

Assessing cubicle dimensions for finishing bulls based on animal behaviour and cleanliness

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Abstract

Finishing bulls need increasingly large cubicles throughout their growth, and optimal cubicle dimensions may differ from those used for dairy cows. The space requirements of finishing bulls was investigated by observing standing-up and lying-down behaviour, lying duration and number of lying bouts, as well as the cleanliness of cubicles and animals before and after increasing cubicle size at four different points in time. Lying area in the cubicles measured 120 × 70 cm at the start and 185 × 110 cm at the end of the finishing period (approx. at 160 and 550 kg, respectively). Twenty animals kept in four groups were observed at weights of approximately 220, 330, 380 and 500 kg before and after cubicle dimensions were increased. The proportion of standing-up events with more than one head lunge decreased with enlargement of the cubicles ($P = 0.01$). As cubicle size increased, bulls hit the partition rails less on standing up, except at 220 kg weight where the pattern was inverted (interaction: $P = 0.001$). Partitions were also hit less on lying down as cubicle size increased, except at 220 kg weight with an inverse pattern (interaction: $P = 0.01$). The number of exploratory head sweeps before lying down did not change with cubicle enlargement ($P > 0.5$). Bulls slipped more often with cubicle enlargement, except at 380 kg where the difference was inverted (interaction: $P = 0.03$). They never fell and never turned around in the cubicles. In general, both animals and cubicles were very clean. On average, lying duration decreased ($P < 0.01$) while the number of lying bouts tended to increase ($P = 0.052$) with enlargement of the cubicles but the absolute differences were small. Consequently at each point in time, the smaller cubicles still seemed to provide sufficient lying space for the bulls. If the impacts with the partitions were minor and did not represent a serious welfare concern, as suggested by qualitative observations, the cubicle dimensions used could be considered suitable for housing the type of finishing bulls used in this study.

Keywords: behaviour, bulls, cubicles, hygiene, loose housing.

Introduction

Cubicles are widely used for housing dairy cows. In recent years, they have also been introduced and tested for finishing bulls (Schulze Westerath *et al.*, 2003, 2004 and 2005; Meier *et al.*, 2004). If equipped with soft lying mats, this alternative housing system can provide a more comfortable lying area for finishing bulls than fully slatted pens, without the need for large quantities of litter as in deep-bedded straw pens. Although hard lying areas with a rough surface have been shown to have negative effects on behaviour and leg injuries in finishing bulls (Ruis-Heutinck *et al.*, 2000; Lowe *et al.*, 2001; Mayer *et al.*, 2002), cubicles with straw bedding are not recommended for bulls because the animals would wet the ground when urinating while standing in the cubicles.

One major issue in cubicle design is size. If cubicles are too small, cattle show changes in their lying behaviour. Hörning and Tost (2002) found changes in lying duration and in lying-

down and standing-up movements in dairy cows when cubicle size varied from about 2.3 m to 2.5 m in length, and from about 1.1 m to 1.2 m in width. In cubicles measuring 229 cm long by 112 cm wide as opposed to larger cubicles measuring 274 cm long by 132 cm wide, dairy cows spent less time lying and more time standing with only the front hooves on the lying surface (Tucker *et al.*, 2004). On the other hand, if cubicles are too large, the lying surface may get dirty (Bickert, 1999; Tucker *et al.*, 2004), which could adversely affect skin and udder health as well as milk quality in dairy cattle.

There are different approaches to defining cubicle size for cattle. Firstly, there is the trial-and-error approach, in which cubicles are built to a size based on an intuitive understanding of how much space cattle need for lying, lying down and standing up. Secondly, several attempts have been made to

base cubicle dimensions on body measurements of milking cows (Süss, 1994; Anderson, 2003; Keil *et al.*, 2004). Two assumptions are implicit in this second approach. The first is that body measurements are highly correlated (e.g. body length and withers height), even in animals of different size. These correlations are only high in young cattle, however (Jauschnegg, 1994). The second is that body measurements can be used to describe the space needed in cubicles by means of simple univariate regression, which can serve as a rule of thumb (e.g. diagonal body length for the length of cubicles and height at withers for the width of cubicles; Commission Internationale du Génie Rural (CIGR, 2002) and Anderson (2003)). Thirdly, 3-D kinematics have recently been used to directly estimate space requirements of cows while lying down (Ceballos *et al.*, 2004). Whereas measurements obtained with the latter method directly show the space needed by cattle, the 'trial-and-error' solutions and the rules of thumb have in almost no cases been verified on the basis of behavioural observations assessing the space actually needed by cows when lying, lying down or standing up (an exception is Keil *et al.* (2004)). It is therefore hardly surprising that recommendations for cubicle size for adult dairy cows span quite a broad range from about 110 to 135 cm in width and 220 to 270 cm in length (Figure 1).

Unlike with dairy cows, there are no studies and hardly any recommendations on the appropriate dimensions of cubicles for growing cattle (Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL, 1991), Müller (1994), Süss (1994), Holmes (2000), CIGR (2002); see Figure 1), and none specific to finishing bulls. Beef cattle may have different proportions

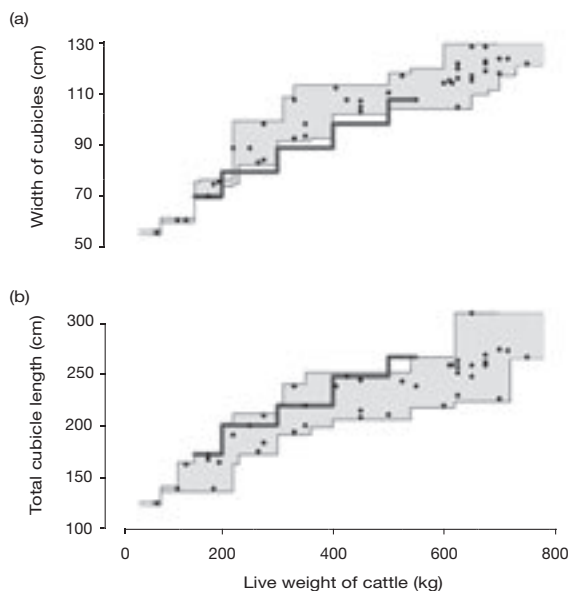


Figure 1 Range of recommendations of (a) cubicle width and (b) total cubicle length (length of lying area plus length of head space for cubicles facing a wall and allowing a forward lunge) for dairy cows and replacement cattle, as indicated by the grey area. Each point indicates the mean of one recommendation. Dimensions used in the current experiment are added with the dark-grey solid lines (data from KTBL (1991), Müller (1994), Süss (1994), McFadden *et al.* (1995), Bartussek *et al.* (1996), Grandle *et al.* (1996), Bickert (1999 and 2000), Holmes (2000), Hilty (2001), CIGR (2002), Anderson (2003) and Hanselmann (2004)).

of body dimensions from dairy cows. Moreover, young bulls are growing fast, so cubicle size must be adjusted to their body size several times over the fattening period.

In our study, we wanted to investigate how well the cubicle dimensions recommended for replacement cattle can be applied to finishing bulls. Therefore, we increased the size of the cubicles at four points in time during the finishing periods of bulls (from on average 160 to 550 kg), and observed the animals' behaviour shortly before and after enlargement of the cubicles. In practice, groups are usually shifted between pens with increasing cubicle dimensions. We tested whether the bulls' behaviour changed with the enlargement, in order to determine whether the size of the cubicles and the points in time at which they were enlarged were aptly chosen. In addition, we rated the cleanliness of the animals and of the lying surface before and after enlargement to identify problems with hygiene, caused, for example, by the bulls turning around in the cubicles before lying down and then later defecating on the front part of the lying surface.

In accordance with observations that the quality of standing-up and lying-down movements change according to the quality of the lying-area (dairy cows: Sambras (1971), Lidfors (1989), Mogensen *et al.* (1997); beef cattle: Konrad (1988)) and assuming that space was restricted before enlargement, we hypothesized that the bulls would have fewer lying bouts in the smaller cubicles, in order to avoid standing up and lying down, and that they would interrupt standing-up and lying-down movements more often, show intensified preparations for standing up and lying down, and bump into the cubicle boundaries (partitions, neck rail) more frequently. On the other hand, we expected dirtier animals and lying surfaces in the larger cubicles.

Material and methods

Animals and housing

The experiment was conducted at the facility of the Swiss Federal Research Station for Agricultural Economics and Engineering (Agroscope FAT Tänikon). Twenty finishing bulls of various breeds (six Brown Swiss, two Limousin, one each of the Red Holstein, Blond d'Aquitaine and Swiss Simmental breeds, and nine crossbreeds) were kept in four groups of five bulls each. Initially, they were assigned to groups so as to yield a similar weight and breed distribution for each group. Each pen (housing one group) had a solid-concrete walking area of about 30 m² and five cubicles, separated by cantilevered loop partitions (made of metal pipes with a round cross section) and limited at the front end by a wooden wall, equipped with soft lying mats at an inclination of 5% (Schulze Westerath *et al.*, 2004). Across the back of the cubicles a pipe was installed to avoid mounting. Bulls stepped into the cubicles under this pipe. Head space was sufficiently large that it should provide enough space to allow a forward lunge (Table 1). All cubicles in a given pen were equipped with one of two mat types (Kraiburg KSL rubber mat with nubs on the bottom; Boutech foam EVA green mat), and the lying area was either sparsely littered with chopped straw, or bare (each mat type/litter combination was provided in one pen and remained unchanged over the entire growth period). The lying area of all cubicles was cleaned after the morning

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Table 1 Cubicle dimensions used for each live-weight range and actual live weight of the animals (the class above 500 kg in italics was used in this study for comparative purposes only and is not usually included in recommendations for animals up to 550 kg)

	Weight class (kg)				
	< 201	201-300	301-400	401-500	> 500
Actual weight (kg)±s.e.†	221.1±6.9	328.8±8.4	382.7±9.7	492.3±9.2	<i>185</i>
Length of lying area (cm)	120	140	150	185	<i>185</i>
Length of cubicle (cm)	160	190	210	240	<i>260</i>
Width (cm)	70	80	90	100	<i>110</i>
Neck rail					
Distance to rear end	115	130	140	165	<i>175</i>
Height above lying area	85	90	95	100	<i>105</i>

† Weights reached in the experiment at the end of the respective weight class.

feeding and topped up with litter as necessary in the two pens containing straw. Additional straw was also provided in the afternoon.

Bulls were given food once daily in the morning with an *ad libitum* ration of (per kg) 900 g maize silage and 100 g hay, with 2 kg concentrate added per animal. In the afternoon, any remaining ration was pushed towards the feeding rack.

Observational design

Since several animals had turned around in the cubicles in a previous experiment, we chose cubicle dimensions that were rather narrow and long compared to the available recommendations (Figure 1). Bulls were put into the experimental pens at an average weight of 160 kg. Cubicles are often enlarged at fixed intervals. In our study, we attempted to do so when bulls reached average weights of 200, 300, 400 and 500 kg (Table 1, Figure 1). At each of these four points in time, data on bull behaviour were recorded up to 3 to 7 days before enlargement in 'small' cubicles, and after 7 to 12 days after enlargement to 'large' cubicles. Bulls were thus allowed at least 1 week to get used to the enlarged cubicles before data collection commenced. Observations were made in eight experimental situations: before and after enlargement at four points in time (time/enlargement combinations). Animals were weighed, and cleanliness of animals and cubicles was assessed about every 4 weeks based on a dirtiness scoring system. Data of the dirtiness scoring which was closest to the point of enlargement of the cubicles was assigned to the respective 'small' and 'large' cubicles (usually about 2 weeks before and after the enlargement). Observations took place from April to December 2003. To account for general changes over the seasons, we included time as an explanatory variable in the evaluation (see *Statistical analysis* section).

Parameters

The quality of standing-up and lying-down movements was quantified by direct observations. The observers were about 6 m away from the cubicles and had an unobstructed view of the animals. We assessed (1) whether standing-up was atypical (forelegs first), interrupted (bulls got up onto their hind legs and carpal joints, and then lay down again), or done only to change lying sides (i.e. bulls getting up onto their carpal joints and lying down on the other side), and how many head lunges were needed to get up; (2) whether lying down was atypical (hindlegs first) or interrupted (bulls lowered themselves onto the carpal joints and then stood up

again), how many times bulls stepped with their forelegs and hindlegs, and whether intensive head sweeps (more than three to-and-fro movements) occurred before lying down; (3) whether bulls slipped or fell while standing up or lying down; (4) whether they hit the cubicle partitions; and (5) whether they turned around in the cubicle.

We attempted to collect data on 10 instances each of standing up and lying down per bull and experimental situation. A total of 1937 standing-up and 1993 lying-down instances were observed (minimum, lower quartile, median, upper quartile and maximum per bull per time/enlargement combination were for standing-up: 0, 10, 11, 14, 27; and for lying-down: 1, 10, 12, 15 and 34 instances, respectively). These direct observations were carried out for about 5 h/day split in half (i.e. 2.5 h in the mornings, from 09:30 to 12:00 h, and 2.5 h in the afternoons from 13:30 to 16:00 h, on 4 to 7 days for each of the eight experimental situations).

Average lying duration in 24 h and average number of lying bouts per group were measured automatically using distance sensors positioned above the cubicles. These sensors were able to differentiate between an empty cubicle, a cubicle with a standing or a cubicle with a lying bull (for technical details see Schulze Westerath *et al.* (2002)). Data from the distance sensors were collected every minute on three consecutive days for each time/enlargement combination.

Around the fourth enlargement of the cubicles, we expanded on our observations by including lying postures. Cubicles were photographed every 10 min on behavioural observation days. On average, 65 (range: 41 to 82) photographs showed the animal lying before enlargement, and 93 (range: 65 to 118) after enlargement. Based on these photographs, the proportion of scans in which the animals lay with outstretched legs (at least one foreleg partly stretched, i.e. not held close to rump, or at least one hindleg stretched with an angle of more than 90 degrees at the tarsal joint), on their side and in physical contact with their neighbours was calculated.

The dirtiness and wetness of the animals and of the lying area in the cubicles were rated early in the morning on 3 days consecutively using a slightly extended scheme taking different regions of the body into account and described by Faye and Barnouin (1985). For each of the body regions dirtiness and wetness was estimated as a score ranging from 0 to 2 in increments of 0.5 from clean to completely soiled, and dry to wet, respectively. For the analysis, an average

score was calculated per bull and experimental situation (time/enlargement combination) for dirtiness of the rear part of the bulls (hind legs and area around tail), the lower part of the body (belly and sternum), and the front part of the body (shoulders and forelegs), as well as for overall dirtiness (all body parts taken together).

Dirtiness and wetness of the cubicles were rated twice daily on the same days. The front two-thirds and rear third of the lying area were scored separately. The score indicated how many quarters of the area were dirty/wet (e.g. score = 2: 25 to 50% of the area). Additionally, the number of dung heaps were counted in the two areas. For evaluation, these scores were averaged per group and experimental situation.

Statistical analysis

Linear and generalized linear mixed-effects models (using a binomial distribution) were used to evaluate the different behavioural and cleanliness parameters (Pinheiro and Bates, 2000; Venables and Ripley, 2002; calculated using R 1.8.1, www.r-project.org). These models are estimated using a restricted maximum-likelihood method and are therefore robust regarding unbalanced data sets (Pinheiro and Bates, 2000). The models were of the form

$$Y_{ijklmno} = \mu + b_i + b_{ij} + b_{ijk} + \alpha_l + \beta_m + \gamma_n + \delta_o + \gamma\delta_{no} + \varepsilon_{ijklmno}$$

with the fixed effects of α_l = litter (no – yes, d.f. = 1), β_m = type of lying mat (0, 1, d.f. = 1), γ_n = points in time (ordered factor, d.f. = 3), δ_o = enlargement (small, large, d.f. = 1) and $\gamma\delta_{no}$ = the interaction of points in time and enlargement (d.f. = 3) and with the nested random effects b_i = group, b_{ij} = individual and b_{ijk} = the time/enlargement combination. Statistical assumptions are that $\varepsilon_{ijklmno} \sim N(0, \sigma^2)$ iid, $b_i \sim N(0, \sigma_1^2)$ iid, $b_{ij} \sim N(0, \sigma_2^2)$ iid and $b_{ijk} \sim N(0, \sigma_3^2)$ iid (iid = independently identically distributed). These assumptions, homoscedasticity and independence of the residuals from the explanatory variables were checked using graphical analysis of residuals. For response variables that described the occurrence of events, the binomial distribution was used (standing-up with more than one head lunge, hitting partitions, interrupted lying-down, high-intensity of head sweeps, slipping). For continuous response variables, the response was log- (animal dirtiness score, number of dung heaps) or square-root-transformed (stepping before lying down) if necessary to ensure assumptions on the distribution of the residuals. The other response variables remained untransformed (lying duration, number of lying bouts, cubicle dirtiness).

The time/enlargement combination was introduced such that each instance of standing up and lying down could be used separately in the model without inflating the degrees of freedom, i.e. the overall sample for these tests was taken to be the number of bulls times the number of experimental situations. This is analogous to evaluating proportions of occurrences or means per individual for each time/enlargement combination.

In the **Results** section, the statistical results of the parameter enlargement will be presented and discussed. Where necessary, the influence of the points in time on enlargement

will also be considered (statistical interaction between time and enlargement). However, as it is not possible to determine whether the influence of the points in time is an effect of the season, growth or ontogenetic development of the bulls, the variable time was included for the sake of completeness only, and no attempt at interpretation is made.

The two mat types and presence or absence of straw on the lying area were included in the experimental design though their statistical power (four groups) was weak. They were included in the analysis of the current study to completely reflect the experimental situations. Since they were never close to statistical significance, however, they are not presented in the **Results** section.

Lying postures at time-point 4 were compared for 'small' and 'large' cubicles using a Wilcoxon matched-pairs test with test statistic V based on the individual bulls' data.

Results

Quality of standing-up and lying-down movements

Interrupted standing up was never observed, and atypical standing up was observed only once. In 2% of all standing-up events, bulls merely changed the side on which they were lying, and these rare instances did not depend on cubicle size. The proportion of standing-up instances with more than one head lunge decreased with the enlargement of the cubicles ($F_{1, 130} = 6.82$, $P = 0.01$, Figure 2a). On average, bulls bumped into partitions 23% of all the times they stood up. Partitions were hit less often after enlargement of the cubicles. In particular, and in decreasing proportion of occurrence, bulls less often bumped their necks on the neck rail ($F_{1, 130} = 6.3$, $P = 0.013$), their heads on the partition ($F_{1, 130} = 8.6$, $P = 0.004$), their heads on the front end of the cubicle (except at time-point 1, interaction: $F_{3, 130} = 6.8$, $P < 0.001$) and their rumps on the partition ($F_{1, 130} = 5.7$, $P = 0.02$). Consequently, the proportion of standing-up movements in which any bump occurred also decreased with enlargement of the cubicles ($F_{1, 130} = 10.7$, $P = 0.001$, Figure 2b).

Atypical lying down was never observed. Interrupted lying-down attempts were quite rare (for most animals in most experimental situations, a zero proportion of all lying-down instances, which only rarely rose to 0.5), and did not change in proportion with enlargement of the cubicles ($F_{1, 131} = 0.19$, $P = 0.67$). The proportion of lying-down instances with a high intensity of head sweeps did not consistently change with enlargement of the cubicles ($F_{1, 131} = 0.44$, $P = 0.51$, Figure 2c). Bulls hit the cubicle partitions mostly with their rumps while lying down (about 17% of all lying-down instances). More rarely, they hit the partition with their head or legs, the neck rail with their necks, or the front end of the cubicle with their heads. None of these individual instances of bumping showed a systematic change with enlargement, but the total number of bumps decreased with enlargement (except at time-point 1, interaction: $F_{3, 131} = 4.2$, $P = 0.007$, Figure 2d). After enlargement of the cubicles, bulls more often stepped with their forelegs before lying down (except at time-point 3, interaction: $F_{3, 131} = 4.19$, $P = 0.007$, Figure 2e), but the number of steps with their hindlegs did not change ($F_{1, 131} = 0.60$, $P = 0.44$, Figure 2f).

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Bulls never turned around in the cubicles. Moreover, they never fell, and seldom slipped, while standing up or lying down. On average, they slipped on their front claws in only 1% and their hind claws in only 0.6% of all instances of standing up and lying down. Nevertheless, the total proportion of slipping increased with enlargement of the cubicles ($F_{1,131} = 4.19$, $P = 0.043$, Figure 3a; foreclaws : $F_{1,131} = 7.45$, $P = 0.055$; hindclaws : $F_{1,131} = 0.24$, $P = 0.63$).

Lying behaviour

Mean daily lying duration per group and time/enlargement combination varied between 625 and 893 min (Figure 3b), and on average was split into 11.3 to 20 bouts per day (Figure 3c). On average, the duration of lying decreased ($F_{1,21} = 9.3$, $P = 0.006$, Figure 3b) while the number of lying bouts tended to increase with enlargement of the cubicles ($F_{1,21} = 4.2$, $P = 0.052$, Figure 3c).

At time-point 4, we observed that the proportion of scans in which bulls lay with outstretched forelegs or hindlegs did not change with enlargement (Wilcoxon test based on the individual bulls; $V = 91$, $P = 0.89$), nor did the proportion of scans in which bulls lay on their side (Wilcoxon test : $V = 71$, $P = 0.81$). Where at least one adjacent cubicle was occupied,

bulls tended to be in physical contact with their neighbours in a lower proportion of scans when the cubicles were enlarged (Wilcoxon test : $V = 140$, $P = 0.07$).

Animal and cubicle cleanliness

Bulls were hardly ever dirty on belly or front part of their body. Individual bulls had maximum average dirtiness scores of 0.6 on a scale of 0 to 2 (median : 0) in these areas per time/enlargement combination. Dirtiness of the rear part of the bulls did not change with enlargement ($F_{1,130} = 0.39$, $P = 0.53$), while overall dirtiness increased with enlargement at time-point 3 (interaction : $F_{3,130} = 5.5$, $P < 0.001$, Figure 3d). Bulls were hardly ever wet (median of 0, maximum 0.3 on a scale of 2, Figure 3e).

The front two-thirds of the lying area was rarely dirty (median 0.17, maximum 0.8 on a scale of 4), wet (median 0.03, maximum 0.26 on a scale of 4) or fouled with dung heaps (median 0, maximum 0.03) at all. The dirtiness of the rear third of the lying area tended to increase with enlargement of the cubicles ($F_{1,21} = 3.44$, $P = 0.08$, Figure 3f). The wetness of the rear third of the lying area increased after cubicle enlargement (except at time-point 3, interaction : $F_{3,21} = 4.6$, $P = 0.01$, maximum value at 1 on a scale of 4). The number

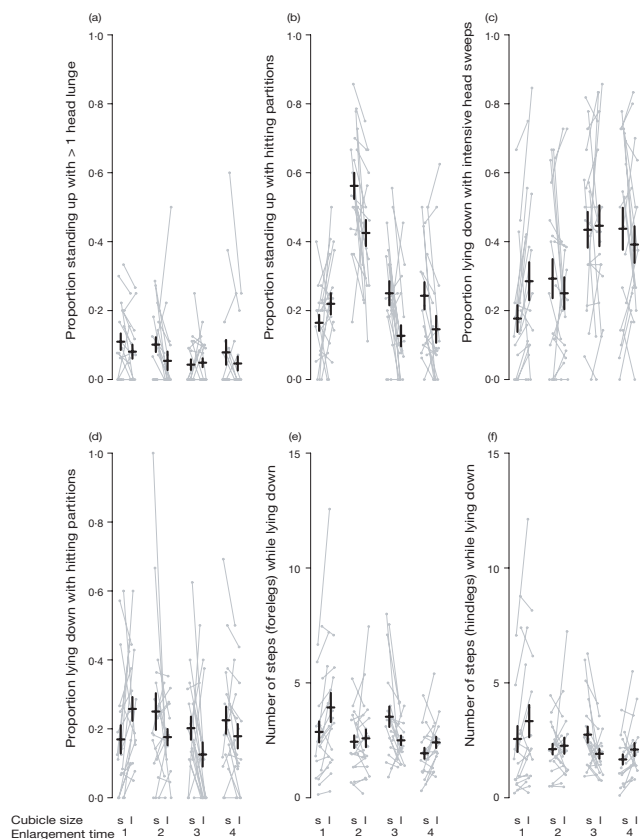


Figure 2 Behaviour of bulls at the four points in time, each before and after enlargement of the cubicles (s = 'small', l = 'large' cubicles): proportion of standing-up movements involving (a) more than one head lunge and (b) hitting partitions; proportion of lying-down movements involving (c) intensive head sweeps and (d) hitting partitions; number of steps taken with (e) forelegs and (f) hindlegs before lying down. Data of the individual bulls are given as grey lines. Mean \pm s.e. are given as black crosses for each observational period.

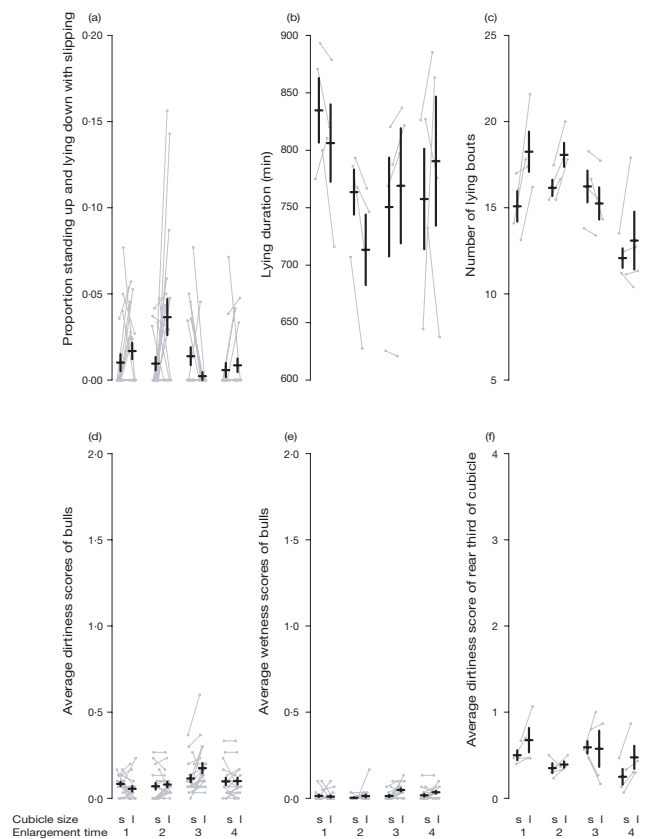


Figure 3 Behaviour and cleanliness at the four points in time, each before and after enlargement of the cubicles (s = 'small', l = 'large' cubicles): (a) proportion of standing-up and lying-down movements with slipping, (b) lying duration, (c) number of lying bouts, (d) average dirtiness scores and (e) average wetness scores of the bulls, and (f) average dirtiness scores of the rear third of the cubicles. Data of the individual bulls (a), (d) and (e), average data per group (b), (c) and (d) and average data per pen (f) are given as grey lines. Mean \pm s.e. are given as black crosses for each observational period.

of dung heaps on the rear third of the lying area increased with enlargement (except at time-point 4, interaction: $F_{3,21} = 6.4$, $P = 0.003$, maximum number of dung heaps was 0.5 per cubicle).

Discussion

Most of the parameters investigated in this study do not clearly favour either large or small cubicles at the time-points chosen for enlargement. There were no differences between small and large cubicles in terms of the following variables: interrupted attempts to stand up or lie down; atypical ways of standing up or lying down; the proportion of changes onto a different lying side; the proportion of intensive head sweeps; the number of instances of stepping

with the hindlegs when preparing to lie down; the occurrence of falls; how often bulls lay on their side; changes in most of the cleanliness measurements of the bulls and the lying area (Table 2). In contrast to the results of Hörning and Tost (2002) in dairy cows, we did not observe changes in terms of how often hindlegs were stretched out in larger cubicles.

On the other hand, the bumping into cubicle boundaries (partitions, neck rail and front boundary) decreased with enlargement of the cubicles, thus indicating the necessity of enlarging cubicles at the time-points examined in this study (Table 2). These bumps were not usually severe, however. In most cases, animals touched rails and partitions in the final phases of standing up or lying down, so that these bumps do not seem to indicate a serious restriction

Table 2 Summary of the parameters investigated, with a rating of the effects due to enlargement of the cubicles

Variables	Significance of effect [†]	Effect of enlargement [‡]	Comment	Rating of range §
Turning around	–	→	Never observed	○
Standing up				
Interrupted standing up	–	→	Never observed	×
Atypical	–	→	Rarely observed	×
Change sides		→		×
> 1 head lunge	T E	↓		△
All hits of partitions	I	↓		△
Hitting neck rail with the neck	T E	↓		△
Hitting partitions with the head	I	↓		△
Hitting the front end of the cubicle with the head	I	↓		△
Hitting partitions with the rump	E	↓	Rarely observed	△
Lying down				
Interrupted lying down	T	→		×
Atypical	–	→	Never observed	×
Head sweeps	T	→		×
Stepping with front legs	I	↑		○
Stepping with hind legs		→		×
All hits of partitions	I	↓		△
Hitting neck rail with the neck		→	Rarely observed	×
Hitting partitions with the head		→	Rarely observed	×
Hitting the front end of the cubicle with the head		→	Rarely observed	×
Hitting partitions with the rump		→		×
Lying				
Duration	T E	↓	Small differences	×
No. of bouts	T (E)	(↑)	Small differences	×
Slipping				
All	I	↑	Rarely observed	○
Front claws	(E)	(↑)	Rarely observed	○
Hind claws		→	Rarely observed	×
Falls	–	→	Never observed	×
Dirtiness scores of cubicles				
Back	T (E)	(↑)	Low overall values	○
Front	–	→	Low overall values	×
Dung heaps in back	I	↑	Low overall values	○
Dung heaps in front	–	→	Rarely observed	×
Wetness scores of cubicles				
Back	I	↑	Low overall values	○
Front	–	→	Low overall values	×
Urination in cubicle	T	→	Low overall values	×
Dirtiness scores of animals				
Overall	I	(↑)	Low overall values	×
Rear part of body	T	→	Low overall values	×
Lower part of body	–	→	Low overall values	×
Front part of body	–	→	Low overall values	×
Wetness scores of animals				
Overall	–	→	Low overall values	×

[†] $P < 0.05$, in parentheses if $P < 0.10$: significant results for points in time, T; enlargement, E; interaction, I; no test conducted, –.

[‡] Effect of enlargement: → = no change, ↑ = increase, ↓ = decrease from 'small' to 'large' cubicles. In parentheses if only a tendential or very small difference on an absolute scale.

[§] Rating of change: ○ = smaller cubicles better, △ = smaller cubicles worse, × = no difference.

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in the bulls' behaviour. Also militating in favour of cubicle enlargement is the fact that bulls more often performed more than one head lunge while standing up in the smaller cubicles, indicating that standing up was easier in the larger cubicles. Similarly, Tucker *et al.* (2004) found that cows stood longer in narrow cubicles, which potentially indicates that the animals found it more difficult to lie down in a narrower space.

In contrast to the observations of Tucker *et al.* (2004) in dairy cows, total lying duration (10 to 15 h per day) decreased with enlargement of the cubicles. In addition, the number of lying bouts (10 to 20 per day) increased with enlargement. At each point in time, however, these differences between small and large cubicles were fairly minor on an absolute scale, and none of the values was outside the range reported in some previous studies (Andreae, 1979; Graf, 1984; Hartmann and Schlichting, 1990; Minonzo *et al.*, 1992) and both, total lying duration and number of lying bouts, were higher than the data reported and summarized in Bockisch (1991). Huge changes in lying duration were not to be expected, as these measurements are assumed to depend mainly on the softness of the lying surface (Andreae and Papendieck, 1971; Andreae, 1979; Graf, 1984; Konrad, 1988; Frickh *et al.*, 2000).

There were even several factors indicating that, at a given point in time, the smaller cubicles provided advantages for the bulls: bulls stepped less often with their forelegs before lying down, slipped less often, and the back third of the cubicles were cleaner and drier before enlargement of the cubicles (Table 2). In principle, the increase in the number of steps taken might also be due to the relatively short time the bulls had to get used to their new surroundings after the cubicles were enlarged, but this would be the only indication of too little familiarization time. Nevertheless, this result contrasts with the negative correlation between the number of steps taken before lying down and the size of the cubicles found by Hörning and Tost (2002) in the case of dairy cows. The increased dirtiness and wetness of the rear third of the cubicles parallels the findings of Tucker *et al.* (2004), who weighed increasingly large quantities of faecal matter with increasing width of the cubicles for dairy cows. In our study, this did not directly translate into reduced animal cleanliness, but it is likely that the cubicles were better cared for in our research facility than one might expect them to be in practice. Finally, bulls never turned around in the cubicles, in contrast to an earlier study with cubicles 10 cm wider, in which at least one animal in each of four groups turned around in the cubicles before lying down. We still do not know for certain why bulls like to turn around, whether just to avoid stepping backwards or because they like to keep other bulls in view. It is thus currently unclear whether restriction of the motivation to do so could have negative consequences for the welfare of finishing bulls.

Summarizing our results, it would appear that bulls were not strongly restricted in their behaviour in the small cubicles as compared with the larger cubicles at each point in time when cubicles were enlarged. Thus, our long, narrow cubicles (Figure 1) would seem to be an adequate compromise for finishing bulls, a conclusion similar to the one reached by

Tucker *et al.* (2004) for dairy cows based on the length of time they spent standing in the cubicle with only the front hooves on the lying surface. The lack of significant changes in behaviour and cleanliness in our study after enlargement of the cubicles corresponds to results of a survey conducted by Veissier *et al.* (2004), who found no influence of cubicle size on the behaviour, injuries and cleanliness of dairy cows. In a direct-choice test with dairy cows, Tucker *et al.* (2004) found only a very slight preference for wide (132 v. 112 cm) and long (274 v. 229 cm) cubicles, indicating that the cows do not react strongly to small changes in cubicle size.

Rules of thumb to derive cubicle measurements from the size of cattle are usually based on simple, bivariate correlations of different body measurements (e.g. Jauschnegg, 1994). If those relationships are not fully described by a linear pattern, however, such rules of thumb have to be considered as oversimplified. Observing how cattle deal with given cubicle dimensions, as we have done in the current study, or directly measuring space requirements for e.g. standing up and lying down when animals can move freely (Ceballos *et al.*, 2004), are more straightforward approaches for identifying adequate cubicle dimensions for cattle.

Conclusion

Enlargement of the cubicles as investigated in this study had fewer favourable effects on the behaviour of the bulls than anticipated. At each point in time, the smaller cubicles still seemed to provide sufficient lying space for the bulls. However, the benefits of cubicle enlargement were a reduced frequency of impacts with the partitions and lower numbers of head lunges while getting-up. If it is assumed that the contacts with the partitions were not a welfare issue (in terms of discomfort, pain or injury to the bulls), as suggested by our qualitative observations, the enlargement of the cubicles to the dimensions used in this study for the various live-weight classes were appropriate for the types of finishing bulls studied.

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