The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK

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Alternative housing systems for fattening bulls under Austrian conditions with special respect to rubberised slatted floors

C Rouha-Muelleder*†‡, E Absmanner‡, E Kahrer‡, H Zeiner‡, T Scharl§#, F Leisch¶, C Stanek¥ and J Troxler‡

† Afritschweg 15/2, A-4030 Linz, Austria
‡ Department for Farm Animals and Veterinary Public Health, Institute of Animal Husbandry and Welfare, University of Veterinary Medicine Vienna, Veterinärplatz 1, 1210 Vienna, Austria
§ Department for Statistics and Probability Theory, Vienna University of Technology, Wiedner Hauptstraße 8-10/1071, 1040 Vienna, Austria
# ACIB GmbH c/o Department of Biotechnology, University of Natural Resources and Life Sciences, Muthgasse 18, 1190 Vienna, Austria
¶ Department of Statistics, Ludwig-Maximilians-University Munich, Ludwigstraße 33, 80539 Munich, Germany
¥ Department for Companion Animals and Horses, University of Veterinary Medicine Vienna, Veterinärplatz 1, 1210 Vienna, Austria
* Contact for correspondence and requests for reprints: cornelia.muelleder@gmx.at

Abstract

Previous studies have noted significant welfare problems in cattle housed on fully slatted floors. The aim of this study was to investigate the suitability of alternative housing systems under on-farm conditions. Health, behavioural and farm data of fattening bulls were collected on seven Austrian farms between January 2006 and April 2007. The housing systems studied comprised fully slatted concrete floor pens (CS), fully slatted floor pens covered with rubber mats (RS), straw-bedded pens (ST) and a system combining straw-bedded pens (for bulls weighing < 450 kg) and fully slatted floor pens (for bulls weighing > 450 kg; SS). The numbers of scabs/wounds on the carpal joint and severe lesions/partial losses of the tail tip were significantly higher in CS and SS than in RS and ST. The claws of bulls in ST and RS showed clear signs of reduced abrasion, but this does not seem to have any negative impact on the corium. Behavioural alterations were observed mainly in CS and SS. The numbers of lying and short standing bouts were significantly higher in ST and RS than in CS; the mean duration of lying bouts was significantly lower. Mean duration of lying down and standing up was significantly lower in ST than in CS and SS. Bulls in ST had a significantly higher daily weight gain than bulls in all other systems. It is concluded that rubber mats improve the welfare of bulls housed on slatted floors. However, neither the RS nor the SS system reached the welfare potential of straw bedding provided throughout life.

Keywords: *animal welfare, fattening bulls, health, housing systems, resting behaviour, rubber mats*

Introduction

In Austria, fattening bulls are housed mainly in group pens with fully slatted concrete flooring. However, many studies noted significant problems concerning the welfare of cattle accommodated in fully slatted floor pens (Graf 1984; Ruis-Heutnick *et al* 2000; Schrader *et al* 2001; Mayer *et al* 2007; Schulze Westerath *et al* 2007). Carpal and tarsal joint lesions as well as pathological alterations of the tail tip were observed more frequently in bulls housed on concrete slats than in those housed in systems with soft lying areas. Furthermore, behavioural alterations, such as a reduced number of lying bouts, atypical standing up and atypical lying down were seen more often in bulls accommodated on concrete slats (Graf 1984; Ruis-Heutnick *et al* 2000; Mayer *et al* 2007).

During recent years, consumers have become more concerned about farm animal welfare issues and become more willing to pay for a policy to address these issues (Bennett *et al* 2002; Seng & Laporte 2005). Both health problems and behavioural changes, as found in fattening bulls kept in pens with concrete slatted flooring, indicate reduced well-being and therefore do not meet the satisfaction of consumers. Thus, the development of alternative housing systems for fattening bulls becomes increasingly important.

In the light of such concerns, improvements of fully slatted concrete flooring were investigated. As a simple improvement, rubber mats for slatted floors have been tested for the housing of fattening bulls. However, in most countries they have not found their way into farm use until recently.

Table 1 Number of pens examined on the seven farms and in brackets number of pens used for behavioural analysis.

Farm	CS	RS	ST	SS
Farm 1	4 (2)	4 (2)		6 (2)
Farm 2	2 (2)	2 (2)		
Farm 3	6 (3)	6 (3)		
Farm 4				6 (4)
Farm 5			5 (3)	
Farm 6			3 (2)	
Farm 7			4 (2)	

CS: Fully concrete slatted floor pens; RS: Rubber-coated slatted floor pens; ST: Straw-bedded pens; SS: Concrete slatted floor and straw-bedded pens.

Previous studies comparing the behaviour and health of beef bulls housed in pens with either concrete slats or slats covered with rubber mats noted fewer behavioural changes, lesions and tail-tip alterations in pens with rubber-coated slats (Koberg *et al* 1989; Mayer *et al* 2007; Schulze Westerath *et al* 2007; Zerbe *et al* 2008). Bahrs (2005) and Platz *et al* (2007) also showed that bulls prefer rubber mats to concrete flooring. Thio *et al* (2005), however, found claw alterations caused by reduced abrasion in bulls fattened on rubber mats. Although these alterations appeared to have no effect on the corium and therefore no impact on the welfare of the animals, the authors argued that with higher body-weight (the bulls were slaughtered at a live weight of about 550 kg) the effects could become more severe. Rubber mats have now been developed further for on-farm use.

Straw-yard systems represent a common alternative to housing systems with slatted floors, and best meet the needs of cattle for a soft lying area. When offered a choice of flooring type, there is a clear preference for fattening cattle to choose straw-bedded pens rather than any other option (Koch & Irps 1985; Lowe *et al* 2001a).

In Austria, another type of housing, in which farmers keep their bulls on straw bedding until they weigh approximately 400–450 kg before moving them into fully slatted floor pens for finishing is becoming more popular. This combination of housing systems reflects the attempts of farmers to improve the welfare of the bulls and save costs for straw at the same time.

The aim of this study was to investigate the effect of different housing systems with different types of flooring (in particular rubberised slatted floors) on the health, behaviour and production of beef bulls under Austrian on-farm conditions (live weight at slaughter approximately 650–700 kg).

Materials and methods

Study animals and housing

The study was carried out on seven beef bull farms with 6–11 Simmental fattening bulls per pen in upper and lower Austria. During the whole fattening period parameters of twelve pens of bulls per system (seven pens per system for behavioural parameters) were assessed. Investigations began in 2005 and ended in 2008. All farms were members of or were supported by the Austrian Fattening Bull Organisation. The number of fattening bulls kept on the farms ranged from 32 animals on the smallest up to 132 animals on the largest farm.

The housing systems studied (see Table 1) comprised fully slatted concrete floor pens (CS) and fully slatted floor pens covered with rubber mats (RS) on three out of the seven farms: half of the bulls were housed on fully slatted floors and half on slats covered with rubber mats (RS; KURA XL, Gummiwerk Kraiburg Elastic GmbH, Tittmoning, Germany). Straw-bedded pens (ST) were investigated on three farms with straw-yard systems, consisting of a deep-litter or sloped-floor lying area and a concrete feeding stand. The fourth system, combining two different housing types, was studied on two farms. Bulls were housed in straw-bedded pens until reaching an average live weight of approximately 450 kg, before being moved into concrete slatted floor pens (SS).

Space allowance differed between housing systems as straw-bedded pens had an additional feeding area and therefore a larger total space allowance per animal. Space allowance per animal was 2.5, 2.4 and 2.7 m^2 on slat/rubber-slat farms and 3.5 m^2 (2.6 m^2 lying area), 4.1 m^2 (2.5 m^2 lying area), and 8.4 m^2 (3.5 m^2 lying area) on straw-yard farms for animals weighing less than 450 kg. For the heavier animals, space allowance per animal was 2.7, 2.9 and 3.2 m^2 on slat/rubber-slat farms and 4.6 m^2 (3.5 m^2 lying area), 4.8 m^2 (2.9 m^2 lying area), and 8.4 m^2 (3.5 m^2 lying area) on straw-yard farms. Where straw-yard and fully slatted floor systems were combined, space allowance was 2.8 m^2 (1.8 m^2 lying area) and 4.9 m^2 (2.6 m^2 lying area) in the deep-litter pens (for animals weighing less than 450 kg), and 3.2 m^2 and 2.9 m^2 in the slatted floor pens (for animals weighing more than 450 kg). The dimensions of the slats were confirmed on all slat and rubber farms, meeting the minimum standards of the Austrian animal welfare legislation (35-mm slat width; 80-mm step surface).

On each farm, bulls were housed within one stable and in visual contact with each other.

The Austrian Fattening Bull Organisation calculated ideal feeding rations for all farms. All animals were fed with corn silage and grass silage or hay — on one farm these were fed as a mixed ration. Additionally, they received concentrate supplemented by hand or mechanically with a special concentrate feeder. Bulls were fed their roughage once a day, and forage was swept towards the feeding place once or twice a day.

Measurements

Health and cleanliness

Twelve pens per housing system were evaluated (423 animals in total). At the beginning of the fattening period and then throughout the year each bull was examined every four to six weeks for skin and joint lesions, tail-tip alterations, ectoparasites, ringworm infection and cleanliness. For further analyses, we differentiated between mild (ie hairless patches, scabs, mild swelling/callosity) and severe (ie wounds, moderate to severe swelling/callosity) lesions at the joints and calculated the percentage of bulls per pen with the different lesions at least at one carpal or tarsal joint.

Tail-tip alterations were classified as mild scabs (≤ 2 cm) and wounds (≤ 5 cm), severe scabs (> 2 cm) and wounds (> 5 cm) or severe lesions (ie contusion, swelling, ulcerous lesion). For further analyses, we calculated the percentage of bulls per pen with the different tail-tip alterations.

Cleanliness of the animals was scored according to Faye and Barnouin (1987), but with a number of modifications regarding the body regions. The following nine body parts were assessed: back view, hind leg above and below the tarsal joint, tarsal joint, abdomen, shoulder, foreleg above and below the carpal joint, carpal joint and lower neck. A low cleanliness score meant clean animals. For further analyses, we calculated the percentage of bulls per pen with low (score 0, 1, 2) and high (score 3, 4) cleanliness scores of the body regions described above.

A lameness scoring was not possible because of the restricted space in the pens but severe and therefore clearly detectable lameness (a strong reluctance to put weight on limb) was recorded.

Records about illnesses and medical treatment of the bulls and early losses were provided by the farmers. For further analyses, we classified cases of illness as 'system related' or 'non-system related', the first category including alterations of the claws, joints and tail tips.

Claws

Claw health was evaluated by examining one foreleg and the diagonally corresponding hind leg of each bull (claws from 679 legs) after slaughter. Both horn and corium of each claw were evaluated.

Claw dimensions, such as dorsal wall length (tip of the claw to coronary groove), diagonal length (tip of the claw to coronary groove/onset of the pad) and toe angle (between dorsal wall and sole) were measured.

Furthermore, the concavity of the dorsal wall and the relief of the dorsal wall (= ridges in the dorsal wall) was assessed.

Claw horn (heel, sole, wall, white line) was examined, and pathological changes, such as erosions, overgrowth (overgrowth of the heel horn covering the horn of the sole; axial/abaxial flexion of the overgrown weight-bearing border, causing pressure on the underlying sole), haemorrhages, horn cracks, defects and ulcers were recorded.

Also, double-sole formation, white line disease and digital dermatitis were assessed.

In order to assess the corium, the cornified capsule was removed according to Ossent and Lischer (1997). The corium was examined, and pathological changes, such as lesions, retractions of the wall or sole corium (caused by an overlap of the claw horn), haemorrhages, ulcers, sinkage of the sole, stair-step pattern (ridges) in the wall and necrosis were recorded.

Most parameters were assessed using a four-point scale system. Certain parameters, such as the presence of digital dermatitis were recorded using a binary measure (yes/no).

Behavioural observations

Using video recordings, the behaviour of 219 bulls (7 pens per system, 6 pens for SS) was observed over 2 × 24 h at an average live weight of the bulls of 450 and 600 kg. For making the video-recordings, video cameras (Panasonic® WV-BP 310 and 330, Panasonic, Hamburg, Germany) were positioned over the pens and a Time Lapse Video Cassette Recorder AG 6124, VHS/Panasonic® (see above) and a 9 Channel Multiplex Sprite SX (GmbH, Neuss, Germany) were used. At most, two pens per housing system were observed simultaneously.

The video recordings were evaluated using the 'Observer® Video Pro, Support Package for Video Analysis', version 5.0 (Noldus, The Netherlands). The ambient temperature as a possible influencing factor on the behaviour of the bulls was measured every 5 min during video recordings using the ELPRO® Data logger ECOLOG TH1 (ELPRO, Schorndorf, Germany).

For further analyses, averages of the observations of bulls between 450 and 600 kg were calculated. The total lying time, number and duration of lying bouts and the number of short standing bouts (less than 5 min) per 24 h were assessed. Lying postures were recorded every 10 min over 24 h using the scan-sampling method (Martin & Bateson 1993). Standing-up and lying-down intentions and slipping were recorded continuously during two 3-h periods in which bulls showed increased activity (start at 1230h and after the evening feed). The following parameters were observed rarely and therefore summarised for further analyses according to Wechsler *et al* (2000).

Atypical lying down + attempts to lie down + interruptions of lying down + slipping when lying down = 'difficulties in lying down'.

Atypical standing up + attempts to stand up + interruptions of standing up + slipping when standing up = 'difficulties in standing up'.

Definitions of the observed behavioural parameters are listed in Table 2.

Farm data

Live weight for each animal was measured at the beginning of the fattening period and before slaughter, and the daily weight gain calculated.

Production data, such as fat classification, carcase quality and slaughter weight were provided by the Austrian Fattening Bull Organisation.

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Table 2 Descriptive list of observed parameters.

Resting behaviour	Description
Total lying duration (min)	Total lying duration in minutes
Duration of lying bouts (min)	Average duration of lying bouts in minutes
Lying bouts (n)	Number of lying bouts
Short standing bouts (n)	Standing bouts of less than 5 min duration
Lying-down time (s)	Time from bending at least one fore leg until lying
Atypical lying down (n)	Lying down with hind legs first
Lying-down intention (n)	Investigating the lying area, stepping forwards and backwards, bending the fore legs but interrupting the process
Interruption of lying down (n)*	Kneeling on the carpal joints then standing up again
Slipping while lying down (n)*	Slipping while lying down
Standing-up time (s)	Time from kneeling on at least one carpal joint until standing
Atypical standing up (n)	Standing up with fore legs first
Standing-up intention (n)	Swinging the head forwsrd but not getting up
Interruption of standing up (n)*	Standing with the hind legs then lying down again
Slipping while standing up (n)*	Slipping while standing up
Problems with head swing (n)*	Swinging the head to the side, attempt to swing the head forward
Lying on the side (%)	Lying flat on the side with all legs stretched out
Lying with fore and hind leg(s) stretched out (%)	Lying on the belly with at least one fore and one hind leg stretched out
Lying with hind leg(s) stretched out (%)	Lying on the belly with one or more hind legs but no fore leg stretched out
Lying with fore legs stretched out (%)	Lying on the belly with one or more fore legs but no hind legs stretched out
Lying on the belly (%)	Lying on the belly with legs underneath the body
Head up (%)	Head raised up
Head down (%)*	Head supported on the ground
Head back (%)	Head turned backwards
Head supported (%)*	Head supported on another animal
Tail tip protected (%)	Tail tip held close to the body
Tail tip unprotected (%)	Tail tip held away from the body

* Rarely observed parameters that were not analysed statistically

Statistical analysis

Statistical analyses were carried out using the statistical computing environment R version 2.11.1 (R Development Core Team 2010). The experimental unit throughout the analyses was the pen. A correlation analysis was conducted in which the response variables were correlated using a Pearson correlation. As assumed, some of the variables were highly correlated and hence showed similar behaviour in the subsequent analyses (eg atypical standing up and difficulties in standing up or lying down and lying-down intention).

A Bartlett's test of homogeneity of variances across systems was carried out for all variables in order to decide whether linear models or rather generalised linear models were the appropriate method. If the assumption of homogeneity of variances was not met, we dichotomised the response variables at the median of the scale. After this transformation, the variables were binary, hence logistic regression was performed. In the models, space allowance per animal, temperature (only for behavioural data) and housing system were used as covariates. The farm effect could not be included in the models as a covariate because not every type of housing system was present at every farm. In the case of a significant effect of the housing system ($P < 0.05$) in the analysis of variance (or analysis of

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Table 3 Mean (± SD), minimum and maximum parameter values for each housing system.

Parameter	CS			RS			ST			SS		
Health parameters (% of animals)	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**
Mild tail-tip wounds	41 (± 29)	9	86	11 (± 10)	0	29	0 (± 0)	0	0	27 (± 17)	9	64
Severe tail-tip wounds	6 (± 7)	0	14	0 (± 0)	0	0	0 (± 0)	0	0	2 (± 4)	0	11
Total tail-tip wounds	46 (± 30)	13	100	11 (± 10)	0	29	0 (± 0)	0	0	29 (± 17)	9	64
Mild tail-tip scabs	59 (± 21)	14	86	20 (± 21)	0	64	3 (± 6)	0	14	54 (± 14)	33	78
Severe tail-tip scabs	15 (± 18)	0	57	1 (± 3)	0	9	0 (± 0)	0	0	9 (± 8)	0	22
Total tail-tip scabs	61 (± 23)	14	86	20 (± 21)	0	64	3 (± 6)	0	14	56 (± 14)	33	78
Severe tail-tip lesions	21 (± 17)	0	57	5 (± 9)	0	27	0 (± 0)	0	0	16 (± 11)	0	36
Partial loss of tail tip	4 (± 7)	0	18	2 (± 4)	0	9	0 (± 0)	0	0	2 (± 4)	0	11
Mild carpal joint lesions	99 (± 3)	91	100	63 (± 24)	18	100	7 (± 10)	0	29	94 (± 10)	73	100
Severe carpal joint	82 (± 13)	57	100	26 (± 26)	0	71	2 (± 5)	0	13	80 (± 14)	55	100
Total carpal joint lesions	99 (± 3)	91	100	64 (± 24)	18	100	8 (± 9)	0	29	95 (± 8)	78	100
Mild tarsal joint lesions	25 (± 26)	0	71	19 (± 24)	0	71	9 (± 10)	0	29	36 (± 23)	0	73
Severe lameness	18 (± 10)	0	30	6 (± 7)	0	14	6 (± 10)	0	29	10 (± 10)	0	27
Ringworm infection	25 (± 29)	0	100	45 (± 31)	0	82	68 (± 32)	14	100	25 (± 28)	0	78
No system-related antibiotic treatments	11 (± 13)	0	43	0 (± 0)	0	0	0 (± 0)	0	0	3 (± 4)	0	9
No non-system-related early losses	3 (± 4)	0	9	0 (± 0)	0	0	7 (± 8)	0	17	4 (± 7)	0	18
Total number of early losses	14 (± 14)	0	36	1 (± 4)	0	14	9 (± 9)	0	25	7 (± 8)	0	27
Cleanliness parameters (% of animals)												
Low cleanliness of abdomen	40 (± 35)	0	88	57 (± 34)	0	100	5 (± 12)	0	40	9 (± 13)	0	36
High cleanliness of back view	19 (± 24)	0	70	24 (± 28)	0	100	88 (± 20)	33	100	60 (± 43)	0	100
Low cleanliness of hind leg above knee	47 (± 34)	0	100	71 (± 27)	14	100	6 (± 13)	0	40	13 (± 14)	0	33
Low cleanliness of tarsal joint	52 (± 39)	0	100	64 (± 40)	0	100	6 (± 13)	0	40	23 (± 28)	0	91
High cleanliness of hind leg below knee	0 (± 0)	0	0	0 (± 0)	0	0	33 (± 33)	0	100	26 (±34)	0	89
Low cleanliness of lower neck	3 (± 9)	0	29	12 (± 19)	0	55	0 (± 0)	0	0	5 (± 8)	0	27
Claw parameters (% of animals)												
Concavity of the dorsal wall	31 (± 26)	0	75	86 (± 12)	63	100	72 (± 33)	0	100	23 (± 16)	0	44
Relief in the dorsal wall (on both extremities)	38 (± 24)	0	86	80 (± 27)	13	100	83 (± 20)	33	100	22 (± 30)	0	100
Defects of the heel horn (> 1 cm)	11 (± 15)	0	50	18 (± 10)	9	43	39 (± 25)	0	80	15 (± 13)	0	38
Horn erosions (> 1/3 of the heel)	18 (± 17)	0	57	60 (± 25)	0	86	33 (± 28)	0	80	8 (± 12)	0	38
Overgrowth on the horn of the heel in the sole	41 (± 21)	0	71	94 (± 10)	70	100	40 (± 29)	0	100	21 (± 20)	0	57
Horn erosions (> 1/3 of the sole)	30 (± 27)	0	71	61 (± 26)	29	100	37 (± 32)	0	88	16 (± 21)	0	64
Excessive wear at the apex	21 (± 20)	0	57	33 (± 25)	0	88	49 (± 29)	0	100	13 (± 11)	0	27
Axial overgrowth of weight-bearing border	11 (± 12)	0	40	19 (± 15)	0	57	27 (± 21)	0	67	4 (± 6)	0	18
Abaxial overgrowth of weight-bearing border	15 (± 16)	0	40	37 (± 24)	0	86	3 (± 6)	0	17	3(± 6)	0	18
Hamorrhages of the white line	97 (± 7)	80	100	69 (± 24)	36	100	86 (± 21)	40	100	86 (± 22)	33	100
Behavioural parameters												
Mean duration of lying bouts (min)	92.0 (± 17.2)	63.3	133.0	66.3 (± 12.1)	47.0	103.7	49.4 (± 12.7)	25.0	74.6	85.9 (± 27.6)	41.8	125.9
Frequency of lying bouts (per 24 h)	9.2 (± 1.6)	7.0	12.7	12.2 (± 1.6)	8.7	15.0	16.5 (± 4.5)	9.1	28.3	10.6 (± 3.9)	6.3	19.4
Frequency of short-standing bouts (per 24 h)	1.6 (± 1.0)	0.6	4.1	4.0 (± 1.0)	2.1	5.5	4.8 (± 1.9)	2.2	8.8	2.1 (± 1.7)	0.3	6.3
Mean duration of lying down (s)	27.6 (± 62.8)	4.3	234.6	14.1 (± 29.8)	3.9	152.1	6.5 (± 5.8)	3.7	35.7	11.0 (± 17.8)	3.6	86.5
Frequency of atypical lying down (per 24 h)	1.7 (± 1.3)	0.0	5.0	0.1 (± 0.4)	0.0	1.6	0.0 (± 0.0)	0.0	0.0	1.0 (± 1.1)	0.0	3.3
Difficulties in lying down	3.3 (± 2.0)	0.9	8.4	0.6 (± 0.6)	0.0	2.3	0.1 (± 0.2)	0.0	0.7	2.0 (± 1.9)	0.0	5.6
Frequency of lying-down intentions (per 6 h)	1.5 (± 1.1)	0.2	4.1	0.4 (± 0.3)	0.0	1.4	0.0 (± 0.1)	0.0	0.5	1.0 (± 1.0)	0.0	2.9
Mean duration of standing up (s)	11.7 (± 17.6)	5.1	88.3	7.6 (± 8.1)	3.7	46.8	6.7 (± 6.6)	3.5	40.0	9.8 (± 12.1)	4.2	60.4
Frequency of atypical standing up (per 6 h)	1.8 (± 1.1)	0.0	4.0	0.3 (± 0.3)	0.0	1.3	0.1 (± 0.1)	0.0	0.3	1.2 (± 1.1)	0.0	3.3
Difficulties in standing up	2.0 (± 1.1)	0.0	4.0	0.5 (± 0.4)	0.0	1.4	0.1 (± 0.1)	0.0	0.3	1.3 (± 1.2)	0.0	3.5
Percentage lying flat on side (per 24 h)	2.8 (± 1.5)	0.7	6.1	2.9 (± 1.7)	0.5	7.0	4.3 (± 2.4)	0.4	11.2	4.0 (± 2.1)	0.1	8.0
Farm parameters												
Daily weight gain (g)	1,322.4 (± 118.3)	1,095	1,477.9	1, 326.7 (± 139.7)	1,068.8	1,555.5	1,382.4 (± 165.1)	1,041.1	1,519.1	1,267.5 (± 139.0)	1,100.1	1,607.9

Table 4 Pair-wise comparisons of housing systems using a Tukey HSD test (*Z*-values and *P*-values).

	RS–CS		ST–CS		SS–CS		ST–RS		SS–RS		SS–ST	
Health parameters (%)	***Z*-value**	***P*-value**	***Z*-value**	***P*-value**	***Z*-value**	***P*-value**	***Z*-value**	***P*-value**	***Z*-value**	***P*-value**	***Z*-value**	***P*-value**
Mild tarsal joint lesions	–1.620	0.360	0.020	1.000	1.360	0.510	0.930	0.780	2.700	0.030	0.830	0.840
Mild tail-tip scabs (% animals per pen)	–5.598	< 0.001	–5.724	< 0.001	–0.791	0.854	–2.057	0.178	4.805	< 0.001	5.290	< 0.001
Total tail-tip scabs (% animals per pen)	–5.731	< 0.001	–5.775	< 0.001	–0.702	0.893	–2.021	0.191	5.027	< 0.001	5.400	< 0.001
Severe lameness (% animals per pen)	–3.183	0.013	–2.969	0.023	–2.203	0.134	–0.884	0.808	0.979	0.757	1.550	0.409
Ringworm infection (% animals per pen)	1.661	0.348	3.004	0.021	0.046	1.000	1.961	0.230	–1.614	0.373	–1.614	0.020
Total number of early losses	–3.160	0.014	–0.890	0.805	–1.791	0.284	1.180	0.635	1.367	0.518	–0.289	0.991
Cleanliness parameters (% of animals)												
Low cleanliness of abdomen	0.929	0.781	–0.592	0.931	–1.931	0.204	–1.088	0.686	–2.608	0.041	–0.432	0.972
High cleanliness of back view	0.371	0.982	3.723	0.003	3.306	0.010	3.480	0.006	2.935	0.025	–1.582	0.391
Low cleanliness of hind leg above the knee	2.507	0.070	–2.066	0.175	–3.546	0.005	–3.708	0.003	–6.052	< 0.001	–0.262	0.993
Low cleanliness of tarsal joint	0.912	0.793	–1.970	0.209	–2.181	0.140	–2.567	0.061	–3.093	0.017	0.549	0.945
Claw parameters (% of animals)												
Concavity of the dorsal wall	6.079	< 0.001	5.004	< 0.001	–0.889	0.805	1.113	0.676	–6.946	< 0.001	–5.649	< 0.001
Relief in the dorsal wall (on both extremities)	3.579	0.005	3.394	0.008	–1.435	0.479	0.874	0.814	–5.172	< 0.001	–4.515	< 0.001
Defects of the heel horn (> 1 cm)	1.148	0.654	5.366	< 0.001	0.758	0.869	4.597	< 0.001	–0.406	0.976	–4.970	< 0.001
Horn erosions > 1/3 of the heel	4.890	< 0.001	–0.264	0.993	–1.271	0.577	–3.361	0.008	–6.131	< 0.001	–0.539	0.947
Overgrowth on the horn of the heel to/in the sole	6.092	< 0.001	1.107	0.680	–2.310	0.108	–2.762	0.039	–8.348	< 0.001	–2.591	0.058
Horn erosions > 1/3 of the sole	2.701	0.045	0.626	0.920	–1.321	0.556	–1.090	0.690	–3.992	0.001	–1.475	0.452
Excessive wear at the apex	1.345	0.531	3.100	0.017	–0.796	0.851	2.224	0.129	–2.123	0.157	–3.656	0.004
Abaxial overgrowth of the weight-bearing border	3.111	0.016	–1.250	0.994	–1.832	0.266	–2.314	0.107	–4.902	< 0.001	–0.966	0.764
Axial overgrowth of the weight-bearing border	1.356	0.524	3.401	0.007	–1.112	0.677	2.516	0.069	–2.443	0.081	–4.162	0.001
Haemorrhages of the white line	–3.568	0.005	0.183	0.998	–1.396	0.500	2.443	0.081	2.201	0.135	–1.073	0.700
Behavioural parameters												
Mean duration of lying bouts (min)	–3.347	0.004	–3.764	0.001	–2.343	0.079	–2.225	0.105	1.135	0.646	2.939	0.016
Frequency lying bouts (per 24 h)	3.535	0.002	3.940	< 0.001	2.095	0.142	2.188	0.116	–1.698	0.306	–3.216	0.006
Frequency of short standing bouts (per 24 h)	4.238	< 0.001	3.933	0.001	1.803	0.266	0.685	0.900	–2.997	0.014	–3.136	0.009
Mean duration of lying down (s)	–0.284	0.992	–2.620	0.042	0.408	0.976	–2.463	0.063	0.664	0.907	3.066	0.011
Frequency of lying-down intentions (per 6 h)	–3.011	0.013	–3.080	0.010	–1.968	0.190	–1.282	0.559	1.083	0.687	2.164	0.126
Mean duration of standing up (s)	–2.232	0.108	–3.360	0.004	–0.715	0.887	–2.168	0.126	1.377	0.502	3.205	0.007
Frequency of atypical standing up (per 6 h)	–2.810	0.023	–2.885	0.018	–1.396	0.482	–1.545	0.391	1.266	0.566	2.436	0.064
Percentage lying flat on the side (per 24 h)	–0.285	0.992	2.686	0.035	2.365	0.082	2.865	0.021	2.589	0.046	–0.909	0.797
Farm parameters												
Daily weight gain (g)	0.090	1.000	3.790	0.002	–0.400	0.975	3.760	0.003	–0.480	-0.957	–4.070	< 0.001

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Table 5 Special cases and model analysis. Pair-wise comparisons of housing systems using a Tukey HSD test (*Z*-values and *P*-values) for parameters, which were never, only occasionally or always observed in one system.

	RS–CS		ST–CS		SS–CS		ST–RS		SS–RS		SS–ST					
	Z-value	*P*-value	*Z*-value	*P*-value	*Z*-value	*P*-value	*Z*-value	*P*-value	*Z*-value	*P*-value	*Z*-value	*P*-value	A	B	C	D
Health parameters (% of animals)																
Severe tail-tip scabs	−2.608	0.024	NA	NA	−0.411	0.910	NA	NA	2.428	0.039	NA	NA	GLM		0.083	0.002
Mild tail-tip scabs	−2.389	0.044	NA	NA	0.348	0.935	NA	NA	2.547	0.029	NA	NA	GLM		0.250	0.006
Severe tail-tip wounds	NA	NA	NA	NA	−1.411	0.158	NA	NA	NA	NA	NA	NA	GLM		0.577	0.142
Total tail-tip wounds	−2.668	0.021	NA	NA	−1.020	0.563	NA	NA	1.856	0.151	NA	NA	GLM		0.332	0.009
Severe tail-tip lesions	−2.060	0.098	NA	NA	−0.361	0.930	NA	NA	1.802	0.168	NA	NA	GLM		0.084	0.056
System-related antibiotic treatments	NA	NA	NA	NA	−1.613	0.107	NA	NA	NA	NA	NA	NA	GLM		0.139	0.082
Non-system related early losses	NA	NA	1.29	0.40	0.032	0.999	NA	NA	NA	NA	−1.289	0.395	GLM		0.882	0.380
Mid carpal joint lesions	NA	NA	NA	NA	NA	NA	−5.459	< 0.001	4.760	< 0.001	8.709	< 0.001	LM		< 0.001	< 0.001
Severe carpal joint lesions	−7.296	< 0.001	NA	NA	−0.077	0.997	NA	NA	7.078	< 0.001	NA	NA	LM		0.876	< 0.001
Total carpal joint lesions	NA	NA	NA	NA	NA	NA	−5.81	< 0.001	4.770	< 0.001	9.070	< 0.001	LM		< 0.001	< 0.001
Cleanliness parameters (% of animals)																
High cleanliness of hind leg below knee	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	−1.053	0.292	GLM		0.883	0.283
Low cleanliness of lower neck	1.317	0.384	NA	NA	1.019	0.564	NA	NA	−0.287	0.955	NA	NA	GLM		0.620	0.363
Behavioual parameters																
Frequency of atypical lying down (per 24 h)	−4.790	< 0.001	NA	NA	−1.844	0.155	NA	NA	3.171	0.004	NA	NA	GLM	0.133	0.114	< 0.001
Difficulties lying down	−4.653	< 0.001	NA	NA	−0.293	0.953	NA	NA	3.747	< 0.001	NA	NA	GLM	0.216	0.110	< 0.001
Difficulties standing up	−4.462	< 0.001	NA	NA	−1.445	0.318	NA	NA	2.781	0.015	NA	NA	GLM	0.153	0.570	< 0.001

NA: No statistics calculated for this comparison; A: Model; B: Effect of temperature; C: Effect of space allowance; D: System effect.

deviance for logistic regression), each pair of housing systems was compared using a Tukey HSD test (*Z* statistic given in the results).

For some parameters we observed considerable differences between the housing systems especially when the parameters were never, only occasionally or always observed in one of the systems. In these cases, only the remaining systems were compared using the Tukey HSD test.

Results

Summary statistics for all parameters are listed in Tables 3, 4, 5 and 6.

Health and cleanliness

Health

We found a considerable influence of housing type on health parameters. Bulls in ST did not have any severe tail-tip alterations like severe scabs, wounds or lesions and

Table 6 Output of the linear model (LM) or generalised linear model (GLM), if available *P*-values are given for the effect of temperature, space allowance and housing system.

Parameter	Model	Effect of temperature	Effect of space allowance	System effect
Health parameters (% of animals)				
Mild tail-tip scabs (% animals per pen)	LM	NA	< 0.001	< 0.001
Total tail-tip scabs (% animals per pen)	LM	NA	< 0.001	< 0.001
Mild tarsal joint lesions	GLM	NA	0.030	0.027
Severe lameness (% animals per pen)	LM	NA	0.628	0.006
Ringworm infection (% animals per pen)	LM	NA	0.023	0.014
Total number of early losses	LM	NA	0.450	0.027
Cleanliness parameters (% of animals)				
Low cleanliness of abdomen	GLM	NA	0.005	0.029
High cleanliness of back view	LM	NA	< 0.001	< 0.001
Low cleanliness of hind leg above the knee	LM	NA	< 0.001	< 0.001
Low cleanliness of tarsal joint	LM	NA	0.002	0.009
Claw parameters (% of animals)				
Concavity of the dorsal wall	LM	NA	0.204	< 0.001
Relief in the dorsal wall (on both extremities)	LM	NA	0.006	< 0.001
Defects of the heel horn > 1 cm	LM	NA	0.027	< 0.001
Horn erosions > 1/3 of the heel	LM	NA	0.131	< 0.001
Overgrowth on the horn of the heel to/in the sole	LM	NA	0.061	< 0.001
Horn erosions > 1/3 of the sole	LM	NA	0.925	0.002
Apex severely rounded	LM	NA	0.052	0.012
Axial overgrowth of the weight-bearing border	LM	NA	0.083	< 0.001
Abaxial overgrowth of the weight-bearing border	LM	NA	0.031	< 0.001
Haemorrhages of the white line	LM	NA	0.580	0.005
Behavioural parameters				
Mean duration of lying bouts (min)	GLM	0.592	< 0.001	< 0.001
Frequency of lying bouts (per 24 h)	GLM	0.441	0.003	< 0.001
Frequency of short standing bouts (per 24 h)	GLM	0.935	0.045	< 0.001
Mean duration of lying down (s)	GLM	0.006	0.002	0.005
Frequency of lying-down intentions (per 6 h)	GLM	0.046	< 0.001	< 0.001
Mean duration standing up (s)	GLM	0.486	0.007	< 0.001
Frequency of atypical standing up (per 6 h)	GLM	0.141	< 0.001	< 0.001
Percentage of ying flat on the side (per 24 h)	GLM	0.200	0.660	0.004
Farm parameters				
Daily weight gain (g)	LM	NA	0.531	0.002

therefore models for these parameters were calculated without ST. They also showed clearly fewer carpal lesions than bulls in all other systems.

In bulls housed in RS, scabs and wounds on the tail tip and severe carpal joint lesions occurred more rarely than in bulls housed in CS and SS (see Figure 1). The total number of early losses was significantly lower in RS than in CS.

Bulls in CS had most total carpal joint lesions (see Figure 2). Furthermore, the incidence of severe lameness was significantly higher in bulls in CS than in bulls in ST and RS.

The tail-tip alterations mild, severe and total tail-tip scabs showed a high positive correlation with mild and total tail-tip wounds ($r_p > 0.70$).

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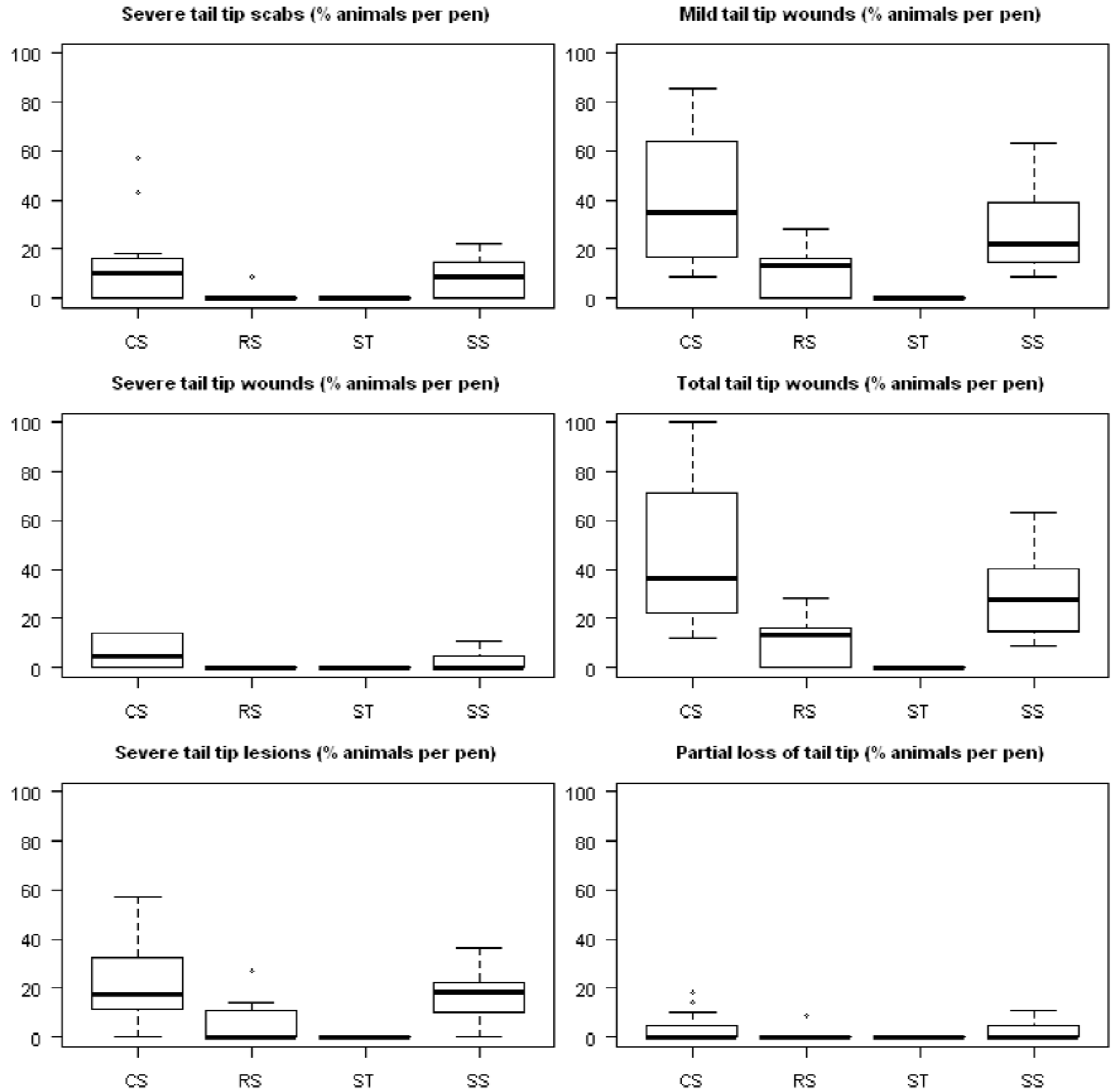
Figure 1



Boxplots of percentages of bulls per pen with tail-tip wounds, scabs, lesions and partial loss of tail tip of bulls in CS, RS, ST and SS.

Mild, severe and total carpal joint lesions also showed a high positive correlation ($r_p > 0.70$). Furthermore, they showed a high correlation with mild and total tail-tip scabs.

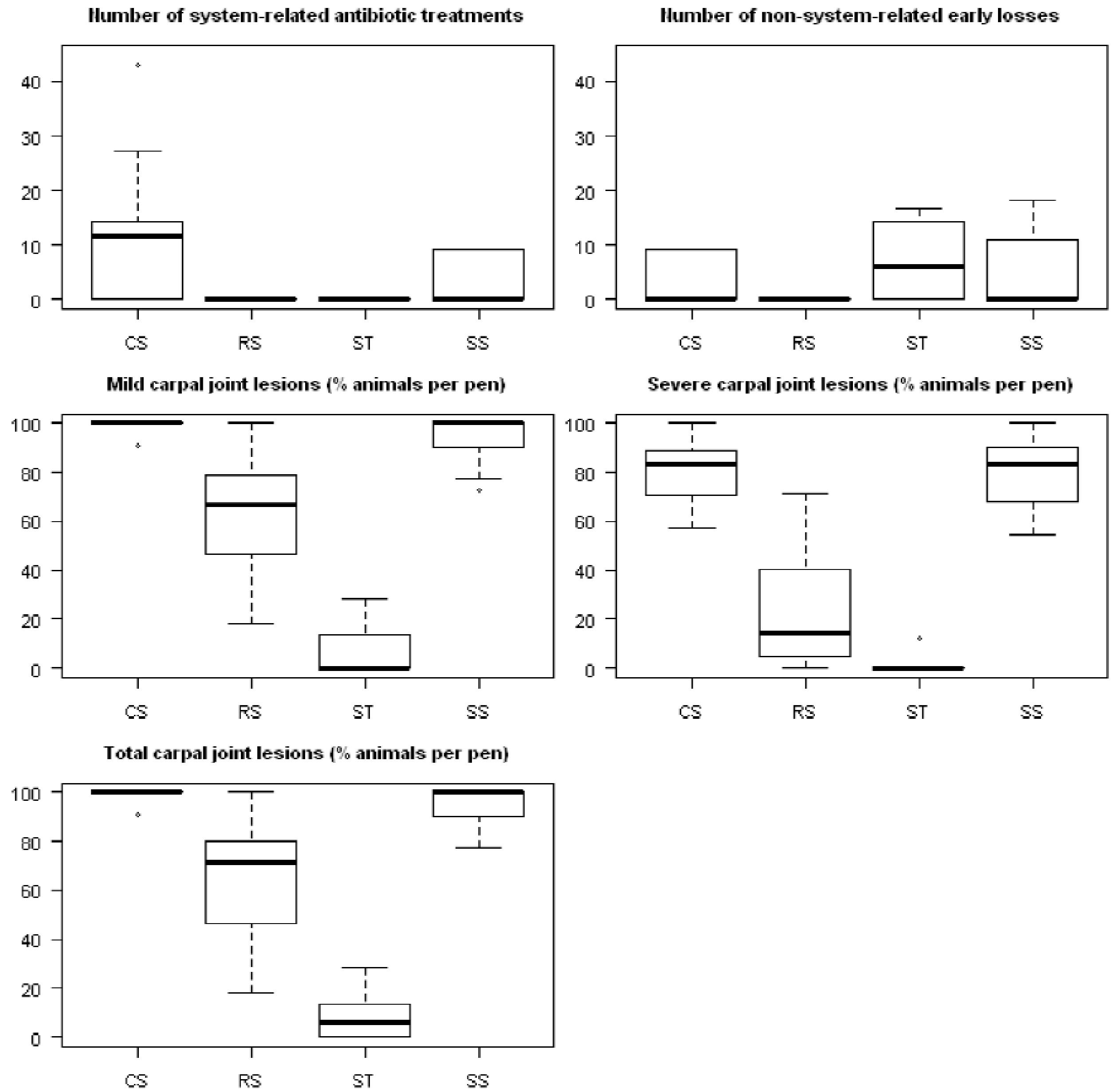
The analysis of the farmers' health records showed an influence of housing system on the number of system-related antibiotic treatments and non-system-related early losses (Figure 2). Bulls in ST and RS never had to be treated with antibiotics because of system-related diseases and non-system-related early losses occurred less frequently in RS than in all other systems.

Cleanliness

We found a significant influence of housing system on the cleanliness of the following body regions: back view, hind leg above the tarsal joint, tarsal joint and abdomen. The back view of bulls in ST and SS were significantly cleaner than those of bulls in CS and RS.

Tarsal joints and abdomen of bulls in RS were significantly dirtier than those of bulls in SS, and their hind leg above the tarsal joint was significantly dirtier than that of bulls in ST and SS.

Figure 2



Boxplots of number of systems-related antibiotic treatments and non-system-related early losses of bulls and percentage of bulls per pen with carpal joint lesions in CS, RS, ST and SS.

Low cleanliness of abdomen, of hind leg above the tarsal joint and of tarsal joint showed a highly positive correlation with each other ($r_p > 0.70$).

Claws

Claw horn

Claws from bulls in ST and RS showed clear signs of reduced abrasion: the dorsal wall was significantly more concave in bulls in ST and RS than in bulls in CS and SS and showed significantly more relief (ridges) in the dorsal wall on both extremities.

We found significantly more defects of the heel horn deeper than 1 cm (> 1 cm) in bulls in ST than in all other systems. Claws of bulls in RS had more heel-horn erosions > 1/3 of the heel and overlapping of heel horn over sole horn than claws of bulls in all other systems. In addition, we found significantly more horn erosions > 1/3 of the claw sole in RS than in bulls in CS and SS.

The apex of the claws was significantly more severely rounded (over the white line) and the axial flexion of the overgrown weight-bearing border more often found in bulls in ST than in bulls in CS and SS. However, abaxial flexion of the overgrown weight-bearing border occurred significantly more often in bulls in RS than in bulls in CS and SS.

Haemorrhages of the white line were found significantly more often in claws of bulls in CS than in RS; values of bulls in ST and SS were intermediate between CS and RS.

Corium

Independent of housing type, many haemorrhages at the corium were observed.

Focal retraction of the corium wall was most often observed in the claws of bulls housed in CS and less often in bulls accommodated in RS. However, the differences did not reach the level of significance.

Behavioural observations

The number and mean duration of lying bouts were influenced significantly by the housing system. The number of lying bouts was significantly higher in ST and RS (ST > CS, SS; RS > CS) and, in contrast, significantly lower in ST and RS (ST < CS, SS; RS < CS).

Mean duration of lying bouts showed a high negative correlation with the number of lying bouts and the number of short standing bouts ($r_p > -0.70$) and showed a high positive correlation with difficulties in lying down and lying-down intention ($r_p > 0.70$)

We found no significant influence of housing system on total lying time.

The number of short standing bouts also differed notably between housing systems and was significantly higher in ST and RS as compared to CS and SS. Furthermore, we found that the mean duration of standing up and lying down was significantly lower in ST than in CS and SS. The number of atypical standing-up events and the number of lying-down intentions was significantly lower in ST and RS than in CS. Atypical lying down, difficulties in lying down and difficulties in standing up were only rarely observed in bulls in ST. The parameters mentioned above occurred significantly less frequently in bulls in RS than in CS and SS.

The number of atypical standing-up and lying-down events showed a highly positive correlation with difficulties in standing up and lying down ($r_p > 0.70$). Furthermore, difficulties in lying down showed a high positive correlation with lying-down intention.

With regard to the lying positions, we found a significantly greater number of animals lying on their side in ST than in CS and RS.

Due to its low frequency, slipping was not analysed statistically. Summary statistics, however, showed a slightly greater frequency of slipping when standing up and lying down in CS than in all other systems. Slipping while licking was observed more frequently in CS and RS than in ST and SS.

Farm data

Bulls were slaughtered at an age of 16–17 months, weighing 703 kg on average.

Bulls in ST had a significantly higher daily weight gain than bulls in all other systems.

Discussion

The aim of this study was to investigate different housing systems under typical conditions on-farm in Austria. All farms participating in this study were members of or supported by the Austrian Fattening Bull Organisation and characterised by good management and high levels of production. However, as regards animal health and welfare, our results showed that the various housing types differed considerably.

As shown in previous studies, carpal and tarsal joint lesions were less prevalent in bulls in ST (Schrader *et al* 2001; Friedli *et al* 2004; Mayer *et al* 2007) — severe lesions or tail-tip alterations were not detected at all in bulls in ST. The resting behaviour of bulls in ST showed the fewest alterations and corresponded generally to what is described as typical of cattle. Therefore, our results indicate that among the housing systems investigated, straw bedding best meets the needs of fattening bulls.

By contrast, bulls in CS had most health problems and behavioural alterations which, again, is in line with the results of previous studies (eg Ruis-Heutinck *et al* 2000; Schrader *et al* 2001; Gygax *et al* 2007a; Mayer *et al* 2007; Platz *et al* 2007; Schulze Westerath *et al* 2007). Both health problems, which are often concurrent with pain (eg lameness) and behavioural alterations, have an immediate influence on the well-being of the fattening bulls. The incidence of severe lameness was highest in bulls in CS. The fact that bulls in CS needed more system-related antibiotic treatments than bulls in all the other systems also gives an indication of the health problems caused by this housing type.

Rubber mats seem to improve the situation of bulls kept in fully slatted pens. Carpal joint lesions as well as severe tail-tip alterations were found less frequently in bulls in RS than in bulls in CS. Behavioural alterations also occurred less often in bulls in RS than in bulls in CS. The lower number of lying periods and compensatory higher mean duration of lying bouts in CS might be due to the hard concrete floor, which can cause pain in the carpal joints and consequently reduce the frequency of getting up and lying down (Haley *et al* 2000).

With regard to claw health, we found alterations caused typically by reduced claw abrasion in bulls in RS and ST. However, these alterations did not cause clinical symptoms and appear therefore to have no negative impact on the bulls' well-being. The incidence of severe lameness and system-related antibiotic treatments, which include treatments caused by claw lesions, was still higher in CS than in RS or ST. Thio *et al* (2005) also found reduced claw abrasion in fattening bulls housed on rubber mats. Differing from the results of our study, Thio *et al* (2005) found no alterations of the corium at all, but the authors argued that with a longer fattening period (bulls in Switzerland are slaughtered as soon as they reach a live weight of approximately 550 kg) claw alterations might become more serious. Eilers and Sekul (2006) also found reduced claw abrasion in German bulls kept on slats covered with rubber mats but no increase in corium alterations although bulls were slaugh-

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tered at around 652 kg. Under Austrian conditions, with a live-weight average of 703 kg at time of slaughter, we found corium alterations (especially haemorrhage) but, surprisingly, irrespective of housing type. Our pathological/histological analyses of the corium revealed no evidence of laminitis. Ossent and Lischer (1998) examined healthy claws, post mortem, and found haemorrhage and oedematous alterations within the corium wall and at the sole, caused by congestion. Therefore, one cannot say for certain whether haemorrhages affect the welfare of the bulls.

With the exception of reduced claw abrasion, the only significant difference between CS and RS regarding claw health was the incidence of white line disease. Claws from bulls in CS were most affected by white line haemorrhages and retractions of the corium wall. According to Ossent and Lischer (1998), retractions of the wall corium occur as a consequence of white line disease.

On occasion, farmers raised concerns that the bulls were dirtier as a result of the surface quality of rubber mats, especially as bulls should be presented for slaughter in a clean condition and a high level of dirt could affect skin function or ectoparasite incidence. However, bulls in CS and RS did not differ in terms of cleanliness, which is in line with the results of other studies (Lowe *et al* 2001b; Schulze Westerath *et al* 2007). Lowe *et al* (2001b) also found significantly cleaner bulls on straw than in fully concrete slatted floor pens or fully slatted floor pens covered with rubber mats. However, repeating their investigations, the authors found no influence of housing system on cleanliness whatsoever. Rubber mats seem to improve the skid resistance of slatted floors as the number of slipping incidents, when standing up and lying down, was lower in pens covered with rubber mats than in slatted floor pens. Due to its low frequency, slipping was not analysed statistically. In any case, our results indicate that rubber mats do not lead to a higher incidence of slipping.

Although rubber mats obviously improve the situation of bulls in slatted floor pens, this improvement had no effect on daily weight gain. One reason might be that the farms investigated had a very high production level with little or no scope for an increase. No differences in the daily weight gain of bulls in CS and RS was found which is in line with the results of Lowe *et al* (2001b) and Eilers and Sekul (2006). However, bulls in straw-bedded pens had a significantly higher daily weight gain than bulls in all other systems. Feed rations were analysed and optimised every year by the Austrian Fattening Bull Organisation. This allowed us to make sure that there were no clear differences in ration composition during the assessment periods. Thus, the weight-gain results are not easily explainable by different feed rations. An influence of housing system on daily weight gain was described in earlier studies: a higher daily weight gain was found in bulls kept in paddocks compared with bulls in slatted floor pens (Hickey *et al* 2002) and with tethered bulls (Stanek *et al* 2007). Herva *et al* (2009) observed a positive relationship between on-farm welfare and daily carcase gain of bulls. In contrast, Mayer *et al* (2007) found no influence of housing type on daily weight gain of fattening bulls. One possible reason for this could be that bulls had already been slaughtered at a live weight of about 550 kg.

The results for bulls kept in SS indicate that the extended rearing period on straw had no long-lasting beneficial effects on welfare. With regard to the whole fattening period, bulls in SS showed more or less the same health and behavioural alterations than those kept in CS. Nevertheless, this housing type is preferable to the conventional slatted floor system for it allows the bulls to be kept under straw-yard conditions for a longer period. A possible way to improve the well-being of fattening bulls in regions poor in straw might be to rear them on straw until they weigh 450 kg and then move them into slatted floor pens covered with rubber mats.

One may argue that not only the floor type but also farm, space allowance, temperature or time of year affected the health and behaviour of the fattening bulls. The influence of space allowance and temperature were considered in the statistical model, and video recordings of the behaviour were made at similar times of the year in all systems. However, values of the effect of space allowance reached significant levels in the models. As space allowance in CS and RS were completely identical within the farms, it appeared that these significant-effect levels seemed to be caused only by ST. The aim of our study was to compare the typically different fattening-housing systems under on-farm conditions: higher space allowance in straw-bedding systems with an additional feeding area are a necessity of, and a particular characteristic of, this system. Therefore, the effect of space allowance on some of our results, especially on bulls' lying behaviour, notably in ST, cannot be ignored. Previous studies (Gygax *et al* 2007b) showed that with increasing space allowance, fattening bulls had more lying bouts per day and lay for longer periods on their sides. Therefore, space allowance could certainly also have affected our results regarding the number of lying bouts (for the statistics for bulls lying on the side showed no effect of the covariate). However, the fact that bulls in RS (where pens had the same space allowance as those in CS) also showed a higher number of lying bouts as well as fewer behavioural alterations than bulls in CS, indicating that the increased softness of the floor had an important effect on the results.

We are aware of the fact that there is the possibility of other farm-related effects influencing our results. In an on-farm study, all possible influencing factors cannot be excluded totally. However, our results are in line with other studies and can be readily explained by the different floor types. For further specific comparisons of rubberised and concrete slatted floors (RS and CS), we also carried out statistical analyses (Mann-Whitney *U*-tests) within the three farms housing their bulls on concrete slatted floors and slatted floors with rubber mats. The results supported those from the statistical models.

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Animal welfare implications

Health problems and behavioural alterations were seen less often in bulls housed on rubber mats than in bulls on hard concrete flooring, so rubber mats improved welfare to some degree. There was no evidence of a negative effect of rubber mats on bulls' cleanliness or on claw health associated with pain. However, rubber mats do not have the softness of straw bedding, and bulls housed on straw bedding displayed the fewest health problems and behavioural alterations. In our study, the bulls in ST also had the highest daily weight gain. Once moved to slats, bulls with an extended rearing period on straw (SS) developed the same behavioural alterations and health problems as bulls housed in slatted floor pens during the entire fattening period.

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