Behavioural effects of housing in dairy cattle stalled in a tie-stall or loose-house system

Maria Hellgren

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Content

1. Abstract

The aim of this study was to compare behaviour in the two most common types of housing for dairy cattle in Sweden, tie-stall and loose-house. The tie-stall was of the so-called short-stall model and the loose-house of the cubicle model. It was assumed that the pasture would reflect the most natural behaviour, so it was used as a baseline. The overall hypothesis was that there would be higher welfare in the loose-house than in the tie-stall since the cows can move around freely in the loose-house. The behavioural observations were divided into five situations; pasture, loose-house after intake, tie-stall after intake, loose-house during autumn and tie-stall during autumn. Observations were conducted both on individual behaviours and group synchronisation. The loose-house does not seem to invite to the same behavioural pattern as on pasture, there where lower group synchronisation, less activity and almost no mounting (heat behaviour) in the loose-house. Some of the behavioural differences seen in the indoor housing systems indicated welfare problems. There was significantly higher frequency of stepping (a possibly stereotypic behaviour) and lying-down difficulties in the tie-stall. In the loose-house there was a tendency for lower group synchronisation, higher heart rate, shorter eating duration and more rising up difficulties. The problems in the tie-stall could though be considered as more severe. Heart rate measures were made to see if there was any difference in stress between the different milking procedures in the systems. No differences in heart rate were found.

Keywords: behaviour, dairy cattle, heart rate, loose-house, milking, pasture, tie-stall

2. Introduction

There has been a growing concern for the welfare of domestic animals used in production. So also for dairy cows kept in varying housing systems. Efforts have been made to construct systems were the cows have better opportunities to express their natural behaviour. Although, there are other demands on a housing-system that needs to be considered such as reduced risk for pathologies, cleanliness, easiness in management and of course economic aspects. Thus, the concern for the natural behaviours of the cows is not the only focus when constructing a housing system.

In Sweden there are mainly two types of housing systems for dairy cows, tie-stalls and loose-housing. The milk production is slowly changing from having tie-stall systems to loose-housing systems (Hultgren 2002). This change will increases the freedom of movement for the animals and

thereby they get better opportunities to express natural behaviour (Bøe & Faerevik 2003, Rousing et al. 2004). Thus, the welfare of dairy cattle could increase when changing to loose-housing systems (Rousing et al. 2004). Since 80 percent of the dairy cows in Sweden still are kept in tie-stall systems (Hultgren 2001) good arguments for changing to loose housing is needed, thus a comparing study like this could be useful.

The two most common types of tie-stall systems, used in Sweden, are short-stall and long-stall. In both types of systems are the cows milked when standing in their places. This study has been conducted in a short-stall where the cow keeps its head over the feeding table in order to have place for lying down or standing in the stall (Hultgren 2001). Especially the cows lying down and rising movements could be restricted in a tie-stall forcing the cow to compensate by other movements. Several authors have described the lying-down and rising movements and have concluded that they are guided by innate behavioural patterns (eg. Zannier-Tanner, 1965 and Schnitzer 1971 cited by Hultgren 2001). Thus, the restriction of the cow's movements, in the tie-stall, inflicts on their natural behaviour. The lying down and rising movements could therefore be used as behavioural parameters when studying different environmental factors (Lidfors, 1989).

The two most common types of loose housing systems are strawyard and cubicles (Fregonesi & Leaver 2001). Milking of the cows occurs outside the loose-house e.g. in a milking parlour or in an automatic milking unit. In a strawyard there is one large bedding area while the bedding area in a cubicle system is divided into individual spaces. Here the cows can move around quite freely, they are not restricted in their movements by any ties and they can interact with all members of the herd. In the loose housing system the rank of the individuals will have greater importance than in a tie-stall system. There can be competition for resources such as lying place (especially in cubicles) and food, the cows will try to displace each other to gain access to these resources (Wierenga 1990). The study of Wierenga (1990) shows that there is a stable dominance relationship in a dairy herd, but that in the competition for resources a subordinate cow can displace or at least try to displace a dominant cow. Thus, the housing and management system might induce that the natural dominance relationship is disregarded by the herdmembers in a loose housing system (Wierenga 1990).

In Sweden, dairy cows are kept on pasture for 2-4 months each summer (Hultgren 2001). During this time they are not kept in these housing systems, at least not for 24 h a day, but move around freely outside on a pasture. The behaviours on pasture can be considered as a baseline since the cows probably have the best opportunities to express their natural behaviour when kept there. This baseline can then be used when comparing

the indoor housing systems. Hemsworth et al. (1995) suggests that cows kept on pasture have a higher welfare due to the increased possibility to perform species-specific behaviours, but also due to better health and less stress.

The milking procedure can be considered in order to further compare the housing systems. The milking situation in the two housing systems can be very different, as mentioned above, even if it usually occurs two times per day and with a milking machine. This could lead to differences in stress responses to the milking procedure.

The aim of this study was to compare the behaviour of dairy cows kept in a loose housing system with cows kept in a tie-stall system to see if there were any behavioural problems that could cause welfare problems. These two indoor systems were also compared with the behaviour of the cows when they were kept at summer pasture, since that can be considered as their most natural state. Also the different milking situations in the tie-stall and the loose-house were considered. Another aim was to see how the cows react when they are brought in from the summer pasture depending on what housing system they are stalled in. The overarching hypothesis was that the cows in the loose-housing system have higher behavioural welfare than cows kept in tie-stalls and that they change their behaviour and daily rhythm when they are brought in from the summer pasture.

The following predictions were made before the study started: The activity is the highest on pasture with a little less in the loose-house and very low in the tie-stall. Social interactions are most frequent in the loose-house and on pasture. The explorative behaviours diminish during the autumn in comparison to directly after intake. Stereotypic behaviours and lying-down/rising up abnormalities are most frequent in the tie-stall. The group synchronisation is the highest on pasture where they can function like a natural herd. The heart rate increase the most in the loose-house during milking since they have to leave their home environment and be crowded with the other herd members.

3. Material and method

3.1 Location, animals and housing

The study took place on the farm Järngården, which belongs to the agricultural school of Vreta-Västerby, Linköping. It is the students of the school and the their instructors that manage the dairy cattle. At Järngården they have both a cubicle loose-housing system with 63 places and a short-stall tie stall system with 42 places. The two housing-systems are located in

the same building. When the herd is taken in from summer pasture individuals are selected for the different systems and thereby there is a possibility that some of them are used to both systems. The individuals are chosen for the different systems from how suitable they are for a certain housing system. All animals are given the same food and are kept on the same summer pasture. In the beginning of the summer the high yield cows are kept inside during the day and outside during the night while the low yields are inside during the night and outside during the day. From the middle to the end of the summer they are kept the other way around. The herd was a mix of three breeds: the Swedish Holstein (SLB), Jersey and the Swedish Red and White (SRB).

There are two different milking systems used on Järngården, in the loose-house the cows are milked in a milking parlour and in the tie-stall they are milked in their stalls. When they are milked in the milking parlour they are first driven up from the loose-house and gathered at the entrance of the parlour. Then they are driven into the two sides of the parlour, seven individuals per side. After the cows in one row have been milked they are let back to the loose-house. In the tie-stall the keepers walks from cow to cow with the machines while the cows stay in their places.

3.2 Observations

The observations were divided into five situations; pasture, loose-house after intake, tie-stall after intake, loose-house during autumn and tie-stall during autumn. Observations were made both before and after milking in all of the above situations, these observations were evenly distributed on morning and afternoon milkings. Each observation session lasted for two hours. In the statistical analysis and the results the five situations will be referred to as “housing” and the milking status will be referred to as “time”, were “1” is before milking and “2” is after milking.

3.2.1 Pasture

The observations began a couple of weeks before the herd was taken in from the pasture. They were then observed out on the pasture by an observer who walked around among the herd. The recordings of group synchronisation were done by instantaneous sampling every minute through the whole two-hour session, the observer made approximations of how big part of the herd that was occupied with a behaviour (the states: lying, standing, grazing, walking (Table 1)) at each sample point. Since one group was outside during the day and one during the night four recording sequences a day were made for five days giving each group five recorded sequences before milking and five recorded sequences after milking.

For observation of individuals 10 animals per session were randomly selected. Five recorded observation sessions before milking and five recorded observation sessions after milking were made for each group. Each individual was observed for ten minutes and then the observer took a one-minute break (more if needed) to select and move to the next focal-animal. The individuals were observed for states, such as lying, standing, ruminating, grazing, walking and drinking, and events such as rising up, lying down, stereotypies and various social interactions (Table 1). The states were recorded using instantaneous sampling (every minute). The frequencies of some events were recorded continuously and the other events were recorded with one-zero sampling.

Table 1. The ethogram used when observing dairy cattle in the five situations; pasture, tie-stall and loose-house after intake and tie-stall and loose-house during autumn.

Code	Behaviour	Explanation
States, interval sampling		
L	Lying	Lying down either flat on the side or with the legs under the body
LR	Lying ruminating	Lying down ruminating
S	Standing	Standing up on all four
SR	Standing ruminating	Standing up ruminating
G	Grazing	Grazing on pasture or eating fodder
GL	Grazing lying	Lying down eating or grazing
W	Walking	Walking around
D	Drinking	Drinking water
T	Tongue rolling	Repeatedley rolling the tongue, stereotypic behaviour
Events, continous observation		
RN	Rising normal	Rising up with a normal pattern
RD	Rising with difficulty	Rising up with an abnormal pattern, during more than 10s, slipping or with obvious difficulty
LN	Lying normal	Lying down with a normal pattern
LD	Lying with difficulty	Lying down with an abnormal pattern, during more than 10s, slipping or with obvious difficulty
L	Looking	Looking around the environment with picked up ears, exploring
B1	Butting someone	Butting or pushing a fellow herdmember
B2	Being butted	Being butted or pushed by a fellow herdmember
C1	Chasing someone	Chasing or displacing (sometimes with just a glance) a fellow herdmember
C2	Being chased	Being chased or displaced by a fellow herdmember
S	Sniffing	Sniffing to explore the environment or the fodder
H	Head-to-head	Head-to-head fighting between two herdmembers
J	Heat behaviour	Either mounting between herdmembers or roaming
Events, 1/0 sampling		
L1	Licking someone	Licking a fellow herdmember
L2	Being licked	Being licked by a fellow herdmember

L3	Licking herself	Licking herself
L4	Licking an object	Licking some object in the surroundings of the cow
ST	Stepping	Repeatedly lifting and setting down limbs while remaining at the same spot
S	Scratching	Scratching against an object

3.2.2 After the intake from pasture

The cows that were going to be housed in the tie-stall were taken in from pasture two weeks earlier than the loose-house cows. Thus, after the intake from the pasture it was possible to concentrate the observations on one group at a time. There were twelve group synchrony observation sequences and 20 observation sequences of individuals made per housing system during five days right after intake. Group synchronisation was recorded every sixth minute at the same observation sessions as the individual observations, giving six recorded sessions before milking and six recorded sessions after milking. At the sample points the observer counted how many cows that were occupied with a behaviour.

For the observation of individuals the cows in each system were divided into two groups of ten, giving five recorded sessions before milking and five recorded sessions after milking per individual. A schedule made sure that all individuals were observed in connection with both morning milking and afternoon milking. The individuals were observed with a rotating focal-animal system where the observer observes a focal-animal for five minutes and then change animal during a one-minute break. They were observed in the same manner as on pasture. These observations will be compared with the observations made on the pasture to try and see if they show any signs stress when they are taken in from summer pasture.

3.2.3 Autumn observations

To follow up the adaptation of being kept indoors, and to compare the welfare in the different housing systems, continuous observations took place during the autumn. Each week there were observations of individuals done in the same groups of ten and in the same manner as in the post-intake study. These observations resulted in ten recorded sessions before and ten recorded sessions after milking per individual. A schedule made sure that all individuals had been observed an equal amount of sessions in connection with both the morning and the afternoon milking. There were also group synchrony observations made in the same manner as in the post-intake study. The observations resulted in ten recorded group synchrony sessions before and ten after milking. All these observations were conducted during a ten-week period using the same method as the observations on pasture.

Additionally there were heart rate measurements made on one individual in the loose-house and one individual in the tie-stall during eight of the ten weeks giving eight recordings per housing system. The measurements would last for five hours beginning two hours before milking and lasting until approximately one hour after milking. The heart rate monitor consisted of a receiver (Polar sport watch), a transmitter (Polar equine transmitter) and two electrodes (one plus and one minus). The transmitter and the electrodes were attached to the cow with an elastic horse-girth on which the receiver then was tied.

3.3 Data analysis

3.3.1 Individual observations

For the observations made on pasture it was assumed that the same twenty individuals had been observed. In the tie-stall and the loose-house twenty individuals per system were observed but some rearrangement took place during the autumn, the analyses were made with the assumption that the same twenty individuals had been observed the whole time. The data from the sessions made before milking was summed for each individual, the same was done with the data from the sessions made after milking.

The states, which all had been recorded with instantaneous sampling, were recalculated in percentage per hour. This was also done with those events, which had been recorded with one-zero sampling. The events that had been recorded with continuous sampling were recalculated into frequency per hour. The dataset that was used in the statistical analysis contained housing, time, cow number, the behaviours before milking and the behaviours after milking.

3.3.2 Group synchronisation

The data from the observations made in the tie-stall and the loose-house were recalculated in percentage of the herd for each behavioural state (lying, standing, grazing and walking) at each sample point. Since the observer made approximations in percentage of the herd in the pasture observations this was not needed for those data. For each sample point was the standard deviation for the percentage of the different behavioural states calculated. For example, if 100 percent of the cows were lying the standard deviation for that sample point was 50. If, on the other hand, there were 25 percent per state the standard deviation became 0. After that the mean standard deviation (group synchronisation) for each observation was calculated. The dataset that was used for the statistical analyses contained

housing, time, mean standard deviation before milking and mean standard deviation after milking.

3.3.3 Heart rate

Two groups of cows with eight individuals per group had been used, the tie-stall and the loose-house group. For these groups a mean for each minute was calculated. These group means per minute was then synchronised with the time where milking occurred, leaving approximately three recorded hours for each group. Milking occurred between the second and third hour. A plot was made on these data. For the statistical analysis the data from each individual was divided into three periods, the first, the second and the third hour. The dataset used contained housing, cow number and the means for each period.

3.3.4 Statistical analysis

The data from the observations of individuals and group synchronisation was analysed in the same way. Normal distribution was analysed by visual inspection of P-P plots made in SPSS 11.0 for Mac OS X. After that the General Linear Model for repeated measures (SPSS 11.0 for Mac OS X) was used to analyse the data. “Time” was analysed as within-subjects factors and “housing” was analysed as between-subjects factors. Tukey’s Post-Hoc, multiple comparisons for observed means (SPSS 11.0 for Mac OS X) was made for the “housing” factor. All variations are given as +/- 1 SE in the plots displayed under “4. Results”.

The heart rate data was analysed with an independent-samples t-test (SPSS 11.0 for Mac OS X). Grouping variable was housing (loose-house and tie-stall) and test variables were the three periods.

4. Results

For the effects of housing and time on the individual behaviours and the group synchronisation see Table 2. In the continuation the p-values mentioned in the text will be from the Tukey’s Post-Hoc test.

Table 2. The statistical results from the analyses of the effects of housing and time on individual behaviours and group synchronisation in dairy cattle. Housing represents the five situations; pasture, tie-stall and loose-house after intake and tie-stall and loose-house during autumn. Time represents before milking and after milking.

Behaviour	Housing	$F_{4, 95}$	Time	$F_{1, 95}$	Housing*Time	$F_{4, 95}$
Lying	NS	1.145	NS	2.016	NS	1.445
Passive states	< 0.01	4.018	< 0.001	17.029	NS	1.189
Active states	< 0.001	10.909	< 0.001	44.018	NS	1.092
Rising difficulties	< 0.05	2.742	< 0.01	7.696	NS	1.383
Lying down difficulties	< 0.05	2.632	NS	0.263	NS	1.722
Looking	< 0.001	7.050	NS	1.206	NS	1.636
Aggressive events	< 0.001	13.797	NS	0.423	< 0.01	3.663
Butting	< 0.001	18.731	NS	0.507	< 0.1	2.141
Chasing	< 0.001	9.139	NS	1.406	< 0.01	0.4063
Heat behaviour	< 0.01	3.779	NS	0.023	NS	0.099
Social behviours	< 0.05	3.555	< 0.05	5.158	NS	0.772
Licking herself	< 0.001	19.377	< 0.001	21.525	< 0.05	2.948
Licking an object	< 0.01	4.694	NS	1.087	NS	0.435
Stepping	< 0.001	57.829	< 0.001	40.356	< 0.05	2.967
Scratching	NS	0.752	NS	0.599	NS	0.977
Sniffing	< 0.001	26.495	< 0.05	4.515	< 0.1	2.079
Rummination	NS	0.691	< 0.01	10.147	< 0.05	2.690

4.1 Individual observations

There was no significant difference in passivity between tie-stall and loose-house, but there was a significant difference between the loose-house and the pasture ($p < 0.05$). In activity there was a significant difference between pasture and the other housing systems ($p < 0.001$). The cows were more active and less passive on pasture than in the other systems, the cows were significantly more active after milking and more passive before milking (Figure 1 a-b, Table 2). Although, there were no significant difference in how much time they spent lying.

The only significant difference in rising difficulties was between loose-house and pasture ($p < 0.05$). In lying down difficulties there was a significant difference between the tie-stall after intake and the pasture ($p < 0.05$) and the loose-house ($p < 0.1$) during autumn. Most lying-down difficulties was seen in the tie-stall while the rising difficulties were most frequent in the loose-house, rising difficulties occurred the most before milking (Figure 1 c-d, Table 2).

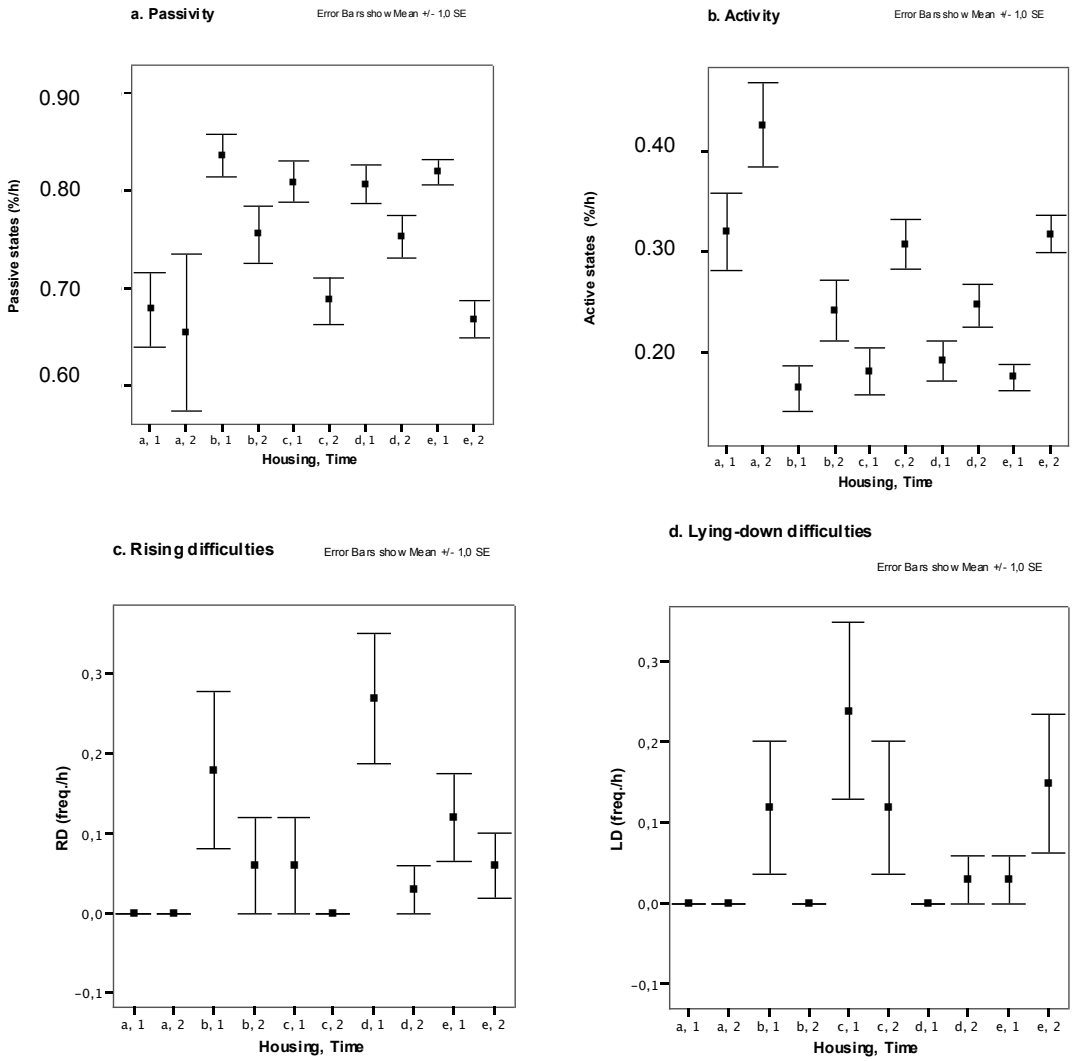

Figure 1 a-d. a. Mean percentage per hour in passivity (lying, lying ruminating, standing and standing ruminating) for the five observed situations. b. Mean percentage per hour in activity (grazing/eating, walking, drinking) for the five situations observed. c. Mean frequency per hour of rise-ups with difficulty observed in the five situations. d. Lying-downs with difficulties, in mean frequency per hour, seen in the five situations observed. Code explanation for "housing, time": a, 1 - pasture before milking, a, 2 – pasture after milking, b, 1 – loose-house after intake, before milking, b, 2 – loose-house after intake, after milking, c, 1 – tie-stall after intake, before milking, c, 2 tie-stall after intake, after milking, d, 1 – loose-house during autumn, before milking, d, 2 – loose-house during autumn, after milking, e, 1 – tie-stall during autumn, before milking and e, 2 – tie-stall during autumn, after milking.

In the exploring behaviour "looking around" there was a significant difference between the tie-stall after intake and the other systems (pasture: $p < 0.001$, loose-house intake: $p< 0.01$, loose-house autumn: $p < 0.1$, tie-stall autumn: $p < 0.05$). Another way to explore the environment is by

sniffing, here there was a significant difference between the pasture and the others (loose-house intake: $p < 0.001$, loose-house autumn: $p < 0.001$, tie-stall intake: $p < 0.001$, tie-stall autumn: $p < 0.001$) and between the tie-stall after intake and the others (loose-house intake: $p< 0.001$, loose-house autumn: $p < 0.001$, tie-stall autumn: $p < 0.05$). The cows mostly performed these exploring behaviours in the tie-stall after intake, sniffing was performed the most on pasture (Figure 2 a-b, Table 2). Sniffing was performed significantly more after milking.

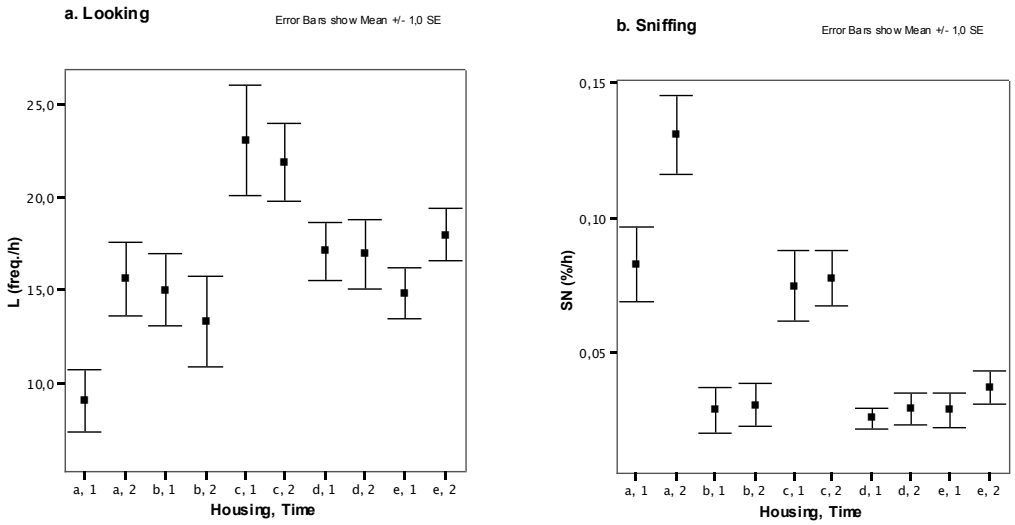

Figure 2 a-b. a. The explorative behaviour looking, in mean frequency per hour, for the five situations observed. b. Mean frequency per hour of sniffing, another explorative behaviour seen in the five situations. For code explanation of "housing, time" see Figure 1.

There was a significant difference in aggressive interactions between the tie-stall after intake (pasture: $p < 0.01$, loose-house intake: $p< 0.01$, loose-house autumn: $p < 0.001$) and during autumn (pasture: $p < 0.01$, loose-house intake: $p< 0.01$, loose-house autumn: $p < 0.001$). Aggressive interactions were mostly seen on pasture and in the loose-house with no difference in time (Figure 3 a, Table 2). The aggressive events chasing and butting was then distinguished. In butting there was a significant difference in loose-house after intake (loose-house autumn: $p < 0.05$, tie-stall intake: $p < 0.01$ and tie-stall autumn: $p < 0.01$) and in loose-house during autumn (pasture: $p < 0.001$, tie-stall intake: $p < 0.001$ and tie-stall autumn: $p < 0.001$). For chasing there was a significant difference in tie-stall after intake (pasture: $p < 0.001$, loose-house intake: $p < 0,05$ and loose-house autumn: $p < 0.05$) and in tie-stall during autumn (pasture: $p < 0.001$, loose-house intake: $p < 0,05$ and loose-house autumn: $p < 0.05$). The nature of

aggressive events changed from mostly chasing on pasture to mostly butting indoors, there were no differences in time (Figure 3 b-c, Table 2). Looking at more friendly social interactions there was a tendency of difference between the tie-stall during autumn and the loose-house during autumn ($p < 0.1$). Between tie-stall during autumn and the pasture there was a significant difference ($p < 0.01$). There were more social interactions taking place in the tie-stall and then significantly more after milking (Figure 3 d, Table 2).

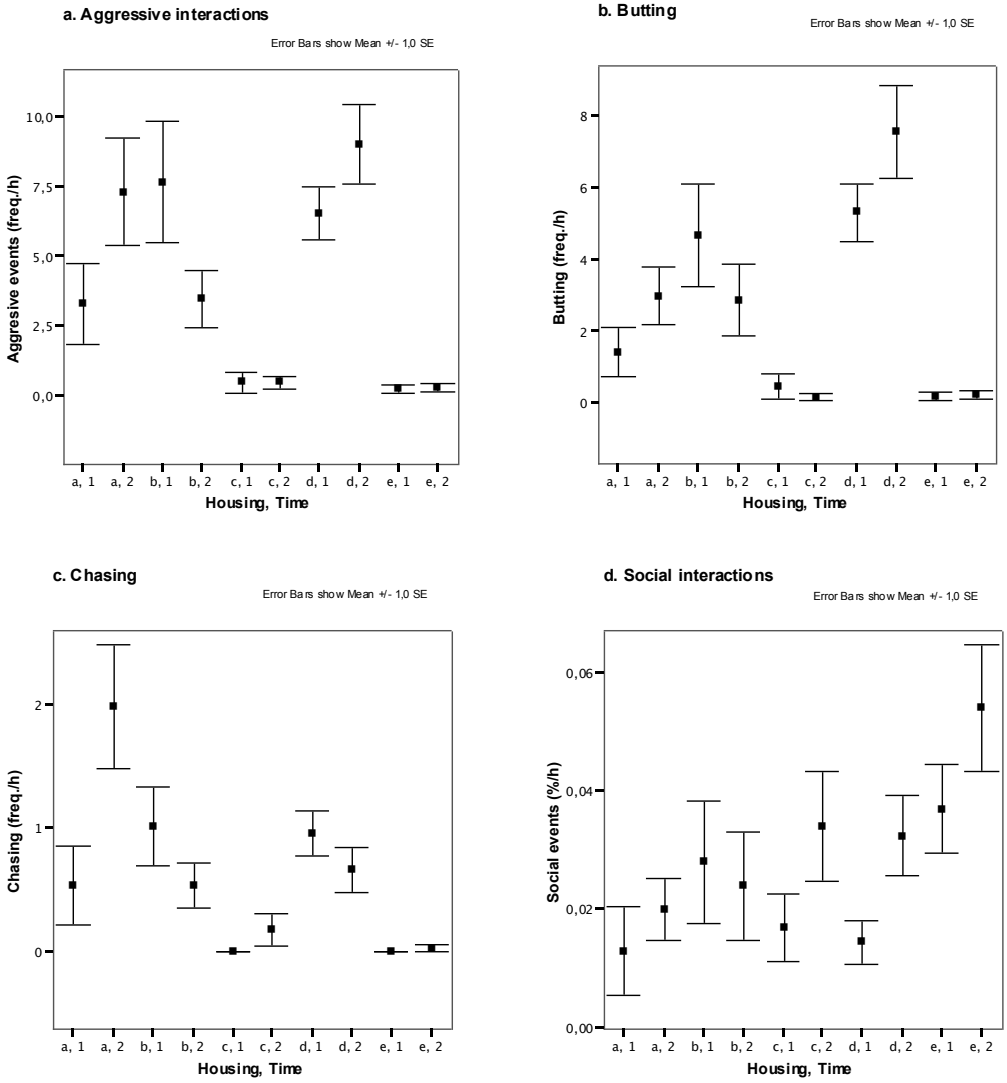

Figure 3 a-d. a. Aggressive interactions (butt someone, being butted, chase someone, being chased, head-to-head fighting), in mean frequency per hour, observed in the five situations. b. Butting (butt someone, being butted), in mean frequency per hour, for the five situations observed. c. Mean frequency per hour of chasing (chase someone, being chased) observed in the five situations. d. Mean percentage per hour of friendly social interactions (licking someone, being

licked) seen in the five situations. For code explanation of "housing, time" see Figure 1.

There was a significant difference in how much the individuals licked themselves between the pasture and the others (loose-house autumn: $p < 0.001$, tie-stall intake: $p < 0.001$, tie-stall autumn: $p < 0.001$) and between the loose-house after intake and the others (loose-house autumn: $p < 0.01$, tie-stall intake: $p < 0.001$, tie-stall autumn: $p < 0.05$). This behaviour took place mostly on pasture and in the loose-house after intake and then significantly more after milking (Figure 4 a, Table 2). They could also lick an object, there was a significant difference between tie-stall intake and the other systems (pasture: $p< 0.05$, loose-house intake: $p < 0.1$, loose-house autumn: $p < 0.1$) and between tie-stall autumn and pasture ($p < 0.05$). This was done the most in the tie-stall with no difference in time (Figure 4 b, Table 2).

They performed their heat behaviour significantly more on pasture than in the other systems (loose-house intake: $p< 0.05$, loose-house autumn: $p < 0.1$, tie-stall intake: $p < 0.05$, tie-stall autumn: $p < 0.05$), there was no difference in time (Figure 4 c, Table 2). The individuals also performed a behaviour where they were standing at the same spot stepping. There was a significant difference between the tie-stall during autumn and the others (pasture: $p < 0.001$, loose-house intake: $p < 0.001$, loose-house autumn: $p < 0.001$, tie-stall intake: $p < 0.001$) and between the tie-stall after intake ($p < 0.001$), loose-house during autumn ($p < 0.001$), loose-house after intake ($p < 0.001$) and the pasture. This behaviour was performed the most in the tie-stall and not at all on pasture, it occurred significantly more before milking (Figure 4 d, Table 2).

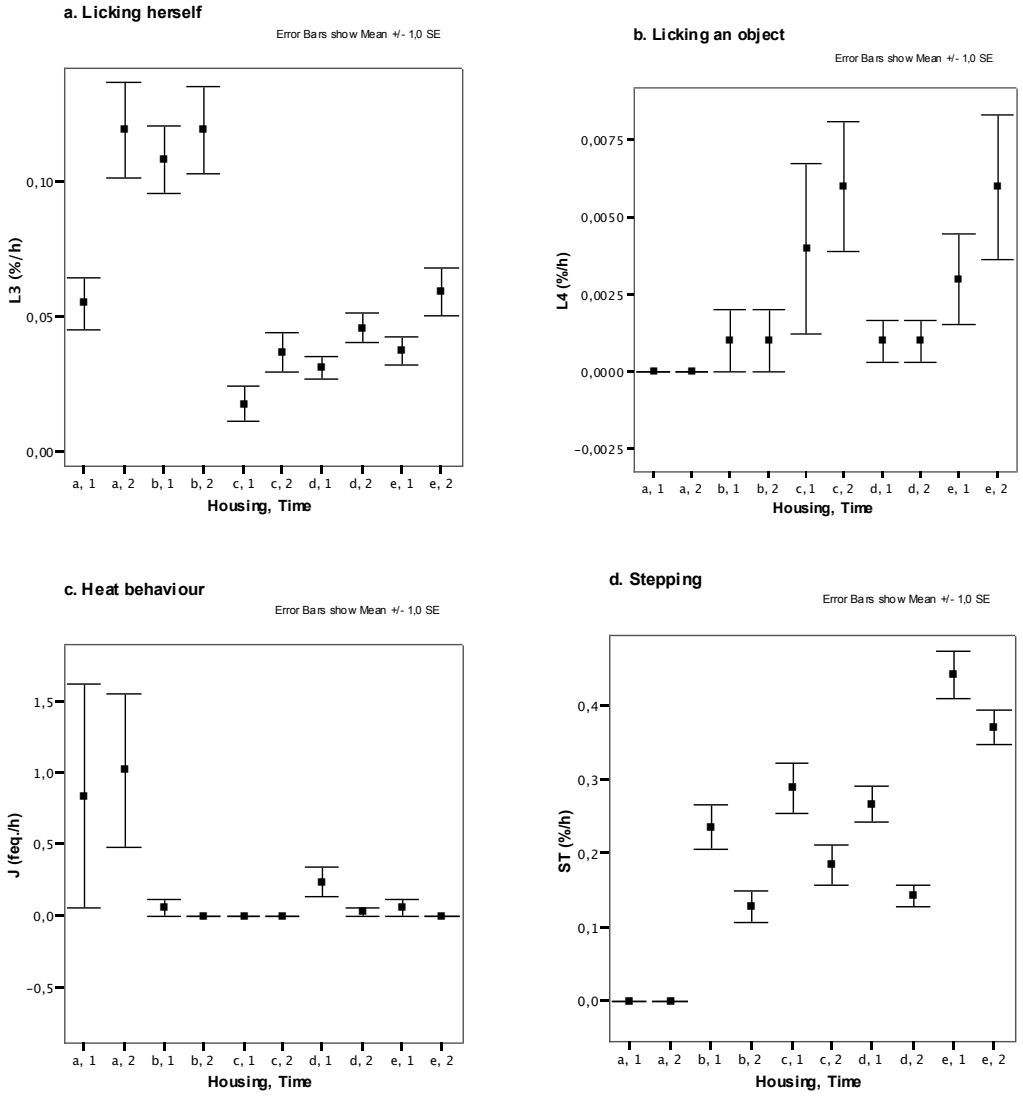

Figure 4 a-d. a. Mean percentage per hour of the behaviour licking herself for the five situations observed. b. Mean percentage per hour of licking an object observed in the five situations. c. Heat behaviour (mounting or roaming), in mean frequency per hour, observed in the five situations. d. Stepping, in mean percentage per hour, for the five situations observed. For code explanation of "housing, time" see Figure 1.

There were no significant effect of housing in how much they were ruminating and scratching themselves against an object (Table 2). There was a significant difference in time for rumination (Table 2).

4.2 Group synchronisation

In group synchronisation there was a significant effect of housing ($p < 0.001$, $F_{4, 37}$ 12.515) but not of time ($F_{1, 37}$ 0.034) or "Housing*Time" ($F_{4, 37}$ 0.102). There was significantly higher group synchronisation on pasture

(loose-house intake: $p < 0.001$, loose-house autumn: $p < 0.001$, tie-stall autumn: $p < 0.001$) and in the tie-stall after intake (loose-house intake: $p < 0.05$) (Figure 5).

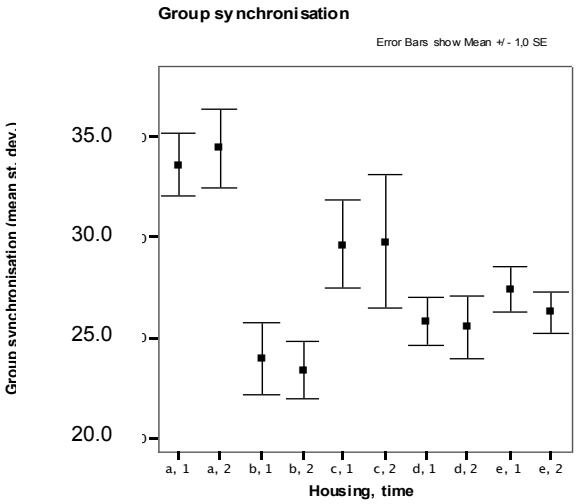

Figure 5. Mean standard deviation of group synchronisation in the five situations observed. For code explanation of "housing, time" see Figure 1.

4.3 Heart rate measures

There was no significant difference between the tie-stall and the loose-house, though there is a tendency of higher heart rate in the loose-house in the beginning and towards the end of the sample-period (Figure 6).

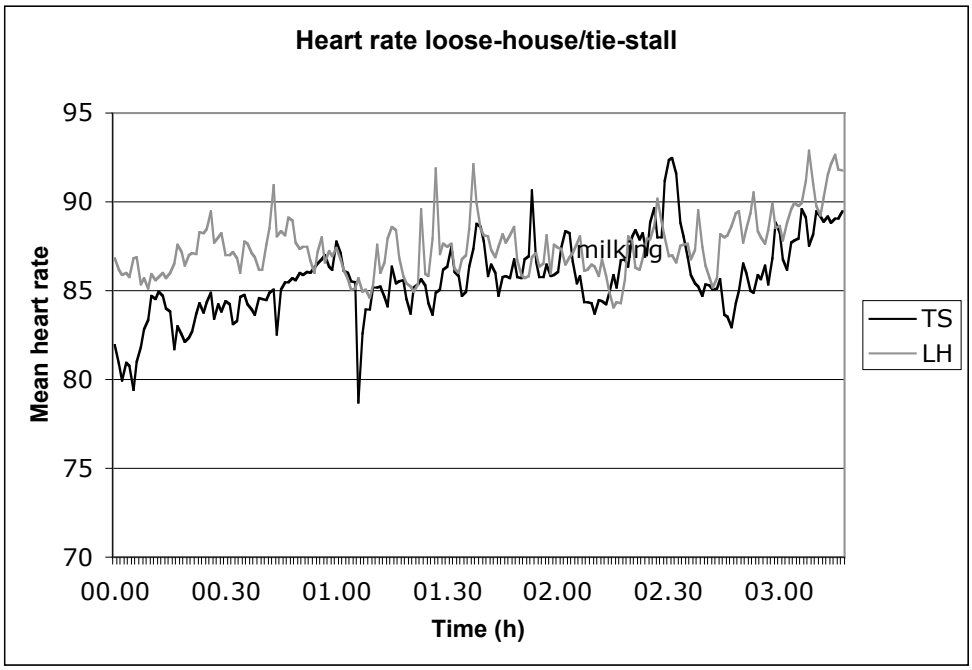

Figure 6. Mean heart rate for loose-house (LH) and tie-stall (TS) before (2 h), during and after (1 h) milking.

5. Discussion

From this study it can be concluded that there are some welfare problems both in the tie-stall and the loose-house. A possibly stereotypic behaviour, stepping, occurs significantly more in the tie-stall, there are also significantly more difficulties in their lying-down movements. In the loose-house there was a tendency of higher heart rate and shorter eating duration, here the cows also showed difficulties in rising up movements. Another problem in the loose-house was a tendency for lower group synchronisation than in the tie-stall. There were problems with short eating duration, difficult rising ups and low group synchronisation in the tie-stall as well, but not to the same extent as in the loose-house. I therefore conclude that the problems in the tie-stall are more severe than the problems in the loose-house. Some differences were seen between post-intake and autumn in the indoor systems. The frequency of explorative behaviours and difficult lie-downs were higher just after intake in the tie-stall, these differences could be signs of stress related to the intake. Despite the freedom of movement the loose-house did not invite to the same behaviour as on pasture; less activity, lower group synchronisation and almost no mounting in the loose-house. There were no differences seen in stress related to the milking procedure. The observations made on pasture have been considered as baseline studies since it was assumed, before the study started, that the behaviour on pasture is the most natural.

5.1 Individual observations

The cows were the most active (grazing/eating, walking and drinking) and the least passive (lying, lying ruminating, standing and standing ruminating) on pasture. Among the activity states observed grazing/eating was the most common. They were the most passive in the loose-house even if they had the opportunity to move around. Thus, there was a tendency for more activity among the cows in the tie-stall, despite the restriction of the tie.

One explanation for this could be that the tie-stall cows could eat from the fodder-table whenever they wanted to, since they could not be replaced by other herdmembers. There was free access to the fodder-table in the loose-house and there were always as many places as individuals, but the ones who ate fast had a tendency to displace those who had not finished and keep on eating someone else's share. It is therefore possible that the cows in loose-house eat faster in order to get what they need while the tie-stall cows can eat slower during a longer period of time. This would give the tie-stall cows a higher activity score. The high activity score on pasture suggests that it is natural for them to spend long time eating. The more

stressed eating situation in the loose-house could therefore interrupt a more natural eating pattern. This is supported by the study made by Lindström and Redbo (2000) where they concluded that the levels of oral stereotypies are lowered by long duration of oral manipulation of feed by eating and ruminating.

There was a significant difference in time both for activity and passivity. The cows were more active after milking and more passive before. Thus, it seems like cows have a need for eating after milking in both the indoor systems and on pasture. Since it is the same in all systems the urge for eating cannot be dependent on management differences.

Fregonesi and Leaver (2001) concluded that the time spent lying could be used as a welfare indicator for dairy cattle. They used this indicator in a later study (2002) where they found differences in time spent lying between two loose-house systems, a stawyard and a cubicle system. The result shows that the cows in the stawyard were lying more. Wierenga et al. (1985) found that cows in an under-crowded cubicle system spent more time lying down and had better lying synchrony in comparison to cows kept in a normal-crowded cubicle system. When Krohn and Munksgaard (1993) compared cows stalled in a tie-stall with cows in a strawyard loose-house with access to a pasture they found that the cows in the loose-house had shorter total lying time than the cows in the tie-stall. In this study there were no significant difference in how much they were lying. The only tendency seen was that they were lying more in the loose-house after milking. Since they did not spend more time lying on pasture, where there is free space and soft grass to lie on, it could be questioned if lying time really is a good indicator of welfare. The behaviour on pasture must after all reflect the most natural behaviour (Hemsworth et al. 1995).

The cows in the loose-house had most difficult rising ups, but there was only a significant difference in comparison to the pasture. The slippery floor and the bar that was placed over the lying cubicles could contribute to this. The bar forced the cow to make compensatory movements, which disturbed its natural rising movements. The difficult rise-up occurred mostly before milking, probably since they were rising up to prepare for the milking at the end of the observation-periods. Lying down difficulties was mostly seen in the tie-stall. There was a significant difference between tie-stall after intake and both the pasture and the loose-house during autumn. Thus, one could suggest that the restriction influenced their movements more just after intake and that they later learned how to perform their normal movements despite the restriction. Only once did a cow make these movements in the wrong pattern. The difficulties that occurred the most were slipping, stepping or taking abnormal long time for rising up or lying

down. Also the study of loose-house/pasture vs. tie-stall done by Krohn and Munksgaard (1993) found more difficulties in the tie-stall during the lying-down process.

The cows in the tie-stall after intake were performing explorative behaviours (looking and sniffing) more than in any of the other housing systems. The only exception is sniffing on pasture, where they were sniffing the most after milking when they also were the most active (grazing). This could be explained by the fact that the cows had not been in the tie-stall for the whole summer, the loose-house was more familiar since they spent either the night or the day there during the summer. They were mostly sniffing to examine the food/grass before eating, this was especially seen on pasture which suggests that it is a natural behaviour which is diminished indoors where they eat ensilage and concentrated feed. Also Krohn and Munksgaard (1994) saw more explorative behaviours in the tie-stall than in the loose-house/pasture. They had excluded sniffing the feed/grass and looking as explorative behaviours. They suggested that the high frequency of explorative behaviours could be caused by poor stimulation from the barren environments and/or the decreased possibility of social contacts.

There were significantly less aggressive interactions (butting someone, being butted, chasing someone, being chased and head-to-head fighting) in the tie-stall then in the other housing systems. Even if there was a lot of fighting for the concentrated feed automat seen in the loose-house there were no difference in comparison to the pasture. Thus, it seems natural that aggressive interactions occur, I therefore do not consider it to be a welfare problem. Wierenga (1984) saw more aggressive interactions in the cubicle system when observing cows that were moved from pasture to a loose-house cubicle system. Also Krohn and Munksgaard (1994) saw less aggressive interactions outdoors than indoors (strawyard loose-house). Like this study there were almost no aggressive interactions seen in the tie-stall during the study of Krohn and Munksgaard (1994). In this study it was found, just as Wierenga (1984), that the type of aggressive events changed from mostly chasing on pasture (no significance between loose-house and pasture, but a tendency) to mostly butting in the loose-house (significance between loose-house and pasture). This was probably due to that the chased animal can be more protected indoors, e.g. by the cubicles or possible neighbours, than on pasture where the chaser can chase only by showing a threat (Wierenga 1984).

More friendly social interactions (licking someone and being licked) occurred the most in the tie-stall during autumn (significance in comparison to pasture and a tendency in comparison to loose-house during

autumn). This social licking seemed to occur more after milking, at least in the indoor systems, probably since the activity was higher during that period. The result is in contrast to the prediction that social interactions should occur more in the loose-house and on pasture where they have better access to each other. A speculation for this is that individuals tied next to each other become more attached socially than the individuals of a herd in a loose-house or on pasture. The tendency for less social interactions in the tie-stall after intake supports the suggestion that it takes some time to develop social bounds. Dairy cattle used in production is often regrouped to meet varying demands (Bøe & Faerevik, 2003) maybe this can result in difficulties to create social bonds. Maybe the situation in a tie-stall makes social bounding easier. Krohn and Munksgaard (1994) on their hand found no effect of housing on social licking when comparing extensive (loose-house/pasture) and intensive (tie-stall) environments.

The cows licked themselves significantly more on pasture and in the loose-house after intake. This also occurred the most after milking when the activity was higher. It was seen on pasture that they often licked themselves in order to get rid of flies. The much lower frequency of licking in the tie-stall after intake could be due to the restriction of the tie. Krohn and Munksgaard (1994) found in their study that the frequency of self-grooming (licking and rubbing) was higher in the tie-stall than in the loose-house/pasture. Although, there were no housing effects on the total time spent licking seen in that study. Krohn and Munksgaard (1994) suggest that short bouts of self-grooming could be a displacement behaviour. They have in an earlier study suggested that high levels of comfort behaviour could be a result of frustration under restrictive tethering (Munksgaard & Krohn, 1990 cited by Krohn & Munksgaard, 1994). Since the data collected show that the cows licked themselves less in the tie-stall this does not seem to be the case in the systems studied. They licked other objects significantly more in the tie-stall both after intake (significance in comparison to all other systems) and during autumn (significance in comparison to pasture). It was mostly seen after feeding, when they kept licking the foddertable after the food was gone. Overall it was low frequency of licking objects among the cows, it can therefore not be considered as a problem in the systems studied.

As heat behaviour, mounting was mostly seen. It occurred significantly more on pasture than in any of the other systems. This despite the fact that they had the opportunity to perform this behaviour in the loose-house. Two reasons for this could be the slippery slatted floor and the more crowded situation in the loose-house.

The stepping behaviour was mostly performed in the tie-stall during autumn, there was also a significant difference between the pasture and the remaining systems. It was performed more before milking than after, this suggest that the behaviour is induced by passivity. This behaviour could be considered as a stereotypic behaviour since it was performed for long periods in the same manner. Since it was done significantly more during autumn than after intake in the tie-stall it seems to be some stress reaction to being tied up for a longer period. It was not seen at all on pasture, thus just being housed indoors seems to cause some stress for the cows. In horses weaving is a common locomotor stereotypie (Cooper et al., 2000). When they perform this behaviour they shift the weight from side to side while they often also swing their head (Cooper et al., 2000). The stepping seen in this study could be a form of weaving in cows since the performance pattern is similar. The stereotypic behaviour tongue-rolling was not seen at all in any of the housing systems. Tongue-rolling had a very low frequency in the study by Krohn and Munksgaard (1994) as well. A suggestion is that the low frequency is caused by the feeding method, as mentioned earlier the levels of stereotypies can be lowered if dairy cows are given the possibility to a long duration of eating and ruminating (Lindström & Redbo, 2000 and Redbo & Nordblad, 1997).

The rumination pattern seems to be unaffected by housing system, as is scratching against an object. There was a scratching device in the loose-house which was widely used by the cows, but they were scratching just as much in the tie-stall and on pasture anyway. Overall this was a behaviour that occurred with low percentage per hour.

5.2 Group synchronisation

Fregonesi and Leaver (2001) concluded that a high lying synchrony is a sign of good welfare. They later used lying synchrony as a welfare indicator in another study (Fregonesi & Leaver, 2002). Also Krohn et al. (1992) used lying synchrony when they studied cows kept in extensive (loose housing/pasture) or intensive (tie-stall) environments. They found that the synchrony was the highest on pasture and the lowest in the tie-stall. In this study there was a significantly higher group synchronisation (lying, standing, grazing/eating and walking) on pasture and in the tie-stall after intake than in the other situations. The high synchronisation on pasture suggests that it is natural for the cows to be synchronised. The synchronisation continued to be high in the tie-stall after intake, this shows that they kept the same pattern as on pasture, at least in the beginning of being stalled indoors.

There was a tendency for higher synchronisation in the tie-stall than in the loose-house, an explanation for this could be that there was more synchronisation in the management of the tie-stall. According to Fregonesi and Leaver (2001) the low synchronisation in the loose-house could be a sign of poorer welfare.

5.3 Heart rate

Earlier studies on stress responses to milking have among other factors used heart rate (Hagen et al. 2004, Hopster et al. 2002 and Wenzel 1999 cited by Hagen et al. 2004). There was no significant difference in heart rate between the two systems observed in this study but there was a tendency for higher heart rate in the loose-house in the beginning and the end of the sampling period. This suggests that the cows in the loose-house could be more stressed than the cows in the tie-stall. Since the biggest difference was seen two hours before milking the stress does not seem to be related to the milking procedure. The activity was not higher in the loose-house during this period. Neither could the difference be a result of differences in management since the keepers mostly absent from in the systems during that period.

No earlier studies where the heart rate in a milking parlour has been compared to the heart rate in a tie-stall during milking could be found. Studies made on milking parlours vs. automated milking all showed varying results. Hagen et al. (2004) compared normal successful milking in a herringbone milking parlour (HMP) with normal successful voluntary milking in an automatic unit (AMU). They found no differences in heart rate between the two milking systems. Hopster et al. (2002) did find differences in heart rate during milking when they compared a tandem milking parlour (TM) with an automated milking system (AM). Although, they could see that the heart rate was higher already half an hour prior to milking among the TM cows, at this time they were waiting in the collection yard while the AM cows where in the cubicle barn in the predefined waiting area. The conclusion from that study was that there were no signs of stress in any of the milking systems. In a third study, where behaviour, heart rate and milk cortisol were measured, it was found that the cows were more stressed in an automated milking unit than in a tandem milking parlour (Wenzel et al. 1999 cited by Hagen et al. 2004). The varying results of this study and the studies mentioned above could be due to differences in method, interpretation, management, milking systems and cows.

5.4 Conclusions

Possible welfare problems were found both in the tie-stall and in the loose-house. There was a significantly higher frequency of stepping and lying-down difficulties in the tie-stall compared to the loose-house. In the loose-house there was a tendency for higher heart rate, lower group synchronisation, shorter eating duration and rising up difficulties in comparison to the tie-stall. There were problems with low group synchronisation, short eating duration and rising up difficulties in the tie-stall as well, but not to the same extent as in the loose-house. The problems in the tie-stall could therefore be considered as more severe. Differences in behaviour between the loose-house and the pasture (activity, group synchronisation and heat behaviour) implies that the loose-house does not invite to the same behavioural pattern as on pasture. There where some signs of post-intake stress in the tie-stall, more lying-down difficulties and more explorative behaviours. No differences in stress during milking were found. The varying results seen in this study and in earlier studies prove that a lot more studies on tie-stall systems vs. loose-house systems is needed, even though there are factors that suggests a poorer behavioural welfare in the tie-stall.

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