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The influence of elevated feed stalls on feeding behaviour of lactating dairy cows

The performance level of high yielding cows can only be guaranteed by high quality forage and high feed intake. An about 15–20 cm elevated and 160 cm long feed stall with rubber flooring doesn't only offer undisturbed meals but also a yielding and dry standing surface. In a pilot stable with 130 dairy cows (German Simmental) the feeding alley was subsequently equipped with elevated feed stalls. The results show that animals frequented the feeding barn less often while the duration of single meals prolonged. The specific behavioural changes differed depending on milk yield and number of lactation.

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Abstract
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Average milk yield of the just under 4.2 million dairy cows in Germany was over 8221 kg in 2013 [1]. Such a production level can only be achieved through cows being able to feed undisturbed [2]. The animals must be able to access feed at any time and not be disturbed during feeding by other cows, the dung scraper or by unsuitable design of the feeding area [2; 3; 4]. As well as access to feed at the feed rail, animal mobility plays a decisive role. This is limited through poor hoof health and has a marked influence on feed intake [3]. Hoof health is impacted by contact with dung and often hard passage and feeding area flooring [5; 6]. Additionally, cows are habitually grazing and ranging animals and barn housing makes it more difficult for them to maintain the related inborn need for a certain space between themselves and other herd members. Lack of this space can lead to aggressive behaviour, a situation exacerbated when the herd group composition is instable through, for example, repeated group member changes because of relatively short production periods of dairying, but also through grouping for feed rationing [7].

Cows feed for four to seven hours per day [8] making the feeding area a central part of the loose-housing barn. In order to ensure undisturbed feed intake as well hoof-friendly standing areas, the elevated feed stall has been developed based on the cow cubicle concept whereby the standing area has a soft overlay and a separation rail is fitted between every second feed stall for the purpose of reducing social antagonism through reduced distances between individuals [9; 10; 11].

The trial reported here is designed to test whether redesign of the feeding area can influence total duration of cow feeding, number and duration of feeding periods and of feeding times. To this end, elevated feed stalls were installed in dairy farm housing with restricted animal:feeding space ratio, without the feeding place breadth per cow being altered.

Material und Methods

The trial was designed as a before and after comparison, being conducted from July 2013 to November 2013 on a dairy farm near Göppingen with a herd of 130 German Simmental cows and followers. The open-fronted barn was built in 2009 as loose-housing with three rows of deep bed cubicles with straw litter and solid concrete floored passages. Four cross passages allow cows to avoid each other and also avoid the dung scraper. The animal:feeding space ratio was 1.5:1. During the trial period the cows received a part-mixed ration to meet requirements for 24 kg per day milk production. Feed was issued at 9 am with shoving-up to the feeding rail at 7 am, 1.30, 5.30, 7.30 and 10.30 pm. Ration components were maize silage, grass silage, hay, barley straw, rapeseed extraction meal, cereal mix, mineral feed and animal salt. Concentrate feed was rationed from two automatic dispensers. Before installation of the elevated feed stalls, the automatic scraper operated nine times daily: 5.00, 6.30 and 11.00 am and 2.00, 4.00, 5.30 and 9.00 pm as well as at midnight and 3.00 am. After installing the elevated feed

Fig. 1

Subsequently installed elevated feed stalls at the farm of investigation (Photo: S. Ehrmann)

stalls the manure scraping took place hourly, whereby feeding routine was not changed. The feed stalls were heightened using self-built components of prefabricated concrete (height approx. 9 cm). The concrete elements were 120 cm long with a gradient of 2%. These were fixed to the floor of the 3.8 m wide feeding passage with metal pins to prevent movement. Together with the already available 40 cm long step, the feed stalls had a total length of 160 cm. The breadth of the individual feed stalls was 75 cm, each stall floor being covered with a 3 cm thick rubber mat (Lenta mats from Kraiburg Elastik GmbH & Co. KG). The rear third of each mat featured an integrated run-off gradient as well as bevelled edge. The feed stalls were in total 12 cm higher than the passage floor. Between every second feed stall place were inserted a free-standing separation rail (DeLaval GmbH) to help prevent cows standing crossways in the stalls or turning around in them (**Figure 1**).

For investigating feeding behaviour, 12 focus animals were arbitrarily selected with predetermined parameters regarding lactation stage (between days 80 and 120), with positive pregnancy check and with no particular health problems. Six cows were in the first or second lactation, six cows in the third to fifth lactation. Because of this age structure, it was assumed that half the cows in each case were low ranking in the group hierarchy and the remainder high-ranking. The cows had an average 305-day milk yield of 7656 kg. Observation of feeding behaviour took place via video camera (T/N-IR colour dome camera with LED lighting, type: VFKUP-600/3-11IR, manufacturer: VC) with long-time exposure of 2 weeks respectively. Evaluated from these periods in a scan sampling process were three days of before-period and, following a familiarisation period of 11 days, three days of after-period. The before-period was from 22.7. to 4.8.2013, the average outdoor temperature during these observation days was around 23 °C. An outdoor temperature of around 13 °C was recorded during the after-period observation from 17.9. to 6.10.2013.

The video data was utilised to determine frequency of cow visits to the feeding area and length of time at the feeding rail. Each observation period began when the respective animal put its head through the feeding rail and ended when it withdrew its head. Based on the recorded feeding periods were additionally calculated per animal and day the number and duration of feeds. One feed was defined as the period of time in which feeding took place for at least one minute, followed by a feeding pause that lasted at least 20 minutes [12]. The statistic program Ri 386 3.01 was used for data processing. Data was tested for normal distribution and variance homogeneity. The requirements for variance analyses were always met. The means comparisons were calculated using the t-test for pair samples. The significance levels were established as $p < 0.05$ (significant*), $p <= 0.01$ (very significant **) and $p <= 0.001$ (highly significant ***).

Results and discussion

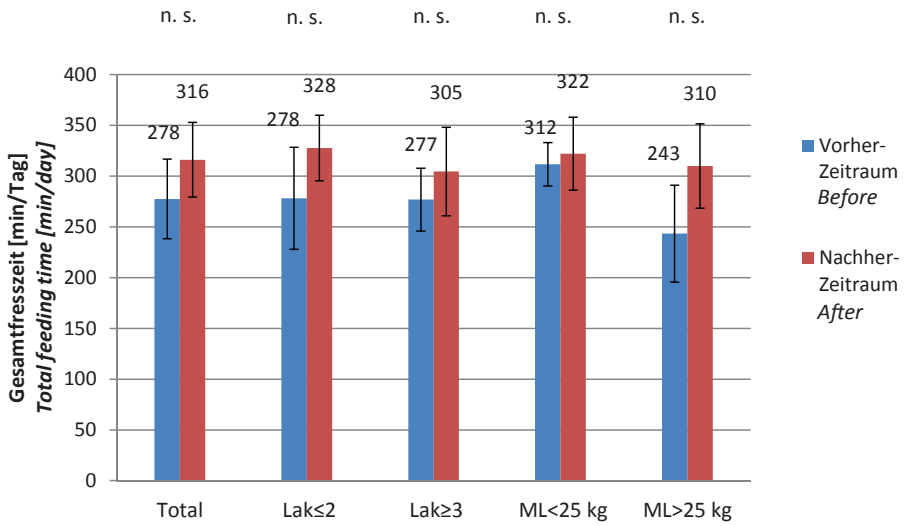
To investigate feeding behaviour, 12 animals were originally planned. Two animals had to be withdrawn from the trial because of ill health. Installing the elevated feed stalls had marked effects on nearly all of the selected behavioural parameters within the function area feed consumption. Because especially the lactation number [13] and level of milk yield [4] influenced the feeding behaviour, these two parameters should be noted in the following. In **Figures 2** to **5** are in each case the results for the complete trial group (total, n = 10) and for the subgroups (lactation number (Lak ≤ 2/≥ 3 and milk yield level (ML) < 25 kg/> 25 kg) conducted with a sample size of n = 5.

Total feeding period

Under pasturing conditions cattle spend about 8–12 hours (480–720 min) grazing daily [8]. Such total feeding times are not achieved under barn housing conditions, where between 201 and 420 min are spent feeding [8; 12; 15; 17]. The average total feeding period per day and animal increased following installation of the elevated feed stalls from 277.5 min (standard deviation SD ± 78.5) to 316.1 min (SD ± 73.4) (**Figure 2**), the difference of 15 % is not significant (p = 0.1411). This could be explained through the small size of sample (n = 10), characterised by a variation coefficient (VK) of 0.28 (before-period) or 0.23 (after-period). Subsequently, number and duration of feeding periods or number of feeds are shown. In terms of the sample size, marked statistically significant differences were also produced. These permitted the conclusion that the feeding area design affected more the method of feed consumption than the total feed intake.

DeVries and Keyserlingk also investigated the use of elevated feed stalls. In this study, total feeding time per day was increased by 3 % from 328.9 min to 339.5 min [9]. Own results lay with 277.5 min and 316.1 min respectively, precisely within the range of the results from other studies for total feeding times [8; 12; 15; 17], although also below the times found by DeVries and Keyserlingk with elevated feed stalls. Because the experiment design was based on a before-after comparison, the outdoor temperatures in both trial periods were different. The average temperature of 23 °C in the before-period July/August could have caused slight heat stress symptoms with the animals. Typical for this would have been a reduced feed consumption linked to a reduction in milk yield. The total feed consump-

Fig. 2



*Total feeding time depending on the number of lactation and the milk yield (Total n = 10, before n = 5, after n = 5; p < 0.05 significant *, p < 0.01 very significant **, p < 0.001 most significant ***, p > 0.05 not significant n.s.)*

tion of the trial animals showed no significant differences. The average herd performance lay, in July/August, (before-period) at 25.8 kg and with that, 1.2 kg higher than in September/October (after-period) when it averaged 24.6 kg. From this, it can be assumed that the different temperatures in both trial periods had no relevant influence on feeding behaviour.

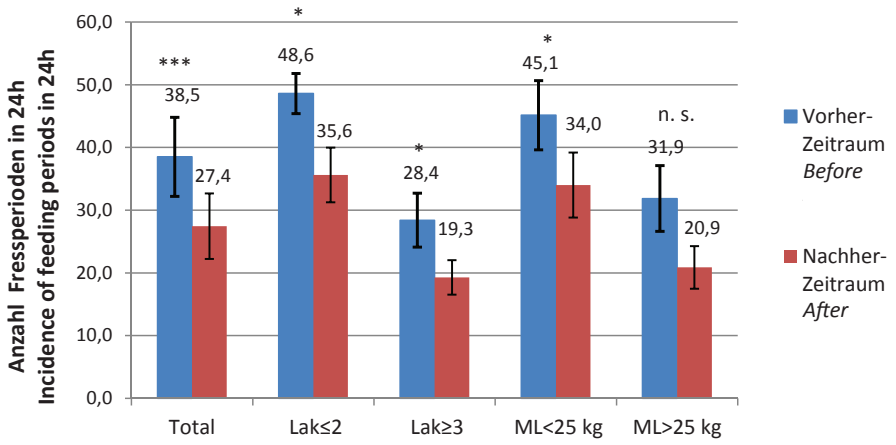
The total feeding duration varied markedly depending on the lactation number and the milk yield of the observed cows (**Figure 2**). On average, the animals with a high lactation number fed in the before-period for 277 min (SD ±61.7/VK 0.22) per day and, in the after-period, 304.5 min (±87.2/VK 0.29) per day (+10 %, p = 0.310). The cows with a lower lactation number recorded, in the before-period, an average feeding period of 278.1 min (SD ±100.4/VK 0.36) per day and in the after-period, 327.6 min (SD ±64.6/VK 0.20) per day (+18 %, p = 0.325). The animals with a high milk yield fed, in the before-period, for on average 243.3 min (SD ±95.6/VK 0.39) and in the after-period 310.0 min per day (+21 %, p = 0.077). This total feeding period is in both observation periods shorter than that of the low yield animals which, with before-period times averaging 311.6 min (SD ±42.7/VK 0.14), showed a not significant increase of 18 % (p = 0.792) to 322.1 min (SD ±71.7/VK 0.22). Hereby, it is notable that the animals with a daily milk yield of over 25 kg achieved the same total feeding time after installation of the elevated feed stalls as the animals with lower yield before the installation (**Figure 2**). However, the high coefficient of variation in the before situation for the higher yield group indicates that, in such small samples, results could be influenced by extreme values. In the after-period the values of both yield groups balance each other.

Feeding periods

Following installation of the elevated feed stalls, the animals reduced the number of their daily feeding periods highly significantly (p = 0.000) by 29 % from 38.5 periods (SD ±13.3/VK 0.35) to 27.4 periods (SD ± 11.5/VK 0.42) (**Figure 3**). The results of previous trials could hereby be confirmed [12; 13; 14]. The relatively large coefficient of variation can be explained through individual animal differences. The analyses of the average duration of a feeding period gave an increase of 8.5 min (SD ±2.6/VK 0.28) to 13.3 min (SD ±4.7/VK 0.35) per period. The difference of +57 % is highly significant (p = 0.001). References in the literature vary between 4 min [12] and 6.8 min [13] per period. However, the results from the different studies cannot be directly compared because conditions, for example with regard to animal:feeding space ratio (with Kaufmann 2 : 1) or age structure of the trial animals (mainly first and second lactation [12; 13]), deviate markedly from one another.

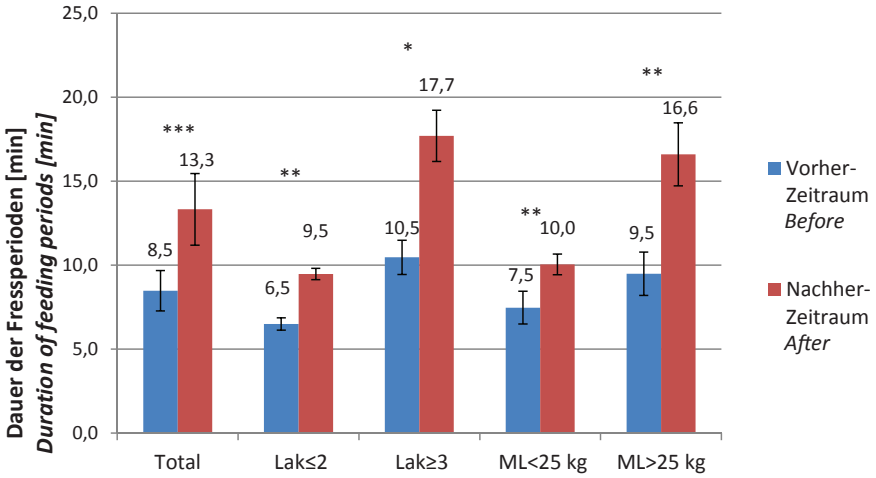
The lactation number and milk yield had a markedly pronounced influence on feeding behaviour. On average, the animals in first and second lactation before installation of the elevated feed stalls came 48.6 times (SD ±7.2/VK 0.15) daily to feed. After installation of the elevated feed stalls, they came 35.6 times (SD ±9.7/VK 0.27), a good quarter less often (-27 %, p = 0.025). The animals in third to fifth lactation fed beforehand 28.4 times (SD ±9.6/VK 0.34) daily and reduced, with 19.3 times (SD ±6.1/VK 0.32) the number of their feeding periods significantly by 32% (p = 0.011) in the after-period. The animals with high milk yield came to the feeding rail during the before-period an average 31.9 times (SD ±11.7/VK 0.37) per day and in the after-period feed visits were reduced by one third (-34 %, p = 0.006), which is significantly less often (20.9 times (SD ±7.5/VK 0.36)). On average, the animals with low milk yield in the before-period recorded 45.1 feeding periods per day (SD ±12.3/VK 0.27) and 34.0 (SD ±11.6/VK 0.34) in the after-period, one quarter (p = 0.047) less (**Figure 2**). Once the feeding period count had been significantly reduced for nearly all animal groups in the trial, it could be assumed that less crowding competition at the feeding area took place after installation of the elevated feed stalls. This assumption is supported by the low-ranking animals (≤ 2 lactations) returning the

Fig. 3



*Average number of feeding periods depending on the number of lactation and the milk yield (Total n = 10, before n = 5, after n = 5; p < 0.05 significant *, p < 0.01 very significant **, p < 0.001 most significant ***, p > 0.05 not significant n.s.)*

Fig. 4

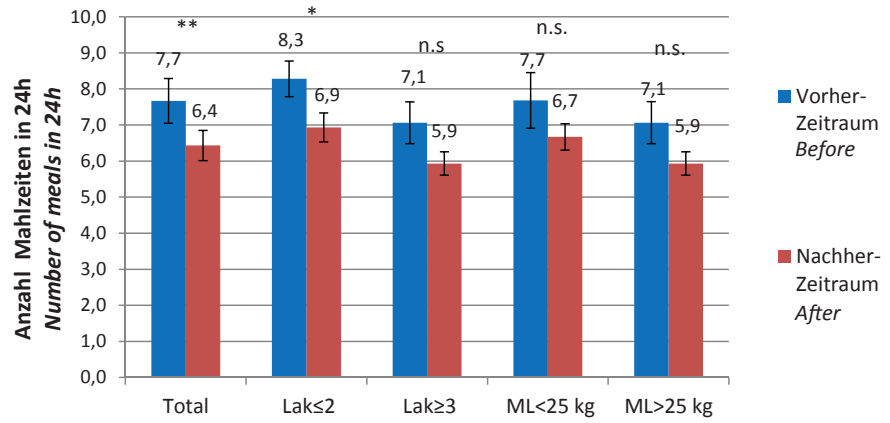


*Average duration of feeding periods depending on the number of lactation and the milk yield (Total n = 10, before n = 5, after period n = 5; p < 0.05 significant *, p < 0.01 very significant **, p < 0.001 most significant ***, p > 0.05 not significant n.s.)*

highest number of feeding periods in the before-period leading to the conclusion that they were more often crowded-out than high-ranking cows. Sorting the animals into groups with under or over 25 kg yields showed a similar picture. In total, the lower yield animals fed more often than those with higher yields, but reduced their number of feeding periods in the after-period. Also responsible for this could be a tendencially lower rank status with respect to crowding-out frequency and not the yield requirement, which would rather tend to have an effect on total feeding time. With all animal groups in this trial, the feeding period durations reduced significantly following installation of the elevated feed stalls. A feeding period in the before-period lasted, with higher lactation number animals, 10.5 min (SD ±2.3/VK 0.22) on average, in the after-period 17.7 min (SD ±3.4/VK 0.20) (-69 %, p = 0.014). The animals with a low lactation number fed, in the before-period an average 6.5 min (SD ±0.8/VK 0.12) and for 9.5 min (SD ±0.8/VK 0.08) per period in the after-period (-46 %, p = 0.001). Animals yielding under 25 kg milk in the before-period fed for an average 7.5 min (SD ±2.2/VK 0.29) and after installation of the elevated feed stalls for 10.0 min (SD ±1.4/VK 0.14) therefore 35 % (p = 0.006) longer. With the higher yielding animals the duration of the feeding periods lengthened between both trial periods from 9.5 min (SD ±2.9/VK 0.30) by 75 % (p = 0.005) to 16.6 min (SD ±4.5/VK 0.27) (**Figure 4**). The altering of the feeding behaviour is markedly more pronounced for the higher yield and higher lactation number animals. With the increasing of their feeding period durations following installation of the elevated feed stalls the lower lactation number and yield animals achieved, however, roughly the starting situation of the animals with higher lactation number and yield.

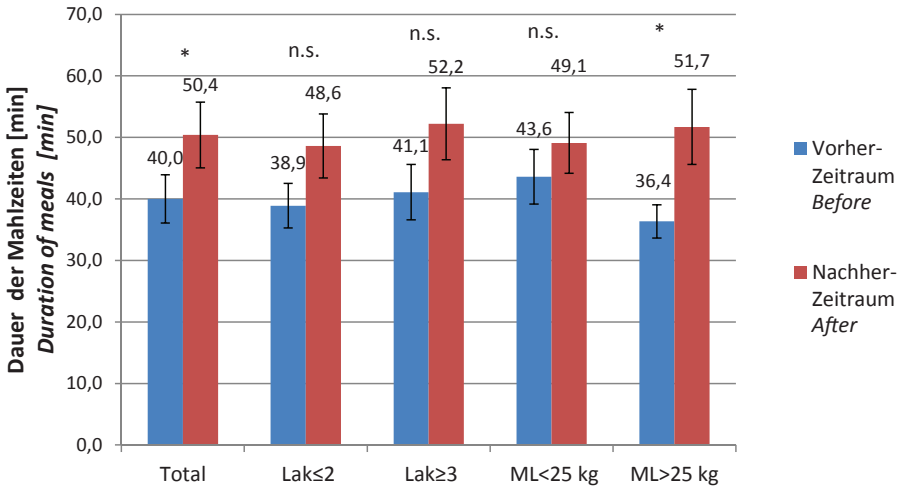
Elevated feed stalls were developed to permit undisturbed feeding. The reduction in the number of feeding periods after installation of the elevated feed stalls goes together with a lengthening of the individual feeding period duration. This result permits the conclusion that the animals are less often disturbed during feeding. Other studies have already shown that antagonistic behaviour in the feeding area occurs less often where elevated feed stalls with separation rails are used [9; 10]. Additionally, the separation rails encourage the ani-

Fig. 5



*Average number of meals depending on the number of lactation and the milk yield (Total n = 10, before n = 5, after n = 5; p < 0.05 significant *, p < 0.01 very significant **, p < 0.001 most significant ***, p > 0.05 not significant n.s.)*

Fig. 6



*Average duration of meals depending on the number of lactation and the milk yield (Total n = 10, before n =5, after n = 5; p < 0.05 significant *, p < 0.01 very significant **, p < 0.001 most significant ***, p > 0.05 not significant n.s.)*

mals to stand straight in the feed stalls. This side effect is relevant to hoof health, reducing degree of dirtiness on the stall flooring [10].

Feeds

The daily feed consumption is structured by cows into 7.1 to 8.8 feeds [15; 10; 12]. In the investigation reported here, the number of feeds were significantly reduced by 16% (p = 0.004) from 7.7 (SD ±1.3/VK 0.17) to 6.4 (SD ±0.9/VK 0.14). Notable was, that the coefficient of variation of the number of feeds was significantly smaller as the coefficient of variation for number of feeding periods. Thus, the feeding periods varied more strongly than the feeds. A feed comprises several feeding periods and accordingly the number of feeds is less influenced by individual animal differences than the duration of individual feeding periods within a feed. The average duration of a feed increased significantly by 26 % (p = 0.044) from 40.0 min (SD ±8.7/VK 0.22) to 50.4 min (SD ±11.8/VK 0.23). From other studies, it has been shown that a feed lasts for between 21 and 47 min [11; 16]. The duration of feeds in the study reported here lay in the upper region of the given range. Possibly contributing to this result, alongside individual animal differences, are conditions on the farm where the trial was carried out, for example composition of part-mixed ration, or effects from the reduced animal:feeding space ratio.

All the animal groups investigated recorded, following installation of the elevated feed stalls, a reduced number of feeds which, however, lengthened in their individual duration (**Figure 5** and **6**).

Animals with lower lactation numbers reduced their feed count significantly (p = 0.020) from 8.3 (SD ±1.1/VK 0.13) to 6.9 (SD ±0.9/VK 0. 13). The cows with higher lactation numbers showed, with 7.1 feeds (SD ±1.3/VK 0.18) in before-period and 5.9 feeds (SD ±0.7/VK 0.12) in the after-period, only a slight trend (p = 0.115) towards reduction. Cows with lower yield fed at the original feeding area with 7.7 feeds (SD ±1.7/VK 0.22) and after installation of the elevated feed stalls with 6.7 feeds (SD ±0.8/VK 0.12), (p = 0.162). With the higher yielding animals the reduction in feeds from 7.7 (SD ±0.9/VK 0.12) to 6.2 (SD ±1.1/VK 0.17) was significant (p = 0.006).

On the basis of the feeds it was demonstrated that, independently from feeding place design, there were differences between the animal groups. Animals with higher lactation number and milk yield fed less often within both trial periods, but over longer feeds and showed a higher total feeding time.

Conclusions

In loose-housing barns, a key role is played by the feeding place. Unrestricted feed consumption is the requirement for a functioning metabolism and performance capability of the high yielding cow. The design of the feeding area with separation rails creates defined feeding places and reduces mutual crowding-out [10]. Additionally, the elevated stances for the animals help prevent, even with hourly working of the dung scraper, not only interruption of the feeding process but also intensive contact of hooves with dung in the feeding area.

Through installation of elevated feed stalls in the trial farm, the number of feeding periods (-29 %) as well as the feeds themselves (-16 %) were significantly reduced, while the length of a feeding period (+57 %) or of a feed (+25 %) significantly increased. The increase in total duration of feeding (+15 %) was not significant, but did indicate a clear trend. Where forced interruption of feed consumption by a cow in connection with changing of feeding space or leaving the feeding area occurs, this is not only to be seen critically under the aspect of a breakdown in unrestricted feed consumption. Excretion in the feeding area at 70 % is the highest [7] in the barn. The more often the feeding passage has to be frequented through interruptions in feeding, the more intensive the mechanical, chemical and bacterial stress action on cows' hooves. Hoof hygiene is subject to a target conflict in the feeding area. On the one hand, regular cleaning is necessary in this area. On the other hand, the action of the scraper leads to disturbances in the feeding process when scraping takes place within two hours of feed presentation [2]. Following installation of the elevated feed stalls on the trial farm, frequency of dung scraper passes could be increased towards optimising hoof hygiene. This action caused no apparent negative effects on the feeding cows. The number of feeding periods and feeds were reduced but their individual duration increased.

Increasing the height of the feeding place floor compared with the level of the feeding passage and inserting feeding place separation in the trial reported here led to markedly quieter feeding behaviour. Especially notably were, hereby, the differences between the animals based on lactation number. These were able to be especially clearly defined in the trial farm through the restricted animal: eating space ratio.

A positive influence of undisturbed feeding on welfare, metabolism and hoof health of animals is clearly necessary from both an ethological and nutrition-physiological standpoint and should be further researched. In addition to this, it would be interesting to observe to what extent a possibly increased total feeding time effects total feed intake and performance parameters.

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