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Studies on dairy cow behaviour with automatic feeding in a herd milked by an AMS

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Increased labour requirements in dairy farming, associated with expanding herds and a greater necessity for performance-related feeding, result in increased expansion of automatic feeding systems (AFS). Additionally, farmers seek to achieve uniform usage of automatic milking systems (AMS) by offering freshly mixed feed rations several times per day. The aim of the investigations reported here is to record the influence of six times per day feed delivery compared to twice daily, both via AFS, on the behaviour of automatically milked dairy cows. With 4.07 h/(cow × day) compared to 2.65 h/(cow × day), the cows with six times daily feeding were in total present at the feed table over a significantly longer time. When feed was offered twice daily, a larger proportion of animals were observed standing in the feed alley and not feeding. When feed was offered more often per day the milking frequency of the cows in the AMS increased significantly.

Keywords
Automatic feeding system, feeding frequency, automatic milking system, behaviour, dairy cows

Structural changes in dairy farming towards larger farms lead to increasing mechanisation and automation of a variety of work procedures in agriculture. Following milking and rearing and care of calves and young stock, feeding the herd represents the third-largest labour input in dairy farming, representing 16 % of total labour requirement (Haidn and Macuhova 2009). Automating feeding therefore offers, after automation of milking, a further potential for reducing labour time requirements. For this reason, use of AFS increases in importance, in particular under the aspects of saving working time, easing workload and bringing more flexibility. However, a further important reason for farmers investing in this technology is the possibility of being able to feed performance groups only portions of the total dairy ration several times per day (DLG et al. 2014).

Own research indicates that in Bavaria 70 % of dairy farmers using automatic feeding, for whom there is information on the milking system used (n = 75), also have an AMS. This identifies a tendency whereby farmers with an AMS also automate feeding of their cows with the aim of encouraging more uniform cow flow through their milking systems.

The feed intake behaviour of dairy cows is characterised by a circadian rhythm with several feeding periods distributed over the day (Albright 1993). Endogenous and exogenous time givers are hereby important factors of influence on behaviour. According to Sambraus (1991), cows housed in a barn and offered feed ad libitum also display a definite biphasic feeding rhythm. Hereby it was emphasised that the action of feed distribution clearly stimulates dairy cow behaviour (DeVries and von Keyserlingk 2005, Melin et al. 2005). Offering feed more often leads, according to several authors, to

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an increase in the daily time spend feeding by the animals and, with that, to a rise in the proportion of animals within a herd that involve themselves in feeding during the day (DeVries et al. 2005; Mäntysaari et al. 2006). Mattachani et al. (2015) can confirm these results. According to their trials, the times spent at the feed table were distributed more evenly throughout the day when the animals were fed 11 times, compared with six times, per day. The amount of time per day spent actually feeding did not differ, whereby the time spent on feed consumption in the first 60 minutes after the delivery of the feed during the lower frequency of six feed offerings per day was longer and, with that, also more confrontations could occur between the feeding cows within this period of time. Grothmann et al. (2014) observed a limited effect of feeding frequency on the feed intake behaviour of dairy cows. The daily dry matter intake increased by 600 g/cow from 16.6 kg with two feeds per day to 17.2 kg with eight daily feed offerings. A common method, alongside the delivery of fresh feed (DeVries and von Keyserlingk 2005), for encouraging dairy cows to consume their feed is, according to DeVries and von Keyserlingk (2009), repeated pushing-up of feed on the feed table to the feed barrier. However, a study by DeVries et al. (2003) showed that with two daily feed deliveries, two further pushing-up actions during the night, in addition to two similar actions carried out in daytime, had only a limited influence on the daily rhythm of feed intake and did not increase feeding activity. Nydegger et al. (2005) also came to this conclusion.

In addition to feeding behaviour, lying behaviour can also be influenced through altered feeding frequencies. Investigation results from DeVries et al. (2005) and Mattachani et al. (2015) showed that frequency of feed offerings had no effect on the daily total time spent lying down, but did have an effect on the number of lying periods. Investigations by Grothmann et al. (2014) observed a tendency towards reduction of time spent lying down with increased frequency of feed offerings. On the other hand, Pompe et al. (2007) discovered a 5 % increase in time spent in the resting area with automatic feeding compared to conventional feeding.

Rodenburg (2002) has already suggested that the delivery of fresh feed several times per day can increase voluntary visits by cows to the AMS, especially where cow traffic is guided. This was not confirmed by Belle et al. (2012). In their comparison of farms with conventional feeding and milking systems and those with automatic feeding and milking, they found no significant effect of an AFS on the number of milkings in an AMS (conventional feeding: 2.57 milkings/day; AFS: 2.61 milkings/day).

The studies on the effects of an altered feeding frequency on the behaviour of dairy cows available at the beginning of these investigations were carried out mainly on farms with conventional milking systems and with routinely fixed milking times involving milking staff. The aim of the research reported here is, therefore, to record the influence of increased feeding frequency via AFS in comparison with conventional feeding management offering two feeds per day on the behaviour of dairy cows on a farm using an AMS. Objective criteria hereby were the herd activities throughout the day within the feeding area, time spent by individual cows in the feeding area and in the cubicles, as well as individual cow milking parameters such as milking frequency, milk yield and length of intervals between milkings.

Animals, materials and methods

The investigations were conducted in winter 2012/2013 at the agricultural educational institution in Triesdorf over a period of 10 weeks. The approx. 60 cow dairy herd was housed in a freestall barn with automatic milking system (MIOne from GEA Farm Technologies GmbH, Bönen, Germany) and with voluntary cow traffic system. The cows had 24 h access to the AMS with exception of two cleaning periods (early morning and afternoon). The minimum interval between two milkings, and thereby access of an individual cow into the milking unit, was determined by respective milk yields. Feeding in this experimental farm was via a semi-automatic feeding system (MixMeister 3000, Wasserbauer GmbH, Waldneukirchen, Austria) (Figure 1).

Figure 1: Concentrate feed silos, mineral feed dispensers and conveyor belt, with feed bunkers in the background in the feed kitchen; Feed mixing and distribution wagon with some of the AMS herd (Photos: R. Oberschätzl)

Components of the feeding system were four feed bunkers for grass silage, maize silage, straw and hay respectively. These were housed in a feed kitchen built as barn lean-to. Each day, the feed components were loaded into the respective bunkers by telescopic handler. Concentrates and mineral feed were stored in mineral dispensers and concentrate feed silos. Depending on the required ration, components from the respective bunkers were dosed onto a conveyor belt and, via a further conveyor belt, transported into the single vertical auger mixing and distribution wagon (3 m^3 filling volume) that was additionally equipped with a weighing system. Concentrates and mineral feed were then added. After mixing the ration, it was distributed to the respective animal group. The two-wheeled mix and distribution wagon was guided by a rail track and powered via an electricity rail (Figure 1).

This feeding system supplied the animals with a balanced mixed ration (20.4 MJ NEL/kg dry matter (DM)). Supplementary feed was offered in the AMS and via a concentrate feeding station. The mixed ration comprised the following ingredients (given as percentage of DM content): maize silage (39.7 %), grass silage (29.7 %), barley straw (4.2 %), lucerne hay (4.2 %), rapeseed extraction meal (10.8 %), concentrate feed mix (10.8 %) and mineral feed (0.6 %). The feed amount offered daily was 16.5 kg DM/cow. Under commercial farming conditions, the animals were automatically fed six times daily. In addition to the feeding times, feed was pushed-up towards the feed barrier by the feed mixing and distribution wagon two or three times daily.

The cubicles were deep boxes with lime-straw bedding. In the AMS area, the feed stalls were separated from the feeding table by a feeding fence as well as a neck rail. The feed stalls for the cows were divided by lateral barriers, each division leaving a space for two cows. 42 feeding places were available for the lactating AMS herd. The animals in the calving area had access to 11 feeding places (Figure 2). The animal/feeding place ratio was in total 1.1 : 1. Average milk production per lactation in the Simmental herd was 8,100 kg with 4.47 % fat and 3.78 % protein. During the trial period, the herd comprised a total 66 cows of differing lactations (1st lactation: 35 %, 2nd lactation: 27 %, > 2nd lactation: 38 %).

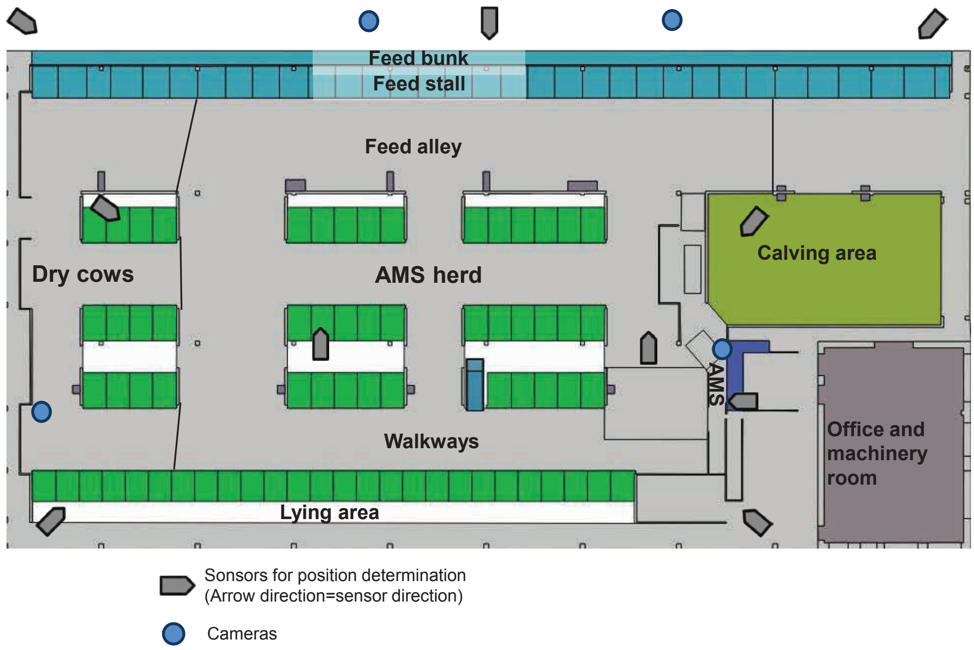

Figure 2: Layout of the freestall barn showing positioning of the recording equipment

The trial period was divided into two trial phases with six or two feed deliveries daily and an adjustment phase in order to be able to assess a comparison with regard to the effect between twice and six times daily offering of feed (the main feeding frequency chosen in practical farming where AFS is in use) (Table 1). Because, in regular operation, the AMS herd was also fed six times daily, no adjustment phase was required before the first trial phase. In the second trial phase, the full 3 m^3 volume of the feed mixing and distribution wagon meant that only half the feed could be distributed to the cows in a single mixing and distribution journey. This meant that two mixing/feeding operations per feeding time had to be carried out morning and evenings as near to one another in terms of time as was technically possible. In trial phase 1 the average daylight length was 8.4 h and in trial phase 2 9.2 h.

Table 1: Trial phases, time periods, feeding frequencies and feeding times in the conducted investigations

Trial phase	Time periods	Feeding frequencies [n/d]	Feed delivery times [h:mm]
1st phase (Farm standard routine)	26-Nov-2012 to 18-Dec-2012	6	2:00, 6:00, 10:30, 16:15, 19:00, 23:00
Adjustment phase	19-Dec-2012 to 15-Jan-2013	2	6:00 and 6:45, 16:15 and 16:45
2nd phase	16-Jan-2013 to 05-Feb-2013	2	6:00 and 6:30, 15:45 and 16:30

For determining animal positions in the barn, a ”Real Time Location System“ (RTLS) was installed (Ubisense Series 7000, Ubisense GmbH, Düsseldorf, Germany). Thereby, 10 sensors were installed in the barn and transponders were attached dorsally to the collars worn by the cows, for identification purposes (phase 1: 46 cows; phase 2: 56 cows) (Figure 3).

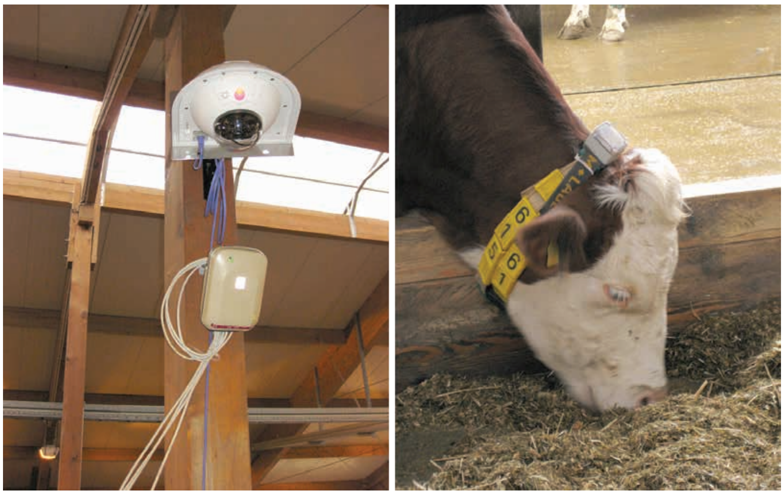

Figure 3: One of the cameras with Ubisense Series 7000 sensor mounted below; Cow with collar and transponder attached in a plastic housing (Photos: R. Oberschätzl)

Communication between transponders and sensors was via radio signal in the frequency range 6–8 GHz. The location system recognized the individual sensors, brought together in a network, through angle of arrival and transit time differences. Angulation and lateration were applied to determine transponder positions. As reference system and for monitoring the behaviour of the animals within the function areas as well as other occurrences within the barn, four video cameras (Mobotix D12 and D14) with in each case two modules were mounted in the barn. Thereby, two cameras covered the feeding area and the other two the lying area, the walkways and the AMS area. Filming was direct to hard disks in Network Attached Storage (NAS) with a filming rate of one picture per second and a resolution of both modules per camera of 2560 x 960 pixels. The recording technique was synchronized with a time server. Figure 3 shows the layout of the cubicle barn used for the investigation including the positioning of the installed recording technologies.

Milking-related data were collected by periodically saving of AMS data. Additional documentation was done by daily protocols detailing work routines and other occurrences taking place on the farm. From this information, four days per trial phase were selected for analysis. Criteria taken into account were functional reliability of milking and feeding technology, presence of visitor groups in the barn, workings carried out, other occurrences that were not routine, and the functional reliability of the trial technology applied as well as the quality and quantity of the recorded data.

Digitalisation of video film material from the feeding area was done by the program Image J (version IJ 1.45 m, National Institutes of Health) according to Time Sampling method. For the herd-based evaluation of the presence of the animals at the feed bunk or in the feed alley, a 5-minute interval was selected (according to Hoy 2009). Based on this, the arithmetic mean was calculated for the relative proportion of animals in the feeding area per 5-minute interval over three of the selected trial days.

The raw data of the applied RTLS (time of recording, transponder number, x and y coordinates) were imported into a PostgreSQL database for further processing. Firstly, the barn layout was determined in vector format and areas (e. g. feed bunk, cubicles) were defined for structured data processing. The positioning data were prepared by a programmed algorithm. Hereby, the threshold parameters time and distance were applied. If the resultant recordings from a selected data set exceeded the threshold time of 60 s or threshold distance of 1 m, then all the data sets lying within this range were grouped into a single data set. The position information of this is calculated from the median of the reported positions and contained the beginning and end of the duration of stay in this position. Based on these processed positioning data, the duration of stay of an animal in the following barn areas were determined: at the feed bunk, in the feed stall, in the feed alley, in the total feeding area and in the lying area (cubicles). Feed stall and feed bunk are hereby separated from one another by the feed barrier. If the animals were detected at the feed bunk they could be consuming feed, whereas positioning at the feed stall meant only that the cow was present and did not have her head through the feed barrier. The positioning data was not able to determine the difference between a cow lying in the cubicles or standing there.

Because there was very high energy requirement by transponders in the second trial phase due to low temperatures, the positioning data for this period was not complete for all the animals. For this reason, 20 cows were selected for evaluation of duration of stay in the barn areas. The data was then applied to both trial phases of the AMS herd. Both first-calvers and cows that had more than one calving were involved (1^{st} lactation: 40 %; 2^{nd} lactation: 25 %; 3^{rd} lactation: 35 %). The milking parameters (milking frequency (milking/(cow × day)), yield (kg/(cow × day)), and intervals between milkings (h/(cow × day)) were determined on the basis of all the cows, because the AMS data was available for the total herd and the selected trial days.

Statistical analyses were done by the open-source software "R". Normal distribution of the data was disproved by the Shapiro-Wilk test. For calculating the differences of factors 'proportion of animals in feeding area', 'duration of time spent in the areas', 'number of milkings', 'milk yield' and 'time between milkings' for animals in both trial phases, the Wilcoxon signed rank test was applied (Hedderich and Sachs 2012). Estimation of the effects feeding frequency and animal, as well as interaction of the factors, took place with the help of non-parametric aligned rank tests available in the R-Paket „npintFactRep" ($p < 0.05$) (Feys 2015).

Results and discussion

Studying the relative proportion of the animals in the feeding area over 24 hours (Figure 4) showed that, in both trial phases, the proportion of the cows at the feed bunk always increased after feed delivery.

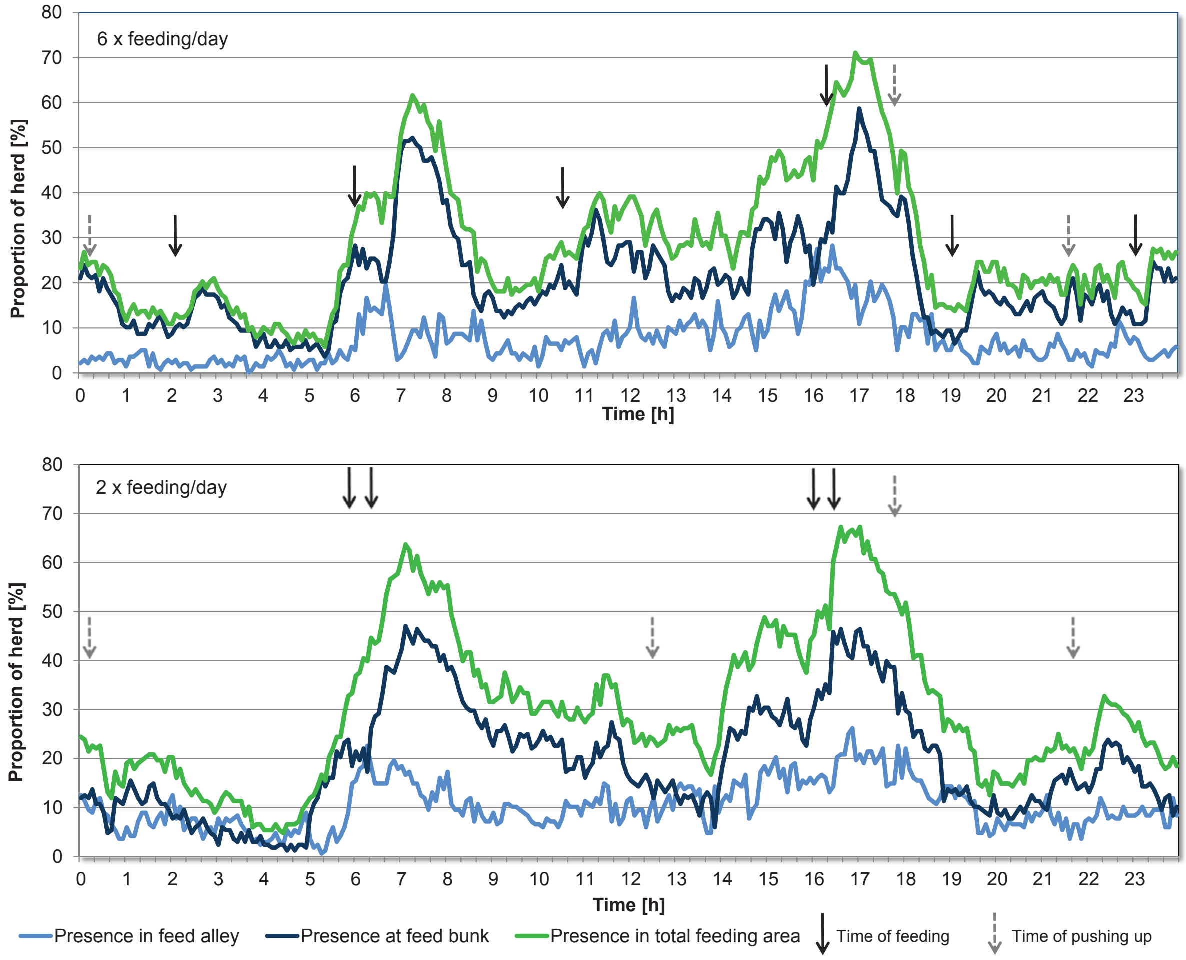

Figure 4: Relative proportion of animals in the feeding area with 6 x and 2 x feeding according to video data analysis (Trial phase 1: n = 46 cows; trial phase 2: n =56 cows; n = 3 days per phase)

In both trial phases, this development was subjected to an obvious biphasic rhythm with peaks at morning and evening. The additional feedings during the night and in the forenoon in trial phase 1 attracted additional animals to the feed bunk, although the attraction was definitely less (approx. 20 % of herd at the feed table during the night hours at around 2.45 am). In comparison, in the two feed deliveries per day, only 5 to 10 % of animals from the herd were at the feed bunk between 2.00 and 3.00 am. The maximum herd proportion at the feed table was achieved with the six times per day with 52 % mornings and 58 % evenings. This represented a higher niveau than in trial phase 2 with the twice per day feeding and maxima of 47 %. The proportion of animals at the feed bunk during the first 60 min following feed delivery over the average of all feedings, with 38 % in trial phase 2, was significantly higher than in trial phase 1 (24 %). Particularly after the morning feeding at 6.00 am, the herd proportion at the feeding area remained at a higher niveau for a longer period than when the animals were fed only twice per day. On the other hand, after the feeding, they left the area more quickly if the daily ration was distributed in six portions. This finding is confirmed by the results of Mattachani et al. (2015).

According to the analysis of positioning data with the 20 focus cows, these stayed at the feed bunk significantly longer, with 4.06 h, when they were fed six times daily (Table 2). In comparison, the daily period per cow at the feed bunk with twice daily feeding was 2.65 h. A significant effect of feeding frequency was determined for this parameter. In addition, the herd-based video analysis permits conclusion that the cows in this area during trial phase 2 were there for significantly shorter periods of time. Mäntysaari et al. (2006) already confirmed a longer active feeding period per cow when feeding was five times daily compared to once per day feeding.

Table 2: Times of presence of selected cows (n = 20) in the function areas (feeding and lying areas) with 6 x and 2 x feeding after assessing positioning data (n = 4 days per trial phase)

Parameter	duration of stay/(cow × day) [hh:mm]						
	Trial phase 1 (6 x feeding/d)			Trial phase 2 (2 x feeding/d)			Difference median[1)]
	Median	Min	Max	Median	Min	Max	
Feed bunk	04:04[a]	01:18	05:53	02:39[b]	01:30	04:59	01:25
Feed stall	01:27[a]	00:46	02:43	02:14[b]	00:39	07:35	-00:47
Feed alley	01:25[a]	00:20	03:01	01:36[b]	00:26	05:08	-00:11
Feed stall & Feed alley	03:03[a]	01:15	04:46	04:06[b]	00:39	09:34	-01:03
Total feeding area	07:18[a]	02:33	09:51	07:00[a]	03:28	12:13	00:18
Lying area	14:23[a]	06:37	18:10	14:19[a]	06:55	17:07	00:04

a, b: Significant differences between the trial phases ($p < 0.05$).
[1)] Differences of median in trial phase 1 and median in trial phase 2

Two feeds per day significantly increased the proportion of occupied feeding places on daily average (trial phase 1: 23 %; trial phase 2: 26 %) whereby the maximum feeding place occupation in both trial phases, with 64 and 63 %, was at a similar niveau. In the same way, the presence of the herd in the feed stalls in trial phase 2 with lower feeding frequency and greater numbers of animals in the herd was significantly higher and thereby the crowding in this area was definitely more intensive. With an average of 1.45 h, a cow remained significantly longer in the feed stall compared with when feed was offered six times daily. Thereby, the animals on average of trial days stood doing nothing and just waiting in the feed alley and feed stalls for 63 min longer, when feed was offered only twice daily. These results from the positioning data can be confirmed by the analysis of the herd based video data whereby the cows in trial phase 2 stood for 42 min longer in the feed alley.

With regard to time spent in the cubicles per cow, no significant effect associated with feeding frequency was determined. If feed was delivered six times per day the median of time per cow in the cubicles was 14.39 h and thereby only minimally longer than in trial phase 2 (14.31 h). The arithmetical average length of stay differed by 27 min, however (trial phase 1: 14.33 h; trial phase 2: 13.88 h). Also, the maximum length of stay in the lying area at 18.10 h/(cow × day) in the first trial phase was definitely longer. DeVries et al. (2005) and Mattachani et al. (2015) observed in their trials, however, that there was also no significant changes in time spent lying where feeding frequency was varied. This confirms the results from MUNKSGAARD et al. (2006), that lying had a higher priority compared with other types of behaviour. These authors had information on the actual lying results; whereby in the investigation reported here the positioning data is only able to give the length of time spent in the cubicle and not the time spent lying.

Evaluation of number of milkings per animal and day showed a significantly higher milking frequency for cows when feed was delivered six times per day (Table 3). In trial phase 1, the median was 3 milkings/(cow × d), in trial phase 2, 2 milkings/(cow × d). The findings of RODENBURG (2002) that offering fresh feed several times per day can increase voluntary visits to the AMS were thus confirmed, whereby BELLE et al. (2012) could not determine any effect on number of AMS milkings through changes in feeding frequency. Milk yields per day from each cow did not differ significantly in the two trial phases at 27.46 and 27.34 kg, whereby differences were recorded on a single animal basis. This effect also related to the times between milkings for individual animals. The intervals between milkings increased significantly by 1.72 h in the second trial phase. In both trial phases, the intervals between milkings featured, however, a greater range at around 21 h. The increase in the length of intervals between milkings was accompanied by reduced milking frequency per animal in trial phase 2 and also with longer waiting times in the feed alley and in the feed stall.

Table 3: Overview of animal individual milkings, yields and intervals between milkings for all cows with 6 x and 2 x feeding after assessing the AMS data (trial phase 1: n = 46 cows; trial phase 2: n = 56 cows, n = 4 days per trial phase)

Parameter	Trial phase 1 (6 x feeding/d)			Trial phase 2 (2 x feeding/d)			Difference median 1)
	Median	Min	Max	Median	Min	Max	
Number of milkings/(cow x d) [n]	3^a	1	4	2^b	1	4	1
Milk yield/(cow x d) [kg]	27.46^a	7.77	54.67	27.34^a	5.17	54.93	0.12
Milking interval/(cow x d) [hh:mm]	$08{:}23^a$	02:14	23:44	$10{:}06^b$	02:51	23:30	-01:43

a,b: significant differences between the trial phases ($p < 0.05$).
1) Differences of median in trial phase 1 and median in trial phase 2.

The increased offerings of feed by an AFS led to an equalling-out of the cow traffic in the experimental dairy farm. The animals had the possibility of intake of fresh feed steadily through the day and subsequently to return to the lying area, or to visit the AMS. The recordings make clear that a limited access to the resource freshly mixed and offered feed can lead to longer time spent in feeding. This time is especially increased because of inactive standing in the feed alley and in the feed stalls and cannot be used for further activities (e. g. resting, feeding) due to the limited daily budget of 24 h. In particular, lower ranking cows can be disadvantaged, as already confirmed by WIERENGA (1990) and OLOFSSON (1999). However, there remains a need to test during further investigations the transferability of these results onto other barn layouts, with herds of different breeds, and under other seasonal influences, as well as over a longer period of time per trial phase.

Conclusions

The results of these investigations regarding animal behaviour with six times delivery of a fresh mixed feed ration compared with feed offered twice per day permits the conclusion that cow traffic flow becomes more uniform throughout the day with six times feeding. This means that a more uniform distribution of animals at the feed bunk can be observed and, as a result, at the AMS too. Additionally, it takes less time for the cows to reach the feed bunk with less time spent waiting in the feeding area before commencing active feeding, and they are less often disturbed there. The reduced amount of time in total required to arrive at the feed bunk when feed is offered several times daily can have positive effects on the expression of further activities by the animals (e.g. presence in cubicles). Distribution of fresh feed rations more often, and thus permanent availability of tasty feed, can therefore lead to improved animal welfare.

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