Effects of introducing weaned heifers to freestall housing on growth performance and behavior

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Research Article

Keywords: housing, heifers, behavior, freestalls, bedded-pack

Posted Date: June 9th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-600940/v1

Abstract

This study evaluated the effects of two housing types (freestalls vs. bedded-pack) on growth performance and behavior of weaned heifers, with no previous experience with freestalls. Heifers (12 heifers/ treatment) were randomly assigned to each treatment at d 80 ± 3 of age. Heifers had free access to diets and water throughout the experiment. The ADG, structural growth, and final body weight were not affected by the housing type. Also, there was no difference in overall DMI between treatments, but the freestall-housed heifers had greater DMI than those housed in bedded-pack during the last 5 d of the study. There were no differences in any behavioral patterns of drinking, standing, and lying time between heifers housed in freestalls than those housed in bedded-pack. The lengths of rumination bouts were less for freestall-housed heifers than those housed in bedded-pack on day 110. Heifers spent less time lying in the freestalls on day 85 compared to day 110 when they get accustomed to using freestall housing. In summary, our results indicate that the growth performance of weaned heifers were not affected by housing type; however, housing heifers in fresstalls can prepare them for using the freestalls facility for a short period.

Introduction

Dairy heifers reared individually or in groups are usually transferred to new housing after weaning. In the period following weaning, different housing management styles such as group housing in a barn, or dry-lot and pasture housing were represented to dairy heifer replacement [1,2]. The freestall barn is considered an appropriate housing as it provides a dry, clean, and comfortable resting area for weaned heifers [3,4]. Another advantage of using freestall housing instead of bedded-pack housing is to reduce the cost of bedding and labor [5,6]. However, adaptation and use of freestalls could be challenging for heifers with no prior experience.

Freestall housing is an issue even in mature heifers and cows. The average rate of stall refusal by dairy cows is about 6% ranging between 0 to 55% on commercial dairy farms in Norway [7]. Further, it has been reported that dairy heifers refuse to lay in the stall when they were introduced to the freestall housing [8,9]. Refusing to use stalls by cows and heifers increases standing time and lying events in the alley; therefore, reducing resting time and increases the risk of lameness and mammary gland infection [10–13]. Lying in the alley could also increase the labor associated with cleaning the udders before milking [8].

Few studies have investigated methods of improving heifer adaptation to freestalls. O'Connell et al. reported that heifers with previous experience of freestalls after weaning had significantly higher total percentage occupancy (lying and standing) per freestalls than those with no experience when they introduced to the main herd [14]. von Keyserlingk et al. has shown that the transitioning dairy heifers at 5 months of age from a bedded-pack housing to a freestall housing has increased time spent down on the barn floor (i.e., outside the lying area), standing idle time, but decreased lying times on the day heifers were moved to the freestall pen [4].

There is a paucity of studies evaluating the effect of housing type after weaning on the growth performance and behavior of dairy heifers. Therefore, the objective of this study was to assess differences between freestall and bedded-pack for feed intake, growth rate, and behavior over the next 4 wk. We hypothesized that housing type would not differ performance and behavior outcomes of dairy heifers during the month-long observation period.

Results

Intake and Growth Performance. The experimental area for both bedded-pack and freestall housing is illustrated in Fig. 1. The ingredient and nutrient composition of the TMR offered to heifers is given in Table 1. Housing conditions did not affect overall DMI in the study (Table 2). However, an interaction between housing type and heifer age was significant for DMI (Fig. 2). The DM intake of heifers was similar between treatments from 80 to 104 d, but freestall-housed heifers consumed more feed than those housed in bedded-pack during the last 5 d of the experiment. The greater DMI during the final d of the experiment was in line with eating time results on day 110 that freestall-housed heifers tended to spend more time eating than those in bedded-pack (Table 3). Hurnik, found that comfortable resting stimulates feed intake [15]. In our study, the usage of freestall by the heifers was increased toward the end of the study and therefore it is plausible to suggest that this adaptation might have improved the comfort and their intake of the heifers. Previously, Bewley et al. reported that 53% of producers who changed to freestall housing in Wisconsin were satisfied with the improvement of the animal performance, including feed intake [3]. The ADG, final BW, and structural growth parameters were not affected by the type of housing (Table 2).

Table 1
Ingredients and chemical composition of the experimental diet.

Item	Total mixed ration
Ingredient (g/kg of DM)	
Alfalfa hay	237
Corn silage	143
Beet pulp	47.0
Corn grain	223.5
Barley grain	126
Soybean meal (44% CP)	80.0
Wheat bran	49.8
Calcium carbonate	6.80
Sodium bicarbonate	3.40
Vitamin premix1	5.70
mineral premix1	5.70
Chemical composition	
Dry matter, % of DM	54.0 ± 1.72
Crude protein, % of DM	17.0 ± 0.45
NDF, % of DM	27.7 ± 0.82
ADF, % of DM	16.4 ± 0.97
Ether extract, % of DM	2.70 ± 0.32
Ash, % of DM	2.45 ± 0.23
Metabolizable energy, Mcal/kg	2.14

1Premix contained (mg/kg) calcium (80,000), phosphorus (8,000), magnesium (10,000), copper (1,000), manganese (1,800), zinc (3,520), cobalt (12), iodine (28), selenium (17) as well as vitamin A (300 KIU/kg), vitamin D (80 KIU/kg) and vitamin E (6 KIU/kg) on a DM basis.

Table 2
Effect of type of housing (freestalls versus bedded-pack) on body weight (BW), dry matter intake (DMI), average daily gain (ADG) and structural growth of dairy heifers

Item	Housing type		SEM	P-value
	Freestall	Bedded-pack		
Initial BW, kg (d 80)	88.5	88.2	1.25	0.89
Final BW, kg (day 110)	117	115	0.80	0.24
DMI*, g/d	2965	2935	27.1	0.81
ADG, g/d	1090	1041	53.2	0.55
Initial body length, cm (d 80)	53.4	52.3	0.94	0.46
Final body length, cm (day 110)	57.1	55.8	1.00	0.41
Initial hip-width, cm (d 80)	26.1	25.7	0.36	0.51
Final hip-width, cm (day 110)	28.1	28.2	0.41	0.80
Initial wither-height, cm (d 80)	94.0	93.7	1.12	0.88
Final wither height, cm (day 110)	98.2	99.2	1.02	0.41

Table 3
Effect of type of housing (freestalls versus bedded-pack) on behaviors of dairy heifers at the beginning (d 85) and end (day 110) of the experiment

Item	Housing type		SEM	*P*-value
	Freestall	Bedded-pack		
Initial eating, 85 day				
Time, min/22 h	262	296	25.5	0.40
Final eating, 110 day				
Time, min/22 h	364	285	23.1	0.07
Initial drinking, 85 day				
Time, min/22 h	7.92	16.7	3.33	0.15
Bout length, min/bout	4.58	4.72	1.02	0.17
Bout interval, min	157	249	95.3	0.51
Final drinking, 110 day				
Time, min/22 h	15.4	13.7	3.89	0.77
Bout length, min/bout	4.89	4.79	0.76	0.30
Bout interval, min	190	416	165	0.19
Initial ruminating, 85 day				
Time, min/22 h	336	293	25.1	0.29
Bout length, min/bout	26.7	24.2	0.96	0.14
Bout interval, min	78.0	84.3	10.0	0.68
Final ruminating, 110 day				
Time, min/22 h	315	377	20.5	0.10
Bout length, min/bout	28.4	36.2	2.03	**0.05**
Bout interval, min	84.0	90.1	8.94	0.65
Initial standing, 85 day				
Time, min/22 h	258	253	33.7	0.90
Bout length, min/bout	11.1	11.9	0.56	0.37
Bout interval, min	41.3	51.8	6.33	0.32
Final standing, 110 day				

Item	Housing type		SEM	*P*-value
	Freestall	**Bedded-pack**		
Time, min/22 h	192	211	19.4	0.52
Bout length, min/bout	9.63	11.9	0.79	0.11
Bout interval, min	60.1	65.7	4.55	0.43
Initial lying, 85 day				
Time, min/22 h	460	467	21.9	0.85
Bout length, min/bout	19.9	22.1	2.32	0.55
Bout interval, min	36.3	36.9	3.36	0.90
Final lying, 110 day				
Time, min/22 h	439	438	28.4	0.98
Bout length, min/bout	25.8	24.5	2.90	0.76
Bout interval, min	49.1	45.8	3.68	0.63

Behavioral parameters. Behavioral parameters of heifers in the freestalls and bedded-pack at the beginning (85 day of age) and end (day 110 day of age) of the experiment are presented in Table 3. Also, the difference for comparisons of the time of behaviors from 85 to 110 day (Fig. 3; A, B) showed that the eating, drinking, ruminating, standing, and lying behaviors in heifers housed in bedded-pack did not change from d 85 to 110, but freestall-housed heifers increased their eating ($P = 0.02$) and decreased standing ($P = 0.03$) activities on 110 day than on day 85. To our knowledge, there has been limited previous work examined the impacts of housing type on the behavior of weaned-heifers.

Drinking and eating behaviors. On day 85 and day 110, no differences were observed between the housing types for the time, length, and interval of drinking bouts. Also, no differences were observed between the housing types for the eating time on day 85. However, freestall-housed heifers tended to have higher eating time (79.0 min/22 h; $P = 0.02$) than those housed in bedded-pack on day 110, which is in line with DMI during the last d of the study (based on only two time-points). Also, freestall-housed heifers tended to increase their time spent drinking ($P = 0.09$) on day 110 than 85 (Fig. 3, B). In the face of any change in environmental conditions, the animal needs a period to investigate habituation and respond appropriately to the new environment [16]. Also, group activities and socialization helped the animal to learn faster [17], so they spend more time eating and drinking water as they get used to housing.

Rumination behavior. No differences were noted between the housing types for time (min/22h) and interval of rumination bouts on day 85 and 110; however, freestall-housed heifers have lower lengths of rumination bouts (-7.8 min/bout; $P = 0.05$) than those housed in bedded-pack on day 110.

The diurnal rumination pattern within 22 h is presented in Fig. 4A, B. Our results indicated that the highest rumination was during midnight (0100 to 0400 h; 28 min/1 h) on day 85. While on day 110 of age, freestall-housed heifers ruminate more evenly at 22 h, but in some hours this behavior was minimized (1300, 1400, 2100, and 0300 h; 6 min/1 h). Other works reported rumination continues throughout the day, but it is more likely to occur at night [18–20] and to some extent during the afternoon when cows are at rest [21,22]. Hafez showed that the peak period of rumination was shortly after the fall of night and thereafter declined steadily and it increased again in the dawn [23]. The rumination of freestall-housed heifers in the stall was more than standing rumination or out of the stall ruminating at the 85 and 110 days. Generally, at the end of the study (110 day) ruminating in the stall increased (from 79.8–94.3%) and rumination out of the stall and standing rumination decreased (from 12.9–2.26% and from 7.32–3.43%; respectively). This change can be due to the adaptation of heifers to use freestall housing.

Lying and standing behavior. There were no differences in any behavioral patterns of lying (lying time, the interval of lying bouts, and lengths of the lying bouts) between heifers housed in free stalls than those housed in bedded-pack on day 85 and 110. Also, no differences were noted between the housing types for total standing time, lengths of standing, and interval of standing bouts on day 85 and 110. Previously, von Keyserlingk et al. reported a decrease in lying times when heifers were first moved from the bedded-pack barn to free stalls (from 14.2 h/ d to 2.9 h/ d) but recovered on the following day [4]. It has been shown that the lack of cow comfort is evident when cows reduce their lying time and spend more time standing idle [24].

The diurnal pattern of lying was reported in Fig. 5A-B. The mean daily duration of time spent lying down is around 20.9 min/ 1 h but varies among heifers from a minimum of 7 min/ 1 h to a maximum of 40 min/ 1 h. Time spent lying varies over the day, with a peak at night (from 2000 to 0000 on day 85; an average of 32 min/ 1 h, and 0100 to 0300 h on day 110 of the study; an average of 30 min/ 1 h). Winckler et al. found that cows lie down during the day as well as during the night, but the majority of their time lying down occurs during the night [25]. Several studies have examined the times of day that cows lie down and have found that they spend most of their lying time at night and very early in the morning hours [17,26].

More lying times are associated with more comfortable housing types for dairy cattle [24]. Pervious study showed that lying times in the free stalls were higher than open housing systems, but other works have found higher-lying times in open designs such as straw yards and sand packs than in freestall housing 27–30. In this study, although the lying time (length, interval, and total time spent for lying) was not different by the type of housing on day 85 and 110 (Table 3); however, as shown in Fig. 6, the lying form of freestall-housed heifers was different. Heifers on 85 and 110 days of the age preferred to lie in the stall rather than lying outside the stall, and the amount of lying outside the stall decreased on day 110 (Fig. 6). The time spent lying out of the stall decreased (from 26–3% of the total lying activity) and the time spent lying in the stall increased (from 74–97% of the total lying activity) from the beginning (85 day) to the end of the experiment (110 day). This result indicates that the heifers soon became accustomed to the freestall housing. Because it is found that recording lying behavior provides information about how cows interact with their environment [31,32]. The results of the present study are in line with the findings of Magsi et al. who reported that lying in free stalls increased from 13% on d 2 to ≥ 90% on d 22 after the buffaloes were introduced to free stalls [13]. Kjæstad and Myren also observed that during the first few days that cows are introduced to the freestalls, they have the highest freestalls refusal [7]. Lying outside the stall can increase the animal's contamination with urine and feces, reduce the animal's hygiene, and increase the risk of intramammary infections and mastitis [12,33].

Under the conditions of this experiment, our results indicate that the growth performance (ADG and skeletal growth), and behavior activities of weaned heifers were not affected by housing type; however, housing heifers in free stalls can prepare them for using the freestalls facility at the short period. Dairy heifers can be kept in the bedded pack or freestall housing after weaning without different effects on their performance and behavior.

Materials And Methods

Heifers, Housing, and Experimental Design. The experiment was conducted in 2019 at a commercial dairy farm (Fazil, Isfahan, Iran). Ethical approval for all procedures involving animals was obtained from the by Animal Care and Use Committee of Isfahan University of Technology (IACUC # 2018824) prior to study onset. All methods were carried out in accordance with Iranian Council of Animal Care regulations and the study complies with the ARRIVE guidelines for reporting in vivo experiments.

Dairy heifers with no history of antibiotic treatment for score (diarrhea) and pneumonia were used in this study. Dairy heifers were in individual hutches (1.5 × 2 m) from birth to d 80 ± 3 of age. Then, dairy heifers (12 heifers/ treatment) were randomly assigned to each treatment at d 80 ± 3 of age (85.3 ± 2.0 kg of BW; mean ± SD). Treatments were: 1) heifers housed in freestalls (5 freestalls in a 4.0 × 5.0 m; 3 pens of 4 heifers /treatment) and 2) heifers housed in bedded-pack (4.0 × 5.0 m; 3 pens of 4 heifers /treatment). The bedded-pack and inside of the freestalls were bedded with straw and completely replaced every 48 h. Animals were fed water from water trough (0.15 × 0.8 × 0.25 m width, length, height respectively) and total mixed ration (TMR) from feed bunk (0.35 × 1.5 × 0.15 m width, length, height respectively) that was accessible from the feed alley. All heifers had free access to diets and clean drinking water during the experimental period. The experimental diets were prepared as TMR and offered once daily at 0800 h in amounts that allowed 5 to 10% refusal. The study was ended with the 110th day of calf age. All animals were under the regular supervision of a veterinarian.

Sampling and Measurements. Samples of TMR and feed orts were collected every week and were frozen at − 18°C for chemical analysis. Dry matter (DM) of samples was determined by oven-drying for 48 h at 65°C, samples were then ground through a 1-mm screen using a Willey mill (Arthur Thomas Co., Philadelphia, PA, USA). The ground samples were analyzed for crude protein using the Kjeldahl (method 955.04)[34], ether extract (method 920.39) [34], and ash (method 942.05)[34]. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined with the methods described by Van Soest et al. using heat-stable α-amylase [35]. Feed intake was measured every morning (0800 h) at the pen level, based on offered and refused quantities of feed. Heifers were weighed at the same time at the start (d 80 of age) and end (day 110 of age) of the study using an electronic balance. Average daily gain (ADG, kg of BW/d) was calculated at the end of the experiment at the individual level.

Body measurements including hip-width (distance between the points of hook bones), withers height (distance from the base of the front feet to the withers), and body-length (distance between the points of shoulder and rump) were taken at the initiation (d 80) and the end (day 110 of age) of the trial according to the method described by Khan et al. [36].

Behavior. Behavioral activity is used as an indication of animal welfare and comfort (Haley et al., 2001). Behavioral data including eating (head in trough accompanied ingesting TMR), drinking (mouth inside trough water), standing (standing with all four feet on the ground or standing with just 2 hooves in the bedded area without any purposeful activity), ruminating (irregular, repetitive chewing without discernible food in the mouth either lying or standing), and lying (lying on flank or sternum with head held in a raised position or down on the bedded area or out of the stall, without rumination) were monitored over 2 periods of 22 h (between 0800 and 0600 h) on day 85 and 110 as previously described previously [9,37]. Behavioral activities of the heifers were recorded by 2 trained observers from a distance of 2–3 m, and every effort was made not to disturb the heifers in any way. All activities were noted every 5 min and each activity was assumed to persist for the entire 5-min interval between observations. A period of ruminating was defined as at least 1 observation of ruminating activity occurring after at least 5 min without ruminating. The bout duration (min/meal) of ruminating was calculated as the time from the beginning of the first ruminating event until an interval between events and averaged for each heifer. Intervals (min) between ruminating events were calculated from the end of a rumination event to the beginning of the next and averaged for each heifer. The same procedure was used to compute the other behaviors (eating, drinking, standing, and lying) pattern.

Data analysis and statistics. Before analyses, all data were screened for normality using the UNIVARIATE procedure of SAS. Data that were not normally distributed were transformed logarithmically. The effect of housing type (freestalls and bedded-pack) on DMI was tested by obtaining the mean value of the pen (based on the mean of the 4 heifers per pen in the treatment) on each experimental day. Intake data were analyzed using the MIXED procedure of SAS (SAS 9.4, SAS Institute Inc., Cary, NC) as completely randomized designs. The model consisted of treatment (housing type), time (day), and respective interactions as fixed effects, and pens (experimental units) as a random effect using pen-based statistical models described by St-Pierre [38]. For DMI, time (day) was a repeated measure using an autoregressive type 1 covariance structure assisted by the lowest Bayesian's information criterion (fit statistic) level.

Power analysis for sample size estimation was performed for ADG based on previously published values [39–41]. From the power test analysis, using $\alpha = 0.05$ and power = 0.80, biologically relevant treatment differences for growth performance could be detected with the target sample size. Data for BW, ADG, growth measurements and behavior [time (min/22 h), bout length (min/bout), bout interval (min)] were obtained from each individual calf and were analyzed using the MIXED procedure of SAS. The model consisted of treatment (housing type) as fixed effect, and pen nested within treatment as random effects. Significance among treatments was tested using ANOVA. The threshold of significance was set at $P \leq 0.05$; trends were declared at $0.05 < P \leq 0.10$.

Further, the effect of time (day 110 vs. d 85) for eating, drinking, ruminating, standing, and lying were statistically analyzed with estimation methods using a paired t-test and presented as paired mean difference estimation plots [42]. Effect size was measured using paired Hedges' g (Greenland et al., 2016) and were referred to as trivial ($|g| < 0.2$), small ($0.2 < |g| < 0.5$), moderate ($0.5 < |g| < 0.8$), or large ($|g| > 0.8$), as per standard practice.

Declarations

Acknowledgments

Appreciation is extended to the staff at the Fazil Dairy Farm (Isfahan, Iran). Thanks to Hamidreza Faghri, Mohammad Mirzaei, Mojtaba Aliakbari, and Ali Nargeskhani (Managers of Fazil Dairy Farm, Isfahan, Iran) for helping to conduct this experiment. The authors confirm that there are no recognized conflicts of interest associated with this publication and there has been no financial support for this work that could have influenced its outcome.

Author Contributions

M. Akbarian-Tefaghi, F. Ahmadi, and M. H. Ghaffari designed the study. M. Akbarian-Tefaghi, performed the farm trial. F. Ahmadi, and M. H. Ghaffari did data analysis and visualization. M. Akbarian-Tefaghi and F. Ahmadi, wrote the original draft. M. Akbarian-Tefaghi, F. Ahmadi, and M. H. Ghaffari revised the manuscript.

Competing Interests: The authors declare that they have no competing interests.

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Figures

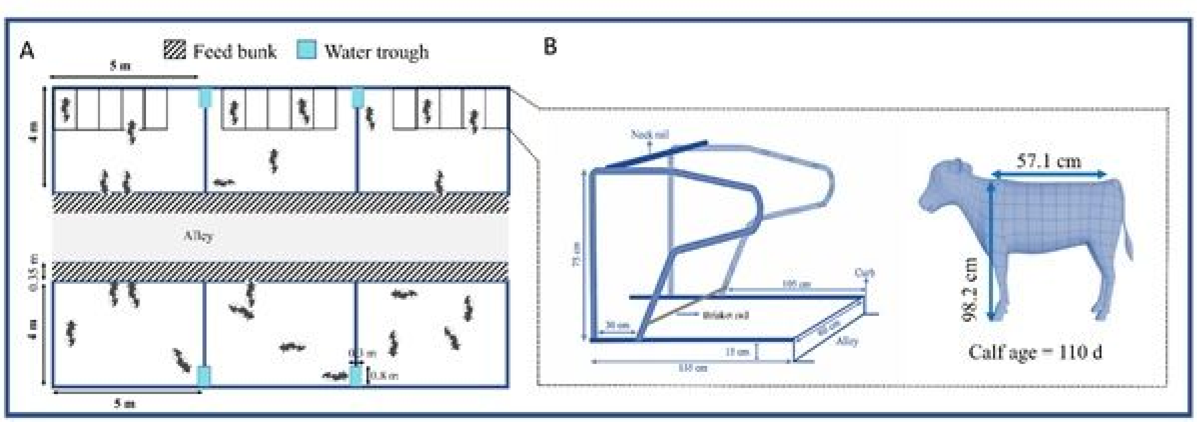


Figure 1

(A) Layout of nursery pens of heifers randomly assigned to 1 of 2 treatments: bedded-pack housing or freestall housing. (B) Dimensions of the different parts of freestalls design as well as body length and wither height of heifers at the age of 110 day.

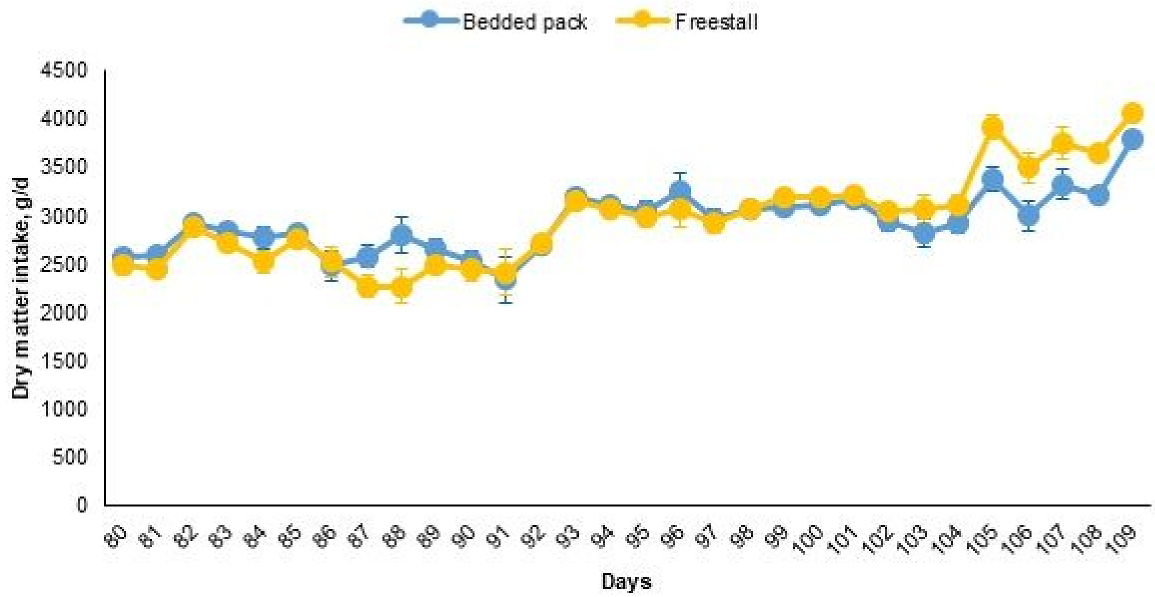


Figure 2

Dry matter intake in heifers with bedded-pack housing or freestall housing during the experiment. Symbols indicate a difference (*P < 0.05) between the groups at a given time. Data are presented as means ± SEM.

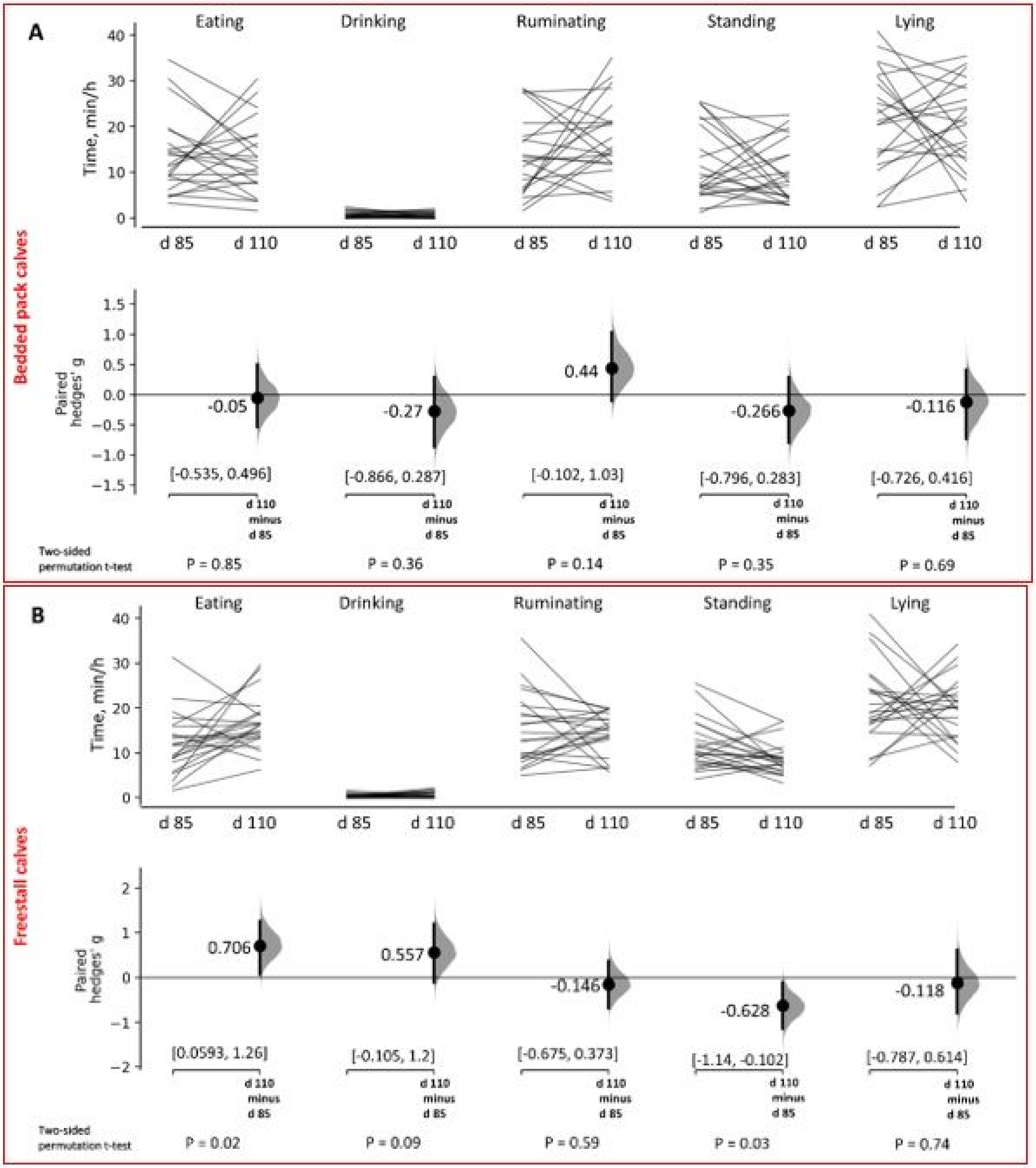


Figure 3

The paired mean difference for comparisons of the time spent eating, drinking, ruminating, standing and lying on day 110 vs. d 85 for A) bedded-pack and (B) freestalls are shown in the above Cumming estimation plot. The raw data is plotted on the upper axes; each paired set of observations is connected by a line. On the lower axes, each paired mean difference is plotted as a bootstrap sampling distribution. Mean differences are depicted as dots; 95% confidence intervals are indicated in the plot. For each permutation P-value, 5000 reshuffles of d 85 and day 110 were performed.

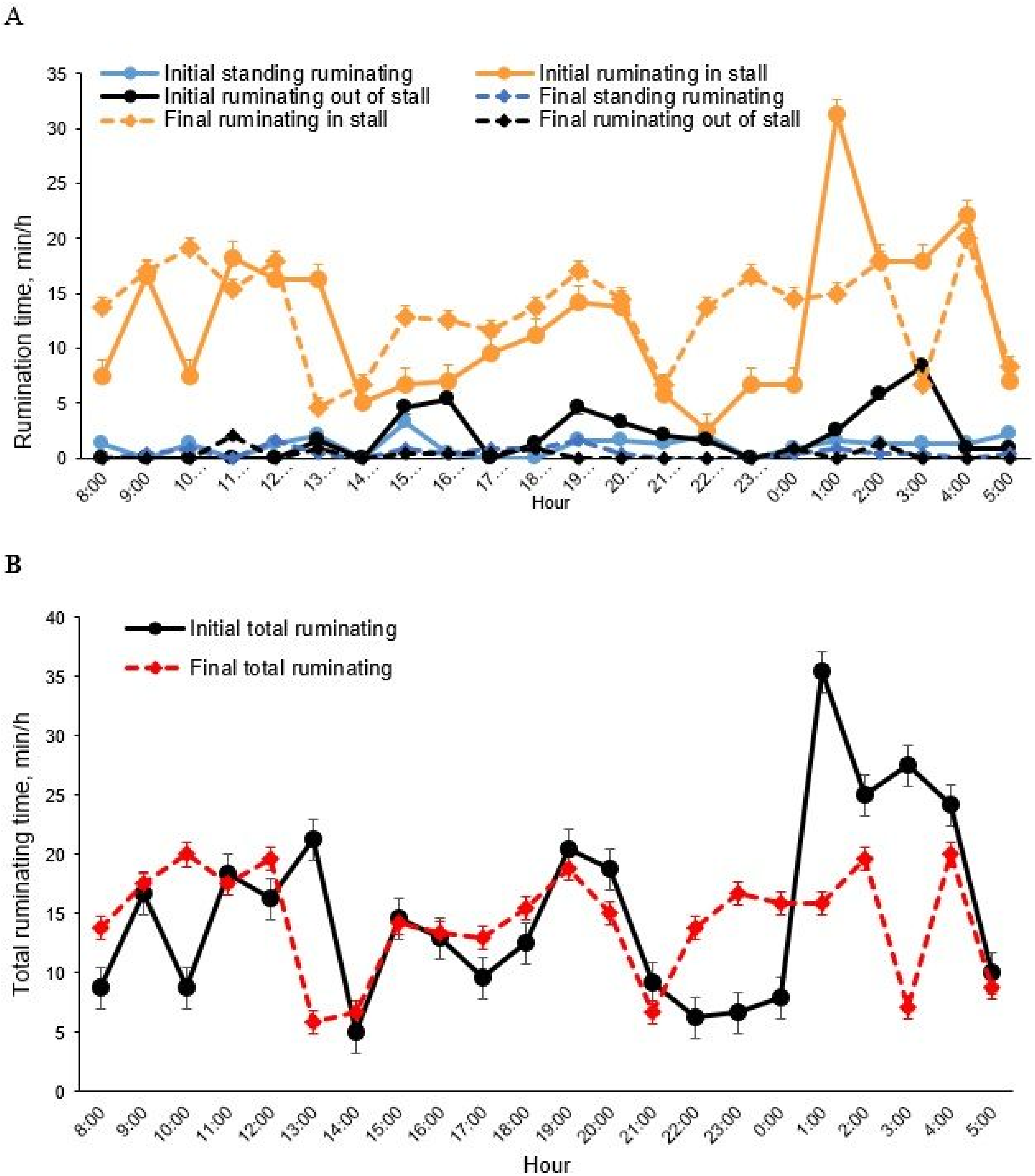
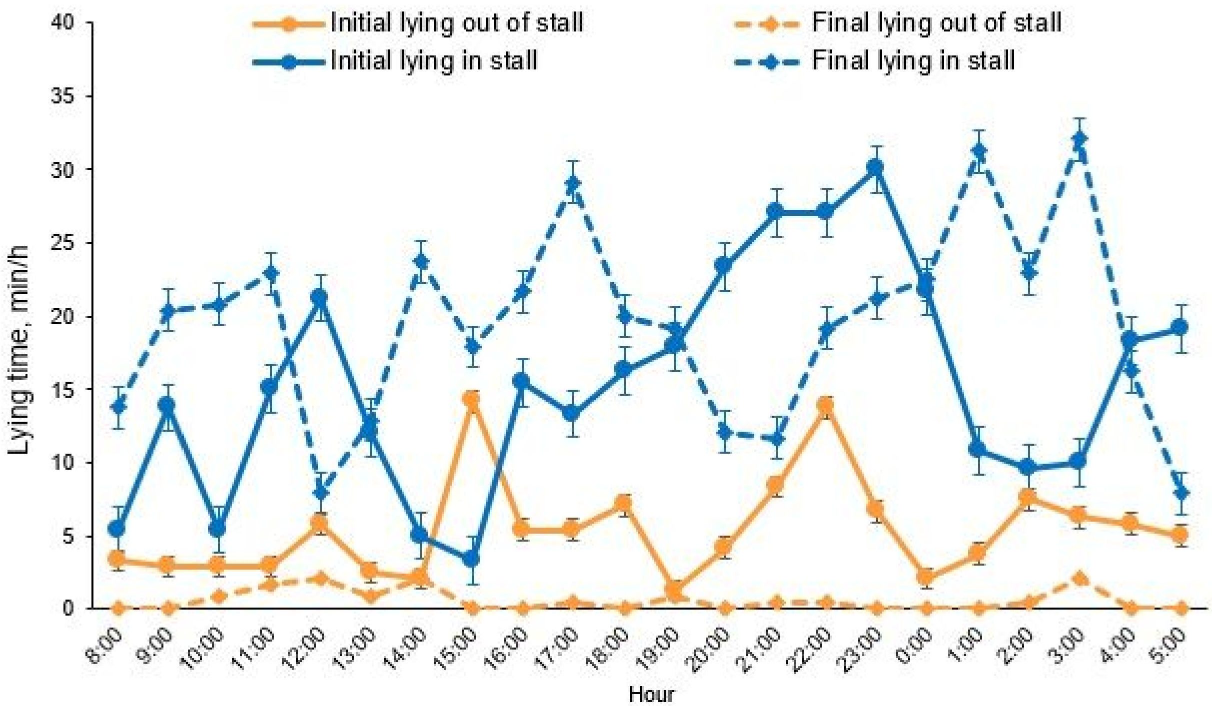


Figure 4

Average ruminating time (min/1 h; means ± SEM) with different position (in the stall, out of stall and standing; a) and total ruminating (min/1 h; b) for freestalls heifers over a 22-h period (from 0800 h until 0500 h) during initial (85 day) and final period (110 day). Averages were calculated for each heifer at each 22 h time point. Data are presented as means ± SEM.

A



B

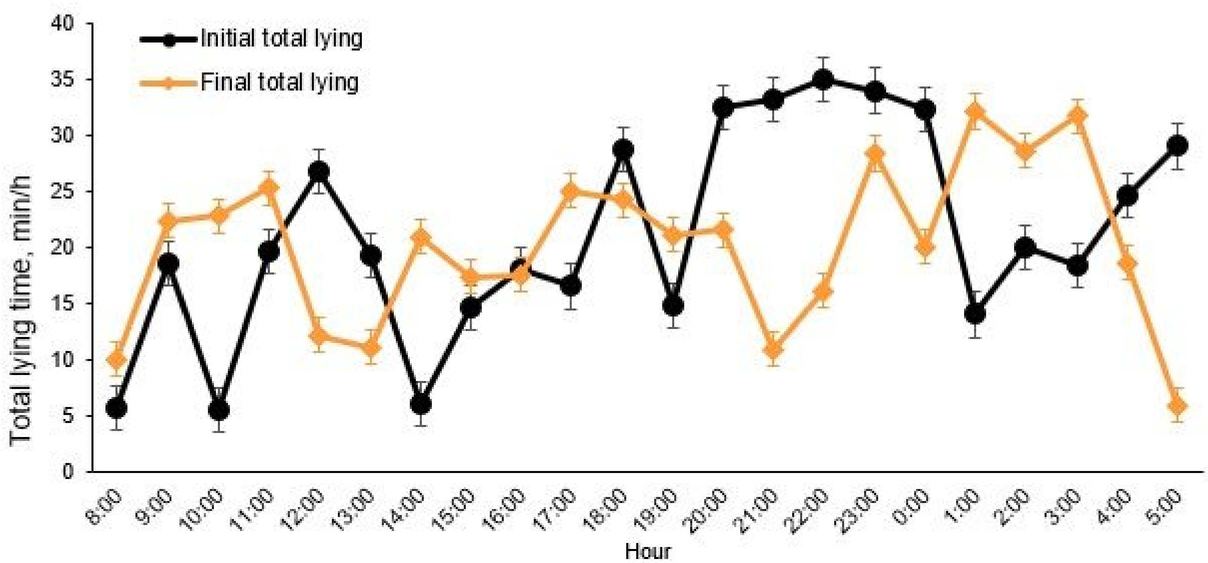


Figure 5

Average lying time (min/1 h; means ± SEM) with different position (in the stall and out of the stall; a) and total lying (min/1 h; b) for freestalls heifers over a 22-h period (from 0800 h until 0500 h) during initial (85 day) and final period (110 day). Averages were calculated for each heifer at each 22 h time point. Data are presented as means ± SEM.

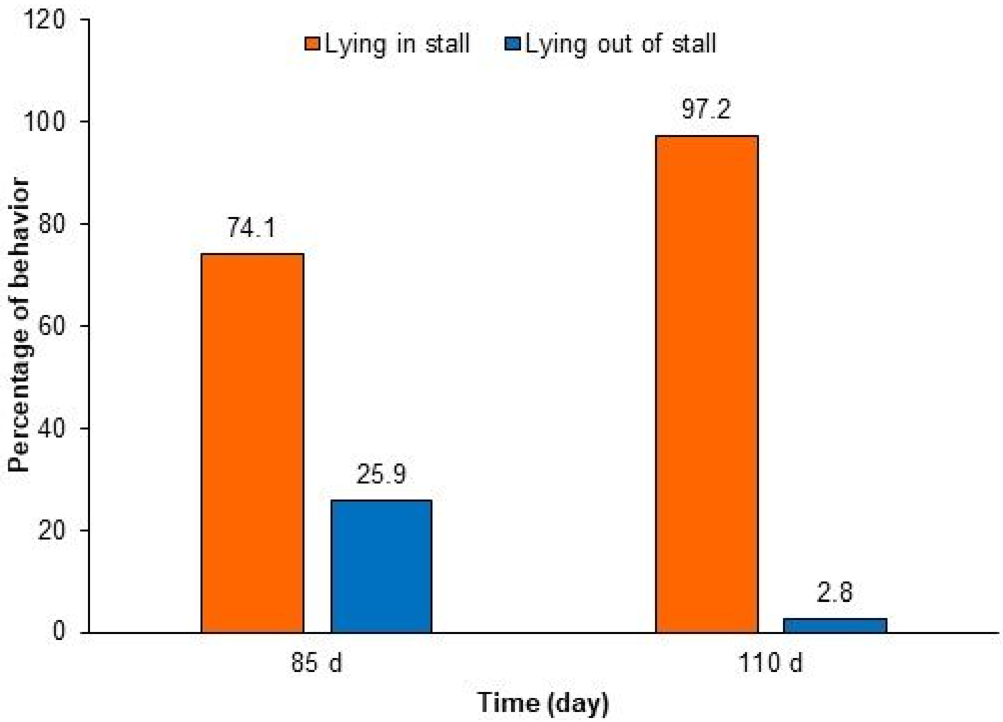


Figure 6

percentage of lying in the stall and lying out of stall in freestalls heifers during 22 h on day 85 and 110.