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Use of space, active and resting behaviour in fattening rabbits (Oryctolagus cuniculus) housed in a combi park system: A case study

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Abstract

*In this case study, a housing system for rabbits (*Oryctolagus cuniculus*) was developed, complying with the new German Welfare Regulation, and evaluated on-farm with regard to the rabbits' behaviour during four fattening periods. The housing system was characterised by the large group size of fatteners (maximum 65 animals per group, 12 animals per m²) due to the merging of six former single units for does and their litters, post-weaning. A large elevated platform, a box with a roof (small elevated platform), a tube and gnawing materials were made available per unit. The aim being to assess the suitability of the housing system for rabbits with regard to animal welfare, based on behavioural analyses. Therefore, the use of space by the rabbits (n = 247) was investigated by video analysis (instantaneous scan sampling) during daytime. Additionally, the individual behaviour of 20 focal rabbits in different locations was assessed by continuous sampling. Results showed that rabbits preferred to huddle together in the outer units in the first weeks post-weaning. The highest animal densities were found under and in front of the large and on the small platforms. The large platforms were visited increasingly from the 10th fattening day onwards. Elevated platforms supported resting and comfort behaviours. Non-elevated open-top areas enabled upright positions and locomotor behaviours. Aggression and stereotypic behaviours rarely occurred. We conclude that the housing system supported species-specific behaviour and seemed to cater for the needs of rabbits in terms of welfare. Nevertheless, further investigation is needed to ascertain the effects on animal health and performance.*

Keywords: *animal welfare, continuous sampling, German welfare regulation, growing rabbits, instantaneous scan sampling, new housing system*

Introduction

Non-domestic, wild rabbits (*Oryctolagus cuniculus*) live in social groups (Parer 1977). They rest during the day in underground rabbit warrens or in dense scrubs, protected from predators, leaving them at dusk or during night-fall (Kraft 1978). Outside the warren, the rabbits stand upright and alert, a behaviour designed to enable scanning of the environment (Kraft 1978) and recognising hazards (Monclús *et al* 2005), which is essential for their survival. It should be common practice to adapt housing systems to the natural habitat and behaviour of animals and doing so would potentially improve animal welfare. Many wild rabbit species-specific behaviours can still be found in the behaviour of domesticated rabbits (Kraft 1978) however several behaviours are suppressed by commercial cage systems. On commercial farms, fattening rabbits tend to be kept in small groups with high animal stocking densities, in cages with wire-mesh flooring, often without places to hide or to jump onto. Cage overcrowding and resultant space restriction (European Food Safety Authority [EFSA] 2005) may impair rabbits' natural locomotor behaviour (Dal Bosco *et al* 2002; Lambertini *et al* 2005; Princz *et al* 2008a). In addition, suitable manipulable materials (hay and straw) are often rejected by farmers due to concerns over hygiene (Lehmann 1990; EFSA 2005). The lack of manipulable materials promotes occurrences of stereotypies such as grid gnawing (Hansen & Berthelsen 2000; Jordan *et al* 2003; Luzi *et al* 2003) and aggression (Lidfors 1997; Verga *et al* 2004; Princz *et al* 2009), which may impact on animal welfare.

Demand for welfare improvements in fattening rabbits, in recent years, has lead to many European countries seeking to undertake scientific investigation into alternative housing systems (Trocino *et al* 2019). To this end, traditional unstructured wire cages may undergo replacement with park or combi park systems, which are mainly characterised by their higher space allowance, larger animal group sizes and additional structural elements, such as an elevated platform or a nest (EFSA 2020) as well as the presence of manipulable materials. By providing boxes, retreat and evasion possibilities are created that should protect rabbits from the aggressive behaviour of pen-

mates. Elevated platforms provide animals with a good overview of their immediate environment in addition to creating possibilities for retreat (Hansen & Berthelsen 2000) and enlarging the functional space (Postollec *et al* 2008). However, the increased aggressive behaviour that may accompany larger animal groups (Lambertini *et al* 2005; Szendrő & McNitt 2012), especially with the onset of sexual maturity (Rommers & Meijerhof 1998), can be a disadvantage of combi park systems.

So far, in Germany, keeping rabbits in commercially alternative housing systems other than small cages has not been established and, to date, there has been insufficient scientific research into the ability of combi park systems to fulfil the new German legal requirements (design of interior fittings such as elevated platforms and boxes, slatted floors [11 mm], lighting with dimming phases, sufficient provision of manipulable materials and roughage), all of which have been a legal requirement on farms since 2019 (TierSchNutztV 2014). Therefore, a new legally compliant housing system was developed for the present study. It was designed as a combi park system, offering an enriched and structured environment as well as a higher space allowance than previous conventional cages in Germany. Rauterberg *et al* (2019a) has already provided results on animal health, performance and hygiene in this new housing system, however in addition to animal health, performance and hygiene, behavioural analyses remain another essential component for assessing the suitability of housing systems (De Jong *et al* 2011). Furthermore, it should be common practice to develop housing systems based on natural habitats and behaviours and, to this end, video analyses were undertaken here to enable behavioural assessment of rabbits in this new housing system.

It has been well established that several behaviours exist which indicate good (positive behaviours) as well as poor welfare (negative behaviours) for animals in housing systems. Generally speaking, welfare (according to the Five Freedoms; Webster [2016]), means animals are healthy, not exposed to any kind of stress or pain due to inadequate housing facilities or malnutrition and not restricted in their natural behaviour (Keeling *et al* 2011). Negative behaviours of rabbits consist of, for example, excessive aggression towards pen-mates or oneself, resulting in injuries and therefore diminishing animal welfare (EFSA 2005), frequent crouching without phases of natural locomotion or relaxed lying (Drescher 1992), restlessness (Lehmann 1987) and gnawing at parts of the cage as an expression of boredom and stress (Luzi *et al* 2003). In contrast, relaxed lying for a longer period of time, locomotion, self- or allogrooming or exploratory behaviours are deemed species-specific (Kraft 1978) indicators of well-being and should be interpreted as positive behaviours. Alert behaviours such as standing upright are part of the natural behavioural repertoire of wild rabbits (Kraft 1978) and thus are considered positive. However, if the occurrence is very frequent they may also be interpreted as a sign of discomfort.

The aim of this case study was to draw conclusions on the animal welfare of rabbits in a new housing system based on a detailed behavioural analysis and seek to determine as to whether the system would be suitable for rabbits from an ethological stand-point. Firstly, the usage (animals per m²) of the units and locations in the housing system were evaluated at group level (quantitative analysis) to determine whether the space provided and the structural housing elements were utilised and enriched the rabbits' environment. Secondly, the behaviour in the single cage units and at the different locations within the units was assessed at group level (qualitative analysis) and, thirdly, the individual behaviour of 20 focal rabbits at the different locations was analysed.

Materials and methods

Study animals and housing

This study was reviewed and received approval from the Animal Welfare Officer of the University of Veterinary Medicine Hannover, Foundation, Germany (protocol TVO2018V55).

It was carried out on a commercial rabbit farm in Northern Germany keeping approximately 600 does (Hyplus PS 19, Hypharm SAS, France) and their kits (Hypharm PS 19× PS 59, Hypharm SAS, France). The behaviour of fattening rabbits housed in a combi park system used for rearing and fattening, and fulfilling the requirements of the German Animal Welfare Regulations (TierSchNutztV 2014) was assessed during four fattening periods. One fattening period lasted from weaning (31st day of life) to slaughter (78th day of life). There were normally five weeks between individual fattening periods. Between the second and third fattening period evaluated, another fattening period occurred, but was unable to be analysed due to technical issues. During the suckling period, the does were kept individually with their kits, whereas after weaning and removal of the does, large groups of 62 (± 3) fattening rabbits (maximum 12 animals per m²) from six litters were formed. For this purpose, the six individual units of the housing system (with one litter per unit) were interconnected by opening interstitial doors to create one big pen with one large group of animals (six litters) (Figures 1 and 2). In the following, units 1 and 6 are also described as outer units and units 2 to 5 as middle units. The pens were positioned in the room as shown in Figure 3.

The combi park system was covered with slatted polyvinyl plastic flooring (11 mm slots, 11 mm slats) and the walls consisted of grids. All single units were open at the top. In addition to the floor area (80 × 80 cm [length × width] per single unit), a 15% perforated, 37 cm high platform (60 × 55 cm) was available per single unit. The former nest-box (30 × 40 × 27 cm; length × width × height), with its roof serving as a small elevated platform (30 × 40 cm), and an additional area next to the former nest-box (open space; 30 × 40 cm, open top) per single unit could also be used by the rabbits. For further analysis in this study, the floor area was subdivided into the area in front of the large elevated platform and the space under the large elevated platform (Figure 1; structure corresponded to that of Rauterberg *et al* 2019a). A plastic, polyvinyl tube

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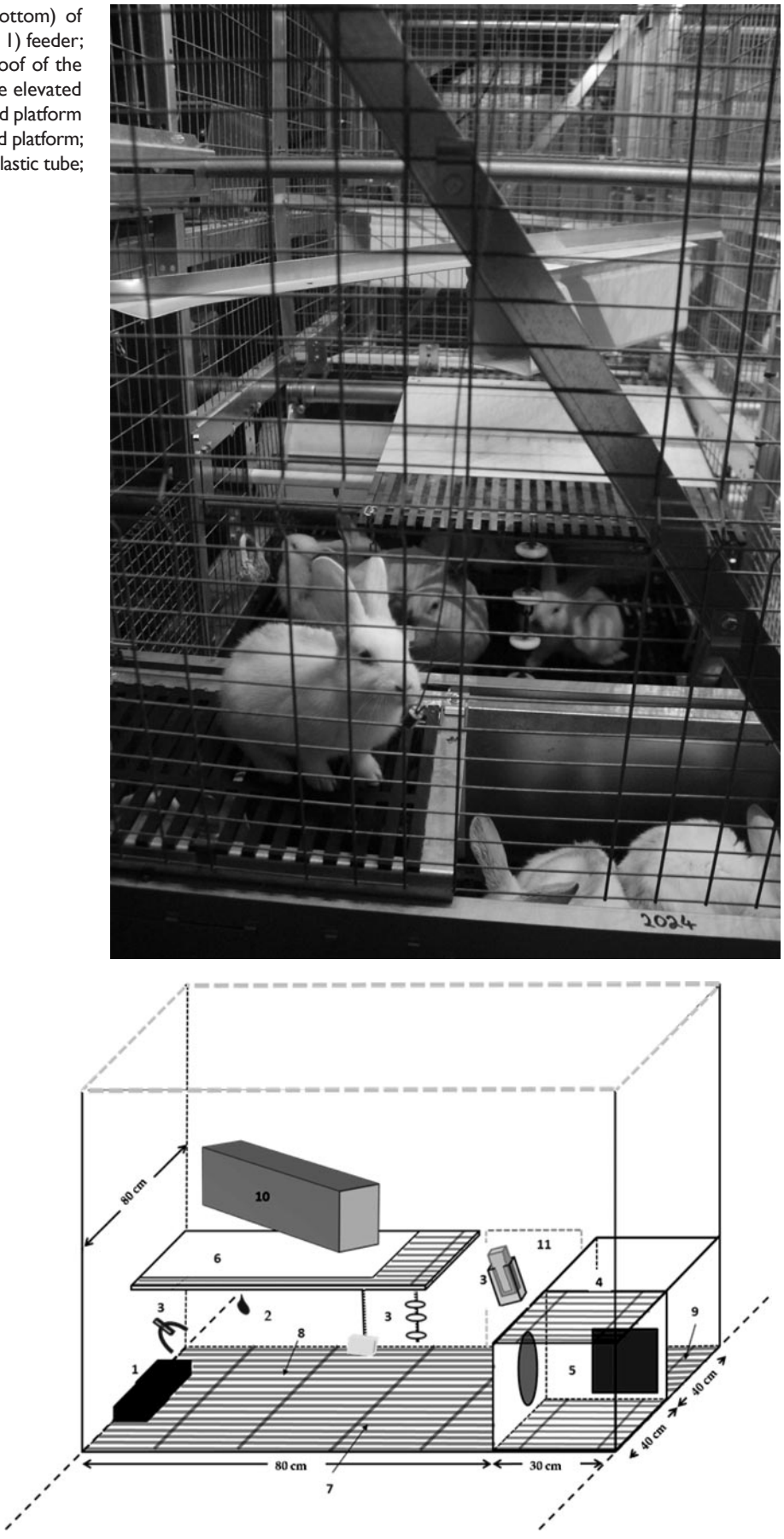
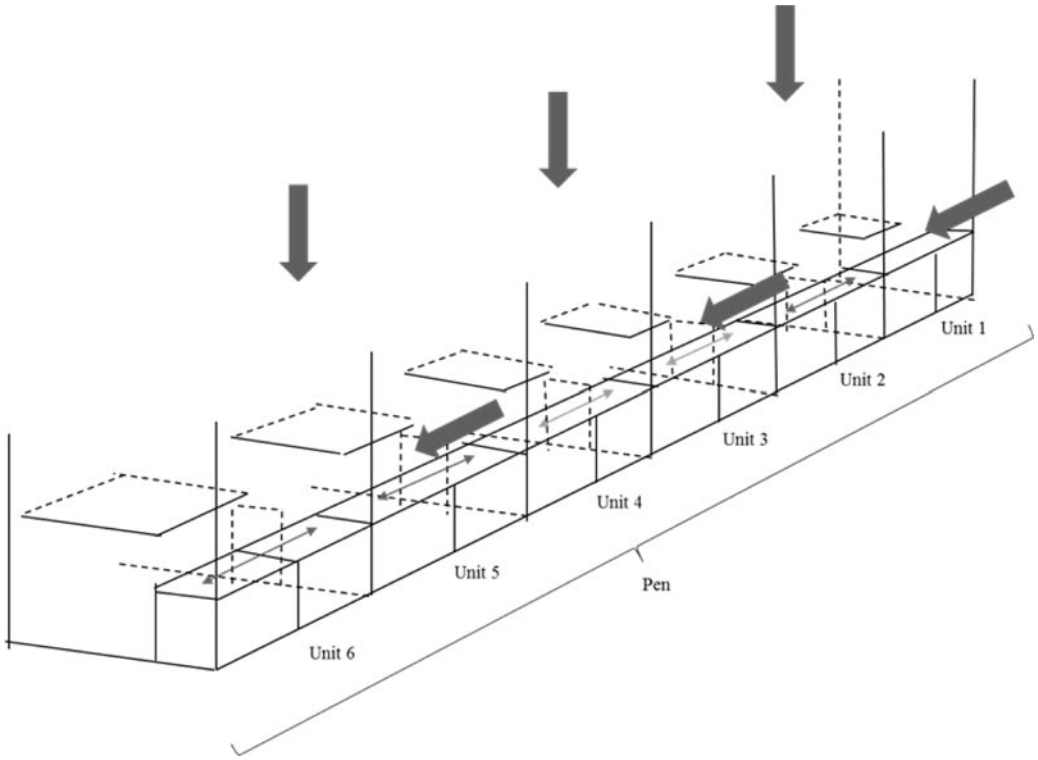
Figure 1



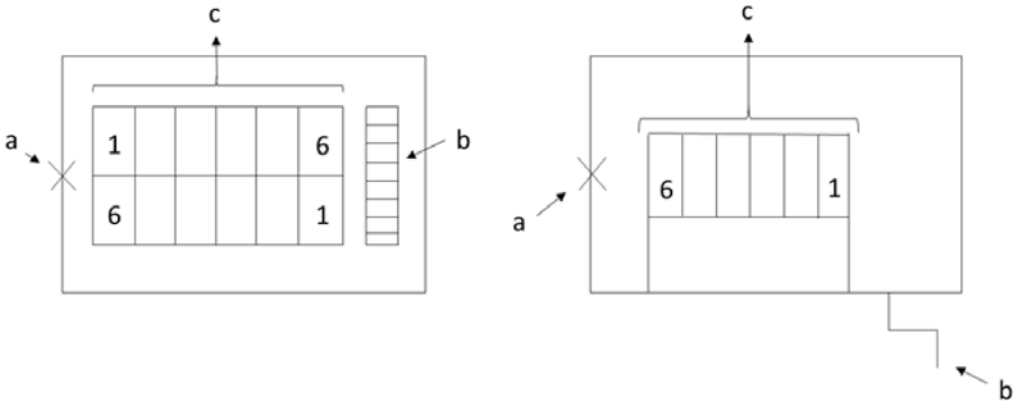
Showing image (top) and scale drawing (bottom) of one single unit (Rauterberg *et al* 2019a) with 1) feeder; 2) nipple drinker; 3) gnawing materials; 4) roof of the box (small elevated platform); 5) box; 6) large elevated platform; 7) space in front of the large elevated platform (floor space); 8) space under the large elevated platform; 9) open space next to the box; 10) polyvinyl plastic tube; and 11) entrance/exit.

Figure 2



Schematic diagram of one large pen. The large arrows indicate the position and direction of the video cameras. The small arrows indicate the possibility for rabbits to choose between different units

Figure 3



Scale drawing of the position of the pens (c) in the room, on the left side from above and on the right side from the front. The ventilation is on the left (a), the staircase (b) to reach the room on the right side of the pens. The numbers symbolise unit 1 and unit 6 of the respective pens.

(40 × 11.5 cm × maximum 15.5 cm) was installed above the large elevated platform as additional structural enrichment (Figure 1). In addition, four different enrichment materials per unit were available: two softwood gnawing materials (spruce), one hanging from a chain and one fixed to the wall, a hanging chain with plastic elements and a fixed cotton rope (Figure 1). The animals were fed with roughage in the form of hay and pelleted fattening feed (up until four weeks after weaning; Viko Safe Wissel + Aco, then with Viko Rendement up until the end of the fattening period, both from the producer, Victoria Mengvoeders, Veghel, The Netherlands). In each single unit, one feeder with hay and one with fattening feed were offered (Figure 2). Water was available *ad libitum* from two nipple drinkers per single unit. The lighting period (daytime) lasted from 0630 to 1830h with dimming phases of 30 min each. The room was illuminated by one LED-tube above each single unit. The temperature in the barn varied between the different seasons. In summer there was a mean (± SD) temperature of

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Table 1 Ethogram of the behaviours for scan sampling and continuous sampling according to Buijs *et al* (2011a), Morton *et al* (1993) and Kraft (1978).

		Definition
Scan sampling (posture)	Lying (passive)	Lateral or prone position, forelimbs and hind limbs under the body or stretched out, squatting inattentively
	Sitting (active)	Sitting on hind limbs, only the paws of the forelimbs having contact with the ground while the animals are attentive or performing actions (eg grooming, eating)
	Upright position (active)	Forepaws lifted off the ground, hind limbs on the ground
	Locomotive (active)	Any behavioural pattern involving movement
Continuous sampling (behavioural patterns)	Resting	Lying/squatting without participating in the environment
	Locomotory behaviours	Hopping, running, jumping, turning, walking, circling, leaping
	Upright position alert	Forepaws lifted off the ground, hind limbs on the ground, pricked ears, with a good overview of the surroundings
	Sitting/standing alert	Sitting on the hind limbs, only the paws of the forelimbs have contact with the ground, ears pricked/standing only on the paws
	Eating	Head in the area of the feeding bowl
	Drinking	Head in the area of the nipple drinker
	Comfort behaviours	Washing, licking, scratching own body; 'body-rolling' (Morton *et al* 1993); head-banging
	Stereotypical behaviours	Gnawing grids; paw-scraping on the ground/interior of the pen
	Aggressive behaviours	Biting, chasing, scratching other rabbits, fighting with other rabbits
	Investigatory behaviours	Contact with gnawing material; slicking, gnawing, smelling, scratching gnawing materials
	Social behaviours	Contact with other rabbits; smelling, washing, licking the body of other rabbits

18.8 (± 0.9)°C (fattening period 2), in spring of 22.1 (± 0.1)°C (fattening period 1) and of 21.4 (± 2.8)°C (fattening period 5) and in winter of 10.6 (± 1.1)°C (fattening period 4).

Behavioural analysis

Two large pens (two × six interconnected single units) were video-recorded (EverFocus EQ900F, EverFocus Electronics Corp, New Taipei, Taiwan) in this study. Six cameras, three positioned from the top and three from the front, monitored one pen (Figure 2). One of the two large pens was evaluated per fattening period.

Irrespective of the infra-red technology, the housing system was unable to be completely illuminated at night due to its structure meaning that video analysis could only be carried out during the lighting period.

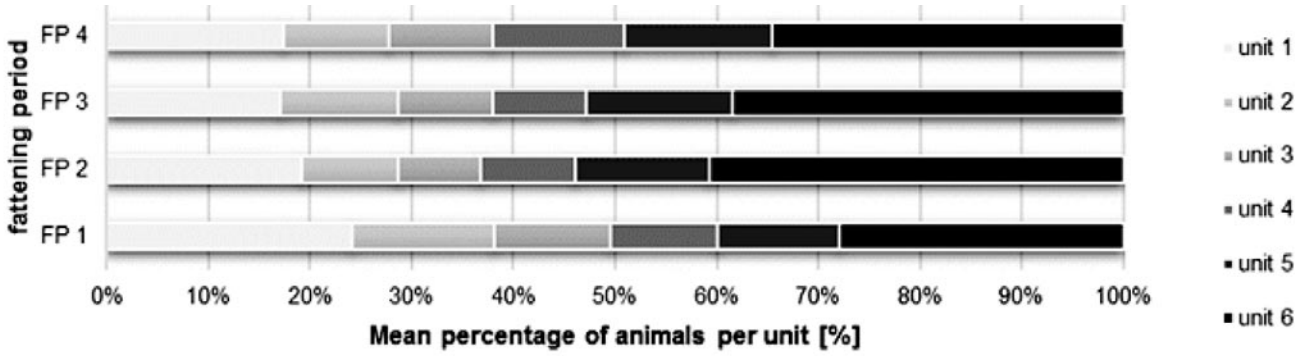
Instantaneous scan sampling for quantitative and qualitative analysis of space use at group level

The instantaneous scan sampling method was used to record the usage of different locations (roof of the box, box, large elevated platform, space under the large elevated platform, floor space in front of the large elevated platform, open space next to the box, tube) and units (units 1–6) by the rabbits (n = 247) (quantitative analysis) and to evaluate their active and passive behaviour at different locations based on their body postures (qualitative analysis) (Table 1). On the 1st, 3rd, 10th, 17th, 24th, 31st, 38th and 45th day of fattening in 2 h each in the morning (in the time between 0700–1000h), at noon (1200–1400h) and in the evening (in the time between 1600–1900h) (daytime) the number of rabbits per m² and their body postures (Table 1) in different units and locations were determined every 10 min. Variations of the evaluated times by a maximum of 60 min were caused by technical problems. Also, the 31st fattening day in the last fattening period was not evaluated due to technical problems.

Continuous sampling on individual level

Continuous sampling was used to further assess preferred activities at different locations and in the units in terms of their duration and frequency. Therefore, all animals were individually marked by animal spray paint (RAIDEX GmbH, Dettingen/Erms, Germany). At the end of the fattening period five focal rabbits were selected per group for continuous behavioural observation via video recordings. Each individual's specific behaviours, including duration and frequency were noted. Important criteria for the selection of the rabbits were that they survived the fattening period until slaughter (mortality rate: on average 29.4 [± 8.8]% of animals per fattening period) and were readily identifiable on the video recording. Furthermore, the observed rabbits originate from as many different litters as possible and both male and female rabbits should be evaluated in each fattening period. Overall, on average, 55 (± 1)% of the rabbits were female. The 17th and 38th day of fattening were each analysed during the periods from 0900 to 1000h, from 1300 to 1400h and from 1700 to 1800h. The evaluated behaviours are shown in Table 1.

Figure 4



Mean percentage (%) of the use of the units (1–6) depending on the evaluated fattening periods (1–4).

Statistical analysis

Data analysis was conducted separately with respect to the appropriate objective and SAS Version 9.4 (SAS Institute Inc, Cary, NC, USA) was used.

Quantitative analysis at group level:

Instantaneous scan sampling data (number of animals per m²) were used to evaluate the usage of the different units and locations. A descriptive analysis was conducted concerning the usage of the system at different times in the day and for the different fattening periods. Furthermore, a generalised mixed linear model (GLIMMIX procedure) was calculated, including units (1–6; Figure 2), locations (4–10; Figure 1), days of the fattening period (1st, 3rd, 10th, 17th, 24th, 31st, 38th and 45th), as well as the interaction between unit × day of the fattening period and location × day of the fattening period as fixed factors. The hierarchical structure of the data and repeated measurements were considered as random effects (location nested in unit, unit nested in 10-min scan sampling interval, 10-min scan sampling interval nested in daytime, daytime nested in day of the fattening period). Multiple pair-wise comparisons were performed using Tukey-Kramer tests. The level of significance was set at $P < 0.05$.

Qualitative analysis at group level:

Here, once more, instantaneous scan sampling data were used. A generalised linear mixed model (GLIMMIX procedure) was calculated for an analysis of the percentage of animals showing a specific body position per unit and location. Here, body position (lying, sitting, upright position, locomotion), the interaction between body position × unit (1–6), body position × location (4–10; Figure 1), body position × day of the fattening period (1st, 3rd, 10th, 17th, 24th, 31st, 38th and 45th) and the three-fold interaction between unit, location and position were set as fixed effects. The hierarchical structure of the data and repeated measurements were considered as random effects (for further information, see *Results*: *Quantitative analysis at group level*). Multiple pair-wise comparisons were performed using Tukey-Kramer tests and the level of significance set at $P < 0.05$.

Individual behaviour of focal animals

Continuous sampling data were used for a detailed analysis of the individual behaviour of the 20 focal animals.

A generalised linear mixed model (GLIMMIX procedure) was calculated for each parameter, ie duration and frequency of behaviour, separately. The respective behaviour (1–11; Table 1), the interaction between behaviour × unit and behaviour × location were included as fixed effects. Repeated measurements were considered as random effects (individual nested in daytime, daytime nested in week of fattening period).

Here, again, multiple pair-wise comparisons were performed using Tukey-Kramer tests and significance level set at $P < 0.05$.

Results

Quantitative analysis at group level

Descriptively, it was clear that the use of the units was similar in the fattening periods (Figure 4).

Likewise, the use of the units was very similar at the different daytimes. Only during the first two fattening days was unit 6 preferred at noon (morning: 18.1 [± 0.5] rabbits per m², noon: 32.1 [± 0.8] rabbits per m², evening: 20.8 [± 0.5] rabbits per m²), whereas the other units were less used at noon (in total: morning: 3.6 [± 0.1] rabbits per m²; noon: 2.4 [± 0.1] rabbits per m², evening: 3.4 [± 0.1] rabbits per m²). Later on, no preference for certain units in the morning, at noon or in the evening was discernible.

The results of the statistical model revealed that the unit ($F_{5.50682} = 14.4$; $P < 0.001$) had a significant effect on the number of animals per m². Thereby, more animals used unit 6 (11.2 [± 0.2] rabbits per m²) compared to the other units ($|t| > 2.9$; $P < 0.05$) where fewer animals were observed (unit 1: 6.4 [± 0.1] rabbits per m², unit 2: 3.5 [± 0.1] rabbits per m², unit 3: 3.0 [± 0.1] rabbits per m², unit 4: 3.0 [± 0.1] rabbits per m², unit 5: 4.0 [± 0.1] rabbits per m²).

Furthermore, the day of fattening ($F_{7.50682} > 19.0$; $P < 0.001$) had a significant effect on the number of animals per m² as well as the interaction between the unit and the day of

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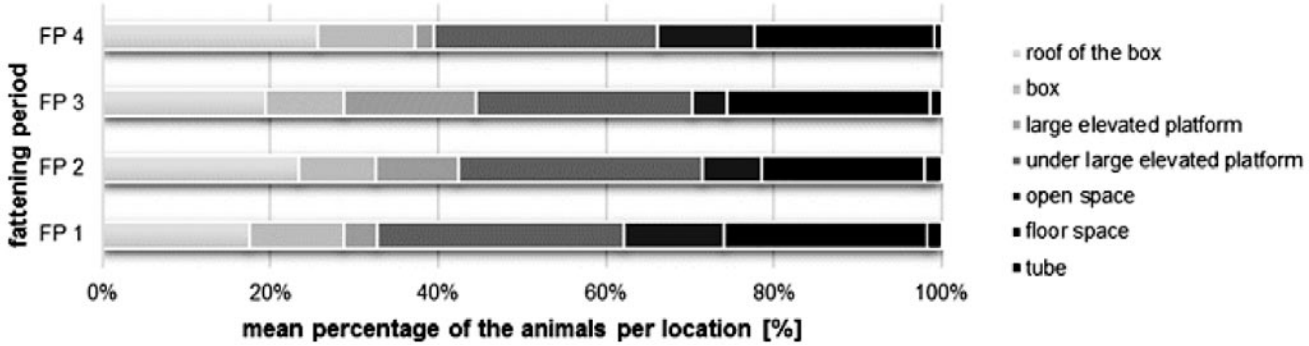
Table 2 Mean (± SEM) animal density (rabbit per m²) in the different units (1–6) at fattening days 1–45.

Fattening day	Animals per m²					
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
1st	7.7 (± 0.1)	1.3 (± 0.1)	0.9 (± 0.1)	1.0 (± 0.1)	3.0 (± 0.2)	24.6 (± 0.8)
3rd	7.4 (± 0.1)	2.3 (± 0.1)	1.9 (± 0.1)	1.4 (± 0.1)	4.3 (± 0.2)	22.8 (± 0.7)
10th	9.1 (± 0.2)	4.2 (± 0.2)	3.1 (± 0.2)	2.9 (± 0.2)	3.7 (± 0.2)	10.7 (± 0.4)
17th	5.8 (± 0.2)	3.5 (± 0.2)	3.0 (± 0.2)	3.7 (± 0.2)	4.7 (± 0.2)	7.3 (± 0.3)
24th	5.2 (± 0.2)	3.4 (± 0.2)	3.6 (± 0.2)	3.8 (± 0.2)	3.6 (± 0.2)	5.4 (± 0.2)
31st	5.5 (± 0.2)	4.9 (± 0.2)	3.6 (± 0.2)	4.2 (± 0.2)	4.4 (± 0.2)	6.6 (± 0.2)
38th	5.3 (± 0.2)	4.0 (± 0.2)	4.2 (± 0.2)	3.6 (± 0.1)	3.8 (± 0.2)	5.3 (± 0.2)
45th	5.0 (± 0.2)	4.6 (± 0.2)	3.9 (± 0.1)	4.0 (± 0.1)	4.3 (± 0.1)	5.6 (± 0.2)

Figure 5



Mean percentage (%) of animals on the locations (roof of the box, box, large elevated platform, under large elevated platform, open space, floor space, tube) relative to the evaluated fattening periods (FP 1–4).

fattening ($F_{35.50682}$ = 260.1; $P < 0.001$). At the beginning of the fattening period (1st day after weaning), most animals were located at the outer units of a large pen (Table 2). However, by the 10th day after weaning, the number of animals in both outer units tended to decrease, while the number of rabbits in the middle units increased (Table 2). At the end of the fattening period (45th day), nearly all units were used equally. Nonetheless, there was still a slight preference for the outer units (Table 2).

In terms of the usage of the locations within the units, hardly any differences were found between the fattening periods when data were analysed descriptively (Figure 5).

As regards the daytime, the roof of the box, the space under the elevated platform, the tube and the floor space in front of the large elevated platform were shown to be used less at noon compared to the morning and evening (Table 3), while the box, the elevated platform and the open space next to the box were visited more at noon than at other times of the day (Table 3).

The results of the statistical model revealed that the different locations within the units of a large pen showed a significant effect on the animal density observed there ($F_{6.50682}$ = 14.7; $P < 0.001$). Most rabbits per m² spent their time under the large elevated platform and on the floor space in front of the large elevated platform during all analysed fattening days (Table 4). Nevertheless, an inter-

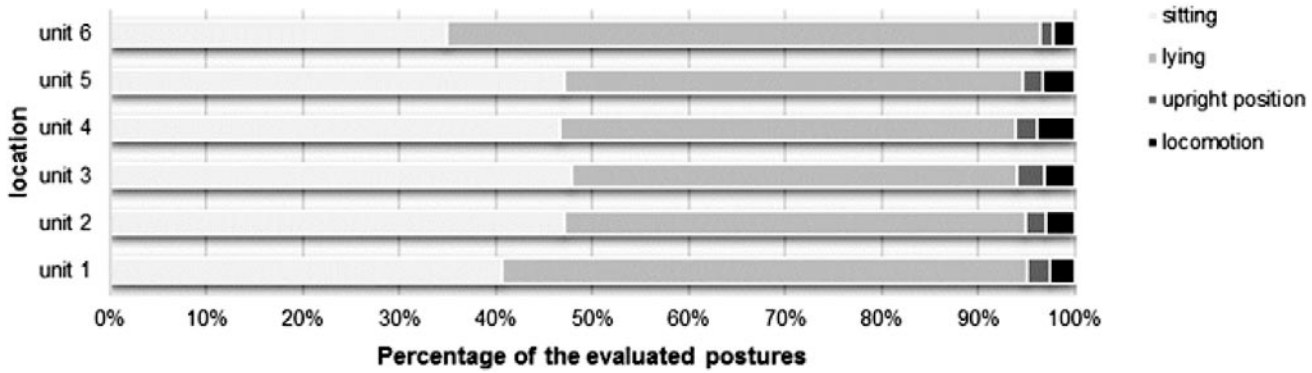
Table 3 Mean (± SEM) number of animals per m² at the different locations in the morning, noon and evening.

Location	Morning	Noon	Evening
Roof of the box	7.5 (± 0.2)	6.7 (± 0.2)	8.5 (± 0.2)
Box	3.2 (± 0.2)	5.4 (± 0.3)	2.6 (± 0.2)
Elevated platform	2.9 (± 0.1)	3.6 (± 0.1)	2.5 (± 0.1)
Under a platform	10.4 (± 0.2)	8.9 (± 0.2)	11.0 (± 0.2)
Open space	2.8 (± 0.2)	4.8 (± 0.3)	1.8 (± 0.1)
Floor space	8.3 (± 0.2)	7.9 (± 0.2)	8.2 (± 0.2)
Tube	0.7 (± 0.1)	0.2 (± 0.0)	0.8 (± 0.1)

Table 4 Mean (± SEM) animal density (rabbit per m²) in the different locations at fattening days 1–45.

Fattening day	Roof of the box	Box	Elevated platform	Space under elevated platform	Open space	Floor space	Tube
1st	8.4 (± 0.4)	6.6 (± 0.5)	0.2 (± 0.0)	13.6 (± 0.7)	5.5 (± 0.5)	10.6 (± 0.6)	0.0 (± 0.0)
3rd	12.5 (± 0.5)	6.0 (± 0.5)	0.5 (± 0.0)	12.7 (± 0.5)	5.1 (± 0.5)	9.7 (± 0.5)	0.2 (± 0.1)
10th	10.7 (± 0.4)	3.5 (± 0.3)	2.1 (± 0.2)	11.9 (± 0.4)	1.8 (± 0.2)	9.0 (± 0.4)	0.3 (± 0.1)
17th	7.8 (± 0.3)	1.8 (± 0.2)	3.9 (± 0.2)	9.7 (± 0.3)	1.6 (± 0.2)	7.4 (± 0.2)	0.5 (± 0.1)
24th	5.1 (± 0.2)	1.8 (± 0.1)	4.6 (± 0.2)	8.9 (± 0.2)	1.1 (± 0.1)	6.7 (± 0.2)	0.8 (± 0.1)
31st	4.9 (± 0.2)	2.7 (± 0.2)	5.0 (± 0.2)	9.2 (± 0.2)	2.8 (± 0.2)	8.4 (± 0.2)	1.0 (± 0.2)
38th	4.7 (± 0.2)	3.0 (± 0.2)	4.2 (± 0.1)	7.5 (± 0.2)	3.1 (± 0.2)	7.1 (± 0.2)	1.0 (± 0.2)
45th	5.9 (± 0.2)	4.0 (± 0.2)	4.1 (± 0.1)	7.1 (± 0.1)	3.9 (± 0.2)	6.2 (± 0.2)	0.7 (± 0.1)

Figure 6



Mean percentage (%) of the body postures sitting, lying, upright position and locomotion in the different units offered during the evaluated time.

action between location and day of the fattening period was found ($F_{42.50682} = 55.1$; $P < 0.001$), with a decreasing animal density under the large elevated platform towards the end of the fattening period (first day vs 45th day: $|t| = -3.9$; $P < 0.001$). The roof of the box was used particularly at the beginning of the fattening period, as an additional elevated platform (Table 4). In contrast, only a few animals were found on the large elevated platform up until the third fattening day. However, with each subsequent day of analysis, more animals per m² were found using it. Enclosed areas, such as the box and the open space next to the box, were used mostly in the first weeks after weaning. Afterwards, the number of rabbits observed in these locations decreased (first day vs 24th day: all $|t| > 4.4$, all $P < 0.001$), this, however, increased again up until the end of fattening (24th day vs 45th day: all $|t| > -2.2$, all $P < 0.001$). As with the large elevated platform, the tube was increasingly used from the third fattening week onwards.

Qualitative analysis at group level

Body position ($F_{3.87908} = 2{,}566.24$; $P < 0.001$) and the interaction between body position and location ($F_{24.87908} = 337.3$; $P < 0.001$) were found to be significant.

The animals showed an almost equal ratio of sitting and lying positions when comparing the middle units (Figure 6). In the outer units, however, fewer active positions (sitting) and more inactive positions (lying) were observed compared to the other units (Figure 6). The movement posture (locomotion) tended to occur more often in the middle units than in units 1 and 6 (Figure 6). The upright position was shown least in unit 6 compared to the other units (Figure 6).

The floor space in front of the large elevated platform and the space under the elevated platform were used significantly more often for active behaviours in a sitting position than for passive behaviours in a lying position (all $|t| > 8.8$, all $P < 0.001$) (Figure 7). Furthermore, in comparison to other locations, the floor space in front of the large elevated platform was used more for locomotor behaviours (tube:

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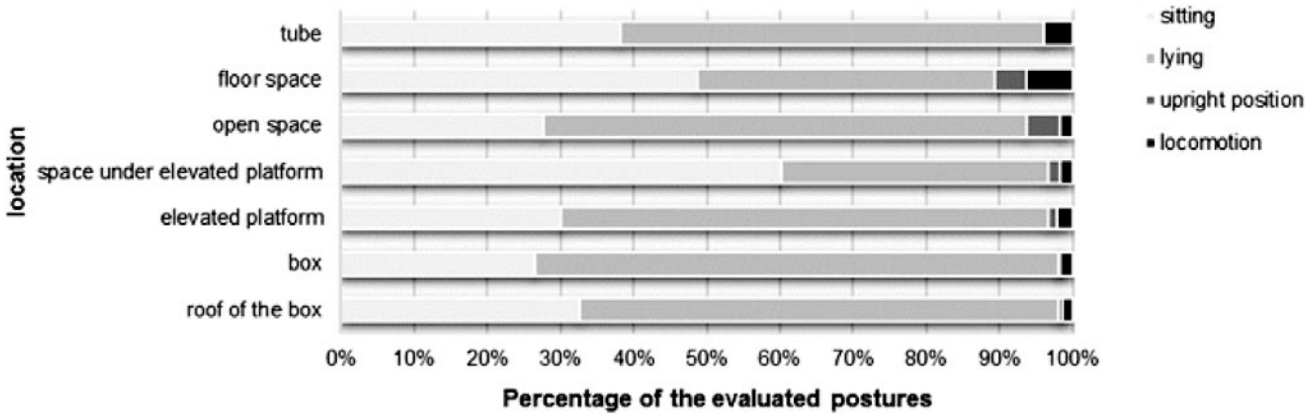
Figure 7



Mean percentage (%) of the body postures sitting, lying, upright position and locomotion in the different locations during the evaluated time.

|t| = 2.5; $P > 0.05$; all other locations: |t| > –3.6; $P < 0.05$) (Figure 7). Otherwise, the number of rabbits in a lying position was higher in small areas (box, open space next to the box) and elevated areas (roof of the box, elevated platform, tube) compared to the floor space in front of the large elevated platform and the space under the large elevated platform (Figure 7). The upright position was, compared to the other locations, mostly observed in open-top locations, ie the open space next to the box (all |t| < 4.1; all $P > 0.05$) and the floor space in front of the large elevated platform (tube and open space: all |t| < 4.7; all $P > 0.05$; all other locations: |t| > –3.0; all $P < 0.05$) (Figure 7).

Behaviours of focal animals at individual level

The type of behaviour was revealed to have a significant effect on the duration ($F_{10.55308} > 142.4$; $P < 0.001$) and the frequency ($F_{10.55308} > 175.4$; $P < 0.001$) of the behavioural patterns shown by the rabbits per hour. Furthermore, the interaction between the location and the type of behaviour had a significant effect on the duration ($F_{66.55308} > 20.6$; $P < 0.001$) and the frequency ($F_{66.55308} > 56.7$; $P < 0.001$) of the behavioural patterns. Animals spent the longest time resting per hour under the elevated platform and on the floor space in front of the large platform compared to the other locations (all |t| > –6.9; all $P < 0.001$). However, this was also, with regard to the frequencies, where the most frequent interruptions of the behaviour occurred compared to the other locations (all |t| > –11.1; all $P < 0.001$) (Table 5; see supplementary material to papers published in *Animal Welfare:* https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material). Thus, a resting phase lasted, on average, shorter on the floor space in front of the large elevated platform (64.9 s) and under the elevated platform (90.6 s) than on the roof of the box (91.9 s), in the box (148.2 s), on the open space next to the box (107.1 s), on the elevated platform (128.9 s) and in the tube (151.6 s). The mean duration per hour of locomotor behaviour was shown to be longest on the floor space in front of the large elevated platform and on the space under the elevated platform compared to the other locations, but the differences were not significant (all |t| < 0.6; all $P > 0.05$). The alert behaviour in an upright position per hour tended to be longest in open top locations such as the open space and the floor space in front of the large elevated platform compared to other locations. However, differences were not statistically significant (all |t| < –0.2; all $P > 0.05$). A phase of attentive standing upright lasted longest on the open space next to the box (10.2 s). The alert behaviour in a sitting position per hour tended to be longest on the elevated platform compared to other locations. Nevertheless, differences were not statistically significant (all |t| < 0.3; all $P > 0.05$). One event of attentive sitting or standing lasted longest in the box (24.5 s) and the tube (17.0 s), and shortest on the floor space in front of the large elevated platform (5.3 s). Eating and drinking were shown at the locations where drinking nipples and feeders were installed, ie under the large elevated platform and on the floor space in front of the large elevated platform. One event of eating and drinking lasted, on average, 113.5 s and 25.3 s under the large elevated platform, and 139.1 s and 26.7 s in front of the large elevated platform, respectively. Comfort behaviour was shown mostly under and in front of the large elevated platform, but one event of self-grooming lasted less time (all < 18.2 s) there compared to the other locations (all > 21.8 s), apart from the tube (11.0 s). Social behaviour was observed mostly in front of the large elevated platform, but also under the large elevated platform and on the elevated platform. However, one single event lasted shorter under (8.8 s) and in front (8.1 s) of the elevated platform than at the other locations. Exploratory behaviour was only shown at locations with manipulable material, ie under and in front of the large elevated platform, sometimes also on the large elevated platform. Aggression or stereotypic behaviours were rarely observed. Aggressive behaviour was mostly observed in front and under the large elevated platform, stereotypic behaviours (grid gnawing) mostly on the elevated platform. The differences at different locations regarding exploratory, social, aggressive and stereotypic behaviours were not statistically significant (all |t| < 1.6; all $P > 0.05$).

Discussion

In order to meet the social and political demands for more animal welfare in rabbit farming, an alternative housing system complying with the German Welfare Regulation was developed for this study and subjected to scientific scrutiny as regard to its animal-friendliness based on the rabbits' behaviour.

There was conspicuous clustering of rabbits after weaning in the outer units of the housing system (mainly unit 6) but this began to dissipate after the first week. A similar huddling together of rabbits was also described by Lehmann (1991) under semi-natural conditions between day 30 and 49, post-partum, and by Matics *et al* (2004) under practical farming conditions during the initial fattening period. The rabbits did not use all the space available to them, although they were given the opportunity to do so. However, after approximately 6.5 weeks of life, the rabbits spread out to occupy the entire available space (Matics *et al* 2004). Rabbits are social animals that often huddle together with conspecifics during resting periods (Kraft 1978). Nonetheless, the fact that in our study, nearly all animals from six different origin litters gathered in one unit at the beginning of the fattening period may be due to an increased need for security up to a certain age. The outer units were more protected than the middle units, since three sides were closed and there was no passageway for running. In the middle units, resting rabbits could have been disturbed more often by rapidly passing rabbits. It was also previously described that rabbits preferred to rest against walls or other protective structural elements as they may feel more safeguarded from predators (EFSA 2005; Buijs *et al* 2011b). The cluster formation in the initial fattening period became particularly obvious at noon, when the rabbits, as crepuscular animals (Jilge 1991), were mostly inactive. The rabbits huddled together to rest in unit 6, while at other times of day, when the animals were more active, time was also spent in other units. Thus, in comparison to the inner units, the outer ones were visited more often for lying down and less for locomotion. However, when the animals grew older and needed more space due to their increased body size, no differences in the use of the units were apparent anymore. Perhaps the rabbits still preferred to lie in areas of less traffic. Nonetheless, due to their larger body size, they were forced to use the middle units as well.

The locations with the highest animal densities during the entire fattening period were the areas under the large elevated platform and on the floor space in front of the large elevated platform. Decreases in animal densities towards the end of the fattening period in these locations could be due to the increasing body size of the animals and therefore less usable space so that the animals spread over all locations with increasing age (Matics *et al* 2017). Also, it must be taken into account that the drinking nipples, feeding bowls and manipulable materials could only be reached by the animals if they were under the large elevated platform or on the floor space in front of the large elevated platform. Visits to these places were therefore inevitable for food and water intake or exploratory behaviour. The observation of the focal rabbits also showed that eating commonly occurred under the platform. If the feeding bowls, drinking nipples and manipulable materials were located elsewhere, the animal density at these places might have shifted. However, other studies have also shown that rabbits prefer places that are closed at the top (Princz *et al* 2008b), such as the area under the large elevated platform, accordingly staying more under than on an elevated platform, especially during the daytime (Lang & Hoy 2010; Szendrõ *et al* 2012; Matics *et al* 2017; Trocino *et al* 2019). This can be due to the fact that rabbits, as flight animals, prefer sheltered positions, and cover from above provides protection against predators from the air (Lombardi *et al* 2003). However, one would assume that these protected areas were increasingly used for resting. Nonetheless, contrary to the other locations, the area under the elevated platform was less used for resting than sitting or locomotion. This may be due to the fact that in our study, the rabbits under the elevated platform were often disturbed by other animals eating and drinking there or jumping to the floor space in front of the large elevated platform. This is confirmed by the analysis of individual rabbits, indicating that one period of resting and also of other comfort behaviours, such as self-grooming or social behaviour, was often interrupted under and in front of the large elevated platform, resulting in shorter periods of these behaviours compared to other locations. Furthermore, aggressive interactions were mostly observed in front and under the large elevated platform. On the other hand, a study by Kraft (1978) pointed out that domesticated rabbits, in contrast to their wild counterparts, also lie more frequently on flat surfaces that are not protected from above, due to a weakened instinct to flee. This was also confirmed by Brusini *et al* (2018). Moreover, observations from another study showed that areas atop elevated platforms were very often used for relaxed lying with the body stretched out (Trocino *et al* 2019), a fact we were able to confirm here, as rabbits frequently visited exposed areas to rest. For example, the animal density on the roof of the box, which was most often used for resting, was higher than the animal density in the box itself. This is in accordance with the results of Hansen and Berthelsen (2000), in whose study, rabbits also used the roof of a box rather than the box itself. Differences in rabbits' fear responses as a result of domestication can play a role in this regard (Brusini *et al* 2018). In addition to the roof of the box serving the purpose of a small elevated platform, the area on top of the large elevated platform was increasingly used for resting from the 10th day of fattening onwards. Previously, the rabbits had been too small to reach the elevated platform directly from ground level. It was observed that only a few animals occasionally used the roof of the box as an intermediate platform to jump onto the large elevated platform. Therefore, the roof of the box probably saw more usage at the beginning of the fattening period, while the animal density there dropped to half by the end of the fattening period when rabbits were able to reach the large platform and grew too large to rest together on the roof of the box. The animals distributed themselves more evenly over both platforms as soon as they were able to reach the large one. In contrast to the other

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locations, attentive sitting was frequently observed on the large elevated platform. Hansen and Berthelsen (2000) already described in their study that elevated platforms were often used as a place for providing an enhanced view of their immediate environment. Nevertheless, the elevated platforms in our study were also used for resting. In contrast to the large elevated platform, the roof of the box was used less for resting at noon, but more in the morning and evening. A single resting phase lasted considerably shorter on the roof of the box than on the elevated platform. Thus, it can be concluded that the rabbits were disturbed more often on the roof of the box, and possibly searched directly for places where they could lie more undisturbed at noon. In addition, the elevated platform was a place where the rabbits could lie more comfortably than elsewhere, as the elevated platform was only 15% perforated, whereas the other locations were fully slatted.

The box and the open space next to the box, both confined places enclosed by walls, were also used mainly for resting at noon. They were visited particularly at the beginning and end of the fattening period. At the beginning of fattening, they may have been used more frequently, mainly because of the need for protection after weaning, but also because other places, such as the elevated platform, were not yet directly accessible. Also, in a previous study, boxes were visited more often in the first weeks after weaning, elevated platforms, however, more in the second half of the fattening period (Maertens *et al* 2004). Moreover, Matics *et al* (2004) described that young rabbits preferred to huddle together in small cages, which is comparable with small areas such as the open space next to the box in the present study. At the end of the fattening period, however, these locations were more likely to be visited due to increased space requirements. The box was an enclosed area where the animals were probably less disturbed than in other areas. Thus, the duration of the individual resting periods was longer there. This area was therefore used at times of greatest need for resting, ie at noon.

Standing upright on their hind legs is a species-specific behaviour in rabbits, which should be facilitated by appropriate housing systems even if it is not expressed very often (EFSA 2005). In places that are open at the top, such as the floor space in front of the elevated platform and the open space next to the box, upright, alert positions were observed more frequently than elsewhere. Thus, the structure of the housing system seemed to allow this species-specific behaviour. Overall, however, also in these locations, this behaviour did not occur so frequently that the animals seemed to be stressed.

The least visited place was the tube which was probably due to its location since it was accessible only via the large elevated platform. In a study by Postollec *et al* (2002), the tube was mostly used in the first two weeks after weaning, ie at a time when the rabbits in our study would still have been too small to reach it. However, Trocino *et al* (2019) also reported tubes as being seldom used and not seeming to visibly improve the well-being of rabbits. Perhaps the tube in our study gained in importance as the rabbits grew up and reached maturity, thus serving as a place to retreat from the aggression of pen-mates. In the study by Rommers *et al* (2014), PVC tubes were described as hiding places for does and seemed to be able to reduce injuries caused by aggressive interactions. Further studies selecting different positions for the tube in our housing system would provide more information in this regard. Additionally, analysing the rabbits' behaviour at night would provide further information on the use of space in this housing system because the usage of the locations, especially the elevated platform, can vary during the day and night (Lang & Hoy 2011). Furthermore, the behaviour of rabbits at night may vary, because they are more active at these times as nocturnal and crepuscular animals.

Negative behaviours such as stereotypies and aggression were observed only to a very limited extent. Aggressive behaviour was only shown in areas with a higher density of rabbits. The structure of the housing system, opportunities for retreat and the provision of manipulable materials seem to prevent aggressive behaviour. Stereotypic behaviours were not often observed and, if so, the behavioural events did not last long. Furthermore, it was not easy to assess whether one event of grid gnawing was motivated by exploration or an expression of stress and boredom. The fact that stereotypic behaviours were observed mainly in the elevated areas was due to the fact that the grids could only be reached from the roof of the box and the elevated platform due to the design of the housing system. Overall, the low evidence of such behaviours suggests that the animals did not experience high stress levels (Broom 1983).

Looking at previous results obtained in the same housing system as used here, it became evident that this housing system, complying with the German Welfare Regulation, showed both positive and negative aspects. Thus, in the new housing system, higher mortality rates and more hygienic problems were found than in conventional wire-mesh cages (Rauterberg *et al* 2019a). The higher mortality rates could explain the significant effect of the fattening days concerning the use of the units and locations in the present study due to there being fewer animals towards the end of fattening. However, behavioural analyses performed for the present study revealed that the new housing system promoted species-specific behaviour due to its structure. Indeed, due to the provision of space enabling retreat from pen-mates, the amount of injuries was reduced at least until sexual maturity (Rauterberg *et al* 2019a) and less aggressive and stereotypic behaviours (Kimm *et al* 2019) were observed than in conventional cages. Furthermore, locomotor behaviour was promoted in the new housing system (Kimm *et al* 2019). Nevertheless, there is still a need for research concerning the arrangement of structural elements in this housing system. The elevated platform seems to be an important structural element, but its optimal height still to be determined. Again, research should be conducted on the installation and supply of tubes as hiding places.

Animal welfare implications

The development of animal-friendly livestock systems is becoming increasingly important in light of greater social and political demands regarding animal welfare in Europe. Good animal welfare should be realised by housing systems supporting species-specific behaviour. By structuring the studied housing system with boxes and elevated platforms, the rabbits were provided with more space and retreat possibilities than in conventional wire-mesh cages, which should minimise aggressive confrontations and therefore injuries. Furthermore, the housing system provided space for resting and activity, such as locomotion or exploration, thus supporting natural behaviour which is the prerequisite for good animal welfare.

Conclusion

The results of the present study revealed that the entire space provided in a housing system for fattening rabbits, which was designed in accordance with the new German legal requirements for rabbit husbandry, was used by the animals for different species-specific behaviours. However, this study also confirmed that rabbits huddle together after weaning and do not use the total space available to them at the beginning of the fattening period. Elevated platforms seem to provide suitable environmental enrichment, as they confer both protection from above and a useful vantage point for overseeing the immediate environment. In addition, elevated platforms seem to allow undisturbed resting and thus may reduce social stress. However, these require specific adaptation to the age and height of the animals in question in order to be reachable throughout the fattening period. The height of the platform (37 cm) in this study seems to be too high in the first weeks after weaning. Aggressive behaviour was not often observed but if it occurred, it was performed at locations with high animal densities, such as under and in front of the elevated platforms. Structural elements, such as boxes, elevated platforms, tubes and closed areas within a housing system allow the animals to retreat from conspecifics and to rest in an undisturbed and protected environment, and thus can be recommended in terms of animal welfare. Stereotypic behaviour occurred only to a very small extent, indicating that the rabbits in this housing system did not experience high stress levels. Overall, the structure of the studied housing system supported species-specific behaviours, provided space for resting and activity and seemed to reduce aggression and stress. From an ethological point of view, the housing system would be suitable for rabbits. Nevertheless, further research is needed to investigate more effects of the new German Welfare Regulation on the behaviour, performance and health of rabbits.

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