Within each experiment, the differences between the investigated systems were tested statistically for each 4-h period. Only the most pronounced differences will be mentioned.

Firstly, a difference in results between the three experiments will be discussed. In Experiment III, for all three automatic feeding systems, it was found that more time was spent at the feeding rack in the last 4-h period (03.00 - 07.00 h) and slightly less in the first 4-h period (07.00 - 11.00 h), when compared with Experiments I and II (Fig. 5). This was probably because milking and feeding started at 06.00 h in Experiment III instead of at 07.00 h. Thus, the cows started eating in the sixth 4-h period (03.00 - 07.00 h), which resulted in a reduced eating time in the next 4-h period (07.00 - 11.00 h). This also resulted in a reduced lying time in the last 4-h period (03.00 - 07.00 h) in all three systems, whereas in the

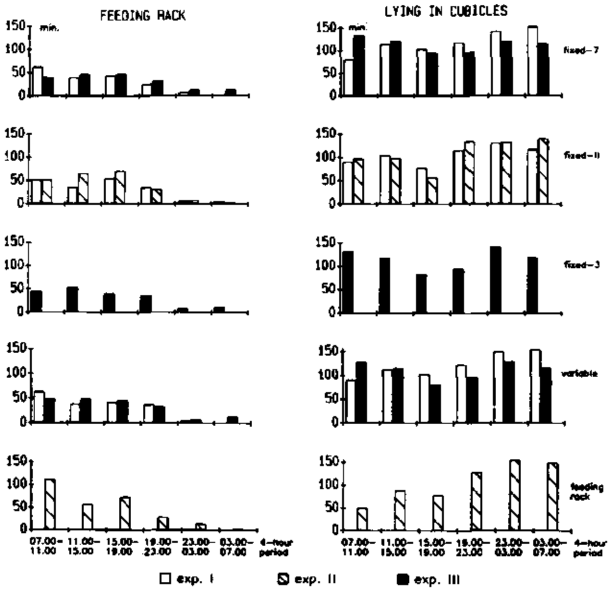

Figure 5. Variation over the 24-h period of the times spent at the feeding rack and lying in the cubicles (min per cow per 4-h period). Further explanation: see Figure 2.

following 4-h period (07.00 - 11.00 h) the lying time increased compared to Experiments I and II.

The time spent at the feeding rack for all the systems investigated was highest in the first three 4-h periods. Concerning time spent at the feeding rack, the most pronounced difference between the feeding systems was the increase found with the feeding-rack system in the first 4-h period (07.00 - 11.00 h). The difference with the fixed-11-time system tested in the same experiment was 60.0 min and was statistically significant ($P \leq 0.05$). Between the automatic feeding systems no statistically significant differences were found in time spent at the feeding rack.

Lying time in the first 4-h period with the feeding-rack system was lower than with the automatic feeding systems. The lying time in this period was 47.5 min less than with the fixed-11-time system tested in the same experiment ($P < 0.05$). Other pronounced differences in lying time between the feeding systems were found in the night. In Experiment I, between 23.00 - 03.00 h, with the fixed-11-time system, the cows spent less time lying down. The difference with the fixed-7-time system was not significant, but compared to the variable-time system the reduction was significant (19.8 min; $P < 0.05$). In the last 4-h period, with the fixed-11-time system, the lying time was significantly less compared to both the fixed-7-time and the variable-time systems (reductions of 35.9 and 38.0 min respectively; $P < 0.05$). In Experiment II, in the fifth 4-h period, a significant reduction (21.0 min; $P < 0.05$) was found with the fixed-11-time system compared to feeding at the feeding rack. In Experiment III, no significant differences between the systems were found in the night period. These results show, therefore, that the observed reductions in lying time per 24 h occurred during the morning in the feeding-rack system and during the night in the fixed-11-time system.

Duration and number of cubicle bouts

The cubicle bouts can also give insight into the consequences of the various automatic feeding systems on the lying behaviour of dairy cows. Compared to feeding at the feeding rack, the number of cubicle bouts could be increased and the duration decreased when the cows interrupted their lying to visit the feeding station.

Table 4 presents both the duration and the number of cubicle bouts recorded with the various systems. In Experiment II a significantly longer duration and fewer cubicle bouts per 24 h were recorded for feeding at the feeding rack compared to the fixed-11-time system. Only in Experiment I was

Table 4. Duration (min) and number of cubicle bouts recorded for the various systems in the three experiments. Results are presented as the mean per cow for the 24-h period and also for the last 4-h period (03.00 -07.00 h). Further explanation: see Table 2.

	Experiment I			Experiment II		Experiment III		
	fixed-7-time (n=6)	fixed-11-time (n=3)	variable time (n=3)	fixed-11-time (n=3)	feeding rack (n=6)	fixed-7-time (n=6)	fixed-3-time (n=6)	variable time (n=6)
24 hours								
duration (min)	99.2[a]	89.9[b]	93.0[ab]	85.0[a]	105.9[b]	106.3	107.3	109.1
number	10.4	10.9	11.1	11.7[a]	9.6[b]	8.1	7.5	7.3
night (03.00 - 07.00 h)								
duration (min)	130.5	101.9	107.3	143.0[a]	257.0[b]	145.9	125.6	127.5
number	1.1[a]	2.1[b]	1.9[b]	2.0[a]	1.3[b]	1.5	1.6	1.6

a significant difference between the automatic feeding systems found in the duration of the cubicle bouts: with the fixed-7-time system the mean duration per 24 h was longer than with the fixed-11-time system. The variation in the number of cubicle bouts between the different systems in the three experiments is small (7.3 - 11.7 per 24 h) and no significant differences were found between the automatic feeding systems (Experiments I and III).

Since differences might be expected to occur particularly in the night, this period was analysed separately (Table 4). Again, in Experiment II the longest duration and lowest number of cubicle bouts were found with the feeding-rack system. In Experiments I and III no significant differences in the duration of the cubicle bouts were found between the automatic feeding systems. In Experiment I the number of cubicle bouts was significantly lower with the fixed-7-time system than with the other two systems tested.

Some consequences of social dominance on visits to the feeding station and on time spent lying down

In this investigation there was one feeding station for 20 cows, therefore competition was expected. To gain information about this, the times spent in the feeding station by the high- and low-ranking animals have been compared. Furthermore, reduced lying times were recorded for the fixed-11-time system, particularly in the night periods. These consequences on lying times have been analysed separately for the high- and low-ranking animals.

visits to the feeding station

Table 5 presents the times spent in the feeding station per 24 h by the high- and low-ranking animals. The results showed that the animals of the high- and low-ranking sub-groups, like the whole group, tended to spend most time in the feeding station under the variable-time system. However, no differences appeared to exist between the high- and low-ranking animals in the total time spent in the feeding station.

Table 5. Time (min) spent in the feeding station per cow per 24-h period by the high- and the low-ranking animals. Further explanation: see Table 2.

	Experiment I			Experiment II	Experiment III		
	fixed- 7-time (n=6)	fixed- 11-time (n=3)	variable time (n=3)	fixed- 11-time (n=3)	fixed- 7-time (n=6)	fixed- 3-time (n=6)	variable time (n=6)
high-ranking	42.9[a]	47.7[ab]	62.6[b]	47.3	42.1	44.0	43.9
low-ranking	43.4	46.3	52.2	50.7	43.1[a]	43.7[a]	53.1[b]

The daily rhythm of time spent in the feeding station by both the high- and the low-ranking cows is described with respect to possible differences in their patterns of intake of concentrates (Fig. 6). With the fixed-time systems, in the first 4-h period of both 12-h cycles, the high-ranking animals generally spent 9.6 - 13.7 min in the feeding station (3 kg concentrates was available). In the second 4-h period of both cycles they spent 6.8 - 10.5 min in the feeding station (1.5 kg concentrates available), whereas in the last 4-h period the high-ranking animals only spent 0 - 4.3 min (in Experiment I, for the fixed-11-time system a more extreme value - 7.1 min - was recorded) in the feeding station. In contrast to the high-ranking animals, the low-ranking ones generally spent only 6.3 - 11.8 min in the feeding station during the first 4-h period of the 12-h cycles. They probably did not manage to eat all their available concentrates. During the second 4-h period they again spent 7.6 - 11.3 min in the feeding station. In the last 4-h period of both 12-h cycles, the low-ranking animals also spent a few (1.1 - 6.4) min in the feeding station. This difference between high-and low-ranking animals was not found with the variable-time system: both sub-groups showed a daily rhythm which was comparable to the rhythm of the whole group.

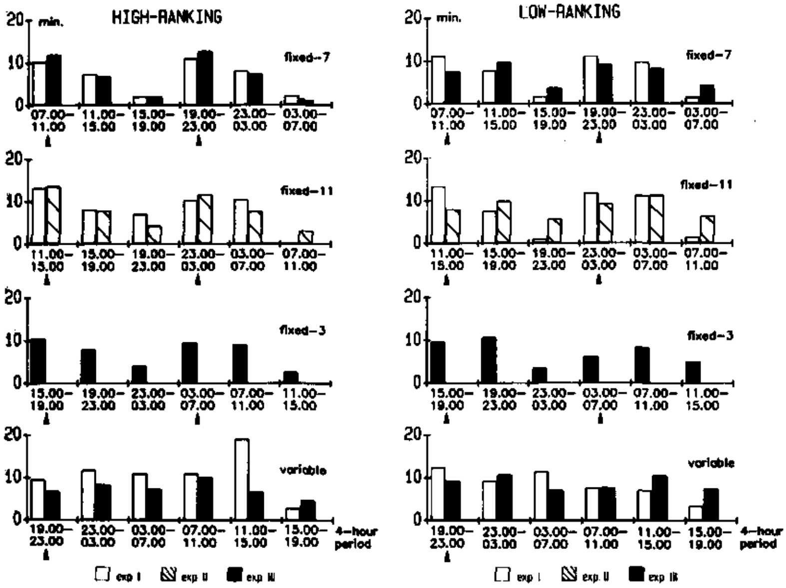

Figure 6. Variation over the 24-h period in the time spent in the feeding station for the high- and the low-ranking animals (min per cow per 4-h period). Further explanation: see Figure 2.

time spent lying down

The data for the time spent lying down (Table 6) show that, for both the high- and the low-ranking animals, lying times per 24 h tended to be lowest with the feeding-rack and the fixed-11-time systems. Only in Experiment I, for the low-ranking animals, was a statistically significant difference found between the fixed-11-time and the other automatic feeding systems. In Experiment I in the first part of the night (23.00 - 03.00 h), the high- as well as the low-ranking animals tended to lie down for a shorter time in the fixed-11-time system than in the other systems, but this reduction was not statistically significant. In the second part of the night (03.00 - 07.00 h) a statistically significant reduction in lying time was found with the fixed-11-time system, which was particularly pronounced for the low-ranking animals. With the feeding-rack system, night lying times were found to be more or less comparable to the lying times found for the fixed-7-, fixed-3- and variable-time systems.

Thus, the reduced lying time per 24 h observed for the feeding-rack system was experienced by all the animals, irrespective of their dominance

Table 6. Time (min per cow) spent lying during the 24-h period and during the last two 4-h periods of the night (23.00 - 03.00 h and 03.00 - 07.00 h). The data are given for the high- and the low-ranking cows separately. Further explanation: see Table 2.

	Experiment I			Experiment II		Experiment III		
	fixed-7-time (n=6)	fixed-11-time (n=3)	variable time (n=3)	fixed-11-time (n=3)	feeding rack (n=6)	fixed-7-time (n=6)	fixed-3-time (n=6)	variable time (n=6)
high-ranking cows								
24-hours	712.0	680.0	724.0	704.0	683.0	727.0	723.0	709.0
23.00-03.00	141.4	118.3	144.3	136.6	152.3	133.1	152.4	138.4
03.00-07.00	161.5[a]	129.9[b]	152.0[ab]	161.0	151.3	123.8	112.3	114.6
low-ranking cows								
24-hours	743.0[a]	579.0[b]	860.0[a]	564.0	579.0	699.0	672.0	626.0
23.00-03.00	143.6	123.2	160.0	128.1	149.3	124.4	117.4	108.4
03.00-07.00	142.9[a]	57.6[b]	160.5[a]	124.8	130.8	113.0	127.6	106.8

value. However, the reduced lying time found for the fixed-11-time system was experienced by the high-ranking animals to a limited extent, but the low-ranking animals experienced it to a greater extent (significantly for the 24-h period).

DISCUSSION

Visits to the feeding station

The experiments have shown that each of the different automatic feeding systems resulted in a typical pattern of visits to the feeding station. Differences were found in number, duration and/or timing of visits particularly between the two main systems (fixed-time system and variable-time system). These differences also resulted in different patterns of intake of concentrates. The fixed-time systems were characterized by 8 - 10 visits per cow per 24 h, of which 3 - 5 were unrewarded. With the variable-time system, the number of visits was much higher (13 - 15 per cow per 24 h) but only a few of these visits (1 - 3 per cow per 24 h) were unrewarded. Comparable results have been found in other investigations (Wierenga and Folkerts, 1986; Van der Burg et al., 1989). How can such differences between the automatic feeding systems be explained? Firstly the number and duration of the visits to the feeding station will be discussed and thereafter the timing of these visits.

With the variable-time system more visits and a higher proportion of rewarded visits were recorded compared to the fixed-time systems, probably because the variable-time system gives the cows a higher chance of being rewarded at any given time. In the most extreme case with this system, a cow could eat her allocated ration of 9 kg of concentrates in one portion of 200 g and 88 portions of 100 g. This would occur if the cow returned to the feeding station each time her allocated ration reached 100 g (i.e. every 14 min). It is understandable that the cows did not visit the station this frequently, but the results showed that the cows did pay regular (rewarded) visits to the feeding station. In theory, with a fixed-time system, a cow could also eat her concentrates in 100 g portions. In contrast to the variable-time system all of the ration is available at the start of each 4-h period. This means that after the start of a rewarded visit the cow would need to leave the feeding station within 20 seconds of receiving 100 g, in order to prevent another 100 g of her total allotted ration (3 kg or 1.5 kg) being delivered. Of course, this is unlikely to happen; it seems more likely that the cow will stay as long as she is receiving concentrates. When the cows visit the feeding station at least once in each 4-h period and eat all the available concentrates at one time, they are rewarded in the first and second 4-h period of each 12-h cycle. This would result in 4 rewarded visits per 24 h. In the experiments, 4.46 - 5.22 rewarded visits were recorded, which shows that the cows often ate a large amount of their total allocated ration at one time. Since subsequent visits often were unrewarded, it is understandable that the cows did not visit the station as often as in the variable-time system.

Each visit allows the cows to test whether a new portion of concentrates has been allocated. It is interesting to note that most unrewarded visits were very short, showing that the cows left the feeding station as soon as they realised that they would not get any concentrates. The higher total time spent in the feeding station with the variable-time system is probably caused simply by the cows visiting the feeding station more often. For actually eating the concentrates the cows took the same amount of time in the feeding station with all the systems, but each visit also uses some unrewarded time for getting in and out of the station. Thus, the way the concentrates were allocated directly influenced the number, duration and timing of both rewarded and unrewarded visits. It needs to be stressed that the patterns of concentrates intake described were found with these systems as programmed in these experiments. With other amounts of concentrates (which can be varied per 24- or 12-h cycle or per 4-h period) other patterns of visits will be found. Based on the results of the described experiments, a prediction of the intake pattern could be made if it is known how the distribution of concentrates is to be programmed.

At first, it seems logical that each feeding system, with its own timing for providing concentrates, should provoke its own pattern of intake. However, as has been stressed, the automatic feeding systems did not provide external signals which the cows could use to learn when the concentrates would be available. If the cows, at the start of each experiment, had adopted a certain daily pattern of visiting the feeding station and had stuck to this pattern independently of the feeding system, they could have obtained all the available concentrates in each of the tested systems. Thus, a change of timing or number of visits was not necessary to obtain all the concentrates but only to obtain them earlier - i.e. immediately they became available. What kind of signals were used by the cows to obtain information about changes in when the concentrates were available? Of course, with providing concentrates at the feeding rack this seems rather simple: when the cows started eating their maize silage they tasted the concentrates. It is interesting to note that the cows responded by spending more time eating than they did normally in the same period. The cows could also have decided to start by eating the normal amount of food (now a mixture of maize silage and concentrates instead of just maize silage) and then to come back later in the morning or at the beginning of the afternoon to eat the rest of their ration. It is difficult to decide whether they simply were hungry, whether it was the more attractive flavour, the slightly higher nutritive value or competition for a limited amount of food which made the cows decide to eat a larger quantity of food. An obvious side-effect was reduction in lying time.

What kind of information was used by the cows when they adopted their feeding pattern after a change from one automatic feeding system to another? Firstly, it has been shown that cows visited the feeding station regularly; these were either rewarded or unrewarded visits. When the feeding system was changed the cow might have visited the station at a time which would previously have been unrewarded, but which was now rewarded. When she unexpectedly received concentrates she would then have stayed and eaten until the system stopped giving concentrates. So it could be that just by visiting the feeding station regularly, the cows experienced changes in the system.

Secondly, an increase in the number of visits was recorded when the system changed from a fixed-time into the variable-time system and a decrease was recorded after the systems were reversed. This showed that the cows also responded to a change of feeding systems by adapting their number of visits, probably because their chances of a reward (= concentrates) had changed.

Thirdly, during the behavioural studies, the observers had the impression that, at the beginning of a new 12- or 24-h cycle, many cows went to the feeding station directly after the first cow had received some concentrates. Generally, for some time before the beginning of a 12- or 24-h cycle (and also before the beginning of the second 4-h period with the fixed-time systems) no or only a few cows received concentrates. Thus, the first cow to visit the feeding station directly after the start of a new cycle or period was the first to receive concentrates for some time. The provision of concentrates in the feeding station made a specific noise which was clearly audible for the whole group of cows. The cows probably learned to associate this noise with the opportunity to eat concentrates; therefore, they could use this information to learn when concentrates were available again. However, this noise was not always a reliable stimulus. Such a stimulus reliably "announced" that new concentrates were available again for all the cows only at the beginning of a new cycle or period. After some time this stimulus was only reliable for those cows which had not eaten (all of) their concentrates.

All three explanations may well account for the differences between the variable and the fixed-time system as well as the differences between the three fixed-time systems. Thus, although the systems themselves did not give clear information announcing (a change in) available concentrates, the cows could use other sources of information to learn about the availability of concentrates. Probably, because the cows were keen to eat concentrates, they responded by changing their pattern of intake of concentrates when the feeding system changed.

Concerning the consequences of competition between 20 cows for the one station, it was shown that, with fixed-time systems, low-ranking animals spent less time in the feeding station compared to high-ranking animals during the first 4-h period and more time during the second 4-h period. During the first 4-h period of the fixed-time systems, 3 kg of concentrates was available for each cow. With a delivery speed of 100 g/20 sec each cow needed 10 min to eat her ration of 3 kg. If the cows only stayed in the feeding station to eat concentrates, the whole group would have needed only 200 of the 240 min available in the first 4-h period. However, the first cow did not always enter the feeding station right at the start of the 4-h period. Furthermore, the cows needed some time to get in and out, and sometimes a cow was displaced by another cow. Thus, for all the cows in a group to eat all their rations took longer than 200 mins. This meant that some cows did not succeed in eating all their concentrates within the first 4-h period, resulting in more than 1.5 kg being available for them in the second 4-h period. However, it is important to note that for the whole 24-h period only the pattern of intake was affected by social dominance and not the total time spent in the feeding station.

It is interesting that social dominance did not exert a comparable influence in the variable-time system. In this system the cows ate fairly small portions at a time, - in particular at the start of a new 24-h cycle - which meant that the cows only needed to stay in the feeding station a short time. Thus, the animals succeeded each other quickly and the low-ranking animals had no difficulty in gaining access to the feeding station.

General activities affected by the concentrates feeding system

The experiments showed that each system had various effects on the cows' general activities. Per 24 h the cows spent about 60 min longer at the feeding rack when concentrates were supplied there compared to the automatic feeding systems. This reduced the lying time during the morning. The cows spent hardly any time in the direct vicinity of the feeding station (= waiting area), resulting in the least time spent in the walking area compared to the automatic feeding systems. Despite this, the cows did not seem to compensate for the reduced lying time in the morning. This observation agrees with earlier suggestions that cows do not compensate for lying time which they have "lost" during the day (Wierenga and Hopster, 1990).

With the various automatic systems for feeding concentrates, the cows spent between 40 - 60 min in the waiting area. So together with the time spent in the feeding station, the cows spent between 90 - 110 min in total in and around the feeding station. With the fixed-11-time system, the cows spent significantly longer in the walking area than with the other systems tested in Experiments I and II, and a comparable trend was found for the fixed-3-time system. The fixed-11-time system resulted in a reduced lying time compared to the other automatic feeding systems. This reduction took place particularly during the night and was experienced most by the low-ranking animals. This effect of the fixed-11-time system can be explained as follows. With this system a new 12-h cycle started at 23.00 h, when many cows were lying down in a cubicle. When the first cow received her concentrates, the other cows heard this and may have stood up and proceeded to the feeding station. Of course, only one cow at a time could enter the feeding station, so the other cows had to wait. This waiting time could be considerable because each cow needed at least 10 min, if she wanted to eat all her available concentrates. At other times of the day the cows could decide to go to the feeding rack and combine waiting for entrance to the feeding station with eating roughage. However, in the night periods the cows spent very little time eating roughage, so they probably had to choose between waiting or going back to the cubicles. It seems that the cows often decided to stay in the neighbourhood of the feeding station, resulting in a reduced lying time. It is not surprising that the low-ranking animals experienced the largest reduction in lying time, since they had to wait the longest.

It is surprising that comparable results were not found with the fixed-3-time system tested in Experiment III. Possibly the cows were much more reluctant to stand up at the time when this system started in the night (03.00 h). Thus, compared with the fixed-11-time system, not many cows were likely to be waiting in the neighbourhood of the feeding station. Secondly, it is also possible that effects were masked in Experiment III because the cows were milked one hour earlier. Thus, the 4-h period in the night, during which a new 12-h cycle started, in fact lasted only three hours. After three hours all the cows had to get up to be milked and when they came back they started eating roughage and/or concentrates.

The automatic feeding systems affected the duration and number of the cubicle bouts. The shorter duration of the cubicle bouts shows that the cows sometimes left the cubicles especially to visit the feeding station. This only resulted in a reduced total lying time for the fixed-11-time system.

The data presented indicate that the cows were keen to eat concentrates. Firstly, with the feeding-rack system the cows stayed longer at the feeding rack, resulting in a reduced lying time. Secondly, with the automatic feeding systems, the cows sometimes stood up especially to visit the feeding station. With the fixed-11-time system the cows appeared to be willing to wait a long time (resulting in a reduced lying time) in the neighbourhood of the feeding station in order to eat concentrates as soon as they were available again.

Advantages and disadvantages of concentrates feeding systems from the cows' point of view

On balance, all the automatic concentrates feeding systems functioned very well for the cows. The cows visited the feeding station regularly and the concentrates intake was always satisfactory.

One advantage of automatic feeding for the cows is that, to a great extent, they can decide when they want to eat concentrates. With the variable-time system there is more freedom to decide about the timing of a visit than with the fixed-time systems, because the availability of concentrates is more evenly distributed over the 24 h. A relatively high number of unrewarded visits with the fixed-time systems may be a negative point. The cows might become frustrated because they do not receive concentrates, but, as shown, such unrewarded visits were short. The high number of rewarded visits with the variable-time system may also hold negative aspects for the cows. There is more "cow-traffic" in the cubicle house which might result in more social confrontations. However, negative consequences of the higher number of visits to the feeding station were not observed: the duration of the cubicle bouts and the time spent in the cubicles was not different to the fixed-time systems. Both the high number of unrewarded visits with the fixed-time systems and the high number of rewarded visits with the variable-time system could be reduced if the system could "announce" that concentrates are available anew at certain times. Such information should be given individually. Wierenga and Hopster (1989) showed that cows learn to respond to such a signal. However, it is questionable, from a practical point of view, whether such a system for giving individual signals is needed.

The reduction in lying time found with the fixed-11-time system has been explained as a consequence of the competition for the one available feeding station. It could be regarded as a negative consequence of this system, especially since the reduction was only experienced by the low-ranking animals. Some consequences for lying behaviour have been described for all the systems: the duration of the cubicle bouts was shorter, and thus the lying time was also affected. However, these did not seem to affect the cows dramatically and, to a large extent, were the result of the cows' own choice.

CONCLUSIONS

The experiments have shown that each of the five feeding systems evoked a typical pattern of visits to the feeding station. The cows adapted the number and timing of their visits to the feeding station, eating all their rations of concentrates as soon as they were made available.

The adaptation to the feeding system sometimes also affected several of the general activities, in particular the time spent at the feeding rack and the time spent lying in the cubicles.

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7. TIMING OF VISITS TO THE CONCENTRATES FEEDING STATION BY DAIRY COWS

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Published in Applied Animal Behaviour Science 30(1991): 247-271.

TIMING OF VISITS TO THE CONCENTRATES FEEDING STATION BY DAIRY COWS

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ABSTRACT

Dairy cows can be fed concentrates in feeding stations with automatic feeding systems. This paper discusses possible factors which influence the timing of the cows' visits to the feeding station. Both 1) factors affecting the dairy cows' behaviour just before and just after the visit, and 2) information which might be used by the cows to decide to visit the feeding station are investigated.

An investigation was done with a group of 20 lactating dairy cows. In successive 3-week experimental periods the cows were fed concentrates with three different automatic concentrates feeding systems (fixed-7-, fixed-3- and variable-time system). 24-h behavioural observations recorded the cows' general activities while the number and duration of visits to the feeding station and the intake of concentrates were recorded automatically.

The three concentrates feeding systems each provoked a typical pattern of visits (total number of visits, timing of rewarded and unrewarded visits). However, the pattern of general activities was not affected by the concentrates feeding systems.

The cows' general activities both before and after their visits to the feeding station were significantly affected by the time of the day. However, the cows' possible knowledge about their chances of receiving concentrates did not affect their general activities significantly. The results suggest that the cows fitted their visits to the concentrates feeding station into their normal daily routine. For instance, the cows did not often leave the cubicles solely to pay a visit to the concentrates feeding station. It was also not possible to show that the cows spent more time eating roughage after an unrewarded visit to the concentrates feeding station than after a rewarded visit.

The cows could have learned the times of the day when concentrates were available and that at certain times they could also expect concentrates when another cow had visited the feeding station and received concentrates. However, it was shown that the cows visited the concentrates feeding station throughout the 24-h period, which means that the timing of their visits was not affected by the time of the day. The results suggested that, to some extent, the cows responded to information from the feeding station. Rewarded visits were more often and more consistently followed shortly by a visit by another cow than unrewarded visits.

It is concluded that the cows: 1) did not respond to variation over the 24-h period in their chances of obtaining concentrates, and 2) did not always respond to information from the feeding station. The cows apparently chose a strategy of paying regular visits to the feeding station, because the cost for such visits is low and the reward is sufficiently high.

INTRODUCTION

An automatic concentrates feeding system is one of the methods available for feeding concentrates to cows. The animals receive concentrates in a feeding station where each cow is identified individually. The amount of concentrates delivered depends on the individual cows' available ration at the time of the visit. Wierenga and Hopster (1991) analysed the pattern of visits to such feeding stations and the general activities of the cows when they were fed with different automatic concentrates feeding systems. They showed that each feeding system had its own typical pattern of rewarded and unrewarded visits to the feeding station, but that there was no great difference between the feeding systems in time spent on general activities (e.g. time spent at the feeding rack or in the cubicles). This paper considers the exact timing of the visits to the feeding station and possible differences between feeding systems in this respect, a point which was not dealt with in the earlier paper.

The timing of visits to the concentrates feeding station has two aspects. First there is an interaction with the cows' other activities; the cows fit their visits in with other activities. In considering the visits one can investigate first what the cows do before and after visiting the feeding station. Because visits occur at different times of the day, this could result in differences between the cows' behaviour before and also after a visit. Secondly, the cows learn when concentrates are available and the cows' behaviour just before a visit could also be affected by their expectations of whether they will receive concentrates or not. For instance, in the night-period when the cows are often lying down there are two possibilities: 1) when they expect concentrates they stand up and leave the cubicle and enter the feeding station immediately, whereas 2) when they do not expect concentrates they stand up - as they usually do - and after some time leave the cubicle, only later to enter the feeding station. Thirdly, a difference might be expected in the amount of time spent at the feeding rack after rewarded and unrewarded visits. If the cows go to the concentrates feeding station because they are hungry and they do not receive concentrates, it would be reasonable to expect them to proceed shortly afterwards to the feeding rack and spend more time there than after a rewarded visit.

The second aspect of the timing of a visit is the information which the cows may use to decide when to visit the concentrates feeding station. If the cows do not visit the concentrates feeding station randomly, what information do they use to determine their chances of being rewarded? Firstly, the cows may gradually learn the times of the day when they will receive concentrates. Secondly, the cows may respond to information from the feeding station. As Wierenga and Hopster (1991) pointed out, the system itself does not give the cows any information about their chances of being rewarded. However, the cows may well respond to group-mates receiving concentrates. The cows can hear the noise of concentrates falling into the trough of the feeding station and they can see that one or more cows spend time in the feeding station.

This paper analyses: 1) the possible factors which affect the cows' behaviour just before (in cubicles) and after (at feeding rack) a visit to the feeding station, and 2) the information (time of the day and information from the feeding station) which the cows use to decide when to visit the feeding station.

MATERIAL AND METHODS

The data for the analysis presented here were collected during Experiment III of the investigation described in detail in Wierenga and Hopster (1991). Only a brief description is given here.

Animals, housing, feeding and experimental design

The experiment was performed with a group of 20 lactating dairy cows. Three of the cows had serious leg problems which affected their visits to the feeding station. These cows were excluded from the analysis. The cows were kept in a cubicle house with one row of 19 cubicles, a feeding rack with 16 eating places and a walking area 2.60 m wide with a slatted floor. The concentrates feeding station was placed in the cubicle row. The cows were milked at 06.00 h and 15.30 h. The animals were fed maize silage (4.0 kg dry matter per cow) directly after morning milking and ad lib. grass silage delivered at 13.30 h and after evening milking (mean total intake: 5.7 kg dry matter per cow). The feeding station, in which the cows were identified individually, supplied each cow 9.0 kg concentrates per day; in addition the cows received 1.0 kg during milking. For providing concentrates in the feeding station three different automatic systems ("programmes") were used. They were called the fixed-7-time system, fixed-3-time system and variable-time system (Wierenga and Hopster, 1991). In both fixed-time systems, the 24-h period was divided into two cycles of 12 h which were again divided into three 4-h periods. At the start of the first 4-h period of a cycle 3.0 kg concentrates was available for each cow. When the cows visited the station they could eat all this portion at once, or part of it and eat the remaining portion later. In the second 4-h period of a cycle 1.5 kg concentrates was added to the available ration for each cow. Again the cows could eat this whole portion at once and also any concentrates left-over from the first 4-h period. In the third 4-h period no extra concentrates were available. The cows could only eat left-overs from the previous period(s). After the start of a new 12-h cycle, the cows did not receive possible concentrates left over from the previous 12-h cycle.

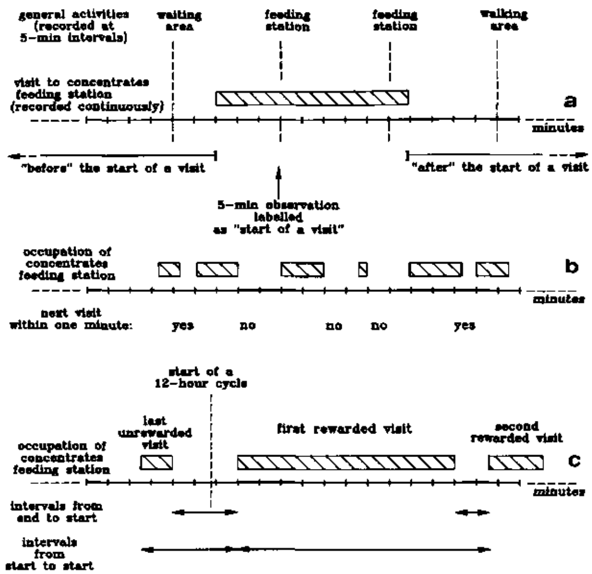
The only difference between the fixed-7- and the fixed-3-time system was the starting time of the 12-h cycles. For the fixed-7-time system the cycles started at 07.00 and 19.00 h, for the fixed-3-time system at 15.00 and 03.00 h. The variable-time system had a 24-h cycle which started at 19.00 h. At the beginning of the cycle each cow started with a balance of 0.2 kg of concentrates and 0.1 kg was added to this balance every 14 min. When a cow visited the feeding station she could eat all her available ration of concentrates. After her visit the balance would gradually build up in steps of 0.1 kg. If a cow visited the feeding station regularly, the maximum ration of 9 kg of concentrates was normally allocated after a period of about 20 h. Thus, after about 16.00 h, the cows' visits were mostly unrewarded.

During six experimental periods, each lasting 3 weeks, the three feeding systems were tested successively in the following order: fixed-7-, variable-, fixed-7-, fixed-3-, variable-, and fixed-3-time system.

Collection and analysis of data

During the last 10 days of each 3-week experimental period, three 24-h observations were carried out to obtain information about general activities. During these observations, the general activity of each cow was recorded every 5 min as standing (including eating) at the feeding rack, standing (including eating) in the feeding station, standing in the waiting area (a square 1 m to either side of the feeding station and 2 m in front of it), standing in the remaining part of the walking area, or standing or lying in a cubicle. During these 24-h observations the visits to the feeding station were recorded continuously by a computer. The amount of concentrates eaten and the total occupation time (= time elapsed between entering and leaving) of the feeding station were also recorded automatically. These data were combined with the data from the behavioural observations, and two analyses were carried out. Firstly, we investigated which general activities the cows performed before and after each visit to the feeding station. Secondly, to find out what information the cows used to decide when to visit the feeding station, we investigated how quickly a visit was followed by a visit of the next cow. Thus, the intervals between visits were analysed, irrespective of which cows visited the feeding station.

The 5-min observations carried out during one hour before and one hour after the start of a recorded visit were used (see Fig. 1) to analyse what the cows were doing just before and after a visit to the concentrates feeding station. We calculated how often the cows were observed to perform each of the general activities for each 5-min period, within the chosen period of one hour preceding or following the start of a visit. These data can first be used to describe the pattern of changes in general activities during the two hours preceding and following a visit. Secondly, the data were



<u>Figure 1</u>. Illustration of methods used to analyse: a) general activities of cows before and after a visit to the concentrates feeding station, b) next visit within one minute, yes/no, c) intervals between last unrewarded visit and first two rewarded visits after the start of a 12-h cycle.

also analysed statistically. The most important changes in activities occurred during the half hour just before and after the start of a visit, so only the data from these half-hour periods were considered in the statistical analysis. The analysis was carried out separately for time spent on general activities before and after visits to the concentrates feeding station. An analysis of variance model was used with main effects and all two-factor interactions for the factors: 1) type of visit (rewarded or unrewarded), 2) concentrates feeding system, 3) time of the day (periods of 4 h which coincided with the 4-h periods of the fixed-time systems). To avoid any complicated dependence structures between observations on individual animals, 24-h group means were analysed. The number of visits corresponding to these means was entered as weights in the analysis.

For investigating the information used by the cows in deciding when to visit the feeding station, we first analysed which factors affected the probability of a visit following the termination of the last visit within one minute (see Fig. 1). A logit model (Cox, 1970) was fitted to the data with Genstat 5 (Lane et al., 1987). Factors in the logit model were: 1) type of visit (rewarded or unrewarded), 2) amount of concentrates fed during a period of 15 min up to the end of the investigated visit (in steps of 1 kg, up to a maximum of 4 kg), 3) concentrates feeding system, 4) time of the day (again in 4-h periods). The main effects and two-factor interactions were inspected. Both the type of visit and the amount of concentrates fed during a period of 15 min up to the end of the visit were introduced as parameters into the analysis, because they could give different information. This occurred when a cow who had eaten her portion of concentrates, and than revisited the feeding station shortly afterwards. Such a visit might well be unrewarded and could occur between two other cows' rewarded visits. Thus, in this situation, the information from the feeding station is that concentrates are being delivered, with only a brief interruption by an unrewarded visit (Wierenga and Hopster, 1991) .

Also the length of the intervals between visits was analysed. Only the intervals between visits around the start of new 12-h cycles in the fixed-7- and the fixed-3-systems were analysed, for reasons which will be explained later. Particular attention was given to the intervals between the last unrewarded visit before the start of a new 12-h cycle and the first rewarded visit after the start, and also to the intervals between the first and second visits after the start (see Fig. 1). Intervals between the start of a visit and the start of the next visit, as well as intervals between the end of a visit and the start of the next visit, were calculated. In an analysis of variance, the main effects and two-factor interactions of the following factors were inspected: 1) type of visit (rewarded or unrewarded), 2) concentrates feeding system, 3) time of the day (again in 4-h periods).

RESULTS

Daily rhythm in visits and in general activities

Figure 2 shows the daily rhythm of the visits to the concentrates feeding station for each of the three feeding systems. With the fixed-7-time system, the average total number of visits per cow fluctuated between 0.2 and 0.5 per hour. However, at certain times these were rewarded visits and

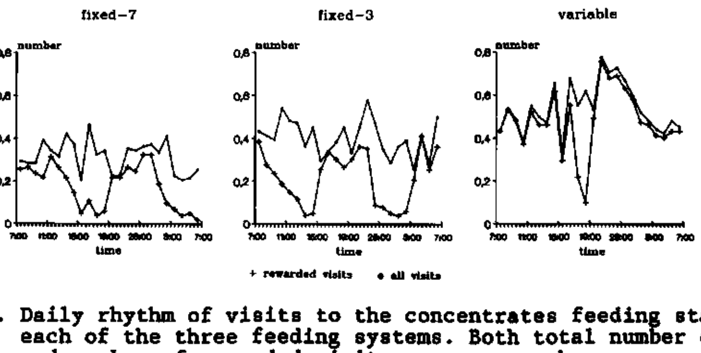


Figure 2. Daily rhythm of visits to the concentrates feeding station for each of the three feeding systems. Both total number of visits and number of rewarded visits per cow per hour are presented. Mean of six 24-h observations per system.

at other times unrewarded. The rewarded visits occurred mainly between 07.00 and 15.00 h and between 19.00 and 03.00 h. With the fixed-3-time system most rewarded visits occurred between 15.00 and 23.00 h and between 03.00 and 11.00 h. With the variable-time system the total number of visits varied between 0.3 and 0.8 per hour. Mostly these visits were rewarded, but between 16.00 and 19.00 h the number of rewarded visits was much lower; mainly unrewarded visits occurred. These patterns of visits are typical for each of the three systems tested and are the result of differences in the distribution of concentrates over the 24-h period.

To compare the daily variation in the number of visits with the general activities, the daily variation in the time spent at the feeding rack and in the cubicles is presented in Figure 3. These activities fluctuate over the 24-h period, but only very small differences were recorded between the three feeding systems. Between 07.00 and 23.00 h the cows spent 10 min per hour or more at the feeding rack, with peaks around 07.00, 14.00 and 16.00 h. In the night period (00.00 - 06.00 h), hardly any time was spent at the feeding rack. The cows spent most of the night period (00.00 -06.00 h) in the cubicles. During the remaining part of the 24 h, the cows spent 45 min per hour or less in the cubicles during those periods when a lot of time was spent at the feeding rack.

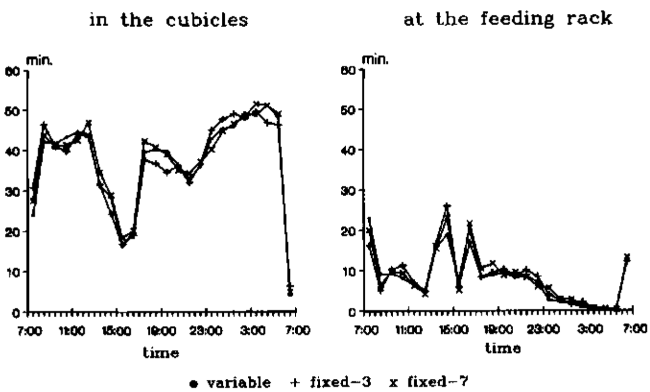


Figure 3. Daily rhythm of time spent (minutes per cow per hour) in the cubicles and at the feeding rack. Results for each of the three feeding systems tested are presented. Mean of six 24-h observations per system.

Thus, Figures 2 and 3 show that there were differences between the three systems in the times when the rewarded and unrewarded visits occurred, but not in the general activities. This means that, for instance, with the fixed-7-time system the rewarded visits occurred mainly in the periods that the cows also spent time at the feeding rack, whereas with the fixed-3-time system particularly during the night period the rewarded visits occurred in the period that the cows spent most time in the cubicles.

Reaction to changing from one concentrates feeding system to another

It has been shown that each concentrates feeding system has its own typical 24-h pattern of visits to the feeding station (Fig. 2). In an analysis into the factors determining the timing of these visits, it is useful to know how long the cows need to adapt to a new concentrates feeding system. The consequences of the transition from one concentrates feeding system to another on the number of visits to the feeding station per 24 h was analysed. In Figure 4, the number of visits to the feeding station (per cow per 24 h) is presented for all the days within this experiment (except for the first two days immediately following each transition because they were not available due to technical problems). This figure shows that after each

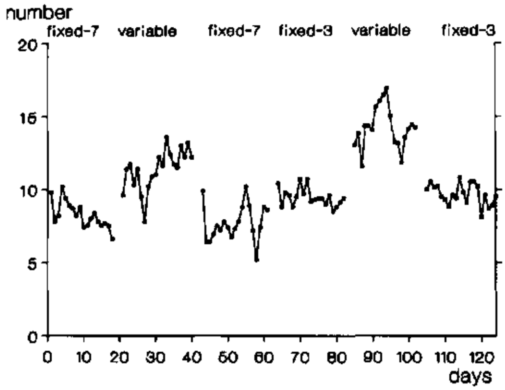


Figure 4. Number of visits to the concentrates feeding station per cow per 24 h. The results are presented for each observation day, for each experimental period separately; the results of the first two days after transition are not given.

transition, the number of visits to the feeding station has clearly changed within two days. For instance, after the transition from the fixed-7- to the variable-time system, the number of visits increased from 6.6 (day 18) to 9.7 (day 21) per cow per 24 h. These results show that the cows responded within two days to changes in the concentrates feeding system, which particularly with the variable-time system coincided with changes in their chances of being rewarded. In addition, the results suggest that following the rapid increase in the number of visits immediately after the first transition from the fixed-time system to the variable-time system, the number of visits gradually increased further. After the second transition from a fixed-time system to the variable-time system, the increase in the number of visits within two days seems to be larger, and no further - consistent - increase was recorded.

Pattern of general activities before and after a visit

all visits

In Figure 5 - for the mean of all visits and of the three systems - the changes in activities during the one hour before and after a visit are shown. These data are based on the results of 2982 visits. On average 66.8 % of the cows were observed in the cubicles one hour before a visit. This percentage gradually decreased to 29.5 % just before a visit. Only in 12.0 % of the visits the cow was again observed in a cubicle in the 5-min period directly following the visit. Gradually the percentage of cows seen in cubicles increased up to 67.2 % one hour after a visit. One hour before a visit 12.5 % of the visiting cows were observed at the feeding rack (Fig. 5). During the hour preceding a visit, gradually the cows were observed at the feeding rack slightly more often. In the 5-min period just before a visit the cows were observed at the feeding rack in 22.6 % of the visits. Directly following a visit gradually cows were more often observed at the feeding rack; 15 min after the start of a visit, cows were observed at the feeding rack in 33.7 % of the visits. Thereafter, this percentage gradually decreased.

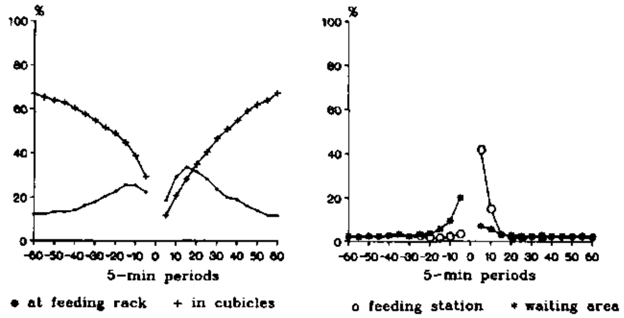


Figure 5. General activity per 5-min period during the hour preceding and following the start of a visit (= 0) to the concentrates feeding station. Mean percentage for all visits and for the three systems.

Between 60 and 25 min before a visit cows were seldom observed in the waiting area (Fig. 5), but in the 20 min preceding a visit, cows were more often observed in the waiting area (on average in 20.1 % of the visits in the last 5-min period just before a visit). In the hour after the visit generally the cows were seldom seen (in less than 3 % of the visits) in the waiting area. In the hour before a visit, the cows were not often observed in the concentrates feeding station (less than 3 %; Fig. 5). This means that a cow seldom visited the feeding station twice within a short time. In the 5-min period directly following the start of the visit the cows were still observed in the feeding station in 41.7 % of the visits. These were visits which took some time, generally because the cows received concentrates. Of course, in the second 5-min period the cows were sometimes still observed in the feeding station (in 15.1 % of the visits), but for the remaining part of the hour following the start of the visit cows were observed in the feeding station in less than 2 % of the visits.

The results of the statistical analysis are presented in Table 1. The mean time spent on the various general activities was corrected for the variation in the number of visits (= weighted means). During the half hour before a visit, the cows spent 2.3 min on average in the waiting area and 0.7 min in the feeding station. The cows spent 5.2 min in the walking area, and 6.6 min at the feeding rack. Almost half of the time (13.6 min) was spent in the cubicles. The general activities before a visit were often significantly affected by whether there was a reward. Also the time of the day often had a significant effect. Only once (waiting area; as an interaction with time of the day) was a significant difference between the three feeding systems observed.

Table 1: Time (min) spent on general activities during the half hour before and after a visit to the concentrates feeding station. Mean of all visits for all three concentrates feeding systems. The factors (whether rewarded or not = r; feeding system = s; time of day = t; and interactions) which had a significant ($P \leq 0.05$) influence on the general activity concerned are presented within brackets.

	before	after
waiting area	2.3 (s x t)	1.1
feeding station	0.7 (r)	2.9 (r x s, s x t)
walking area	5.2 (r, t)	7.4 (s, t)
feeding rack	6.6 (r, t)	8.1 (t)
cubicle	13.6 (r x t)	9.7 (r, s, t)

During the half hour following a visit, little time was spent in the waiting area or in the feeding station itself (to eat concentrates). More time was spent in the walking area (7.4 min) and at the feeding rack (8.1 min), and 9.7 min was spent in the cubicles. Again, being rewarded or not often significantly affected the amount of time spent on several activities. Also the time of the day often had a significant influence. The type of feeding system had a significant influence on the time spent on general activities in several cases.

The statistical analysis often showed a significant influence of both the time of the day and reward on the behaviour before or after a visit, so these factors will be briefly analysed. Because the main questions concern behaviour in the cubicles and at the feeding rack, the analysis will be restricted to these two behaviours. Thereafter, lying behaviour before a visit and feeding behaviour after a visit will be analysed in more detail.

visits in the morning and during the night

The statistical analysis often showed a significant influence of the time of the day on the time spent on general activities both before and after a visit. This probably will be associated with a variation in the time spent at the feeding rack and in the cubicles over the 24-h period (Fig. 3). To test this, the activity pattern before and after a visit has been described separately (Fig. 6) for a 4-h period during which a relatively long time was spent at the feeding rack (07.00 - 11.00 h; 506

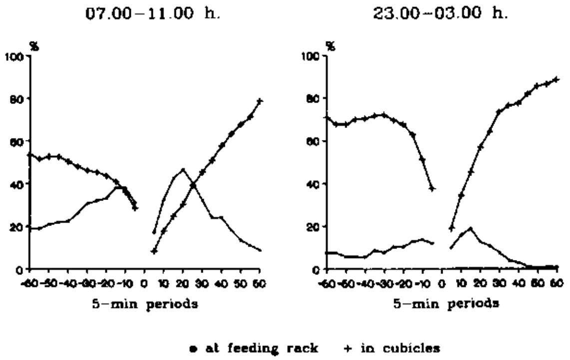


Figure 6. At feeding rack or in cubicles per 5-min period during the hour preceding and following the start of a visit (= 0) to the feeding station. Mean percentage for visits in the 4-h periods 07.00 - 11.00 h (left) and 23.00 - 03.00 h (right).

visits) and a 4-h period during which a lot of time was spent in the cubicles (23.00 - 03.00 h; 397 visits). As might be expected, the cows were more often observed at the feeding rack - both preceding and following a visit - in the morning compared to the night. In contrast, cows were less often observed in the cubicles, both preceding and following a visit, in the morning compared to the night. But the pattern of changes - gradually more often at the feeding rack and less often in a cubicle before a visit and at first more often and then less often at the feeding rack and gradually more often in the cubicles after a visit - was similar and also comparable to the pattern of changes described for the mean of all visits over the 24 h.

rewarded and unrewarded visits

The statistical analysis also often showed a significant influence of the reward on the time spent on general activities both before and after a visit. To illustrate this, Table 2 presents the (weighted) mean time spent at the feeding rack and in the cubicles - both before and after the start of a visit - for rewarded and unrewarded visits separately.

Table 2. Time (min) spent at the feeding rack and in the cubicles during the half hour before and after the start of a visit to the concentrates feeding station. Mean for all systems presented separately for rewarded (n = 2065) and unrewarded (n = 917) visits; significant differences ($P \leq 0.05$) between rewarded and unrewarded visits, but within the "before" or "after" period are marked by ([a], [b]).

	before		after	
	rewarded	unrewarded	rewarded	unrewarded
feeding rack	6.0[a]	7.8[b]	7.9[a]	8.4[a]
cubicle	14.2[a]	12.1[b]	8.5[a]	12.3[b]

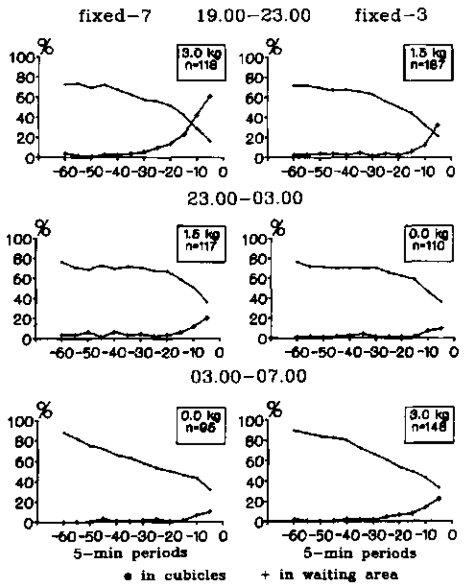
Before the start of a rewarded visit, slightly but significantly less time is spent at the feeding rack compared to the time before an unrewarded visit. The time spent in the cubicles before a rewarded visit is significantly (but again only slightly) higher compared with the unrewarded visits. The analysis showed a significant interaction between reward and the time of the day (Table 1). This will be analysed in more detail later.

After the start of a visit no difference was found - in contrast to expectation - between rewarded and unrewarded visits in the time spent at the feeding rack. The time spent in the cubicles was significantly shorter after a rewarded visit (8.5 min) than after an unrewarded visit (12.3 min). It is likely that this is because the cows stay longer in the feeding station after a rewarded visit than after an unrewarded visit, which leaves less time for lying down in the first half hour after the start of a visit.

chance of being rewarded and the time spent in the cubicle before a visit

It was hypothesized that if the cows learned when concentrates were available, their activities before a visit would vary depending on the cow's expectation of receiving concentrates. This was tested for the night-period, because in this period for the hour before a visit the cows showed the same behaviour (lying or standing in a cubicle) for the majority of visits.

The time spent in the cubicles before a visit will be described for the night-period for the fixed-7- and the fixed-3-time systems. These systems were chosen because they provided comparable amounts of concentrates and only differed in the time at which these amounts were made available. In the three 4-h periods of the night (19.00 - 23.00 h; 23.00 - 03.00 h; 03.00 - 07.00 h) 3.0, 1.5 and 0 kg of concentrates respectively, were available for the cows with the fixed-7-time system, while with the fixed-3-time system 1.5, 0 and 3.0 kg of concentrates respectively were made available in these three 4-h periods. Thus, depending on the system, for each of the three 4-h periods the cows should have different expectations of the amounts of concentrates to be received. In Figure 7 the changes in activities before a visit are presented for the two systems and for each of the three 4-h periods. Information about the use of cubicles and about the waiting area is given because the time which the cows were forced to spend in the waiting area affected the time when they could finally enter the feeding station.



<u>Figure 7</u>. In cubicles or in waiting area per 5-min period during the hour before the start of a visit (= 0) to the feeding station. Mean percentage for all visits in the 4-h periods 19.00 - 23.00 h, 23.00 - 03.00 h and 03.00 - 07.00 h, for the fixed-7- (left) and the fixed-3-time (right) system. The amount of concentrates which is added to the cows' ration in each situation is presented; n = number of visits analysed.

The pattern of changes in activities in the cubicles presented in Figure 7 shows that, in the same 4-h period, a comparable pattern was found with both systems and thus with the different chances of receiving concentrates. In the 4-h period 19.00 - 23.00 h, on average 72.6 % (fixed-7), and 71.6 % (fixed-3) of the cows were observed in the cubicles one hour before the visit in both systems. Gradually this percentage decreased until 5 min before the visit 16.0 % and 21.3 % respectively of the cows were observed in the cubicles. Particularly in the first night-period, there was a big difference in the percentage of cows observed in the waiting area. Five minutes before the visit, cows were recorded in the waiting area, in 61.5 % of the visits with the fixed-7-time system, whereas with the fixed-3-time system cows were observed in the waiting area in only 32.3 % of the visits. Longer waiting times with the fixed-7-time system are due to the fact that the cows occupied the feeding station for longer in this period (19.00 - 23.00 h), because they received 3.0 kg of concentrates compared to 1.5 kg with the fixed-3-time system. In the second 4-h night-period (23.00 - 03.00 h), 1.5 kg of concentrates is provided in the fixed-7-time system and no new concentrates are added to the ration in the fixed-3-time system. However, no differences were found in behaviour before the visits.

In the last 4-h period of the night (03.00 - 07.00 h), a slightly different pattern of percentage of cows in cubicles is found compared to the preceding two 4-h periods in both systems. This is probably because the cows were milked in this period, which interrupted the cows' cubicle bout. But again the difference in the pattern between the two systems is small, even though the cows in this 4-h period did not receive any extra concentrates in the fixed-7-time system and 3.0 kg of concentrates in the fixed-3-time system.

The statistical analysis showed a significant interaction of reward x time of day concerning the amount of time spent in the cubicles, but no significant influence of the feeding system (Table 1). The latter is confirmed by the pattern presented in Figure 7. In Table 3 the (weighted) mean

Table 3. Time (min) spent in the cubicles during the half hour before the start of a visit to the concentrates feeding station. This mean for the three systems is presented per 4-h period and separately for rewarded and unrewarded visits; significant differences ($P \leq 0.05$) within 4-h periods between rewarded and unrewarded visits are marked ([a], [b]).

	rewarded	unrewarded
07.00 - 11.00 h	12.7[a]	8.9[a]
11.00 - 15.00 "	16.3[a]	11.4[b]
15.00 - 19.00 "	7.4[a]	10.5[a]
19.00 - 23.00 "	13.9[a]	11.0[a]
23.00 - 03.00 "	19.0[a]	18.7[a]
03.00 - 07.00 "	16.6[a]	12.8[a]

time spent in the cubicles before a visit is given for rewarded and unrewarded visits separately for each 4-h period. The significant reward x time of day interaction is probably due to the significant difference between rewarded and unrewarded visits found in the 4-h period 11.00 - 15.00 h. In the other five 4-h periods no significant difference was recorded concerning the time spent in the cubicles before a rewarded or an unrewarded visit.

This analysis thus shows that the cows' lying behaviour just before a visit to the feeding station is not affected by their chances of receiving concentrates.

Influence of the reward on time spent at the feeding rack after a visit

Our second hypothesis was that after a rewarded visit, the cows would spend less time at the feeding rack than after an unrewarded visit. The data presented in Tables 1 and 2 showed that only the time of the day and not the reward or the type of feeding system significantly affected the time spent at the feeding rack after a visit. To illustrate this in more

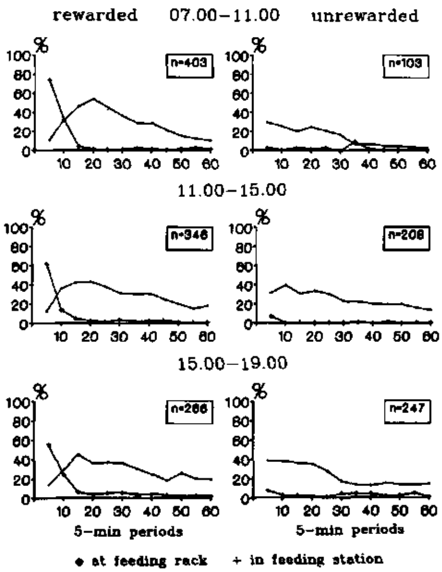


Figure 8. At feeding rack or in the concentrates feeding station per 5-min period during the hour after the start of a visit to the feeding station. Mean percentage for all systems - separately for rewarded (left) and unrewarded (right) visits - in the 4-h periods 07.00 - 11.00 h, 11.00 - 15.00 h and 15.00 - 19.00 h. n = number of visits analysed.

detail, information about the pattern of the percentage of cows at the feeding rack after a rewarded or an unrewarded visit is given in Figure 8 for the day period, which was chosen because the cows were regularly recorded at the feeding rack (Fig. 3). Because the time spent in the concentrates feeding station may influence the time at which the cows subsequently arrive at the feeding rack, information on visits to the feeding station is also given in Figure 8. The results are presented as the mean of all three feeding systems. Figure 8 clearly shows a different pattern for rewarded and unrewarded visits and only smaller differences between the three 4-h periods. The difference between rewarded and unrewarded visits is mainly caused because after the start of a rewarded visit the cows spent longer in the concentrates feeding station. This delays the visit to the feeding rack. Thus, for these three 4-h periods, after the start of the visit between 30 % - 40 % of the rewarded visits were followed by a visit to the feeding rack within 10 - 15 min, while 30 % - 40 % of the unrewarded visits were immediately followed by a visit to the feeding rack. The statistical analysis has shown that during the first half hour after the start of a visit there was no significant difference between rewarded and unrewarded visits in the total time spent at the feeding rack (Tables 1 and 2). Thus, only the pattern of visits to the feeding rack, but not the total time spent at the feeding rack, was affected by the reward.

This analysis thus shows, that the cows' feeding behaviour just after a visit to the feeding station hardly is affected by their chances of receiving concentrates.

Information used by the cows to determine the timing of their visits

We hypothesized that the cows might base their decision to visit the concentrates feeding station on: 1) information about the time of the day combined with a pre-learned relation on the availability of concentrates, and 2) information from the feeding station. These two sources will be discussed. It should be stressed that a cow visiting the feeding station and receiving concentrates is not always a reliable signal for the other animals that they will also receive concentrates at a visit. Only those cows which, after the start of the first two 4-h periods of the 12-h cycle of a fixed-time system or after the start of the 24-h cycle of the variable-time system, had not yet received concentrates would be rewarded at their next visit. If they had already made one visit, it would then depend on the amount of concentrates eaten and on the elapsed time (at least 14 min for the variable-time system, to a maximum of 4 h for the fixed-time system) whether they would receive again concentrates at their next visit. So, only the sound of concentrates falling into the trough and/or the occupation of a feeding station are not reliable signals; the cow needs to consider also the time of the day, time elapsed since last visit and amount of concentrates eaten at last visit.

time of the day

In Figure 2 it was shown that for all three systems the cows visited the feeding station throughout the 24-h period. This suggests that the time of the day did not play a major role in the cows' decisions to visit the concentrates feeding station.

next visit within one minute

To test the possible influence of a cow visiting the feeding station (rewarded or unrewarded) on visits by other cows, we analysed how often a visit occurred within one minute following the visit of the last cow (which was mostly a different cow). This interval of one minute was chosen based on the information from a preliminary analysis that in those periods in which the intake of concentrates was high, the mean elapsed time between visits was less than one minute. Secondly, based on the information presented in Wierenga and Hopster (1991), it can be calculated that the mean interval between the end of one visit and the start of the following visit lasted 3.4, 2.5 and 1.4 min for the fixed-7-, the fixed-3- and the variable-time systems respectively (this variation in interval-length is caused by variation between systems in number of visits per 24 h). Thus the interval was chosen to be shorter than the mean interval recorded for the variable-time system.

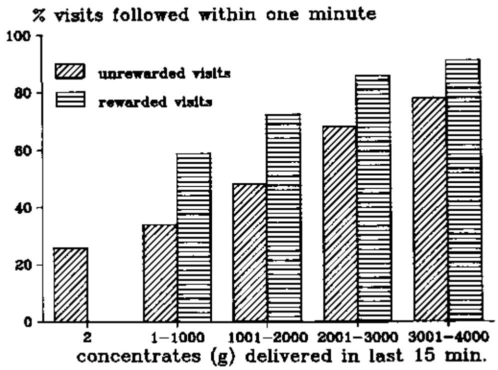
The regression analysis showed statistically significant influences ($P \leq 0.05$) of the reward, the level of concentrates delivered in the last 15 min up to the end of the preceding visit, the concentrates feeding system and of the time of the day (4-h periods). No significant interactions were found ($P > 0.05$) between these four factors.

Table 4. Mean percentages of visits which were succeeded within one minute by the next visit. Means of all visits and of rewarded and unrewarded visits per 24 h for each system separately, and the means of all three systems are given. (n = number of observed visits; [a], [b], [c]: significant differences ($P \leq 0.05$) within a column; [1], [2]: significant differences ($P \leq 0.05$) within a row).

	all visits		rewarded visits		unrewarded visits	
	%	(n)	%	(n)	%	(n)
fixed-7	64.8[a]	(2950)	80.9[a,1]	(1701)	42.9[a,2]	(1249)
fixed-3	60.3[b]	(3696)	77.6[b,1]	(2076)	38.1[b,2]	(1620)
variable	74.4[c]	(4635)	79.4[a,1]	(4038)	40.7[a,2]	(597)
all systems	67.3	(11281)	79.2[1]	(7815)	40.3[2]	(3466)

Table 4 shows the mean percentage of visits (corrected for variation in number of visits = weighted means) which followed a preceding visit within one minute. On average over all systems, 67.3 % of the visits took place within one minute of the preceding visit. A subsequent visit took place significantly more often within one minute when the preceding visit was rewarded (79.2 %) compared to unrewarded (40.3 %). Only small differences between systems in the frequency of a subsequent visit within one minute were found.

In Figure 9 the relation between the amount of concentrates delivered in the last 15 min up to the end of a visit and the percentage of subsequent visits following within one minute is presented both for rewarded and unrewarded visits. The results are presented as a mean for all feeding systems because no significant differences were found between the systems.



<u>Figure 9</u>. Relation between percentage of visits which were followed by the next visit within one minute and both the reward of those visits and the amount of concentrates fed during the 15 min up to the end of those visits. Mean for the three systems tested (logit-analysis).

Significant differences ($P \leq 0.05$) were found in the percentage of visits (both for rewarded and for unrewarded) followed within one minute by a subsequent visit between the five different levels of amount of concentrates delivered in the last 15 min. When an unrewarded visit to the concentrates feeding station took place at a moment when for a period of at least 15 min no concentrates had been delivered, a subsequent visit was recorded within one minute in only 25.8 % of the visits. If an unrewarded visit took place when between 1 and 1000 g concentrates had been delivered during the last 15 min, still a subsequent visit took place within one minute in only 33.8 % of the visits. However, under the same conditions (between 1 and 1000 g of concentrates delivered during the last 15 min) in 58.7 % of all rewarded visits a subsequent visit had followed within one minute. As more concentrates were delivered during the 15 min up to the end of a visit, a subsequently visit took place within one minute increasingly more often. If between 3 and 4 kg of concentrates had been delivered, 90.5 % of the rewarded visits were followed by a subsequent visit within one minute. The results thus show that the actual feeding of concentrates affected the likelihood that the next visit would take place within a short time.

Two factors may affect the interval between visits and the interpretation of these results. Besides the possible reaction to the delivery of concentrates, the interval between the end of one visit and the start of the next visit may also be affected simply by the time the cow spent in the feeding station. When a cow receives concentrates she will stay longer in the feeding station than when she does not receive concentrates (Wierenga and Hopster, 1991). The more concentrates the cow receives, the longer she will stay in the feeding station, and the greater is the chance that the next cow will already have arrived in the neighbourhood of the feeding station and will enter it soon after the first cow has left. The role of this occupation time may be expected to be important, in particular because the cows paid so many visits to the feeding station. As already mentioned the mean interval between two visits was 3.4, 2.5 and 1.4 min for the three systems respectively. The influence of occupation time is least when only small amounts of concentrates were given: this is in the category 1 - 1000 g of concentrates. Because in this category a significant difference was found between rewarded and unrewarded visits, it seems that the animals do sometimes respond to information from the feeding station.

Interval between visits at start of a cycle

In fact mainly the occupation of the feeding station by another cow and/or concentrates falling into the trough, at the beginning of the first two 4-h periods of each 12-h cycle of the fixed-time systems and at the beginning of the 24-h cycle of the variable time system, are reliable signals to the cows that they will receive concentrates again. Therefore an analysis into variation in length of intervals between visits can best be restricted to these periods. Because of the great difference in the distribution of concentrates between fixed-time systems and variable-time systems, this analysis has been restricted to the two fixed-time systems. Furthermore, during the first 4-h period of the fixed-time systems, the concentrates feeding station was generally occupied continuously by cows receiving concentrates, so that the transition from the first to the second 4-h period may often have gone unnoticed by the cows. Thus, we can best analyse whether cows reacted differently to rewarded and unrewarded visits particularly at the start of a new cycle (Fig. 1). We hypothesized that after an unrewarded visit (which in the analysed situation occurred just before the start of a new cycle), it would be longer before the next visit occurred than after a rewarded visit (which occurred shortly after the start of a cycle). These intervals were calculated both excluding and including the duration of the visit, because the duration of the visit may also be of influence. Furthermore, those unrewarded visits which took place after a period of at least 15 min when no concentrates were delivered, were analysed separately.

The analysis of variance showed that the interactions and the main effects for the factors feeding system and time of the day were not significant ($P > 0.05$). Therefore, in Table 5 the intervals between the last

Table 5. Mean length (min) and standard deviation of interval to the next visit after the last unrewarded visit before, and the first rewarded visit after the start of a 12-h cycle. Results are presented both excluding and including the duration of the visit itself. Significant differences ($P \leq 0.05$) between rewarded and unrewarded visits are marked by [a], [b] (mean length) or [1], [2] (standard deviations).

	after last unrewarded visit		after first rewarded visit	
	mean	st.dev.	mean	st.dev.
interval (min), excluding duration of visit itself				
all visits (n = 79)	11.7[a]	11.1[1]	1.5[b]	4.0[2]
visits; no concentrates delivered 15 min before unrewarded visit (n = 54)	12.2[a]	11.6[1]	1.9[b]	4.7[2]
interval (min), including duration of visit itself				
all visits (n = 79)	13.5[a]	10.9[1]	12.1[a]	5.2[2]
visits; no concentrates delivered 15 min before unrewarded visit (n = 54)	14.1[a]	11.3[1]	12.5[a]	5.3[2]

unrewarded and the first rewarded visit are presented as the mean of the two systems and the 4-h periods analysed. Means were compared with a modified t-test (for unequal variances; Welch, 1938). When the duration of the visit was excluded, the interval after the unrewarded visit appeared to be significantly longer than after the rewarded visits. However, when the duration of the visit was included, no significant difference was found for the interval after an unrewarded or a rewarded visit. Comparable results were obtained when those unrewarded visits were excluded which were preceded by one or more rewarded visits during the last 15 min.

The standard deviations were very large, which shows that there were large variations in the mean intervals. Thus, both the response to an unrewarded visit and to a rewarded visit was variable. The standard deviations were compared by referring the ratio of squared standard deviations to the F distribution. The standard deviations of the mean interval after the start of a rewarded visit were significantly smaller ($P \leq 0.05$) than the standard deviation of the mean interval after the start of an unrewarded visit. This shows that the response to a rewarded visit was more consistent than that to an unrewarded visit.

The aim of this analysis was to test whether cows respond differently to unrewarded and rewarded visits. Although no difference was found in the interval after the start of an unrewarded or a rewarded visit, a second explanation is also possible: the cows simply visited the feeding station regularly which resulted in one visit every 10 - 15 min in the analysed periods, irrespective of the information from the feeding station. The shorter interval after the rewarded visit and also the smaller variation in interval length leaves the possibility that the cows responded to the rewarded visit, but with our available information this cannot be proven. A different experimental design is needed to be able to determine this.

DISCUSSION

Timing of visits and consequences for general activities

In all the systems, visits to the feeding station occurred throughout the 24-h period, but the timing of rewarded and unrewarded visits varied between the three feeding systems tested. For instance, for the fixed-7-time system the rewarded visits occurred mainly between 07.00 - 15.00 h and 19.00 - 03.00 h, which means that they partly coincided with eating roughage, while for the fixed-3-time system, particularly in the night period, rewarded visits took place in the cows' "resting-period". We hypothesized that such differences between the systems might affect general activities both before and after a visit to the feeding station.

The results have shown that only minor differences were found between feeding systems and between rewarded and unrewarded visits concerning behaviour both before and after a visit. The observed differences in time spent in the waiting area just before a visit and time spent in the feeding station following the start of a visit, hardly affected activities such as times spent at the feeding rack and in the cubicles. It was shown that, independent of the feeding system and also independent of the reward, the cows generally left the cubicle some time before the visit and ate at the feeding rack or just stood in the walking or waiting area. After a visit the cows generally spent - in addition to time in the feeding station itself - a short time at the feeding rack or in the walking area and gradually returned to a cubicle. No differences between rewarded and unrewarded visits were found. The time of the day had a significant influence on the the cows' behaviour before and after a visit to the feeding station.

Only in one 4-h period did the cows spend significantly more time in the cubicles before a rewarded visit than before an unrewarded visit. Thus, the first hypothesis - that the cows' behaviour shortly before a visit would be affected by the chance to become rewarded - has to be rejected. The hypothesis has two elements: 1) the cows would learn when to expect concentrates;

2) they would act in anticipation with such knowledge. Both elements will be discussed later.

The second hypothesis - that the cows would spend more time at the feeding rack after an unrewarded visit compared to after a rewarded visit - also has to be rejected. This hypothesis was based on the assumption that cows visited the feeding station because they were hungry. Of course, hunger could affect the visits to the feeding station as well as the visits to the feeding rack. Thus the cows may have combined visits to the feeding station and the feeding rack, but varied the order in which these feeding places were visited. To find out to what extent eating roughage and concentrates were combined, data on the total time spent eating roughage from this and an earlier publication (Wierenga and Hopster, 1991) were combined. Based on the information on the time spent at the feeding rack during the half hour before and the half hour after a visit (14.7 min; Table 1) and the number of visits per 24 h (Wierenga and Hopster, 1991), it was calculated how much time per 24 h was spent at the feeding rack just before and after a visit to the feeding station (Table 6). Because the time spent at

Table 6. Comparison of time spent at feeding rack during the period half an hour before and half an hour after the visits to the feeding station (= mean time spent at feeding rack around a visit, times total number of visits) and total time spent at feeding rack per 24 h (derived from Wierenga and Hopster, 1991).

	time per 24 h at feeding rack during half hour before and after a visit to concentrates feeding station	total time at feeding rack per 24 h
fixed-7-	110 min	196.0 min
fixed-3-	140 min	198.5 min
variable	190 min	201.6 min

the feeding rack around a visit to the feeding station is only a rough estimate - for instance, when visits succeeded each other within half an hour, the total time at the feeding rack will be overestimated - these data should only be considered as a rough indication. It appeared that with the fixed-7- and the fixed-3-time systems, one half and two-thirds respectively of the total time per 24 h spent at the feeding rack took place just before and after a visit to the feeding station. With the variable-time system almost all the time spent at the feeding rack took place in the hour around a visit to the feeding station. Thus, it can be concluded that the cows often interchange visits to the concentrates feeding station and to the feeding rack.

Metz (1975) showed that the feeding rhythm of dairy cows consists of a regular alternation of "meals" and "other activities". These behaviour patterns were thus not random but "organized". The results of the present experiment suggest that the cows "organize" their visits to the feeding station in a comparable way: they fit their visits to the feeding station into their other activities. Because automatic feeding of concentrates results in a slightly higher number of cubicle bouts (Wierenga and Hopster, 1991; Kempkens, 1989) the cows will sometimes even stand up with the particular aim of visiting the feeding station. The majority of the visits, however, seemed to occur while the cows were already active, particularly at the feeding rack.

Information used to decide when to visit the feeding station

The next question was what information the cows used for their decision when to pay a visit to the feeding station. With all three systems the number of visits occurred throughout the 24-h period, which shows that the time of the day was not a factor in this respect. Because the cows responded so quickly (see also Wierenga and Hopster, 1988) to a transition from one feeding system to another (in particular the change from a fixed-time system to the variable-time system) with their number of visits to the feeding station, it is likely that they did not just visit the feeding station at random but responded to changes in their chances of being rewarded. Thus, the cows will have registered their increased chances of receiving concentrates with the variable-time system (the difference between the feeding systems in number of visits were statistically significant; Wierenga and Hopster, 1991). During the first experimental period with the variable-time system, the cows even showed a further gradual increase in the number of visits, due to their high chances of being rewarded. The question remains whether the cows - in addition to such information - also use other sources of information to decide when to visit the station. Because both a cow's direct response to a visit by another cow and a difference in occupation time between unrewarded and rewarded visits could affect the timing of the next visit, the analyses which have been carried out could not really prove that cows did indeed show a direct response to information from the feeding station. Nevertheless, the results of both analyses suggested that the cows may sometimes respond to information from the feeding station.

The cows' strategy for visiting the concentrates feeding station

It can be concluded that the cows responded quickly - in total number of visits per 24 h - to changes in their chances of receiving concentrates (variable- vs. fixed-time system), but that they did not show a variation in the number of visits directly related to differences in their chances of being rewarded within a 24-h period. Furthermore, it could not be proven that the cows responded (consistently) to the occupation of the feeding station and/or to the sound of concentrates falling into the trough. Thus, one might ask whether cows: 1) are able to respond to information from the feeding station, and 2) are able to learn when they may expect concentrates, and if so, 3) how they will respond to such sources of information. Of course, dairy cows are able to learn a relation between a signal (acoustic) and the availability of food (Hammell and Hurnik, 1987; Wierenga and Hopster, 1987). One can imagine that the cows did not respond to the station being occupied and/or the sound of concentrates falling into a trough, because this information alone seldom reliably predicted the cows' chances of receiving concentrates. Aschoff (1986) showed that bees and rats as well as monkeys responded within a few days to changes in the time of availability of food by changing their daily rhythm. Thus, one might expect that dairy cows - within a few days - would also be able to learn changes in the availability of concentrates and with this information vary the timing of their visits depending on their chances of being rewarded. Thus, the answer to the third question may be that the cows neglected variations in their chances of being rewarded and simply decided to visit the feeding station regularly. Such a strategy seems understandable. In general, animals tend to explore their environment to stay informed about any possible changes (Krebs, 1978). Cowan (1977) showed that rats kept in a cross-maze in which only two arms contained food or water, visited all four arms an equal number of times. The time spent in the four arms, however, differed greatly; the visits to the empty arms were always short. This is similar to the described experiments with dairy cows: unrewarded visits were generally short (Wierenga and Hopster, 1991). The amount of time or energy spent on exploring the environment will depend on the effort required and the benefits to the animal (Birke and Archer, 1983). For the dairy cows in the described experiment one may expect the effort to be fairly low. The results of the experiment suggest that most of the visits occurred at moments when the cows were already active. Because the cubicle house in which the cows were kept was small, the cows did not need to put a lot of energy into reaching the feeding station, while the benefits were relatively high. Even in the third 4-h period of the fixed-time system the cows sometimes received concentrates (left-overs from previous periods). It is reasonable that under such conditions - low effort, high benefits - the cows decided to visit the feeding station regularly and "ignored" information about the time of the day. With increasing effort the number of visits may decrease. This was found, for instance, by Hopster and Wierenga (1989) in an experiment where the distance which the cows had to walk to the feeding station was increased.

CONCLUSIONS

The cows regularly visited the concentrates feeding station and responded quickly to changes in their chances of receiving concentrates. Generally, they simply fitted their visits to the station into their daily routine: what they did before and after the visit was mainly dependent on their normal daily rhythm and not on variations in their chances of being rewarded.

The cows did not respond to variations in their chances of obtaining concentrates over the 24-h period, nor did they respond consistently to information from the station, e.g. occupation of the feeding station or the noise of concentrates falling into the trough. The cows probably chose a strategy of visiting the feeding station regularly, because the costs for a visit were low and the reward (concentrates) was high enough.

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8. GENERAL DISCUSSION: ADAPTATION OF CUBICLE-HOUSED DAIRY COWS TO THEIR HOUSING AND MANAGEMENT, AND THE CONSEQUENCES FOR THEIR WELFARE

H.K. Wierenga

GENERAL DISCUSSION: ADAPTATION OF CUBICLE-HOUSED DAIRY COWS TO THEIR HOUSING AND MANAGEMENT, AND THE CONSEQUENCES FOR THEIR WELFARE

INTRODUCTION

The way in which farm animals are kept is regularly discussed from an animal welfare point of view. Studies of the animals' behaviour can reveal the consequences of their housing and management and provide an essential basis for discussions about the acceptability of these systems. In discussing the animals' welfare, insight into their potential to adapt to different housing and management systems plays a central role (McBride and Craig, 1985; Wiepkema, 1987; Broom, 1988a; Tennessen, 1989; Nichelmann and Bilsing, 1989; Barnett and Hemsworth, 1990). Adapting to changes in their environment is a normal reaction of animals. When animals have difficulty in adapting to certain circumstances, under natural conditions they will try to avoid or to escape from such situations. Farm animals kept indoors have limited opportunities of avoiding or escaping from adverse conditions. Thus, their adaptation will sometimes be more complex and difficult. Dawkins (1988) assumed that animals suffer when they are motivated to avoid or escape a situation but are unable to. In connection with the opportunities for adapting to changes in the environment, the ability to exert some degree of control over the environment (controllability) and the possibility of foreseeing or predicting relevant events (predictability) are also seen as important for the animals (Wiepkema, 1987). With low controllability and/or low predictability, the animals will have more difficulty in adapting.

When the animals are able to adapt successfully to a new environment, only an acute but temporary decrease in comfort or welfare will be observed (Gonyou, 1986). The more problems the animals encounter in adapting to their environment, the more serious will be their stress-state and the more the welfare of the animals will be impaired (Wiepkema, 1987). How can we measure success of adaptation or problems with adaptation? Traditionally, discussions on farm animal welfare and thus on the adaptation of animals to their housing and management are based on information about their behaviour. However, data about physiology, health and production can also give useful information about adaptation and welfare (Broom, 1988a). This discussion about dairy cows' welfare will be restricted to information from behavioural data. First of all the behaviour of the animals should be observed and one can discuss in general terms whether there are any signs of the animals having problems with the conditions in which they are kept. Examples will be presented later. Secondly, disturbed behaviours can be studied. When the animals have great difficulty in adapting to their environment or are not successful, disturbed behaviours like stereotypies may result (Wiepkema, 1987; Broom, 1988a; detailed examples give by, e.g., Cronin, 1985; Blokhuis, 1988; Kooijman et al., 1990). A third method of obtaining information about possible problems with the cows' adaptation to their housing or management is to measure their willingness to "work" towards adapting to their environment (Dawkins, 1988). The "price" which the animals are willing to pay can be measured experimentally (Dawkins, 1988). The animals will be willing to pay a high price to obtain important "commodities" (inelastic demand) while for less important commodities (elastic demand) the animal will work less (Matthews and Ladewig, 1990).

In discussions on measuring and interpreting animal welfare, the price for adaptation and the success of this adaptation are two separate elements. To facilitate the discussions, for example three types of environments can be distinguished, with corresponding classes of amount of work which the animals have to perform to adapt (price of adaptation), and three classes of how successful this adaptation is (Table 1). There are no clear borders between these three types of environments and three classes of adaptation. Firstly, the animals can be kept in an environment which they easily and successfully adapt to. At least the important (inelastic) demands of the animals are fulfilled. In such a "friendly" environment, the welfare of the animals will not be impaired. Secondly, the animals can be kept in an environment which they find (partly) difficult to adapt to. They

Table 1. Price and success of adaptation, and resulting level of welfare of the animals in three types of environment.

	type of environment		
	1	2	3
	"friendly"	"demanding"	"unfriendly"
price of adaptation	low	high	high
adaptation successful	yes	yes, partly	no
welfare impaired?	no	yes or no	yes

have to "work hard" and may not fully succeed in fulfilling important (inelastic) demands. With current knowledge there is some difficulty in translating this into terms of animal welfare. The welfare may be impaired to some degree in this "demanding" environment. It could be argued that any level of impairment of welfare is unacceptable, or that some level of impairment has to be accepted. Research now has to focus on this area of adaptation, to develop methods to study adaptation problems and to determine levels of acceptability. In the third type of environment ("unfriendly"), the animals are kept under circumstances which may cause serious problems or where adaptation may not be successful. The animals show disturbed behaviours and/or other aberrations (e.g. injuries and diseases), which indicate that their welfare is impaired to an unacceptable level (Wiepkema et al., 1983; Broom, 1988a). For all types of environment the final decision about the acceptability of a system will be based not only on information about the animals' behaviour or health in that environment but also on other values (e.g. reason - aim - why the animals are kept in that environment, possible alternative production methods, etc.). The final decision about acceptability of a system thus remains an ethical one.

The aim of this general discussion is to describe briefly, for the examples presented in previous chapters, how the cows adapted to the types of housing and management investigated and what price they paid in adapting to them. The consequences of housing and management systems on the cows' behaviour will be discussed in terms of their welfare in considering information on social dominance, the significance of cubicles and automatic concentrates feeding systems. Finally, some other current and future aspects of housing and management, which seem to be relevant to the welfare of dairy cows, will be mentioned briefly.

SOME EXAMPLES OF ADAPTATION AND THE CONSEQUENCES FOR THE DAIRY COWS' WELFARE

Social dominance

An important aspect of the existence of dominance relationships seems to be that each cow at any time can reliably predict whether she will win or lose a confrontation with a group-mate. The experiments have shown that clear dominance relationships do exist, but that sometimes a subordinate cow did not yield to a dominant animal, or did displace a dominant animal. It was hypothesized that housing, in general, and overcrowding, in particular, caused such contradictory interactions. The result of such contradictory interactions is that to some extent the predictability of outcome of a confrontation is reduced. The dominant animals have more difficulty in predicting whether they will be able to stay in a feeding or a lying place, and the subordinate animals are less sure whether it is worthwhile to try and displace another animal. However, particularly low-ranking animals may increase their chances of obtaining an eating or a lying place, for instance, because they can try to displace more animals and their chances of success may increase. It was shown that contradictory interactions occurred most in overcrowded conditions, less often in normal conditions, and least in natural conditions. Furthermore, it was shown that these interactions were performed most by low-ranking animals; i.e., the animals which have most problems with obtaining and retaining resources. It was, therefore, suggested that these contradictory interactions are an adaptation to crowded conditions, although no data are available on whether the animals become more successful in obtaining or retaining an eating or a lying place. The possible increase in chances of obtaining and retaining resources (increased controllability), particularly for the low-ranking animals, may be more important than the loss in predictability. The reduction in predictability is probably so small that it does not reduce the animals' welfare. For the high-ranking animals, contradictory interactions result both in loss of predictability and loss of controllability, but there is no information to show that this causes problems for these animals. For instance, even under very high levels of overcrowding, their lying behaviour was hardly affected, which suggests that the loss of controllability was not substantial. Thus, for social dominance, it may be suggested that the low-ranking cows have successfully adapted to their environment and therefore, the occurrence of contradictory interactions does not indicate serious impairment of the cows' welfare.

Lying behaviour

In the two chapters on lying behaviour and the significance of cubicles, it was concluded that for dairy cows, lying is an important behaviour, which suggests that it represents an inelastic demand. Many aspects of housing and (lying) behaviour have been discussed in these chapters, but because the described experiments focused on the consequences of variation in the number of available cubicles on the lying behaviour, the present discussion will be limited to this aspect. Both lying time and lying postures will be discussed. In the chapter on the significance of cubicles it was concluded that the minimum time per 24 h that cows need to lie down in cubicles is not yet known. This point will be discussed further based on the decision scheme in Table 1.

The results of the experiments with a reduced number of cubicles showed that the cows had to "work" (e.g., lying down more quickly, lying down at other times of the day, displacing other cows more often) to adapt to overcrowded conditions. With a level of 50 % overcrowding the cows seemed to be successful in adapting to these overcrowded conditions: no reduction in lying time was recorded. However, higher levels of overcrowding seemed to cause problems for some animals. In particular, when 55 % overcrowding was applied, the low-ranking animals were not able to adapt to such an extent that they were able to achieve lying times which they would normally have obtained. With overcrowded conditions, leaning was observed more often (Wierenga, 1983; Wierenga et al., 1982). Assuming that leaning is an abnormal behaviour or a stereotypie, this could suggest that the cows had problems in adapting to higher levels of overcrowding. Based on the results of the various experiments, it was concluded that for dairy cows, lying is an important behaviour. As soon as possibilities for lying down are restricted, the cows responded ("worked"), to prevent a reduction in lying time, suggesting that lying down is an inelastic demand. It is not known exactly what price the cows have to pay, so that the inelasticity of the demand could be questionable. However, lying down more quickly could mean that the cows take less time to prepare themselves for lying down, so that they do not lie down carefully enough. This could result (= the price) in them hurting themselves or in uncomfortable lying postures. Secondly, occupying a cubicle as soon as it becomes vacant, means that the cow is less selective concerning the cubicle itself and her possible neighbours. This may mean that she lies down in an unattractive cubicle and/or next to "unattractive cows". Thirdly, the price of more displacements could include both the extra energy needed to displace a cow, and the risk involved, e.g., of being displaced herself.

In the "old cubicle house" a mean lying time of about 11 h per 24 h was recorded. In the "new cubicle house" mean lying times of about 12.5 - 13.5 h per 24 h were recorded in the three experiments. The difference in lying time between these two cubicle houses can be explained partly by the difference in use of the cubicles as a safe area to prevent confrontations with group-mates. In the "new cubicle house" the cubicles were the only available hiding place, but in the "old cubicle house" the feeding rack - with its separations - was also used as a safe area by the cows. Knowing that lying time is very variable and assuming that part of the recorded lying time was for hiding, it might be suggested that the cows need a lying time of about 10 - 12 h per 24 h for resting. It should be realized that this value of 10 - 12 h lying time is a very rough estimate. Also it is a mean value for a group of cows; the individual variation between cows is so large that it is difficult to use this value for an individual cow. The suggested value agrees to some extent with the conclusion of Friend (1989) that cows probably need > 10.4 h lying time per 24 h.

In the experiment with extra available space, it was shown that the cows dispersed over the available cubicles and more often adopted lying postures which needed extra space. In normal conditions and, even more so, in overcrowded conditions the cows have fewer opportunities of adopting such "space-consuming" postures. However, there is no information which shows that the cows had problems with the reduced opportunities for adopting such postures. If such lying postures were important to the cows, in normal and overcrowding conditions the cows could have responded with less synchronised lying down, for instance. This would have increased a cow's chances of lying down with no neighbours, and enabled her to adopt such "space-consuming postures". Such a desynchronization was only recorded to a small extent when undercrowding and normal conditions were compared. Adopting such a lying posture is - in the conditions investigated - probably an elastic demand.

The results suggested that, for the conditions investigated, lying time was more "critical" for the animals than lying posture: lying time was a less elastic demand than lying posture. With regard to variation in the number of available cubicles, it seems that with more than 50 % overcrowding, the welfare of the cows is impaired at an unacceptable level ("unfriendly" environment; Table 1). Wierenga et al. (1982) have shown that even with low levels of overcrowding the cows' behaviour is affected. Thus, with between 0 % and 50 % overcrowding the cows have to "work", but may well succeed in adapting ("demanding" environment). However, the welfare of the cows is impaired to some extent and it might even be advisable not to apply any degree of overcrowding. No indications are available that with normal and undercrowded conditions, the cows had problems in adapting ("friendly" environment); their welfare was not impaired.

Eating concentrates

Feeding concentrates with an automatic feeding system resulted in a pattern of intake of concentrates (distribution of rewarded and unrewarded visits over the 24-h period, and also timing and duration of visits) which appeared to depend on the feeding system used. When concentrates were fed mixed with maize-silage at the feeding rack, the cows immediately spent more time at the feeding rack; when the chances of obtaining concentrates were increased (e.g. with the variable-time system), the cows visited the feeding station more often. To a large extent the cows fitted their visits to the feeding station into their normal daily routine.

The results of the experiments with the different automatic feeding systems suggest that the cows do not experience problems in adapting to such systems. This conclusion needs to be discussed in more detail. It is based mainly on the observation that after a change from one feeding system to another the cows always adopted the typical pattern of intake of concentrates of the new system within a few days. For the cows the price of such a change seems to be low, partly because in many situations it simply meant that they received concentrates at times when they would otherwise have made an unrewarded visit. But with a variable-time system, for instance, the total number of visits also increased, which means that the price of adapting to the system also included making more visits to the feeding station. The available information (general activities) did not reveal that this increased number of visits affected other behaviours.

One other aspect, which relates to adaptation and welfare, also needs to be discussed. The analysis of factors affecting the timing of visits did not prove that the cows were able to reliably predict when they would receive concentrates. For for the cows this unpredictability could be interpreted as reduced welfare, but it seems unlikely that this is the case. It was shown that the visits to the feeding station occurred mainly when the cows were active anyway, which means that the cows did not have to put a lot of extra energy into visiting the feeding station: the price of visits with an unpredictable outcome was low.

Compared to feeding at the feeding rack or in the milking parlour - when the farmer decides at what time concentrates will be fed - the cows have more freedom to decide when they will eat concentrates with automatic feeding systems. Although there is no indication that it is important to the cows, this "freedom" to decide means more control and thus - to a small extent - may result in better welfare for the cows.

Wierenga and Van der Burg (1989), who discussed different investigations with automatic feeding systems (comparison - under practical and experimental conditions - of several different concentrates feeding systems, various positions of the feeding station, various distances to walk to the feeding station, acoustic signals announcing concentrates), concluded that there was no evidence that automatic concentrates feeding systems have negative consequences for the dairy cows' welfare. They suggested that particularly the consequences for the cows' daily rhythm needed to be considered in more detail. Thus, in general, it can be concluded that the cows seem to adapt easily to the systems for automatic feeding of concentrates and only have to pay a limited price (many visits, sometimes less lying down) to obtain the concentrates ("friendly" environment). This conclusion is based mainly on analyses with means of groups of cows. However, there were no indications that individual cows differed very much from these group-means. Finally, it can be concluded there were no indications that the systems for automatic feeding of concentrates caused welfare problems for the dairy cows.

CONCLUSIONS

This discussion about the price and success of adaptation of dairy cows to their housing and management has shown that in many cases the reaction of an animal to its environment has to be described in detail and discussed from various points of view before a - sometimes subjective - conclusion about the impairment of the animal's welfare can be drawn. Problems with the two extremes - the "friendly" environment: adaptation successful; the "unfriendly" environment: serious problems with adaptation - can be solved relatively easily. Discussions about the consequences of a "demanding" environment on the welfare of the animals will not always result in a clear-cut answer. There will be variation in the degree of adaptation problems which will be considered to be acceptable. Further research is needed in this area. Methods have to be developed to better describe possible problems which the animals encounter while adapting to their environment. This can be done partly by describing in detail how animals change their behaviour when they are placed in the new environment. In addition experiments to test what price the animals are willing to pay could be carried out. But detailed information about the physiological responses of the animals is also essential.

Nonetheless, discussing the price to be paid in adapting to an environment and the success of adaptation separately, has proved to be a useful method for discussing the consequences of housing and management for the welfare of dairy cows. In this discussion, as much as possible the welfare of the individual animal is discussed instead of the "mean welfare" of a group of cows. Those animals which are the first to have serious problems with adaptation - the "weakest animals" - should have a major influence on discussions about the acceptability of a certain environment. With regard to the aspects investigated, it can be concluded that no welfare problems need exist, if no or only a limited level of overcrowding is applied. From a welfare point of view, the results can even be interpreted positively: they suggest that dairy cows can easily change their behaviour when their housing or management is changed. This means that, in many respects, current housing and management does not force the cows close to their limits of adaptation.

WELFARE OF DAIRY COWS UNDER CURRENT AND FUTURE HOUSING AND MANAGEMENT

In these experiments only some aspects of the behaviour of adult dairy cows and of their interactions with housing and management have been investigated. Dairy animal welfare in general has been discussed more extensively by Albright (1987), Broom (1988b) and Metz et al. (1986). These reviews give a good insight into current knowledge on the interaction between cows and their housing and management, and about interpretations in terms of welfare, in addition to the aspects mentioned in this chapter. Metz et al. (1986) and Broom (1988b) mention other important aspects of current housing and management of dairy cows which need further attention from the point of view of animal welfare: 1) the rearing system (ontogeny of behaviour and adaptation to future housing and management); 2) the man-animal relationship (stockmanship); 3) other recent/future developments in automation; 4) lameness (the relation between behaviour, the floor, and claw and leg disorders). In addition to this, there are new developments in dairy cattle production which might affect (in a positive or negative way) the welfare of dairy cows. Three developments, in particular, need to be mentioned: 1) systems for automatic milking (in particular, questions like location of the milking station, daily rhythm of the cows, consequences of more frequent milking); 2) developments in biotechnology (i.e. bST, genetic manipulations); 3) development of new housing systems with reduced ammonium emission (in particular, new types of floor, micro-climate). In connection with the first two examples, how increased production levels affect the welfare of dairy cows needs to be investigated.

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9. SUMMARY

SUMMARY

Behavioural studies of farm animals can provide insight into the adaptation of the animals to their housing and management. Such information is needed for both producers (production results) and consumers (animal welfare). Examples of dairy cows' behaviour under some modern housing and management conditions are presented. Primarily the results of the experiments are discussed in terms of the interaction between housing and management and the cows' behaviour. In a general discussion, the costs and success of adaptation of the cows to their environment are presented and discussed with respect to their welfare.

Social dominance in dairy cattle was studied because the concept of social dominance is still discussed regularly. Information on social dominance in dairy cows and on the influence of housing and management was collected in four experiments with seven different groups of cows in total. The investigations showed that stable dominance relationships between animals do exist, but that a subordinate animal could displace a dominant animal or might not yield to a dominant animal. Both housing and management greatly influence the occurrence of these so-called contradictory displacements. Social dominance plays only a limited role in the distribution of important resources between the members of a group. This might be partly due to various disturbing factors resulting from both housing and management at the farm, but in general the role of social dominance is limited under normal conditions (this is also true for other species). However, social dominance is important because the existence of stable dominance relationships means that often the animals can reliably predict the result of an interaction in which they are or could become involved.

Social dominance is best described by the dominance value of each animal based on aggressive displacements. It was concluded that if all the dominance relationships need to be known, 2000 - 3500 displacements need to be collected for groups of 15 - 20 cows. When less detailed information is required, about 90 % of the dominance relationships still need to be known to obtain sufficiently reliable information. This means that about 800 displacements need to be collected for groups of 15 - 20 cows.

For dairy cows a large variation is found in the daily time spent lying down. Both individual cow variations and differences between housing and management are known to affect the time spent lying down. The consequences of some details of the housing system and of over- and undercrowding on the time spent standing and lying in the cubicles were studied in five experiments with nine different groups of cows in total. The primary aim of these studies was to determine the significance of cubicles for resting and for hiding. On average, the cows spent about 13 h lying down and 2.5 h standing in the cubicles per 24 h. When the cubicles were smaller, and also when the cows could hide from confrontations with group-mates in other places, less

time was spent in the cubicles. Overcrowding resulted in a reduction of time spent in the cubicles, whereas with undercrowding, the time spent in the cubicles was only slightly more. In particular, with high levels of overcrowding (50 %, 55 %) low-ranking animals did not succeed in achieving their normal lying times. When extra cubicles were available (undercrowding), the cows' lying and eating times were slightly more synchronized and the animals lay down more widely dispersed throughout the cubicle house. This gave the animals the opportunity to lie down more comfortably. It is concluded that particularly lying down, and thus the use of a cubicle, is important to the cows. Based on the results of the experiment with undercrowding, it was concluded that extra space is not a prime necessity for the cows.

The behaviour of dairy cows when fed concentrates with an automatic concentrates feeding system was investigated to obtain insight into the cows' adaptation to such systems. Both the visits to the feeding station and the general activities of the cows were investigated. The factors which affected behaviour just before and immediately following a visit and the information a cow used to decide when to visit the feeding station at a certain time, were analysed in detail. Three experiments with three different groups of 20 dairy cows were carried out, in which four different systems for automatic concentrates feeding (fixed-7-, fixed-11-, fixed-3- and variable-time systems) were compared with feeding concentrates at the feeding rack. Each of the feeding systems tested evoked a typical pattern of intake of concentrates (timing, number of visits). Generally, the cows adapted quickly to each new feeding system, by eating the concentrates as soon as they were available. Time spent at the feeding rack and time spent lying in the cubicles was sometimes affected by the feeding system. Particularly with the fixed-11-time system, the low-ranking cows sometimes had to wait a long time before they could enter the feeding station, resulting in reduced lying time.

The behaviour of the cows just before a visit to the feeding station was affected by the time of the day, but hardly at all by their chances of receiving concentrates. It was suggested that the cows simply fitted their visits into their normal daily routine. A cow's decision to visit the feeding station was based only to a limited extent on information from the feeding station; a rewarded visit was followed more often and more consistently by another cow's visit than an unrewarded visit. The cows mainly chose a strategy of regularly visiting the feeding station throughout the day and night because little effort was needed to make such visits and the reward was high enough.

Finally, the results of the various investigations were also discussed in terms of costs and success of adaptation and welfare of the dairy cows. From a welfare point of view, stable dominance relationships are important, because they mean that the animals can reliably predict the outcome of a confrontation with a group-mate. However, the occurrence of contradictory displacements is not seen as a sign of serious impairment of welfare because for the low-ranking animals the advantage (increased chances of obtaining important resources) seems to be important, while the disadvantages for the high-ranking animals do not seem to be significant. With very high levels of overcrowding (50 %, 55 %), particularly the low-ranking cows did not succeed in adapting to the situation. It was suggested that for these animals their welfare was impaired to an unacceptable level. Between 0 % and 50 % overcrowding the cows have to "work hard" to adapt, to achieve their normal lying times. Whether such levels of overcrowding are acceptable from a welfare point of view, needs to be further discussed. Under normal and undercrowded conditions the cows did not show any problems in adapting and their welfare was not at risk. It was concluded that there was no evidence that the cows experienced problems in adapting to the concentrates feeding systems. The relatively high number of visits and the consequences for eating roughage and lying down which were sometimes observed, were seen as a limited price which the cows pay, and their welfare was not impaired.

Finally, in addition to the aspects discussed, other important aspects of current housing and management of dairy cows were mentioned: 1) the rearing system; 2) the man-animal relationship; 3) other recent/future developments in automation; 4) lameness. As new developments in dairy cattle production which might affect the dairy cows' welfare were mentioned:
1) automatic milking; 2) biotechnology; 3) new housing systems with reduced ammonium emission.

10. SAMENVATTING: HET GEDRAG VAN MELKKOEIEN ONDER DE HUIDIGE HUISVESTING EN VERZORGING

SAMENVATTING: HET GEDRAG VAN MELKKOEIEN ONDER DE HUIDIGE HUISVESTING EN VERZORGING

Gedragsonderzoek aan landbouwhuisdieren kan een inzicht geven in de aanpassing van de dieren aan hun huisvesting en verzorging. Zowel voor de producenten (produktieresultaten) als voor de consumenten (welzijn dieren) is dergelijke informatie van belang. In dit proefschrift komen voorbeelden van het gedrag van melkkoeien onder huidige huisvestings- en verzorgingsomstandigheden aan de orde. In eerste instantie wordt aan de hand van de resultaten van de experimenten telkens de interactie tussen de huisvesting en verzorging en het gedrag van de koeien besproken. In een algemene discussie worden de kosten en de mate van de aanpassing van de koeien aan hun omgeving behandeld, en aan de hand hiervan tevens het welzijn van de dieren.

Sociale dominantie bij melkkoeien werd onderzocht omdat dit concept nog steeds regelmatig ter discussie staat. Gegevens over de sociale dominantie bij melkkoeien en de invloed van de huisvesting en verzorging hierop werden verzameld gedurende vier experimenten met in totaal zeven verschillende groepen. Uit het onderzoek bleek dat er tussen de dieren in een groep stabiele rangverhoudingen bestaan, maar dat het soms voorkomt dat een ondergeschikt dier een dominant dier verjaagt of niet opzij gaat voor een dominant dier. Zowel de huisvesting als de verzorging hebben een belangrijke invloed op het optreden van deze zogenaamde tegenstrijdige interacties. Sociale dominantie heeft slechts een beperkte invloed op de verdeling over de dieren van belangrijke zaken, zoals een ligbox of een plaats aan het voerhek. Dit zal ten dele veroorzaakt zijn door een storende invloed van zowel de huisvesting als de verzorging, maar in het algemeen zal de sociale dominantie onder normale omstandigheden een beperkte rol spelen (dit is ook het geval bij andere diersoorten). De sociale dominantie is echter wel belangrijk, omdat het gepaard gaat met stabiele rangverhoudingen waardoor de dieren in staat zijn een betrouwbare voorspelling te doen van de uitkomst van een interactie die zich voordoet dan wel voor zou kunnen gaan doen.

De sociale dominantie kan het beste weergegeven worden met de dominantiewaarde die gebaseerd is op agressieve interacties. Geconcludeerd werd, dat wanneer alle rangrelaties bekend moeten zijn, er bij groepen van 15 - 20 koeien 2000 - 3500 verjagingen verzameld moeten worden. Wanneer minder gedetailleerde informatie nodig is, moet toch nog 90 % van de rangrelaties bekend zijn om een voldoende betrouwbaar inzicht te krijgen. Voor groepen van 15 - 20 koeien moeten dan 800 verjagingen verzameld worden.

Bij melkkoeien wordt een grote variatie aangetroffen in de dagelijkse ligtijd. Zowel verschillen tussen individuen als ook verschillen in de huisvesting en verzorging veroorzaken deze variatie in ligtijd. In vijf verschillende experimenten met negen verschillende groepen koeien werd de invloed van enkele aspecten van de huisvesting en van over- en onderbezetting op de tijd die de koeien staand en liggend in de ligboxen doorbrach-

ten, onderzocht. Het belangrijkste doel van dit onderzoek was om vast te stellen hoe belangrijk de ligboxen voor de koeien zijn om te rusten en om zich terug te trekken. Gemiddeld lagen de koeien per etmaal ongeveer 13 uur en stonden ze ongeveer 2,5 uur in de ligboxen. Als de ligboxen kleiner waren en als de koeien elders confrontaties met groepsgenoten konden ontwijken, brachten ze minder tijd in de ligboxen door. Overbezetting van de stal leidde tot een afname van de tijd doorgebracht in de ligboxen, terwijl anderzijds bij onderbezetting de tijd doorgebracht in de ligboxen slechts weinig toenam. Vooral bij hoge niveaus van overbezetting (50 %, 55 %) slaagden de ranglage koeien er niet meer in de gebruikelijke ligtijden te realiseren. Wanneer extra ligboxen beschikbaar waren (onderbezetting), vond het eten en liggen wat meer gesynchroniseerd plaats en bovendien lagen de koeien meer verspreid over de gehele stal. Daardoor konden de dieren comfortabeler liggen. Geconcludeerd werd dat het liggen, en dus de ligboxen, belangrijk is voor de koeien. Op grond van het experiment met onderbezetting werd geconcludeerd dat extra ruimte niet van wezenlijk belang is voor de koeien.

Het gedrag van melkkoeien bij geprogrammeerde krachtvoerverstrekking werd onderzocht om een inzicht te krijgen in de aanpassing van de koeien aan dergelijke systemen. Zowel het bezoek van de koeien aan het voerstation als de algemene activiteit van de koeien werd onderzocht. De factoren die mogelijk het gedrag direct voor en direct na het bezoek aan het voerstation beïnvloedden, werden gedetailleerd geanalyseerd, als ook de informatie die de koeien mogelijk gebruikten bij hun beslissing om op een bepaald moment het voerstation te bezoeken. Er werden drie experimenten met drie verschillende groepen van 20 koeien verricht. Tijdens de experimenten werden vier verschillende systemen voor geprogrammeerde krachtvoerverstrekking (perioden-7-, perioden-11-, perioden-3- en spaarsysteem) vergeleken met het verstrekken van krachtvoer aan het voerhek. Elk systeem kende een typerend patroon van krachtvoeropname (tijdstip en een aantal bezoeken). In het algemeen pasten de koeien zich snel aan een nieuw systeem aan: zodra krachtvoer beschikbaar was, namen de koeien het op. De tijd doorgebracht aan het voerhek en ook de ligtijd werden soms beïnvloed door het voersysteem. Met name met het perioden-11-systeem moesten de ranglage dieren soms lang wachten voor ze een voerstation konden binnentreden, wat bij deze dieren een daling van de ligtijd tot gevolg had.

Het gedrag van de koeien vlak voor ze het voerstation bezochten was afhankelijk van het tijdstip van de dag en werd nauwelijks beïnvloed door de kans op een beloning. Op grond van de uitkomsten van de analyse werd verondersteld dat de koeien in het algemeen hun bezoeken aan het voerstation gewoon inpassen in hun normale dagelijkse activiteit. De beslissing van een koe om het voerstation te bezoeken, werd in beperkte mate beïnvloed door informatie uit het voerstation: een beloond bezoek werd vaker dan een onbeloond bezoek gevolgd door een bezoek van een volgende koe. In hoofdzaak volgden de koeien een strategie van regelmatig - zowel overdag als 's nachts - bezoeken van het voerstation, omdat de bezoeken weinig moeite kostten en omdat de beloning voldoende hoog was.

Tenslotte werden de uitkomsten van de diverse onderzoeken nog besproken in termen van de kosten en het succes van de aanpassing aan de huisvesting en verzorging en in termen van de gevolgen voor het welzijn van de melkkoeien. Vanuit een oogpunt van welzijn zijn stabiele rangrelaties belangrijk, omdat de dieren daardoor in staat zijn om de uitkomst van een confrontatie met een groepsgenoot betrouwbaar te voorspellen. Echter, het optreden van tegenstrijdige interacties lijkt geen ernstige vermindering van het welzijn, omdat voor ranglage dieren het voordeel (grotere kans om belangrijke zaken als voer of ligplaats te veroveren) van wezenlijk belang is, terwijl het nadeel voor de ranghoge dieren niet van groot belang lijkt. Bij vrij hoge niveaus van overbezetting (50 %, 55 %), bleken met name de ranglage dieren niet in staat zich succesvol aan te passen. Op grond hiervan werd gesuggereerd dat onder deze omstandigheden het welzijn van deze dieren in een niet acceptabele wijze was verminderd. Tussen 0 % en 50 % moesten de koeien (hard) werken om zich aan te kunnen passen; om normale ligtijden te kunnen realiseren. Of dergelijke niveaus van overbezetting vanuit een oogpunt van welzijn acceptabel zijn, staat ter discussie. Bij normale bezetting en bij onderbezetting leken de koeien geen problemen te hebben om zich aan te passen, zodat hun welzijn derhalve niet geschaad was. Ook werden geen aanwijzingen verkregen dat de koeien problemen hadden om zich aan te passen aan de systemen voor geprogrammeerde krachtvoerverstrekking. Het vrij hoge aantal bezoeken en ook de gevolgen voor de opname van ruwvoer en voor de ligtijden welke soms werden vastgesteld, werden gezien als een geringe prijs welke de koeien betaalden. Dergelijke systemen van krachtvoerverstrekking leidden derhalve niet tot een vermindering van het welzijn.

Tenslotte werden, naast de onderzochte, nog de volgende andere voor de koeien belangrijke aspecten van huisvesting en verzorging genoemd: 1) de wijze van opfokken; 2) de mens-dier relaties; 3) andere recente/toekomstige ontwikkelingen in de automatisering; 4) kreupelheid. Verder werden de volgende nieuwe ontwikkelingen in de melkveehouderij, die gevolgen zouden kunnen hebben voor het welzijn van de dieren, genoemd: 1) automatisch melken; 2) biotechnologie; 3) ontwikkeling van nieuwe huisvestingssystemen met het oog op de beperking van de ammoniak-emissie.

KORT LEVENSOVERZICHT VAN DE PROMOVENDUS

Herman Karel Wierenga is geboren op 30 maart 1951 te Oudeschip (Gr.). Na de HBS-b te Warffum studeerde hij van 1968 tot en met 1976 aan de Rijksuniversiteit te Groningen. Hij studeerde af in de biologie met als specialisatie ethologie en als bijvakken dieroecologie, plantenoecologie en planologie. Van 1977 tot en met 1990 was hij werkzaam op het Instituut voor Veeteeltkundig Onderzoek "Schoonoord" te Zeist. Onder andere verrichtte hij daar onderzoek naar het gedrag van runderen. Sinds 1990 is hij als Hoofd van de Afdeling Welzijn Landbouwhuisdieren werkzaam bij de Veterinaire Dienst van het Ministerie van Landbouw, Natuurbeheer en Visserij.