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Head partitions at the feed barrier affect behaviour of goats

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ABSTRACT

Space allowance at the feeding places often forces goats to feed in close proximity, that is, less than their individual distances. In consequence, agonistic behaviour may increase as well as stress and injuries, while access to feed may decrease, especially in low-ranking goats. Partitions between single feeding places may reduce individual distances and may enhance the acceptance of goats feeding close by. The aim of this study was to investigate the influence of non-transparent head partitions at the feed barrier on agonistic behaviour, activity budget, feeding place occupancy, adrenocortical activity, nutritional status (body weight and body condition), and injuries in loose-housed dairy goats.

The study involved 72 pregnant dairy goats of the German Improved Fawn breed. Two groups of 36 animals each were tested in a cross-over design. At the beginning, one group was provided with head partitions at a wooden palisade feed barrier, whereas the other group stayed without head partitions. After 11 experimental days, the head partitions were switched to the other group. Social interactions were recorded for 13 h and 20 min per treatment (2 h and 40 min on 5 days each group). Activity budget and feeding place occupancy were observed via scan sampling for 48 h per treatment. Body weight, body condition score, and occurrence of injuries were assessed, and faeces were sampled for analysis of cortisol metabolites. Data were analysed by Wilcoxon-tests for dependent data, except for feeding place occupancy, where *t*-tests were used. Goats displayed less agonistic behaviour in the feeding area with head partitions at the feed barrier ($p = 0.003$). In addition, with head partitions a lower number of displacements from feeding place by an actor standing inside the feed barrier was found ($p = 0.002$). The impact was most pronounced in low-ranking animals ($p = 0.009$), but effects were also found in middle-ranking goats ($p = 0.030$). Low-ranking goats were observed less often feeding ($p = 0.009$) and more often lying ($p = 0.026$) during the first hour after feed supply with head partitions. With head partitions more goats were feeding directly next to each other, i.e. without an empty feeding place in between ($p = 0.017$). Regarding the nutritional status of the goats, the lumbar body condition scores were higher in high-ranking animals with head partitions ($p = 0.007$). Presence of head partitions had no effect on sternal body condition scores, body weight, concentrations of faecal cortisol metabolites, and occurrence of injuries. In summary, non-transparent head partitions seemed to reduce the accepted distance between goats and therefore showed beneficial effects in terms of lower levels of social disturbances during feeding. Thus, head partitions can be recommended for feed barriers in goat loose-housing systems.

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1. Introduction

Animals strive to keep a minimum distance, termed "individual distance", to conspecifics (Hediger, 1940; Wilson, 2000; Aschwanden et al., 2008). If possible, subordinate animals avoid intruding the individual distance of dominant animals and withdraw from approaching dominant individuals (Bouissou et al., 2001). However, in housed animals limited space and clumped resources make such avoidance behaviour difficult. Indeed, the number of agonistic social interactions and injuries increases with reduced space allowance (Weng et al., 1998; Menke et al., 1999; Boe et al., 2006). The space per goat at the feeding place is often 40 cm and less (Jørgensen et al., 2007; Waiblinger et al., 2010). In contrast, the individual distance, being defined as the critical distance at which further proximity would trigger agonistic behaviour by one of the animals (Hediger, 1940), was shown to range from 0.1 m to 4 m in goats during feeding, but only for 14% of the pairs it was below 0.5 m, while the freely chosen distance was even higher (Aschwanden et al., 2008). Therefore adjacently feeding goats are often forced to intrude another goat's individual distance, which increases social tension in the feeding area. Consequently, agonistic interactions, displacements, and avoidance behaviour will be displayed, which could impact on feeding behaviour, feed intake and thus nutritional status (Andersen et al., 1999; Olofsson, 1999), the risk of injuries, as well as stress level.

One possibility of reducing the accepted social distance and thus agonistic behaviour is the use of physical separations (for review Waiblinger, 2009). Physical separation between feeding places can be classified into several levels. Firstly, offering fixed feeding places induces a definite distance between the necks of the animals and can reduce agonistic interactions (Endres et al., 2005; Huzzey et al., 2006; Nordmann et al., 2011). Secondly, partitions can be installed between the heads (head partitions) or between the bodies (body partitions, i.e. neck backwards only) of feeding animals. Head and body partitions as well as a combination of both were shown to reduce agonistic interactions and displacements and increase feeding time and access to feed, especially in low-ranking animals, in horses, pigs and cattle (Holmes et al., 1987; Andersen et al., 1999; DeVries and von Keyserlingk, 2006).

In goats, non-transparent body partitions (including protection of the head) were more effective in reducing agonistic interactions as well as in increasing the time spent feeding simultaneously and the latency to feeding place change than a transparent partition (Aschwanden et al., 2009). Further, the effects were more pronounced the longer the partitions (Aschwanden et al., 2009).

Non-transparent head partitions had no effect on feeding behaviour and little on agonistic interactions in unrestrained goats (Hillmann et al., 2014). When animals were restrained in the feed barrier, the number of agonistic interactions was lower and feeding scans higher, especially in low-ranking horned goats, with head partitions (Hillmann et al., 2014). In this study goats were kept in small groups of only 6–7 animals. There it might be even more difficult for some pairs of animals to keep the individual distance, because high-ranking animals occupy several feeding places and low-ranking animals have to share feeding places (Loretz et al., 2004). What is more, in larger groups there are more possibilities for individual goats to avoid specific others by choosing a distant feeding place.

Therefore, we investigated the effects of non-transparent head partitions at a feed barrier on behaviour, nutritional status, and stress of dairy goats in larger groups. We hypothesised that for the feed barrier with head partitions lower numbers of agonistic interactions and displacements, higher percentages in feeding, higher feeding place occupancy, and less stress, as measured by lower faecal cortisol metabolites, would be found. Furthermore, we expected, in accordance with a decrease in agonistic interactions due to head partitions, a reduction in the number of injuries.

2. Animals, materials, and methods

2.1. Animals, housing, and management

The experiment involved 72 pregnant dairy goats of the German Improved Fawn breed at the Thünen-Institute of Organic Farming in Germany, and was conducted from October to November 2008. Seven weeks before the start of the experiment, the goats were divided into two groups (group 1 and group 2) of 36 animals each. At the time of the study, the goats were 2–7 years old (mean ± s.d.: 4.2 ± 1.6). Both groups were similar in milk yield, numbers of lactation, and age. The average 240-day milk yield was 552 kg/animal, with an average of 3.30% fat and 2.98% protein. Almost all goats were horned, only two animals in group 1 and one in group 2 were hornless. As the animals had been mated shortly before the experiment and had kidded in spring (February/March) 2008, they were in their late lactation period. The goats were kept in two pens with straw litter. The two pens slightly differed in shape and size (group 1: 180.6 m^2 = 5.0 m^2/goat, group 2: 193.1 m^2 = 5.4 m^2/goat) due to constructional conditions of the stable. Both pens were equipped with a water bowl, a lick stone, and a brush for self-grooming. Before the experiment, goats were fed roughage in a hay rack. All goats were individually marked with numbers on their body sides by using hair dye.

Prior to the experiment, a feeding table and a wooden palisade feed barrier had been installed in the stable, which was accessible for the animals two weeks before data recording started. The wooden palisade provided 36 feeding places for each group (animal/feeding place-ratio 1:1). Each feeding place was 40 cm wide, consisting of 28 cm of solid wooden arcs and 12 cm space in between, where the goats could put their head trough and feed from the feeding table.

Since the palisades were 90.5 cm high from ground level of the pen (79 cm from feeding table), the feed barriers were stanchioned at the top, in a height of 106 cm from feeding table, to prevent the goats from jumping over it.

The head partitions had a dimension of 34.5 cm height and 25 cm depth from the feed barrier to the front (Fig. 1). They were installed at the feed barrier 26 cm over the ground level of the feeding table. The goats were fed hay ad libitum at the feeding table and got concentrates in the milking parlour. In the morning, the goats were provided with hay (08:30 h). At 13:00 h and 17:30 h, the remaining

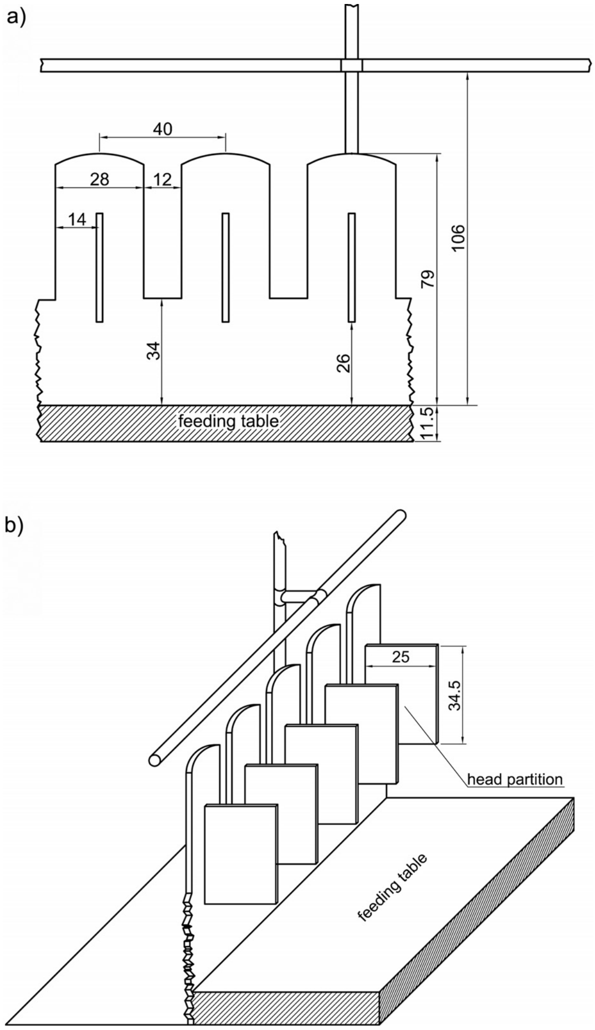

Fig. 1. Draft of head partitions at the feed barrier used in this study. (a) Front view and (b) side view of head partitions from the feeding table side. Measures are provided in centimetre.

hay was pushed towards the feed barrier again. Milking was performed twice a day (05:30 h and 15:30 h) and lasted approximately two hours for both groups. The milking procedure always started with the goats from group 1 to be milked.

2.2. Experimental design

Two weeks before the experiment started, the animals were kept in the pens with the wooden palisade feed barriers to get used to it. At this time, head partitions had already been installed at the feed barrier of group 2. The experiment was performed in a cross-over design, with two treatments (treatment 1: with head partitions at the feed barrier; treatment 2: without head partitions) in two groups. It started with group 1, which had no head partitions, and group 2, with head partitions installed at the feed barrier. After 11 days of data recording, the head partitions were switched from group 2 to group 1. After 3 days of getting used to the new situation, another 11-day period of data collection was started. Both groups remained in the same pen for the entire experiment.

2.3. Social behaviour

Social behaviour was observed on 5 days for each group in each situation (with and without head partitions) of the study (day 4, 5, 8, 10, and 11). Each group was observed for 2 h and 40 min per day on 5 days, which sums up to 13 h and 20 min per group and treatment. The goats were observed with a focus on the main feeding times (08:30–10:30 h, 13:00–15:00 h, and 17:30–18:50 h) by the same single observer. The observations were made from a heightened position, i.e. from a ladder in the middle of the feeding table. Since it was difficult to observe 35 goats at the same time, each pen was divided into 2 segments, resulting in a total of 4 segments. Each segment was observed for a 10-min period, and then the observer switched to the next segment. The 2 segments of the same group were observed in a row before switching to the other group.

Data were recorded by using the observational software "The Observer®, Version 5.0"; Noldus Information Technology, The Netherlands. At the end of each 10-min period of observation of a segment, the number of animals and their individual activity in the segment was recorded by scan sampling.

Agonistic interactions in the entire segment were recorded by continuous behaviour sampling (Martin and Bateson, 1993). We recorded the identities of the initiator (actor) and the receiver of an interaction as well as their locations during the interaction. One part of the observed area was the "feeding area", which was defined as the area of one length of a goat behind the feed barrier and inside the feed barrier. With regard to the "feeding area", it was differentiated if actor and receiver of an interaction were (a) "in(side) the feed barrier" (the goat in the "feeding" position having her head fully through the feed barrier and above the feeding table), and (b) "outside the feed barrier" (the goat standing directly behind the feed barrier, but having her head not put through the feed barrier). With regard to the observed agonistic interactions, we categorised the behaviours according to intensity (with or without physical contact) and their consequences (resulting in displacement or not).

Interactions with physical contact were butts, horn kicks, levering outs, hits, pushes, and bites. Interactions without physical contact consisted of threats and avoidance behaviour. Avoiding describes a goat leaving her place (receiver) in response to another goat (actor), but no threatening sign from the actor was recognisable to the observer.

Only data from the feeding area were included for a comparison of the feed barriers with and without head partitions. All these data were analysed in relation to the receiver of agonistic interactions. We calculated the following variables for each individual goat:

(1) All agonistic interactions in the feeding area (Ago_total).
(2) Furthermore, we considered the feed barrier itself and focused on agonistic interactions that included a receiver standing inside the feed barrier, distinguishing

between displacements and agonistic interactions without success as well as an actor standing either inside or outside the feed barrier:

(a) All displacements from feeding place by an actor in the feed barrier, i.e. with and without physical contact (Displace_total_ActorIN): all agonistic interactions leading to a displacement of the receiver from its feeding place, both receiver and actor standing in the feed barrier.
(b) Displacements from feeding place by an actor in the feed barrier, with physical contact (Displace_Phys_ActorIN): all agonistic interactions with physical contact leading to a displacement of the receiver from feeding place, both receiver and actor standing in the feed barrier.
(c) Displacements from feeding place by an actor in the feed barrier, without physical contact (Displace_nonPhys_ActorIN): all agonistic interactions without physical contact leading to a displacement of the receiver from feeding place, both receiver and actor standing in the feed barrier.
(d) Agonistic interactions without success by an actor in the feed barrier (Ago_no success_ActorIN): all agonistic interactions to which a receiver does not react and stays in the feed barrier, both receiver and actor standing in the feed barrier.
(e) All displacements from feeding place by an actor outside the feed barrier (Displace_total_ActorOUT): all agonistic interactions leading to a displacement of the receiver from its feeding place, the receiver standing in the feed barrier and the actor interacting from outside the feed barrier.
(f) Agonistic interactions without success by an actor outside the feed barrier (Ago_no success_ActorOUT): all agonistic interactions to which a receiver does not react and stays in the feed barrier, the receiver standing in the feed barrier and the actor interacting from outside the feed barrier.

Data were corrected by the number of segments in which an animal was observed in a treatment ((number of interactions for an individual/number of times the individual was observed in a segment) × total number of segments observed).

To gain sufficient amount of social interactions for information on social status of individual goats, social behaviour was observed additionally on 8 days prior to data recording for effects of head partitions after installation of the wooden palisade feed barrier. These additional observations were made for approximately 2 h and 30 min per group and day. All interactions from the recordings prior and during data collection leading to a displacement of the receiver in the entire pen were used to calculate the dominance value of each individual within its group as described by Sambraus (1975) and Nordmann et al. (2011). Dominance value was used to allocate goats to rank categories. The categories were defined as follows: a dominance value ranging from 0.00 to 0.33 specified low-ranking ($n = 23$), from 0.34 to 0.66 middle-ranking ($n = 27$), and from 0.67 to 1.00 high-ranking ($n = 22$) animals.

2.4. Activity budget

The individual activity of the goats was observed directly for 48 h with each treatment. Two observers, in a rotating system of 6 h per person, observed the goats over a period of 48 h by using focal scan sampling in 10-min intervals. At each scan the activity for all 72 goats was recorded as feeding, standing, or lying. These behavioural patterns were calculated in percent, representing in sum 100% of the daily activity budget. Milking periods were omitted because of differences in duration between the two groups due to management reasons. A goat was defined as feeding when she had her head put completely through the feed barrier and over the feeding table. Standing described the goats standing as well as moving, more precisely, when the feet had to carry the goat's body weight. Lying included resting and sleeping behaviour, when goats were lying on all four legs. Activities were analysed for a period of 48 h (Feeding_48 h, Standing_48 h, Lying_48 h) as well as for peak feeding hours, describing the hour after food supply (Feeding_1 h, Standing_1 h, Lying_1 h).

2.5. Feeding place occupancy

Feeding place occupancy was observed in conjunction with recordings of activity budget by the same two observers using a 10-min-scan sampling as well. All feeding places from the feed barriers were numbered. Within each 10-min scan subsequent to the recording of the activity of all goats, it was recorded whether a feeding place was unoccupied or occupied by a goat, in which case the identity of the goat was noted.

The average number of goats feeding simultaneously (occupied feeding places = FPO) during 1 h after feed supply, including 6 scans per feeding, was calculated for both treatments, either with head partitions (withHP) or without head partitions (noHP). Further, it was distinguished between morning and evening feed supply (FPO_withHP_morning, FPO_noHP_evening).

Regarding feeding place occupancy during 48 h, we looked at whether animals tended to stand further apart from each other than expected in the case of a random choice of the feeding place. For this, we looked at the number of runs (i.e. the number of changes between segments of occupied and segments of unoccupied feeding places (Changes_Occupancy)), as well as the longest run, i.e. the longest homogeneous segment of either occupied or unoccupied feeding places (Max_inRow). For details see Section 2.9.

2.6. Adrenocortical activity

Faecal samples were collected to analyse cortisol metabolites as a measure of the activity of the hypothalamic-pituitary-adrenocortical axis. At the end of both treatments, undischarged faeces were sampled rectally from each goat on two consecutive days before milking during morning hours (5:30–7:30 h). In goats, concentrations of faecal cortisol metabolites (FCM) reflect cortisol production around 13 h before faecal sampling (Kleinsasser et al., 2010). In our experiment this was the evening before. Samples were stored at −20 °C until analysis. An aliquot (0.5 g) of each faecal sample was extracted with 5 ml of methanol (80%). A group of cortisol metabolites (with a 5β-3α-hydroxy-11-oxo-structure) was determined by an 11-oxoaetiocholanolone enzyme immunoassay (Möstl et al., 2002). The method used has already been successfully validated for the evaluation of adrenocortical activity in goats (Kleinsasser et al., 2010).

2.7. Body condition score and body weight

Body condition score (BCS) was assessed manually in all individuals at the beginning and at the end of both treatments. Body condition was measured at the lumbar spine (BCS_lumbar) and at the sternum (BCS_sternal) of each goat and determined with a score number. Scores ranged between 0 (cachexia) and 5 (adiposis; von Korn et al., 2007).

In addition, at the end of each treatment all goats were weighed on an electronic weighing machine with an accuracy of 0.5 kg, and their individual body weights were recorded.

2.8. Injuries

Injuries were assessed in all goats individually at the beginning and at the end of each treatment. The abdominal side and the udder were visually inspected (adspection) by using a hand mirror and a torch. The rest of the body was directly visually inspected and manually scanned (palpation). Occurrence and characteristics of the injuries such as type of injury (superficial lesions, deep lesions, scars, swellings, calluses), shape (circular, horizontal, vertical, v/l shaped), size (<1 cm, 1–3 cm, <3 cm), and location of injuries were recorded.

Moreover, it was distinguished between injuries of the body and injuries of the udder. These characteristics allowed for analyses of the following variables: Superficial lesions_Body, Deep lesions_Body, Swellings_Body, Scars_Body, Calluses_Body, Injuries total_Body, Superficial lesions_Udder, Deep lesions_Udder, Scars_Udder, Swellings_Udder, Injuries total_ Udder. Because of long-term visibility, scars and calluses were calculated by subtracting the number of injuries at the beginning of the treatment from the numbers of injuries at the end of the treatment for each animal. By subtracting data from the beginning, we tried to exclude injuries already existing before the experiment and thus being not related to potential effects of the head partitions. The other variables are presented as results from the recordings at the end of each treatment, because for them short-term visibility was assumed. Due to a generally low occurrence of injuries, it was not distinguished between location, shape, and size of the injuries in further analyses.

2.9. Statistical analysis

For statistical analysis the programme PASW 17.0 was used. Since the error distributions were usually far from normal, most of our analysis is based on non-parametric tests. Paired sample Wilcoxon-tests for dependent data were used for the outcome variables of social behaviour, activity budget, adrenocortical activity, body condition score, and body weight. The tests were calculated for all goats together as well as for each rank category separately to allow for testing possible differences in effects depending on social status. Since no group effects were visible, the two groups were combined in the analyses. Data on injuries are presented descriptively.

With respect to feeding place occupancy, the influence of the number of animals feeding at a particular time point was removed by standardising these quantities with expected value and standard deviation computed under the null model where the currently feeding number of animals has chosen the feeding place purely at random. The required expected values and standard deviations have been obtained by simulating from the null model. T-tests were used to test for effects of head partitions.

3. Results

3.1. Social behaviour

The total number of agonistic interactions in the feeding area (Ago_total) was significantly lower with head partitions installed than without head partitions (all goats: $p = 0.003$, $Z = -2.943$; Fig. 2): This effect was strongest in low-ranking goats, but also tended to exist in middle-ranking goats (high-ranking: $p = 0.858$, $Z = -0.179$, middle-ranking: $p = 0.079$, $Z = -1.754$, low-ranking: $p = 0.007$, $Z = -2.707$).

The number of all displacements from the feeding place by an actor standing inside the feed barrier (Displace_total_ActorIN) was significantly lower in the feed barrier with than without head partitions (all goats: $p = 0.002$, $Z = -3.130$; Fig. 3a). This was mainly due to low- and middle-ranking goats, which were, with respect to the median, about half as often receivers of interactions in the situation with than without head partitions, whereas no

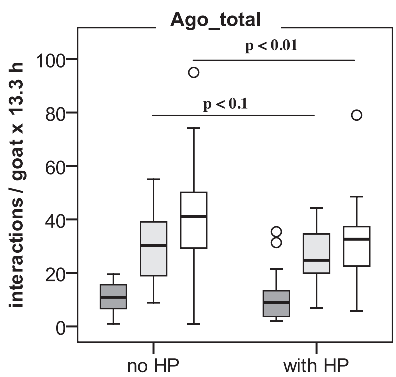

Fig. 2. All agonistic interactions in the feeding area (Ago_total) with a feed barrier either without head partitions (no HP) or with head partitions (with HP) being installed. Data were recorded within 13 h and 20 min of observation per treatment and are related to rank (dark grey: high-ranking ($n = 22$), light grey: middle-ranking ($n = 27$), white: low-ranking ($n = 23$) animals). Data are presented as box-and-whiskers plots with boxes (25% and 75% percentiles, central bar = median), whiskers (ranging from minimum to maximum, but excluding outliers and extremes), and dots (○ = outliers).

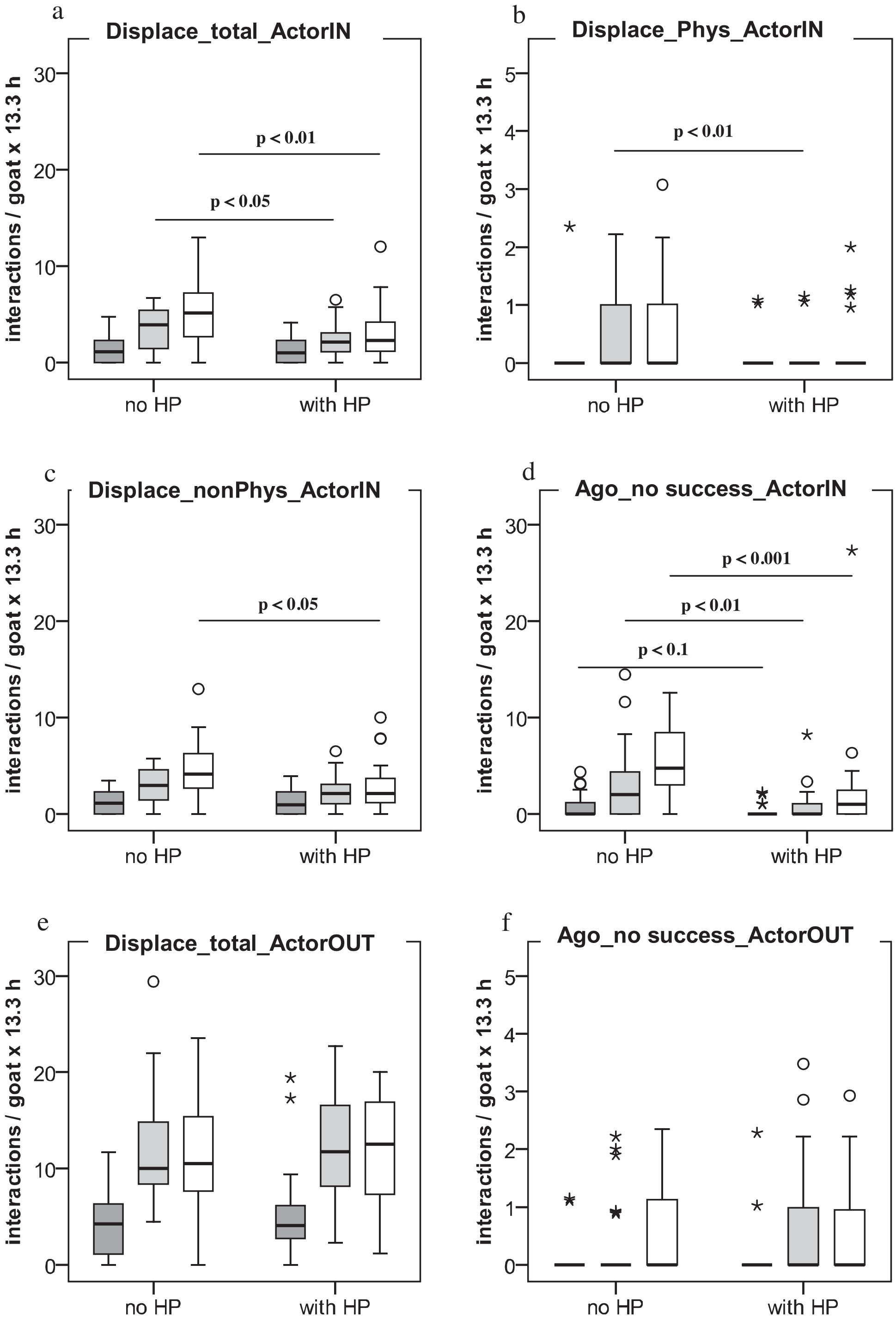

Fig. 3. Agonistic interactions with a feed barrier either without head partitions (no HP) or with head partitions (with HP) being installed. Data were recorded within 13 h and 20 min of observation per treatment and are related to rank (dark grey: high-ranking ($n = 22$), light grey: middle-ranking ($n = 27$), white: low-ranking ($n = 23$) animals). (a) All displacements from feeding place by an actor standing in the feed barrier next to the receiver, (b) displacements from feeding place by an actor in the feed barrier with physical contact, (c) displacements from feeding place by an actor in the feed barrier without physical contact, (d) agonistic interactions where the receiver stays at its place, (e) all displacements from feeding place by an actor standing outside the feed barrier, (f) agonistic interactions where the receiver stays at the feeding place. Significant differences for all goats were found for (a, b) $p < 0.01$, (c) $p < 0.05$, and (d) $p < 0.001$. Please note the different scales between (a, c, d, e), and (b, f). In (d) one extreme value (star) at 58 interactions/goat × 13.3 h was excluded. Data are presented as box-and-whiskers plots with boxes (25% and 75% percentiles, central bar = median), whiskers (ranging from minimum to maximum, but excluding outliers and extremes), dots (○ = outliers) and stars (* = extremes).

difference was found for high-ranking goats (high-ranking: $p = 0.658$, $Z = -0.443$; middle-ranking: $p = 0.030$, $Z = -2.166$, low-ranking: $p = 0.009$, $Z = -2.613$). Displacements with physical contact by an actor inside the feed barrier (Displace_Phys_ActorIN) were generally at a very low level, but were further reduced with head partitions (all: $p = 0.007$, $Z = -2.691$; Fig. 3b) due to the effect on middle-ranking goats (high-ranking: $p = 1.000$, $Z = 0.000$, middle-ranking: $p = 0.005$, $Z = -2.825$, low-ranking: $p = 0.139$, $Z = -1.478$). Displacements without physical contact by an actor inside the feed barrier (Displace_nonPhys_ActorIN) were also lower for all goats with head partitions (all: $p = 0.012$, $Z = -2.507$; Fig. 3c), with differences being largest in low-ranking animals, which received, with respect to the median, half as many interactions with head partitions (high-ranking: $p = 0.778$, $Z = -0.282$, middle-ranking: $p = 0.201$, $Z = -1.278$, low-ranking: $p = 0.028$, $Z = -2.191$). Agonistic interactions that did not lead to a displacement performed by an actor inside the feed barrier (Ago_no success_ActorIN) were markedly reduced with head partitions (all: $p = < 0.001$, $Z = -5.213$; Fig. 3d). In general, with head partitions very low numbers of this kind of interactions were observed. While for high-ranking goats, which were rarely receivers of such behaviour, Ago_no success_ActorIN only tended to be fewer with head partitions (high-ranking: $p = 0.075$, $Z = -1.779$), median levels in middle-ranking goats decreased from 2.0 without head partitions to 0.0 with head partitions (middle-ranking: $p = 0.003$, $Z = -2.949$), and low-ranking goats received about five times fewer interactions with head partitions (low-ranking: $p = < 0.001$, $Z = -3.703$).

The frequency of goats being displaced or receiving an agonistic interaction without success while feeding by an actor outside the feed barrier (Displacement_total_ActorOUT, Ago_no success_ActorOUT) was not influenced by the presence of head partitions (all goats and rank categories: $p > 0.1$; Fig. 3e/f). Displacements by an actor outside the feed barrier happened about twice as often than by an actor inside the feed barrier.

3.2. Activity budget

The number of feeding scans during 48 h (Feeding_48 h) tended to be slightly lower with head partitions for all goats (all goats: $p = 0.068$, $Z = -1.824$; Fig. 4a), showing the same tendency as in middle-ranking goats (high-ranking: $p = 0.910$, $Z = -0.114$, middle-ranking: $p = 0.097$, $Z = -1.658$, low-ranking: $p = 0.107$, $Z = -1.612$). For low-ranking animals, there was a lower percentage of feeding scans (Feeding_1 h; low-ranking: $p = 0.009$, $Z = -2.614$; Fig. 4b) and a higher percentage of lying scans during the first hour after hay provision with than without head partitions (Lying_1 h; low-ranking: $p = 0.026$, $Z = -2.221$; Fig. 4f). Low-ranking goats also tended to stand slightly more often during 48 h (Standing_48 h; low-ranking: $p = 0.052$, $Z = -1.947$; Fig. 4c). For all goats together as well as for the other rank categories (high- and middle-ranking), there was no effect of head partitions on these three variables (Feeding_1 h, Lying_1 h, and Standing_48 h: $p > 0.1$). No influence of head partitions existed on lying during 48 h (Lying_48 h; all goats and rank categories: $p > 0.1$; Fig. 4e) and on standing during the peak feeding hour (Standing_1 h; all goats and rank categories: $p > 0.1$; Fig. 4d).

3.3. Feeding place occupancy

Generally, during the period of 1 h after feed supply the level of feeding place occupancy in the feed barrier with head partitions was higher in the morning and in the evening (FPO_withHP_morning: mean ± s.d.: 10.4 ± 3.5, min/max: 3/16; FPO_withHP_evening: 8.7 ± 3.0, min/max: 2/14) than without head partitions (FPO_noHP_morning: mean ± s.d.: 9.8 ± 2.2, min/max: 6/15; FPO_noHP_evening: 7.8 ± 2.7, min/max: 2/13).

In the feed barrier without head partitions, the standardised number of changes between segments of occupied and unoccupied feeding places (Changes_Occupancy: $p = 0.017$, $t = 2.4$, df = 1017) was significantly higher, i.e. the goats were more likely to leave empty feeding spaces between each other than in the case where partitions were present. An analogous result is obtained when looking at the standardised longest run of animals in consecutive feeding places. Here, the runs were longer when partitions were present (Max_inRow: $p = 0.006$, $t = -2.75$, df = 1028).

3.4. Adrenocortical activity, body condition score, and body weight

The concentration of faecal cortisol metabolites was not influenced by head partitions (Table 1). In terms of the nutritional status of the goats, the body condition score from the lumbar spine (BCS_lumbar) in all goats as well as in high-ranking animals differed between treatments, with the median score being 0.5 higher with head partitions (Table 1). No effect was found for the sternal body condition (BCS_sternal) and for body weight (Table 1).

3.5. Injuries

In general, the number of injuries was very low, and no difference between the situations with or without head partitions was found. The injuries that were recorded mainly consisted of superficial lesions, swellings on the body, and scars at the udder (Table 2).

4. Discussion

The results confirm the hypothesis of reduced social tension during feeding with head partitions: the number of agonistic interactions with and without displacements was lower in the feed barrier with head partitions. In addition, goats were more often feeding directly next to each other, with fewer changes of occupied and unoccupied feeding places along the feed barrier, although this effect was quite small. Contrary to our hypothesis, with head partitions low-ranking goats were observed less often feeding and more often lying in the first hour after food provision. Further, lower stress levels and fewer injuries in the pens with head partitions at the feed barrier could not be confirmed.

In line with studies on body partitions in pigs, cattle, and goats (Andersen et al., 1999; Jensen et al., 2008;

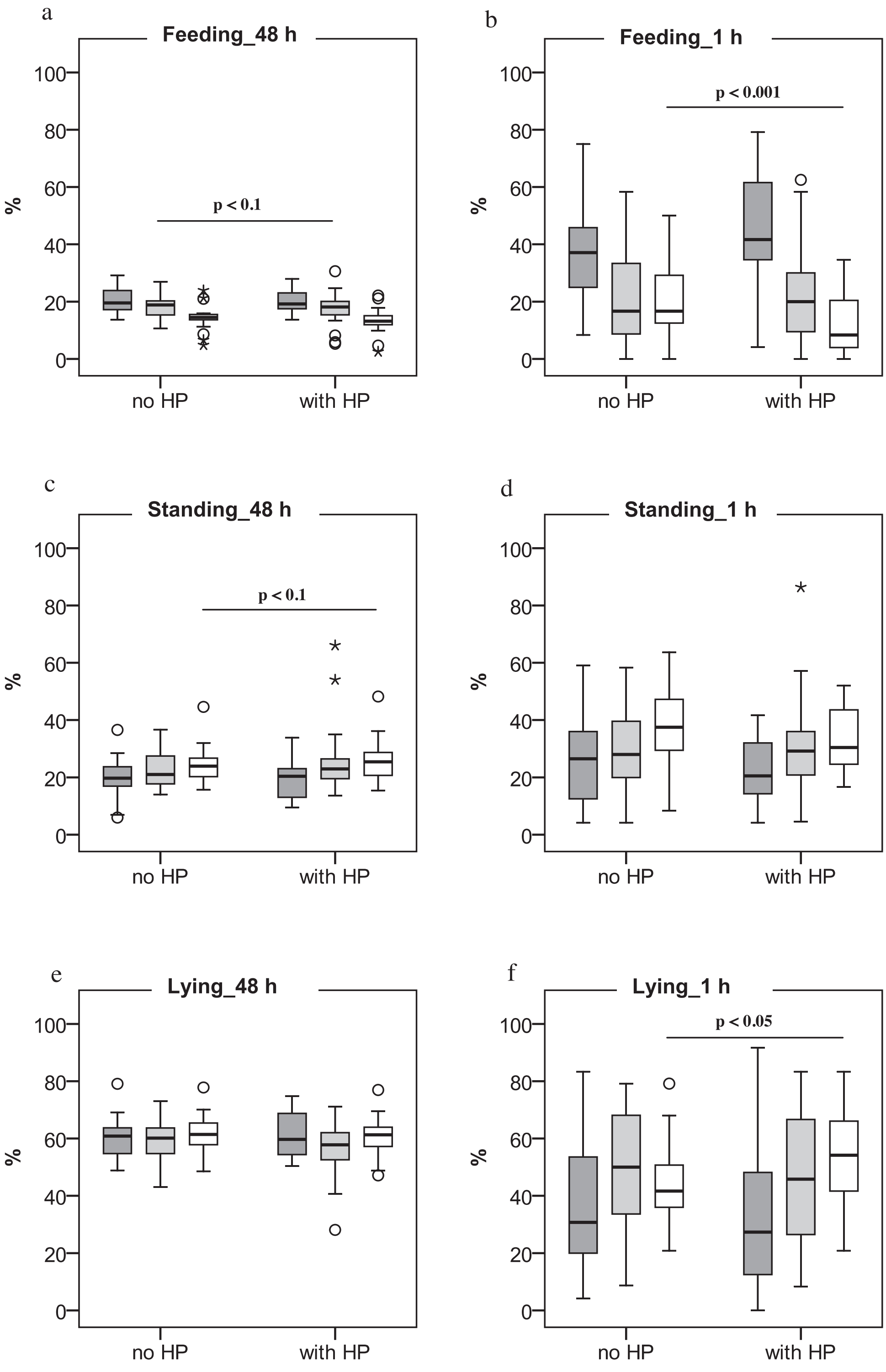

Fig. 4. Percentage of different activities of goats during 48 h (a, c, and e) and during 1 h of peak feeding times (b, d, and f) in the pens with a wooden palisade feed barrier either without head partitions (no HP) or with head partitions (with HP). Data are related to rank (dark grey: high-ranking (n = 22), light grey: middle-ranking (n = 27), white: low-ranking (n = 23) animals). Data are presented as box-and-whiskers plots with boxes (25% and 75% percentiles, central bar = median), whiskers (ranging from minimum to maximum, but excluding outliers and extremes), dots (○ = outliers), and stars (* = extremes).

Table 1
Results (*p*- and *Z*-values) from Wilcoxon-tests for faecal cortisol metabolites (FCM), body condition score (BCS; BCS_lumbar, BCS_sternal), and body weight in all goats ($n = 72$) and, for BCS_lumbar, depending on rank (high-ranking: $n = 22$, middle-ranking: $n = 27$, low-ranking: $n = 23$). Apart from BCS_lumbar there was no significant effect of rank on the other parameters.

Outcome variables	Rank	Without head partitions			With head partitions			*p*-value	*Z*-value
		Median	Min	Max	Median	Min	Max		
FCM (ng/g)	All	299	54	781	257	98	1117	0.686	−0.404
BCS_lumbar (score)	All	3.0	2.0	4.0	3.5	2.0	4.0	0.014	−2.466
	High	3.0	2.5	4.0	3.5	3.0	4.0	0.007	−2.714
	Middle	3.5	2.5	4.0	3.5	2.5	4.0	0.134	−1.500
	Low	3.0	2.0	3.5	3.0	2.0	4.0	1.000	0.000
BCS_sternal (score)	All	3.5	3.0	5.0	3.8	3.0	5.0	0.290	−1.057
Body weight (kg)	All	63.0	48.5	87.0	63.3	51.0	84.5	0.474	−0.716

Aschwanden et al., 2009), in our study, aggressive interactions in terms of displacements of a receiver as well as unsuccessful agonistic interactions by an actor standing inside the feed barrier were displayed at lower levels with head partitions, with pronounced effects in lower-ranking animals. In a study on non-transparent head partitions, effects were tested in combination with a headlock barrier where goats were either restrained in the feed barrier or free to enter and leave (Hillmann et al., 2014). In the study, some beneficial effects of head partitions on agonistic behaviour without physical contact are documented, but the effect was small without headlocks. The number of agonistic interactions with physical contact was lower with head partitions only when goats were restrained in the feed barrier. Contrary to our study, Hillmann et al. (2014) analysed the agonistic interactions of goats all over the pen and only during the first 60 min after feed supply, which might explain the lower effect of head partitions in her study.

Basically, a palisade feed barrier does already provide physical separation between adjacently feeding goats, which reduces agonistic interactions and displacements as compared to neck rail feed barriers (Nordmann et al., 2011). Our results indicate that head partitions have additional beneficial effects. Not only were displacements within the feed barrier lower with head partitions, but, particularly, interactions not followed by displacement of the receiver (Ago_no success_ActorIN) were clearly reduced in all goats. Moreover, the number of agonistic interactions displayed by an actor standing outside the feed barrier did not differ between situations with and without head partitions, which indicates that there was no change in strategy in terms of attacking more from the outside. Such change in strategy was observed in cows when body partitions were installed at the feed barrier (DeVries and von Keyserlingk, 2006) and in goats in palisades feed barriers (i.e. with separated feeding places) as compared to neck rail barriers (Nordmann et al., 2011). In sum, head partitions, which hindered the view and direct physical contact between adjacently feeding goats, seem to reduce the intention of feeding dominant goats to displace an adjacently feeding animal, i.e. it reduced the distance within which a dominant animal accepts a subdominant one as long as visual contact is hindered. Subsequently, they caused fewer agonistic interactions in the feed barrier and an absolute decrease in agonistic behaviour in the total feeding area.

Results from feeding place occupancy are in line with interpretations of a reduced individual distance. Although differences were small, with head partitions more animals were feeding simultaneously, they were feeding more often directly next to each other, with a lower number of changes of occupied and unoccupied feeding places along the feed barrier. What is more, a higher number of animals were feeding adjacently in a row with head partitions. But despite overall smaller distances between feeding goats, the number of agonistic interactions was lower. Thus, head partitions seem to enable goats to feed more often directly

Table 2
Number of injuries in the goats kept in the pen with a wooden palisade feed barrier with and without head partitions. A descriptive overview of total numbers of injuries in all animals ($n = 72$) and the number of affected animals. It was differentiated between injuries of the body and injuries of the udder of the dairy goats.

Injuries	Without head partitions		With head partitions	
	Total injuries	Affected animals	Total injuries	Affected animals
Injuries total_Body	*10*	*9*	*13*	*6*
Superficial lesions_Body	1	1	5	1
Deep lesions_Body	0	0	0	0
Swellings_Body	5	5	6	4
Scars_Body	2	2	1	1
Calluses_Body	2	1	1	1
Injuries total_Udder	*15*	*11*	*19*	*15*
Superficial lesions_Udder	4	3	8	4
Deep lesions_Udder	0	0	1	1
Swellings_Udder	0	0	0	0
Scars_Udder	11	9	10	10

next to each other, without an increase but even a decrease in agonistic behaviour, as has already been shown for body partitions (Aschwanden et al., 2009).

In our study, during peak feeding hours low-ranking goats were observed feeding less often with head partitions. It seemed that they substituted feeding by lying activity. A lower feeding activity is in contrast to other findings with either head or body partitions (Bouissou, 1970; DeVries and von Keyserlingk, 2006; Aschwanden et al., 2009) where longer feeding times were found. Whereas the partitions used in those studies all increased the effort of changing feeding places, this is not the case in our study. Further, if the goats spent less time feeding in the hour after feed supply it could be argued that this might have led to the decrease in the number of agonistic behaviour in the feed barrier. However, we did not find a difference in the number of feeding scans for low-ranking animals during the period of time in which behavioural observations were conducted.

In our case, the only difference between the situations with and without head partitions might be the visibility of an adjacently feeding animal. Hence, the lower number of feeding scans during peak feeding hours might be explained by the low-ranking goats not being able to see an adjacently feeding higher-ranking goat leaving the feed barrier in order to start an attack from outside with the non-transparent head partitions. This could reduce predictability and thus enhance the feeling of insecurity for the lower-ranking goat, resulting in reduced feeding during peak feeding times. In line with this argument is a study in horses documenting higher feeding times in subdominant horses with wire head partitions in comparison to solid ones and to no head partitions (Holmes et al., 1987). A way to cope with insecurity, while still maintaining a sufficient feed intake for the animals, could be to shift the feeding time to other times of the day (Jørgensen et al., 2007). As lying consumes the least energy, it could be the preferred activity to switch over to when goats refrain from feeding. This interpretation could explain that low-ranking goats were lying more often during peak feeding time when head partitions were present, but showed no difference over 48 h.

However, middle-ranking goats, like all goats together, tended to be observed feeding over 48 h less often with head partitions. This supports the findings on fewer disturbances during feeding that might allow to feed more effectively and thus reduce the total time at the feed barrier for animals that are more likely to be displaced than high-ranking goats. What is more, the slightly higher observations of standing over 48 h in low-ranking goats with head partitions may hint that these animals had more time left due to fewer disturbances causing shorter time necessary for feeding. This time might be spent standing rather than lying, since levels in lying over 48 h, which are quite equal to those of high-ranking animals, seem to be already sufficient. As expected, there was no effect on the activity budget of high-ranking goats and little effect on the number of agonistic interactions received by them. High ranking goats have priority access to feed (Barroso et al., 2000) and are rarely receivers of agonistic interactions (Nordmann et al., 2011) explaining these results.

Our hypothesis of lower levels of stress due to lower social tension during feeding with head partitions was not confirmed by means of faecal cortisol metabolites. Animals may have adapted behaviourally to the situation without head partitions by keeping larger distances (see feeding place occupancy). Food was provided ad libitum in our study, reducing competition for it and enabling the goats to slightly shift feeding time as a strategy to avoid social encounters (Olofsson, 1999) and stress. For future studies, more frequent sampling or sampling at other times of the day, e.g. in the evening hours to reflect feeding in the morning, might be alternative options to mirror short term and small differences in levels of stress. Another promising method for future studies will be measurements of heart rate variability as we already used it successfully for this type of intermittent chronic stress in goats at the feed barrier (Nordmann et al., 2011).

Regarding the nutritional status in terms of body condition and body weight, only the body condition score measured at the lumbar spine was affected in high-ranking goats, with higher scores with head partitions. They may have felt less disturbed by adjacently feeding animals due to the visual cover, as discussed above for agonistic behaviour. Accordingly, for them it may have been less necessary to interrupt feeding and display aggressive behaviour and thus they were able to ingest more feed. Indeed, high-ranking animals often defend their individual space or special feeding places at the expense of feeding (Sherwin, 1990; Csermely and Wood-Gush, 1990; Brouns and Edwards, 1994). The beneficial effect of head partitions on BCS of higher-ranking goats underlines the importance of reducing social tension, not only for lower-ranking animals. The fact that only BCS of the lumbar region was affected agrees well with descriptions that body fat is mobilised faster at the lumbar region than at the sternal region (von Korn et al., 2007). An effect in high-ranking but not in low-ranking goats was nevertheless surprising, because low-ranking goats were most affected in terms of displacements from feeding place and feeding activity during peak feeding times. However, the overall feeding time in low-ranking goats was not affected by head partitions. It would be interesting for future studies to investigate the actual feed intake, real durations of feeding or alternative activities at the feeding place and long-term effects.

The number of injuries did not differ between the situations with or without head partitions, which might be a consequence of the equal number of agonistic interactions by an actor outside the feed barrier. The generally low occurrence of injuries can be ascribed to the sufficient amount of total space in the pens and of food as well as to stable groups over a quite long period of time.

5. Conclusion

The non-transparent head partitions were beneficial for goats independent from their social status in terms of reducing social tension and disturbances during feeding and, subsequently, for higher-ranking goats in terms of increases in body condition. Adrenocortical activity was not affected by the presence of head partitions, so that levels of stress may have been equal in situations with and without head partitions or differences may have been too small to be detected for this parameter. In sum, head partitions as tested in this study can be recommended for goats in loose-housing systems.

Conflict of interest

We declare that there are no known conflicts of interest associated with this publication.

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