THE OCCURRENCE OF TAIL TIP ALTERATIONS IN FATTENING BULLS KEPT UNDER DIFFERENT HUSBANDRY CONDITIONS

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Abstract

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Pathological alterations of the tail tip are a severe problem for fattening cattle husbandry with respect to animal welfare and economic losses. We compared the frequencies of tail tip lesions and less severe skin damage in bulls on farms with slatted-floor pens (slat, n = 10), slatted floor pens with prophylactic tail docking (slat/dock, n = 9), and deep bedding pens (straw, n = 10). In addition, the subjects' weight, their space allotment and the season of the year were determined to test whether they were related to the frequency of tail tip lesions and skin damage. Results are based on 8782 tail inspections in 764 pens. The frequency of the more severe tail tip lesions was highest in slat farms, less high in slat/dock farms, and lowest in straw farms. However, the incidence of the less severe skin damage was highest in slat farms, less high in straw farms, and lowest in slat/dock farms. The frequency of tail tip lesions increased with the weight of bulls in slat and slat/dock farms, but not in straw farms. In addition, in slat and slat/dock farms the incidence of tail tip lesions increased with a decreasing space allotment. The frequency of skin damage increased with increasing weight of bulls in each housing condition. The effect of weight on the number of tail tip lesions and skin damage was stronger in autumn, ie the period following the warm season, compared to spring. Our results suggest that a soft floor and an enlarged space allotment are the most suitable means of preventing tail tip lesions in fattening bulls. Prophylactic tail docking can reduce the occurrence of tail tip lesions only to a lesser degree and may impair the animals' welfare.

Keywords: *animal welfare, fattening cattle, housing condition, tail docking, tail tip necrosis*

Introduction

Pathological alterations of the tail tip are a severe problem for cattle husbandry, especially in intensively housed fattening bulls. In housing systems with slatted floors, about 25 per cent to 90 per cent of beef cattle can be affected by pathological alterations of the tail tip, such as skin lesions, inflammations, and necrosis (Kunz & Vogel 1978; Drolia *et al* 1991; Metzner *et al* 1994). In some cases, about 6 per cent to 30 per cent of fattening cattle exhibit the most severe alteration of the tail tip, ie a purulent-necrotic inflammation (George *et al* 1970; Buczek *et al* 1984a; Eckert & Dirksen 1989; Martelli *et al* 1993).

Although the aetiology of tail tip necrosis is still not fully understood, it seems to originate from skin alterations such as irritation or traumatic lesions of the tail tip (Kunz & Vogel 1978; Lenk 1981; Drolia *et al* 1991; Heckert *et al* 1995). These injuries become secondarily infected (mainly by *Corynebacterium pyogenes*, Buczek *et al* [1984b]; Cygan *et al* [1984]; Bisgaard Madsen & Nielsen [1985]) which may lead to cellulitis (suppurating inflammation of the subcutis), abscessed inflammations of the tail and haematoma. Reduced blood supply to the end of the tail may then result in necrosis. The early stage of infection may often pass unnoticed. These infections can progress from necrosis to a pyemia (bacterial generalized infection) resulting in inflammations of other parts of the body and organs and finally to death if not treated early enough (eg by antibiotics or tail amputation, Lenk [1981]; Buczek *et al* [1984a]; Bisgaard Madsen & Nielsen [1985]). Thus, tail tip necrosis may lead to great economic losses due to reduced weight gain, veterinary costs, total condemnation at slaughter or death of animals. In addition, severe tail tip lesions are a significant welfare problem, since the animals suffer from illness and pain.

Several factors seem to enhance the risk of occurrence of tail tip lesions and necrosis. Among these, the floor type and the space allotment per animal seem to be the most important factors. In various studies, the highest incidence of tail tip lesions was reported by farmers who housed their fattening cattle on slatted floor, compared to solid floor, from which only few cases or none were reported (Bisgaard Madsen & Nielsen 1985; Drolia *et al* 1990; Drolia *et al* 1991). The occurrence of tail tip lesions was also found to be more frequent at low space allotment (Bisgaard Madsen & Nielsen 1985; Eckert *et al* 1989; Drolia *et al* 1990). Moreover, there is some evidence that the incidence of tail tip lesions increases with weight, which often covaries with stocking density and/or a change in the housing system (Eckert & Dirksen 1989; Metzner *et al* 1994). In addition, a Danish study found an increase in amputations due to tail tip necrosis in summer and late summer, which suggests an effect of season (Bisgaard Madsen & Nielsen 1985).

These studies provide valuable insights into the factors which are likely to covary with the occurrence of pathological alterations of the tail tip. However, they also suggest that these different factors interact in the pathogenesis of tail tip alterations. Previous studies were either designed to investigate the relationship between particular factors and tail tip alterations, often did not assess these alterations in vivo, or did not take into account different degrees of tail tip alterations. In addition, none of these studies systematically investigated the effect of prophylactic amputation of the distal part of the tail on the occurrence of tail tip alterations.

Prophylactic tail docking can reduce the occurrence of tail tip lesions in fattening cattle (Lenk 1981). This is done by constricting blood flow with a rubber ring, or by surgery under anaesthesia in calves (< 3 months) or at the beginning of the fattening period (< 6 months). The length of the amputated part differs from a few centimetres (ie only the skin at the tail tip is removed) up to almost the whole length of the tail. As a prophylactic intervention, tail docking in fattening cattle is banned in principle in some countries (eg Denmark, Germany, The Netherlands, Norway, Sweden, Switzerland, United Kingdom), allowed under particular circumstances (eg Germany, Switzerland), or is not covered by legislation (eg Canada, USA). However, when animals already suffer from necrosis, tail docking is often the only possible treatment. In order to prevent pathological tail alterations it is important to identify the different factors which enhance their incidence.

Our study was designed to test whether both prophylactic tail docking and floor type are related to the frequency and severity of tail tip alterations. In addition, we examined the relationship between space allotment, subjects' weight, season of the year and the frequency of tail tip alterations. We examined the tails of fattening bulls housed i) in slatted floor pens; ii) in slatted floor pens with prophylactic tail docking; and iii) in deep bedding pens which are suggested to minimize the occurrence of tail tip alterations (Kunz & Vogel 1978). In order to obtain a differentiated picture of possible alterations of the tail tips, we distinguished between mild alterations such as indurations (hardened skin), scales and cracks, and more severe lesions such as injuries, swellings and purulent lesions or necroses.

Animals and methods

Farms and subjects

We conducted our study on 30 fattening farms which were divided into three groups of 10 farms with different husbandry conditions: i) pens with slatted floor (slat); ii) pens with slatted floor plus tail tip docking (slat/dock); or iii) pens with deep litter (straw). One slat/dock farm changed its husbandry condition after the first sampling period and, thus, was excluded from analysis. All the farms were located throughout Switzerland.

Subjects (fattening bulls) were mainly pure or cross breeds of Simmental and Swiss Brown. In Switzerland, since fattening bulls are kept in fattening pens from a weight of > 150kg until they are slaughtered at a weight of > 500kg, only subjects within this weight range were included in our analysis.

Data collection

We collected the data during two periods which followed the warm season (autumn: August 15th to October 31st) and two periods which followed the cold season (spring: March 1st to October 31st). Each farm was included in each period. Data collection started with the first autumn period in 1992 and ended with the second spring period in 1994.

We clinically examined the tails of 8782 subjects in 764 pens by palpation and by macroscopic and olfactory inspection during weighing of the bulls. All inspections were conducted by the same investigator (C Winterling) who had been trained intensively by veterinary surgeons before the start of the study. The examination distinguished between six findings:

1. Negative findings: no alteration of the tail and the tail tip was found by macroscopic and olfactory inspection or by palpation.
2. Indurations: the skin at the tail tip was harder and tougher than on clinically inconspicuous tail tips.
3. Scales: different forms of an excessive production of the epidermis such as keratinizations.
4. Cracks: cracks in the skin due to a reduction of skin elasticity in combination with scales or keratinizations.
5. Injuries: injuries of the skin (either covered with scab or blood or secreted tissue fluid). In addition we recorded whether injuries were purulent or necrotic.

6. Swellings: enlargement of the circumference of parts of the tail in combination with alterations of the consistency of tissue but without macroscopic injuries.

For statistical analyses we categorized indurations, scales, and cracks as 'skin alterations' and injuries and swellings as 'lesions'.

To standardize for the different number of animals in pens, we calculated the mean number of skin lesions and alterations per subject in each pen and multiplied the outcome by 100. Thus, our dependent variables reflect the percentage of tail tip alterations and lesions per animal and not the number of affected animals.

In addition to tail tip lesions and alterations, we recorded the weight of subjects, the size of pens, and the number of animals per pen. Thus, we were able to calculate the mean weight of subjects per pen and the space allotment per subject (pen size/number of animals) per pen.

Statistical analyses

Since the frequencies of tail tip lesions and alterations approximated a Poisson distribution, we applied the variance stabilizing square-root transformation. We tested for effects of the following factors, husbandry condition (system), farm (farm), sampling period (period), and season (season), and the covariates weight (weight) and space allotment (space) on the dependent variables tail tip alterations and tail tip lesions, by using a General Linear Model (procedure GLM of SAS® Version 6.12 with the option of Type III SS). GLM provides analysis of covariance for the factors and covariates including the interactions between factors and covariates. For both the tail tip lesions and the tail tip alterations we did two analyses.

First, we tested whether the husbandry conditions differed with respect to the frequencies of tail tip lesions and alterations, irrespective of the covariates weight and space allotment. Here, we corrected the frequencies of alterations and lesions per pen by the effect of sampling periods and, subsequently, used the corrected mean values per farm as input. Post hoc comparisons between the three husbandry conditions were done with Fisher's Least Significant Difference (LSD) test.

In the second analysis, we simultaneously tested the effects of three factors (farm, period and season) and of two covariates (weight and space allotment) on the frequencies of tail tip lesions and alterations per pen ($n = 764$). Thus, the effect of each of the factors and covariates included in the model was corrected by the effect of the other factors and covariates. By a stepwise backward elimination (a method to simplify a model by reducing the number of included factors), we found that the dependent variables, lesions and alterations, were differently affected by the covariates (see Results). For lesions we fitted the model 'lesions = constant + period + farm + weight*system + weight*season + space*system + error' and for alterations we fitted the model 'alterations = constant + period + farm + weight*season + space*system + space*weight + error'.

Differences between the husbandry conditions with respect to the mean number of animals per farm, the mean number of animals per farm and pen, the mean pen size, the mean space allotment per farm, the mean weight of subjects per farm, and their mean gain in weight were tested by univariate ANOVA with post hoc comparisons between the three husbandry systems done by Fisher's Least Significant Difference (LSD) test.

Since the distributions of the numbers of purulent and necrotic lesions per farm did not meet the assumption of homogeneity of variances, here we used the Kruskal-Wallis One-Way analysis of variance by ranks with post hoc comparisons as described in Siegel and Castellan (1988). To estimate the relationship between the covariates, weight and space allotment, we calculated the correlation between them using Pearson's correlation coefficient and corrected the probability levels by the Bonferroni adjustment. All parametric statistics were performed using the software SAS® (SAS Institute Inc, Cary, NC, USA, Version 6.12). The level of statistical significance was set as $P < 0.05$.

Results

General differences between husbandry conditions

Farms were comparable in the number of animals per pen ($F_{2,26} = 1.09$, ns), the mean weight of fattening bulls ($F_{2,26} = 0.32$, ns), and their mean daily gain in weight ($F_{2,24} = 0.187$, ns) (Table 1). Slat/dock farms tended to hold the highest and straw farms the lowest total number of animals, but these differences did not reach significance ($F_{2,26} = 3.01$, ns) (Table 1). Pen size differed significantly between husbandry conditions ($F_{2,26} = 23.63$, $P < 0.001$) (Table 1). Straw farms had significantly greater pen sizes compared to slat farms ($t = -5.90$, $df = 26$, $P < 0.001$) and slat/dock farms ($t = -5.95$, $df = 26$, $P < 0.001$). The pens in straw farms consisted of a standing area plus a bedded lying area that had a size of 32.3 ± 9.7 m^2 which was about 73 per cent of the total pen size (Table 1). The pen size in slat farms did not differ significantly from slat/dock farms ($t = 0.20$, $df = 26$, ns). Farms differed significantly in their space allotment ($F_{2,26} = 23.21$, $P < 0.001$) (Table1). Straw farms had a significantly higher space allotment than slat farms ($t = -5.27$, $df = 26$, $P < 0.001$) and slat/dock farms ($t = -6.34$, $df = 26$, $P < 0.001$). The space allotment in relation to the lying area on straw farms was 2.76 ± 0.97 m^2 per subject (Table 1).

Table 1 Basic data (mean ± SD) comparing the three different husbandry conditions in the study.

Type	Number of farms	Animals per farm	Animals per pen	Pen size [m^2]	Space allotment [m^2 subject^{-1}]	Weight [kg]	Gain in weight [gd^{-1}]
Slat	10	76.8 ± 17.6	10.8 ± 1.9	22.6 ± 4.0	2.15 ± 0.27	339.4 ± 18.9	1239.0 ± 50.6
Slat/Dock	9	93.5 ± 20.6	12.3 ± 3.4	21.8 ± 7.1	1.77 ± 0.16	333.7 ± 18.9	1222.2 ± 69.0
Straw	10	64.7 ± 36.9	13.2 ± 4.8	44.3 ± 11.6 [a]	3.73 ± 1.10 [b]	334.4 ± 13.1	1242.1 ± 95.7

[a] Mean size of lying areas was 32.2 ± 9.7
[b] Mean space allotment of lying area was 2.76 ± 0.97

The frequencies of both tail tip lesions ($F_{2,26} = 59.23$, $P < 0.001$) and alterations ($F_{2,26} = 40.59$, $P < 0.001$) differed significantly between husbandry systems (Figure 1). The frequency of tail tip lesions was significantly higher on slat farms compared to slat/dock farms ($t = 7.44$, $df = 26$, $P < 0.001$) and straw farms ($t = 10.56$, $df = 26$, $P < 0.001$), and on slat/dock farms compared to straw farms ($t = 2.84$, $df = 26$, $P < 0.01$). Tail tip alterations occurred significantly more often on slat farms compared to slat/dock farms ($t = 8.99$, $df = 26$, $P < 0.001$) and straw farms ($t = 3.85$, $df = 26$, $P < 0.001$). We also found significantly more tail tip alterations on straw farms than on slat/dock ones ($t = -5.25$, $df = 26$, $P < 0.001$).

The frequencies of the most severe tail tip lesions (ie purulent and necrotic lesions) also differed significantly between husbandry conditions ($KW = 20.54$, $df = 2$, $P < 0.001$) (Figure 2). We did not find any purulent or necrotic lesions on straw farms. The frequency of these lesions was significantly higher on slat farms compared to slat/dock farms ($z = 4.86$, $P < 0.001$) and straw farms ($z = 16.80$, $P < 0.001$). The difference between slat/dock farms and straw farms was also significant ($z = 11.94$, $P < 0.001$).

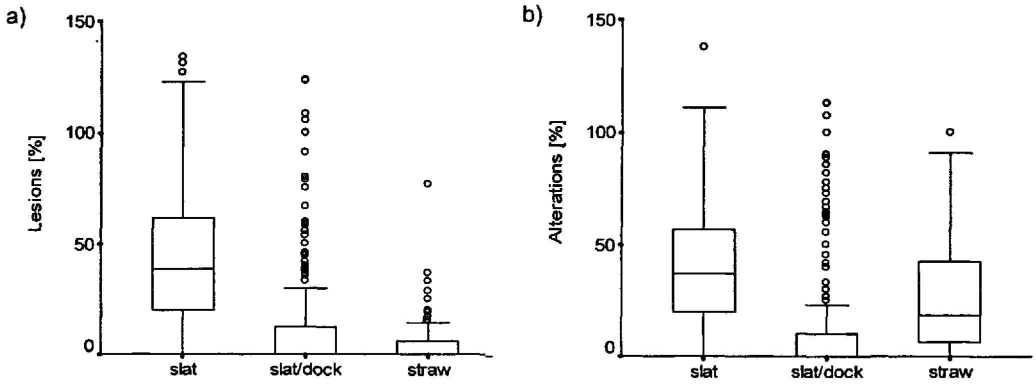

Figure 1 **Boxplot (quartiles and outside values) of the frequencies of (a) tail tip lesions and (b) alterations in the three husbandry conditions. All differences between housing systems were significant (see text).**

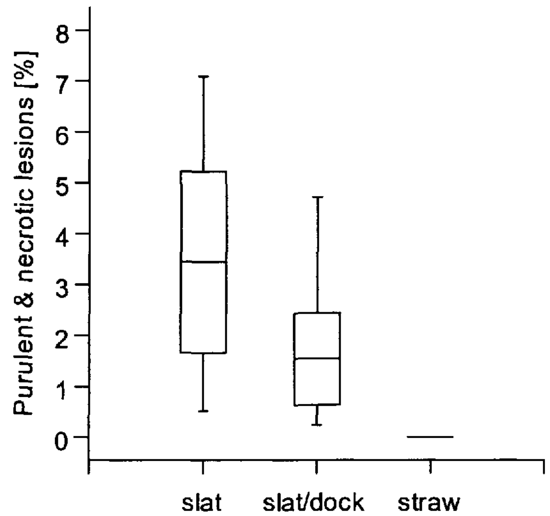

Figure 2 **Boxplot (quartiles and outside values) of the frequency of purulent and necrotic lesions in the three husbandry conditions. All differences between husbandry conditions were significant (see text).**

Effects of weight, space allotment and season

The frequency of tail tip lesions was significantly related to the weight of subjects, but this relationship differed between husbandry conditions (weight*system: $F_{2,725}$ = 26.87, P < 0.001). On slat (t = 8.46, P < 0.001) and slat/dock farms (t = 6.37, P < 0.001) the number of lesions increased significantly with the weight of subjects, but not on straw farms (t = -0.70, ns) (Figure 3a). This relationship was modified by the season of sampling and in autumn the regression coefficient was slightly higher compared to spring (weight*season: $F_{1,725}$ = 6.34, P < 0.05). The frequency of lesions was also significantly related to space allotment, but again this relationship differed between husbandry conditions (space*system: $F_{3,725}$ = 6.47, P <

0.001). With an increasing space allotment we found a decreasing frequency of lesions on slat (t = -2.66, P < 0.01) and slat/dock farms (t = -3.50, P < 0.001), but not on straw farms (t = 0.28, ns). This relationship held for young (200-300 kg) as well as older (400-500 kg) subjects (Figures 4a & 4b).

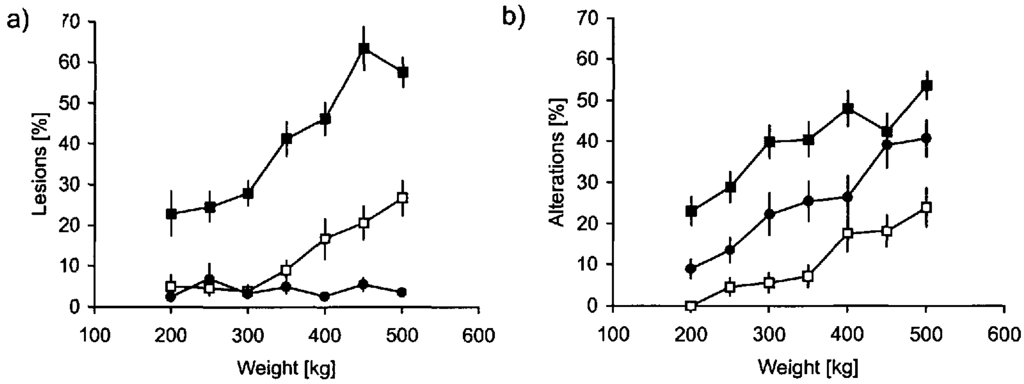

Figure 3 **Mean (± SEM) frequencies of lesions and alterations for different weight classes of subjects on slat farms (filled squares), slat/dock farms (open squares) and straw farms (filled dots): (a) tail tip lesions; (b) tail tip alterations.**

The frequency of tail tip alterations increased significantly with increasing weight of subjects in each of the three husbandry conditions (Figure 3b). As for lesions, the regression coefficient was higher in autumn compared to spring (weight*season: $F_{2,726}$ = 23.19, P < 0.001). With an increasing space allotment, the frequency of alterations increased (space*system: $F_{3,726}$ = 4.73, P < 0.01), but this relationship was only significant on straw farms (t = 3.54, P < 0.001) and neither on slat (t = 0.97, ns) nor on slat/dock farms (t = 1.03, ns). However, space allotment also interacted significantly with the weight of subjects and this interaction reduced the frequency of alteration with an increasing weight of subjects (space*weight: $F_{1,726}$ = 4.59, P < 0.05).

The correlation between weight and space allotment was higher on slat farms (r = 0.59) and slat/dock farms (r = 0.65) than on straw farms (r = 0.30) (all P < 0.001; pooled within groups correlation r = 0.39).

Discussion

Our study systematically investigated whether and how the occurrence of tail tip lesions and less severe tail tip alterations was related to the floor type of pens (slatted floor vs deep bedding) and to prophylactic tail docking (in slatted floor systems). Concurrently, we examined the relationship between the frequency of tail tip lesions and alterations and subjects' weight, space allotment and season. Our results show that the frequency of tail tip lesions and alterations in fattening bulls differed significantly between the three husbandry conditions. In addition, the frequency of tail tip lesions and alterations covaried with the subjects' weight and space allotment and with the season of the year. These relationships also interacted, to some extent, with the effect of husbandry condition.

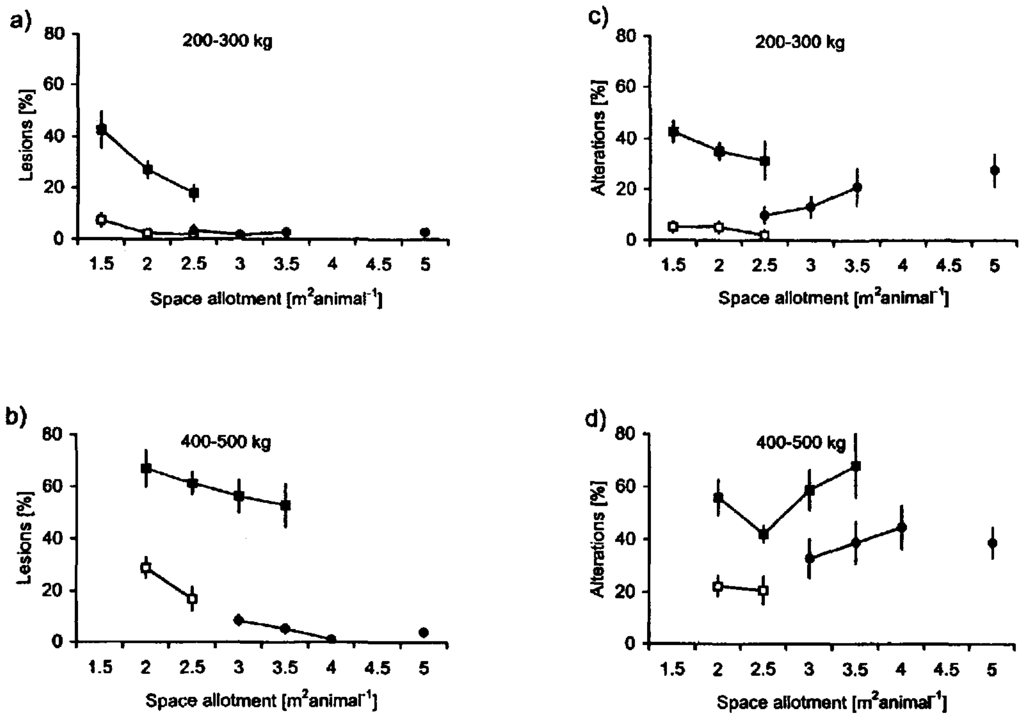

Figure 4 **Mean (± SEM) frequencies of lesions and alterations for different space allotments and weight classes of subjects on slat farms (filled squares), slat/dock farms (open squares) and straw farms (filled dots): (a) tail tip lesions in 200-300 kg bulls; (b) tail tip lesions in 400-500 kg bulls; (c) tail tip alterations in 200-300 kg bulls; (d) tail tip alterations in 400-500 kg bulls.**

Differences between slatted floor and deep bedding pens

The frequency of both tail tip lesions and tail tip alterations was higher in slatted floor pens compared with deep bedding pens. This finding is in line with other studies which reported the highest incidences of tail tip lesions and alterations in housing systems with slatted floors (Bisgaard Madsen & Nielsen 1985; Drolia *et al* 1990; Drolia *et al* 1991). However, these studies compared systems with slatted floors to solid floor systems. We found only one study, apart from our own, which included deep bedding systems (Kunz & Vogel 1978). In that study, however, the authors did not find any tail tip inflammations in the deep bedding system.

Trampling by pen mates seems to be one major cause of tail damage. The tail tip of lying bulls normally lies on the floor away from the animal's body and, thus, relatively unprotected against trampling by the claws of pen mates (Eckert & Dirksen 1988; Eckert *et al* 1989). Trampling on a tail that lies on a hard, inflexible, rough, and sharp-edged floor such as a slatted floor is more likely to result in severe damage than trampling on a soft and flexible floor such as deep bedding which can absorb at least part of the force of the step. In addition, high percentages (up to 50%) of abnormal patterns of standing up and lying down have been reported in slatted floor systems (Graf 1984; Drolia *et al* 1990). It has been suggested that these abnormal behavioural patterns may lead to self-inflicted tail injuries since the tail may come to lie between the hock and the floor (Drolia *et al* 1990). Another possible cause of tail damage could be that the tails sometimes get stuck between the slats. However, the findings that tail tip lesions and alterations can be found almost exclusively within the first 5cm of the tail tip do not support this possibility (Winterling & Graf 1995). Damage resulting from getting the tail stuck between the slats should result in a higher number of lesions and alterations away from the tail tip. Tail damage may also result from striking the tail against the furniture and equipment of the pen (eg walls, bars), but this risk should be comparable between different housing systems. Some authors have also proposed that tail chewing and tail biting may result in damage of the tail, at least in calves (Van Der Mei 1986). However, these behaviours have almost never been observed in studies of beef cattle (Graf 1984; Drolia *et al* 1990).

Effect of prophylactic tail tip docking

On farms with slatted floor pens and prophylactic docking of tail tips, the occurrence of tail tip lesions and alterations was significantly reduced compared to farms with slatted floor pens. Studies on the innervation of docked tails, for instance in pigs, have demonstrated uneven nerve distribution and regressive changes in the distal part of the docked tails (Simonsen *et al* 1991). During the regeneration of the nerves, hyperalgesia (increased sensitivity to pain) may occur. In addition, traumatic neuromas were found, and it has been suggested that the amputation stump becomes more sensitive to pain. This is likely to result in a different lying behaviour since animals seem to protect their docked tails by keeping them close to the body (Winterling & Graf 1995). Alternatively, the reduced occurrence of tail lesions and alterations in docked tails could result from a reduced chance of damage occuring to the reduced length of tail. However, in our study, only 3.5cm of the tails had been docked (about a quarter to a half of the tail tuft) on average.

Apart from hyperalgesia and enhanced sensitivity of the amputated tail stump to pain, this intervention may have additional disadvantages with respect to animal welfare. The tail of cattle serves different functions; it is used to repel insects, for thermal regulation, and it plays a role in communication. These primary functions may be impaired in docked tails. First, the function of the tail might be impaired by the reduced length. The reduction or total loss of the tail tuft is particularly likely to reduce the efficiency of the tail against insect infestation. Secondly, the enhanced pain sensitivity might result in a reduced frequency of relevant behaviours (eg tail wagging). An additional serious welfare problem can arise from the amputation itself, if not performed by a professional. Amputations have to be performed between the vertebrae. However, since the vertebrae of the tail are concave, the amputation is often executed incorrectly within the vertebra, for instance if rubber bands are used. This can result in pathological alterations of the vertebrae such as the development of a bony outgrowth (exostosis) (Kimpfel-Neumaier 1997).

Comparison of the three husbandry conditions

Although we found the lowest frequency of tail tip lesions and no purulent or necrotic lesions in farms with deep bedding pens, the frequency of tail tip alterations was significantly higher in this system than in farms with slatted floor pens plus prophylactic tail docking. Thus, in both slatted floor pens and deep bedded pens, the frequency of trampling may be higher than in slatted floor pens with additional tail docking. However, the consequences of trampling might be less severe in deep bedding pens compared to slatted floor pens. This suggestion is supported by the number of lesions and alterations. In slatted floor pens, the incidence of tail tip lesions was nearly equal to that of alterations, whereas in deep bedding pens we found many more tail tip alterations than lesions. Overall, this indicates that in deep bedding pens the soft quality of the floor is responsible for the reduced incidence of severe tail tip damage, whereas in slatted floor pens with additional tail docking, it is the altered behaviour of animals that is responsible for the reduced frequencies of tail damage. This interpretation is also in accordance with suggestions by Drolia *et al* (1991). In their study they did not find an enhanced risk of less severe alterations becoming severe lesions. Instead, they argued that the development of less severe alterations somehow seems to protect the animals against affliction with severe lesions.

Effects of weight, space allotment and season

Weight

In slatted floor pens and slatted floor pens with prophylactic tail docking, the incidence of both tail tip lesions and alterations increased with an increasing weight of fattening bulls. It seems reasonable that trampling by a heavy animal, ie with great force, would result in more serious damage of the tail than trampling by a light animal. Interestingly, for pens with deep bedding floors, the frequency of lesions remained at a low level, independent of the subjects' weight. As already discussed, deep bedding seems to absorb the force of trampling and, thus, limits serious tail lesions to a minimum. In contrast to lesions, tail tip alterations increased significantly with weight in deep bedding pens. Again, this suggests that the risk of trampling may be comparable at least between slatted floor and deep bedding pens, but that the consequences of trampling are less severe in deep bedding pens.

Space allotment

The frequency of tail tip lesions decreased with an increasing space allotment in slatted floor pens and slatted floor pens with prophylactic tail docking, but not in deep bedding pens. Other studies have shown that with lower space allotments per subject (or higher stocking densities), fattening bulls are more often found lying with tails close to their body, and subjects more often show abnormal patterns when lying down (Eckert & Dirksen 1988; Eckert *et al* 1989). As discussed earlier, this altered lying behaviour may increase the risk of self-inflicted tail injuries with decreasing space allotment on a hard surface such as in slatted floor pens.

In contrast to our findings for lesions, the number of tail tip alterations was not significantly related to space allotment in slatted floor pens and slatted floor pens with prophylactic tail docking. In deep bedding pens we even found an increasing number of tail tip alterations with an increasing space allotment (Figures 4c & 4d). This might result from an enhanced activity of fattening bulls in the larger pens, which may increase the risk of being trampled on the tail tip. However, we also found that space allotment reduced the effect of weight on tail tip alterations. At least in slatted floor pens and slatted floor pens with prophylactic tail docking, the interaction between weight and space allotment resulted in a decreasing effect of weight on the frequency of tail tip alterations with an increasing space allotment. In other words, the age-related increase of tail tip alterations was diminished by increasing space per animal.

A critical point is that in our data, weight and space allotment were positively correlated. Farmers regroup their fattening bulls or house them in larger pens when they reach a certain weight (most often depending on the local legal requirements). Thus, with increasing weight, the space per animal is often increased. However, the correlations between weight and space allotment were relatively low in each housing condition, so it was possible to separate the effects of both covariates by including them simultaneously in our statistical models.

Season

For both tail tip lesions and alterations we found a significant interaction between the weight of subjects and the season of the year in which we sampled. In autumn, ie following the summer, the increase of the frequency of lesions and alterations with increasing weight was higher compared to spring, ie following winter. This result confirms the finding of one study in which the incidence of tail tip necrosis peaked in summer and late summer (Bisgaard Madsen & Nielsen 1985). Studies on the relations between the behaviour of fattening bulls and tail tip necrosis revealed that during lying, at high temperatures, the tails were more often laid down away from the body than at low temperature (Eckert & Dirksen 1988; Eckert *et al* 1989). Furthermore, at high temperatures, subjects move their tails more often, which was additionally correlated with a higher incidence of flies at these temperatures. These behavioural reactions at high temperatures may enhance the risk for tail trampling. In addition, Bisgaard Madsen and Nielsen (1985) have discussed the possibility that hygiene levels might be lower and the environmental conditions for micro-organisms might be better, during the warm season.

Animal welfare implications

Our data suggests that the slatted floor pen was the least appropriate housing system for fattening bulls with respect to the prevalence of tail tip lesions and alterations. We found the highest incidence of purulent and necrotic lesions, of other lesions, and of less severe alterations in this system. Prophylactic tail docking reduced the frequency of tail tip lesions and alterations, and for that reason it is still practised in certain countries. However, the frequency of purulent and necrotic lesions and other lesions were still higher compared to farms with straw pens. In addition, amputation of the tail tip may impair the animals' welfare; amputation aims to treat the symptoms of being kept on a slatted floor with insufficient space allotment, rather than curing the cause of tail tip alterations. Fattening bulls should be allowed to use their tail in an adequate manner. Our data suggests that the most suitable form of husbandry to achieve this requirement would be the provision of a soft floor and sufficient space allotment, as occurs in the deep bedding pens.

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References

Bisgaard Madsen E and Nielsen K 1985 A study of tail tip necrosis in young fattening bulls on slatted floors. *Nordisk Veterinaermedicin 37:* 349-357

Buczek J, Cygan Z and Kostyra J 1984a Purulent necrotic infections of tail in fattening cattle. I. Appearance, clinical course and anatomo-pathological lesions. *Medycyna Weterynaryjna 40:* 643-647

Buczek J, Deptula W and Deptula D 1984b Enzoothy of purulent and necrotic inflammation of tail in fattening cattle in a large scale farm. *Medycyna Weterynaryjna 40:* 592-595

Cygan Z, Buczek J, Kostyra J, Guzik Z and Stankiewicz J 1984 Purulent necrotic infection of the tail in fattening cattle. II. The role of aerobic and anaerobic nonsporulating bacteria. *Medycyna Weterynaryjna 40:* 707-710

Drolia H, Luescher U A and Meek A H 1990 Tail tip necrosis in Ontario feedlot cattle: Two case control studies. *Preventive Veterinary Medicine 9:* 195-205

Drolia H, Luescher U A, Meek A H and Wilcock B P 1991 Tail tip necrosis in Ontario beef feedlot cattle. *Canadian Veterinary Journal 32:* 23-29

Eckert B, Grauvogl A, Matzke P and Dirksen G 1989 Untersuchungen über die Ursache der Schwanzspitzenentzündung bei Mastrindern. *Bayerisches Landwirtschaftliches Jahrbuch 66:* 47-70

Eckert B and Dirksen G 1989 Neue Beobachtungen über Vorkommen und Entstehung der Schwanzspitzenentzündung beim Rind. *Praktischer Tierarzt 70:* 57-59

George P O, Cheeran J V and Aleyas N M 1970 Necrosis of the tail in bovine animals. *Veterinary Record 87:* 231-233

Graf B 1984 *Der Einfluss unterschiedlicher Laufstallsysteme auf Verhaltensmerkmale von Mastochsen.* PhD Thesis No 7533, Swiss Federal Institute of Technology Zurich, Switzerland

Heckert H P, Appel G, Hofmann W and Metzner M 1995 Untersuchungen zur Schwanzspitzenentzündung bei Mastbullen. *Tierärztliche Umschau 50:* 155-159

Kimpfel-Neumaier C 1997 Schwanzamputationen durch elastische Ringe bei einjährigen Rindern. *Amtstierärztlicher Dienst und Lebensmittelkontrolle 4. Jahrgang IV:* 281-282

Kunz W and Vogel O 1978 Schwanzspitzenentzündung - ein neues Gesundheitsproblem in der Rindermast. *Tierärztliche Umschau 33:* 344-353

Lenk T 1981 Zum Wundinfektionsgeschehen in Bullenmastanlagen mit Laufstallhaltung unter Berücksichtigung prophylaktischer Schwanzamputationen. *Monatshefte für Veterinärmedizin 36:* 699-702

Martelli P, Corradi A, Borghetti P, Ceccato C and Cabassi E 1993 'Arthropathy - tail necrosis' syndrome and trichothecenes in beef cattle. Preliminary observations. *Atti della Societa Italiana di Buiatria 25:* 395-405

Metzner M, Hofmann W, Heckert H P, Koberg J and Raue F 1994 Zur Epidemiologie der Schwanzspitzenentzündung bei Mastbullen. *Tierärztliche Umschau 49:* 348-355

Siegel S and Castellan N J 1988 *Nonparametric Statistics for the Behavioural Sciences, 2nd Edition.* McGraw-Hill International: New York, USA

Simonsen H B, Klinken L and Bindseil E 1991 Histopathology of intact and docked pigtails. *British Veterinary Journal 147:* 407-412

Van Der Mei J 1986 Staartnecrose na staatbijten bij vleeskalveren in groepshuisvesting. *Tijdschrift voor Diergeneeskunde 111:* 83-85

Winterling C and Graf B 1995 Ursachen und Einflussfaktoren von Schwanzspitzenveränderungen bei Mastrindern. *KTBL-Schrift 370:* 128-139