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HEALTH, PERFORMANCE AND SOILING OF BREEDING DOES AND THEIR KITS KEPT IN TWO DIFFERENT HOUSING SYSTEMS ON A GERMAN RABBIT FARM

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Abstract: The aim of the present study was to compare a new housing (NC) for rabbit does and their kits that complies with German welfare regulations with established wire mesh cages (CC) on a commercial rabbit farm. Rabbit does were single-housed from five days *antepartum* until weaning at 31 d *postpartum* either in large pens (80×80 cm with an open top) with slatted plastic flooring (11 mm slats and 11 mm gaps), nestbox, elevated platform (15% perforated) and different manipulable materials (NC) or in cages (70×50×30 cm) with wire mesh flooring (12×70 mm holes and 3 mm wire diameter), nestbox and one gnawing stick (CC). Skin lesions, weight development, fertility, morbidity, cleanliness and kit performance of 272 rabbit does in a total of six batches were investigated. While there was no difference in performance of their kits, rabbit does showed an impaired performance with less weight gain and less body weight at weaning, lower fertility, more injuries and a higher incidence of mastitis and diarrhoea at the end of the rearing period in NC housing compared to CC housing. Additionally, soiling of hind feet was higher in NC than in CC housing. Overall, the poor hygienic conditions may have affected the animals' health and make an improvement in the new housing system necessary, especially with regard to the floor design.

Key Words: legal requirements, floor type, breeding rabbits, parity, welfare, pododermatitis.

INTRODUCTION

Breeding does in Europe are usually single-housed in wire mesh cages (DG Health and Food Safety, 2018), even though the welfare of reproducing does in these cages may be impaired (Saxmose Nielsen *et al.*, 2020).

The widely used barren cages with restricted space allowance are known to limit normal rabbit behaviours such as gnawing, hopping and standing upright (DG Health and Food Safety, 2018). In addition, the commonly used wire mesh flooring is associated with the development of pododermatitis, which is a painful health and welfare problem in rabbit does (Rommers and Meijerhof, 1996; Rosell and de la Fuente, 2013; Buijs *et al.*, 2014). Moreover, wire mesh flooring may also have negative effects on the locomotor behaviour of young kits, as it has been shown that the frequency of unsteady movements in kits increased with larger slat distances and was the highest on wire flooring (Petersen *et al.*, 2000).

In the past, different alternative and enriched housing systems have been developed and investigated in order to improve the welfare of rabbit does and their kits (Szendrő *et al.*, 2016). Enriched cages with a box and extended height were found to have positive effects on behaviour and animal welfare, especially in female rabbits (Hansen and Berthelsen, 2000). In addition, it was shown that enlarged and heightened cages had a positive impact on productivity of rabbit does with an increased number of kits born alive and weaned. In an enlarged and heightened cage with an alternative type of flooring, kits were also found to be heavier at weaning (Rommers and Meijerhof, 1997). Heavier kits were also observed in large cages with an elevated platform compared to smaller cages without

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platforms (Miko *et al.*, 2014). Moreover, an elevated platform gives rabbit does the opportunity to escape from their kits from the time they can leave the nest (Alfonso-Carrillo *et al.*, 2014). If the platform is made of plastic mesh, it can additionally reduce the severity of pododermatitis in rabbit does (Miko *et al.*, 2014). Nevertheless, it has to be considered that depending on the degree of perforation, elevated platforms may lead to hygiene problems due to the accumulation of faeces or faeces and urine that may fall onto animals under the platform (Alfonso-Carrillo *et al.*, 2014; Saxmose Nielsen *et al.*, 2020).

Providing footrests (Rosell and de la Fuente, 2013; Miko *et al.*, 2014) or plastic mats (Rommers and de Jong, 2009) for rabbit does on wire mesh flooring reduced the severity of pododermatitis, but not as much as a flooring completely made of slatted plastic (Buijs *et al.*, 2014). Changing the floor design may also have a positive effect on the frequency of unsteady movements made by young kits, as these decreased with smaller slat distances, the lowest being on plastic flooring with 10 mm slats and 10 mm gaps (Petersen *et al.*, 2000).

Nevertheless, alternative floor types such as slatted plastic floorings are also known to entail some hygienic disadvantages when causing a high soiling, depending on their degree and shape of perforation. In severe cases, this may also lead to negative effects on animal health (Masthoff and Hoy, 2019; Rauterberg *et al.*, 2019a; Tillmann *et al.*, 2019; Saxmose Nielsen *et al.*, 2020). An increased risk of soiling should be taken even more into consideration for rabbit does, as their larger droppings can easily block the gaps in perforated floorings if the slat distance is too small (Schlender-Böbbis, 1999).

Even if different housing systems for rabbits are already available (Saxmose Nielsen *et al.*, 2020), there is an urgent need to develop suitable alternatives to commercial cage systems which are both animal friendly and economic. This particularly applies to Germany, as the legal requirements for the protection of rabbits kept for meat production have recently been amended (TierSchNutztV, 2014) and most of the new requirements have been mandatory for farms since 2019. Housing systems in accordance with German welfare regulations have to provide, inter alia, an unrestricted floor space of 6000 cm^2 for breeding rabbits with an average weight of up to 5.5 kg. In addition, if a perforated floor is used, gap or hole widths must not exceed 14 mm for breeding rabbits and 11 mm for fattening rabbits and slat widths must be at least the same as the gap or hole widths. Furthermore, an elevated platform with a maximum degree of perforation of 15%, as well as roughage and gnawing material, must be provided for all rabbits (TierSchNutztV, 2014).

At the beginning of the present research, no commercial housing system in compliance with the new regulations was available and there was a great uncertainty as to whether, and to what extent, housing systems which consider the new regulations would influence the animals' health and welfare, as well as the feasibility. Therefore, the aim of the present study was to develop and assess a new housing system for breeding does and their kits used on a German rabbit farm which complied with current legal requirements. As this housing system provided increased floor space allowance and height in comparison to the most widely used conventional cages (Saxmose Nielsen *et al.*, 2020) and different enrichment and structural elements, it was expected to have a positive impact on the welfare and performance of rabbit does and their kits. As the housing system was intended to be used for both breeding and fattening rabbits after weaning, it additionally provided slatted plastic flooring with 11 mm gaps and slats to comply with the German requirements for all age groups. Moreover, an elevated platform with a 15% degree of perforation, meeting current German specifications, was installed. As this type of flooring might have hygienic disadvantages, with a negative impact on animal health due to its low degree of perforations (Masthoff and Hoy, 2019; Rauterberg *et al.*, 2019b), the soiling and health of rabbit does in particular were investigated in the present study. Furthermore, data on the biological performance and skin lesions of does and their litters were collected and all parameters were finally compared to those of does and their kits kept in an established conventional cage system on the same farm.

MATERIALS AND METHODS

Animals

This study was approved by the Animal Welfare Officer of the University of Veterinary Medicine Hannover, Foundation, Hannover, Germany. The investigations were carried out on a German commercial rabbit farm keeping about 600 rabbit does (HYPLUS PS 19) and their offspring (HYPLUS PS 19×PS 59, HYPHARM S.A.S., Sèvremoine, France)

in a semi-intensive reproduction system with a 42-d reproductive rhythm and artificial insemination (AI) at day 11 *postpartum* (pp).

All experimental rabbit does had previously been kept in conventional wire cages (CC, 70×50×30 cm (length×width×height)) or, in the case of primiparous rabbit does, either in single cages (50×40×50 cm) or in group rearing cages with four to five rabbit does each (100×50×37 cm). For the present research, rabbit does were moved to the experimental housing systems and were kept there from five days *antepartum* (ap) until weaning at day 31 pp. Kits stayed with their mother until weaning at 31 d of age. All rabbit does on the farm were vaccinated against RHD (rabbit haemorrhagic disease), enteritis and *Pasteurella multocida*.

Housing

Does were single-housed either under established conventional housing conditions (CC) or under new housing conditions (NC). NC housing provided 24 pens measuring 80×80 cm with an open top and a slatted plastic floor (11 mm slats, 11 mm gaps). Each pen had an elevated platform (60×55×37 cm) with a partly solid floor (42×55 cm) and a nestbox with wood shavings as nesting material (30×40×27 cm). The walls of NC pens were made of wire mesh. Additionally, each pen provided environmental enrichment such as a plastic tube and gnawing and manipulable materials (wood chain, wood holder, chain with plastic elements and a cotton rope, Figure 1). While does were

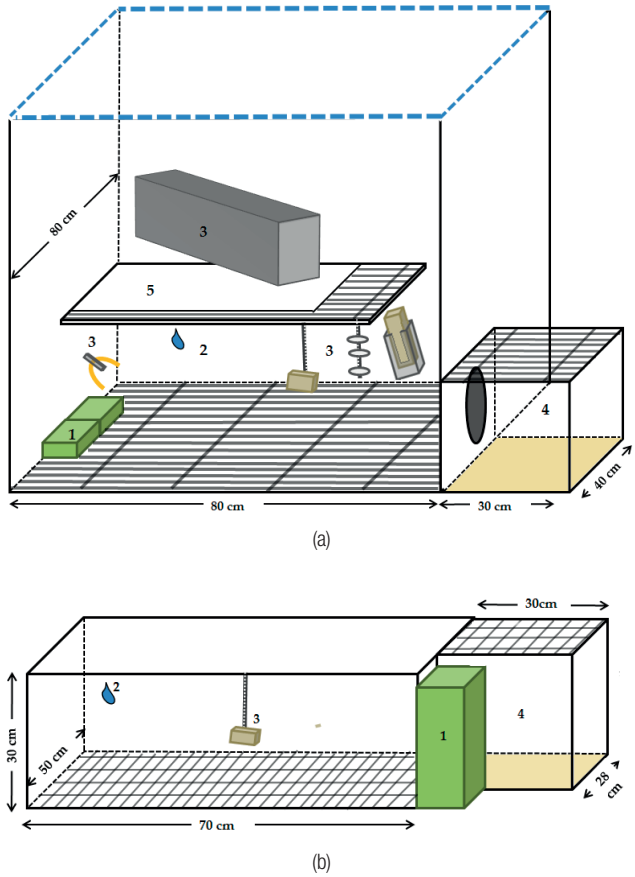

Figure 1: Pen of the new housing system (a) and conventional cage (b) with feeder (1), nipple drinker (2), environmental enrichment (3), nestbox (4) and elevated platform (5). Blue dashed lines indicate open walls (Sketch: S. L. Rauterberg).

removed at weaning, kits stayed in the NC system until slaughter at 78 d of age. In CC housing, 24 does were kept in 24 wire cages measuring 70×50×30 cm equipped with wire mesh floor (12×70 mm holes and 3 mm wire diameter), one piece of wood attached to a chain as gnawing material and a nestbox (30×28×28 cm) with wood shavings as nesting material (Figure 1). In CC, kits were moved to other cages at weaning for fattening, while does stayed in the cages or were moved to other cages of the same system in the event of unsuccessful AI.

All nestboxes were closed after parturition. Until the AI at day 11 pp does were allowed to enter the nest for controlled suckling in the morning once daily. Thereafter, AI nests were opened for free suckling and from day 21 pp nests were closed. A commercial pelleted diet (Fok Lapin, Fransen Gerrits-Victoria B.V., Veghel, the Netherlands), chopped hay and water from one nipple drinker per CC cage and two per NC pen were available *ad libitum*. Both housings were equipped with a negative-pressure ventilation system and artificial lighting during daytime. This lasted from 06:00 to 18:30 in CC and from 06:00 to 19:00 with dawn from 06:00 to 06:30 and dusk from 18:30 to 19:00 in NC, except for the last three days before AI, when artificial lighting was extended until 22:00 in both housing systems. Manure in CC housing was stored in pits below the cages, which were emptied every three weeks. Manure removal in NC housing was carried out daily by means of a manure belt placed below the pens.

Data collection

A total of 272 rabbit does and their offspring from NC (n=135) and CC (n=137) were investigated in six batches. Parity in all rabbit does studied ranged from the first to the sixth kindling, and does were equally distributed to both housing systems according to their parity.

Data were collected at the start of the housing period five days ap, seven days pp and 30 d pp. At these days, does were weighed and weight gain during lactation from day 7 to day 30 pp was calculated. Additionally, each doe was scored for skin lesions. To this end, different parts of the body (ears, head, body, tail, limbs, belly, and genitals) were assessed using the scoring system of Rauterberg *et al.* (2019b) ranging from 0 to 4 (Table 1). Subsequently, a cumulative lesion score for each animal was calculated as the sum of the different body regions (minimum: 0, maximum: 28). In addition, for each rabbit doe it was noted whether she fell ill with rhinitis, conjunctivitis, mastitis or diarrhoea during the housing period or not, and the incidence of each symptom was calculated for both housing systems.

Does' hind feet were scored for the severity of pododermatitis using a modified scoring system based on the scoring system of Rommers and Meijerhof (1996) and Rommers and de Jong (2011) (Table 1, Figure 2). Hind feet were additionally assessed for soiling using the four-stage scoring system of Rauterberg *et al.* (2019b, Table 1). Both feet of each doe were assessed separately and the maximum score was subsequently assigned to the respective individual.

At day 30 pp, fertility was evaluated by abdominal palpation and afterwards the pregnancy rate in % (number of pregnant does×100/number of AI) was determined for each housing system.

Table 1: Scoring systems for evaluating the severity of skin lesions in rabbit does, skin lesions in litters and pododermatitis and soiling of hind feet in rabbit does.

Score	Skin lesions	Litter score	Pododermatitis	Soiling
0	Skin intact	Skin intact	Skin & hair intact	Clean and dry
1	Small skin lesions (≤5<1 cm)	Scratches	Loss of hair	Dry soiled ≤50% of total foot area
2	Severe skin lesions (≤5>1 cm, or >5<1 cm)	Wounds, Traces of blood	Callus formed ≤2.5 cm^2	Dry soiled >50% of total foot area
3	Wounds or skin lesions (>5>1 cm)	Partial or total loss of tissue	Callus formed >2.5 cm^2	Wet soiled
4	Partial or total loss of tissue	–	Callus cracked	–
5	–	–	Callus open, bloody wounds	–

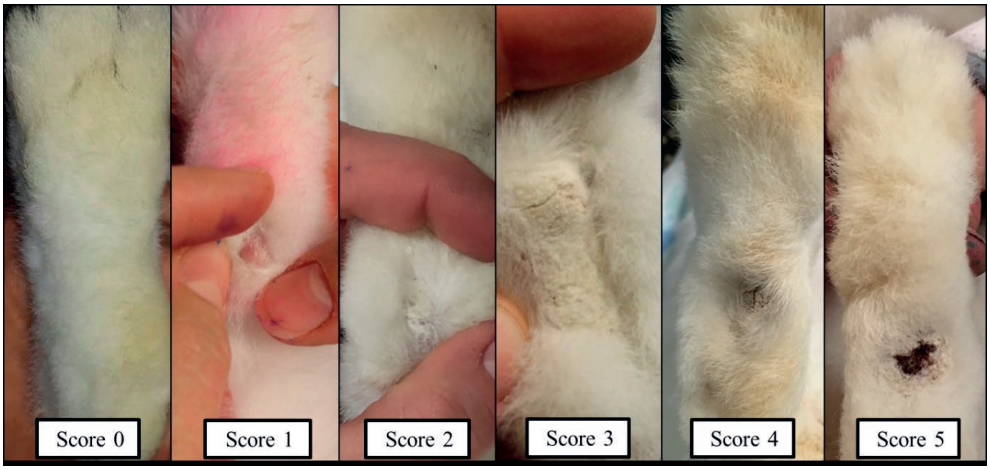

Figure 2: Scoring system for pododermatitis of rabbits' hind feet ranging from 0-5 according to Table 1.

Litters were equalised at days 1, 3 and 7 pp by the animal caretakers within one housing system to an average of 11.0±1.1 kits per litter in multiparous does and 10.4±1.0 in primiparous does at day 7 pp. Kits of deceased rabbit does were distributed to the other does in the same housing system. Whole litters were weighed after equalisation at day 7 and at day 30 pp. Subsequently, the average body weight and weight gain per kit were calculated. To evaluate skin lesions, the whole litter was additionally scored with a fast litter score (Table 1); for instance, score 1 was given for the whole litter even if only one kit of this litter showed scratches. The same applied to scores 2 and 3, i. e., at least one kit had wounds or loss of tissue. The total number of weaned kits was counted at day 30 pp and afterwards the number of kits weaned per doe was calculated.

Statistical analysis

Statistical analyses were performed using R 3.6.1. (R Core Team, 2019). The level of significance was set at $P<0.05$ and data are presented as means. All examined data were initially assessed for normal distribution using histograms and Shapiro-Wilk tests. Weight data of rabbit does and kits were analysed for each observation day using linear models that included housing, batch and parity as fixed effects. In addition, the average number of kits weaned per doe was analysed using a linear model, with housing and batch as fixed effects. Logistic regressions were performed to analyse differences in the fertility and the number of diseased rabbit does, with housing, parity and batch as fixed effects. The cumulative lesion score of rabbit does was tested for differences using a generalised linear model with housing, observation day, parity and batch as fixed effects. Lesion scores concerning the different body parts were analysed using ordered logistic regression models which included housing, observation day, parity and batch as fixed effects. In addition, for multiple testing correction the Bonferroni correction method was used to adjust the *P*-values. Litter score, soiling and pododermatitis score were also analysed using ordered logistic regression models which included housing, observation day, parity and batch as fixed effects. For this purpose, the R packages MASS (Venables and Ripley, 2002), lmtest (Kleiber and Zeileis, 2008) and AER (Kleiber and Zeileis, 2008) were used.

RESULTS

Rabbit does

Skin Lesions. The observation day, batch and parity were shown to have an effect on the overall cumulative lesion score of rabbit does ($P<0.001$). The highest cumulative lesion score was detected at day 30 pp ($P<0.001$; Figure 3). In terms of parity, primiparous rabbit does showed the highest cumulative lesion score (data not shown).

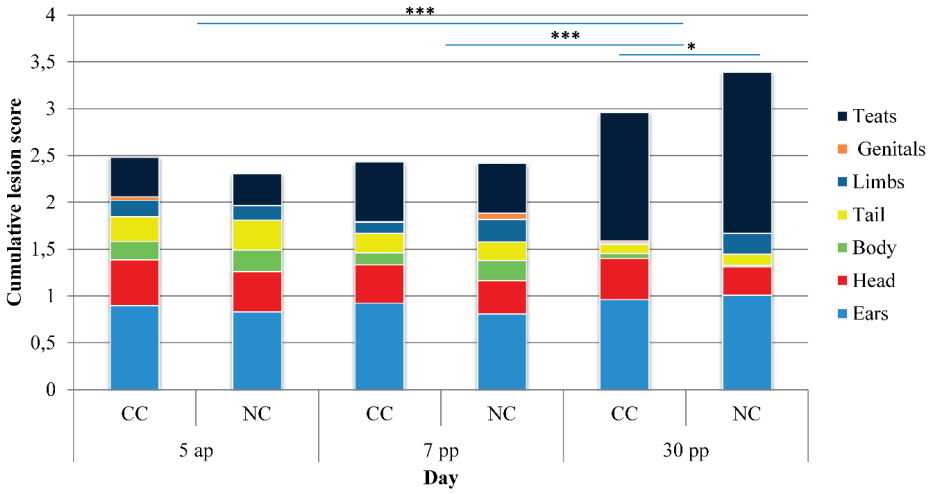

Figure 3: Cumulative lesion score and mean lesion score for the different body parts of rabbit does kept in conventional (CC) and new housing conditions (NC) at 5 d *antepartum* (ap), 7 and 30 d *postpartum* (pp), *P<0.05, ***P<0.001.

At day 5 ap (P=0.389) and day 7 pp (P=0.964), no effect of the housing system on the cumulative lesion score was observed. However, at day 30 pp, an effect of housing on the cumulative lesion score was detected, with a mean cumulative lesion score of 3.0±1.7 in CC and 3.4±1.9 in NC housing (P=0.044; Figure 3).

Regarding the body parts, a significant effect of observation day was observed on lesions at the body (P=0.002), tail (P=0.016) and teats (P<0.001). While the lesion score of body (P<0.001) and tail (P=0.002) decreased until day 30 pp, the lesion score of teats increased until day 30 pp (P<0.001). Housing only had an effect on the lesion score of teats at day 30 pp, with higher lesion scores in NC housing compared to CC housing (P=0.032). Parity had an effect on the lesion scores of ears (P<0.001), body (P=0.003), tail (P<0.001) and teats (P<0.001), with the lesion scores at the ears, body and tail decreasing and the lesion score of the teats increasing with increasing parity (data not shown). Batch affected the occurrence of lesions at the head (P<0.001), tail (P=0.001) and limbs (P=0.046, data not shown).

Figure 4 shows the percentage of the given skin lesion scores for the different body regions at the end of the housing period (day 30 pp) in NC and CC housing. Most injuries were assigned to the teats, with more injuries in NC than in CC rabbit does, especially with score 3. The second most injuries occurred at the ears followed by the head, both mostly recorded as score 1 lesions. Lesions at the body, tail, limbs and genitals were less frequent (Figure 4).

Pododermatitis was affected by batch and parity (P<0.001), but not by the respective housing system (P=0.211) or observation day (P=0.267). Figure 5 shows the distribution of the given scores for rabbit does according to their parity at day 30 pp. Score 0 was never observed during the investigated period and the score of pododermatitis increased with increasing parity.

Body weight and weight gain. At the beginning of the housing period (five days ap), the body weight of does did not differ between housing systems (NC: 4737±375 g, CC: 4728±452 g; P=0.635) and was only affected by the parity (P<0.001), as body weight increased with increasing parity. While body weight seven days pp was also not affected by the housing system (P=0.229) or batch (P=0.099), but again by parity (P<0.001), an effect of parity (P<0.001), housing (P=0.012) and batch (P=0.047) was observed at day 30 pp, with higher body weight in CC than in NC rabbit does (Table 2). Body weight also increased with increasing parity (Figure 6). Daily weight gain of rabbit does from day 7 to day 30 was only affected by housing (P<0.001), with higher weight gain in CC than in NC rabbit does.

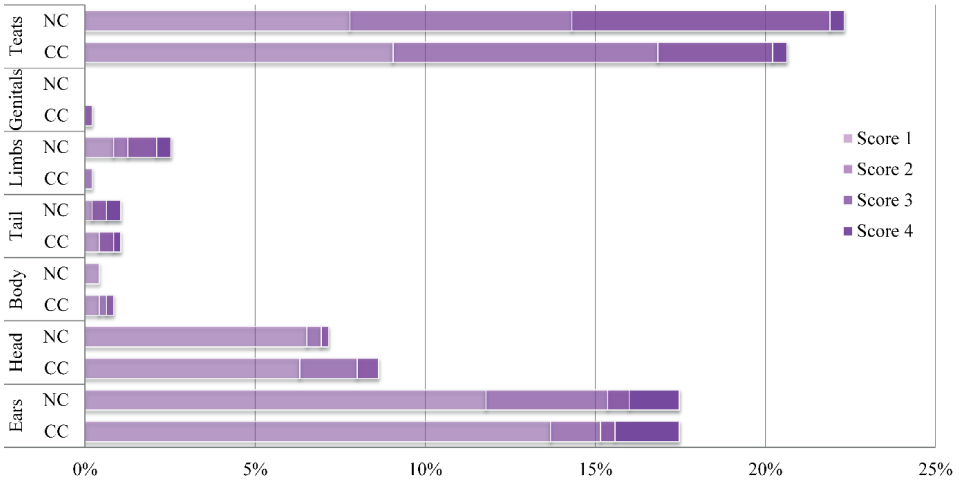

Figure 4: Percentage of the given lesions scores 1-4 (Table 1) for the different body regions in rabbit does under conventional (CC) and new housing conditions (NC) at day 30 *postpartum* (n=475 lesions).

Fertility and Morbidity. Fertility of rabbit does was not affected by batch (P=0.081), but affected by housing (P=0.037) and parity (P=0.047), with higher fertility in CC than in NC housing (Table 2) and with primiparous does having the lowest fertility (68 *vs.* 84 *vs.* 76 *vs.* 81 *vs.* 95 *vs.* 89%, parity order 1-6, respectively). During the investigations, three times, an abortion was observed; twice in CC and once in NC housing.

Rhinitis had the highest incidence of the recorded symptoms but was only affected by parity (P=0.049), with primiparous does having the highest incidence. Incidence of conjunctivitis was low and not affected by any of the parameters considered in the statistical model (P>0.05). On the contrary, the incidence of mastitis was affected by parity (P=0.029) and housing (P<0.029) and the occurrence of diarrhoea was affected by housing (P=0.030), both with a higher incidence in NC than in CC housing (Table 2).

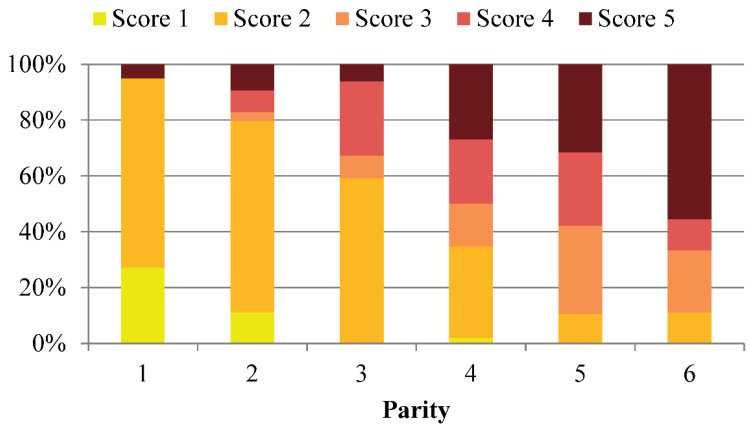

Figure 5: Percentage of rabbit does' hind feet assessed with scores 1-5 for pododermatitis (Table 1) according to their parity at day 30 *postpartum*.

Table 2: Mean performance of rabbit does from new (n=135) and conventional housing conditions (n=137).

Day pp	NC	CC	SD	*P*-value
Body weight, g				
7	4496	4461	385	NS
30	4564	4738	533	*
Weight gain, g/d				
7-30	2.9	11.6	16.3	***
Fertility, %	73	84.8	10.7	*
Rhinitis, %	20.6	19.8	6.1	NS
Conjunctivitis, %	1.6	2.4	2.3	NS
Diarrhoea, %	9.5	2.4	2.8	*
Mastitis, %	19.1	8.7	4.9	*

pp=*postpartum*; NC=new housing conditions; CC=conventional cages; SD=standard deviation, NS=not significant.
*P<0.05, ***P<0.001.

Soiling of hind feet did not differ at the beginning of the housing period (five days ap, P=0.673), but was affected by the housing system at days 7 and 30 pp, with NC rabbit does assessed as being more soiled than CC rabbit does (P<0.001, Figure 7). While no effect of observation day was observed (P=0.429), parity (P=0.002) and batch had an effect (P<0.001). There, primiparous rabbit does were assessed as being the most soiled, while rabbit does with parity six were assessed as having the lowest degree of soiling (data not shown).

Kits

Litter score was affected by the observation day (P<0.001) and parity of the nursing doe (P=0.003, data not shown), but not by the housing system (P=0.773) or batch (P=0.188). At seven days pp, score 1 was mostly observed, while at 30 d pp, most litters were assessed with score 0. The percentage of litters with score 3 increased from day 7 to day 30 pp, especially in NC housing, where more litters were assessed with score 2 and 3 than in CC housing. On the contrary, in CC housing, more litters received score 1 and fewer scored 0 than in NC housing at day 30 pp (Figure 8).

Litter performance and number of weaned kits. Average kit weight at 7 and 30 d pp and daily weight gain from day 7 to day 30 pp were affected by parity of the nursing doe (P<0.001), but not by the housing system (P>0.05, Table 3). Average kit weight at both observation days as well as weight gain increased with increasing parity, with the largest

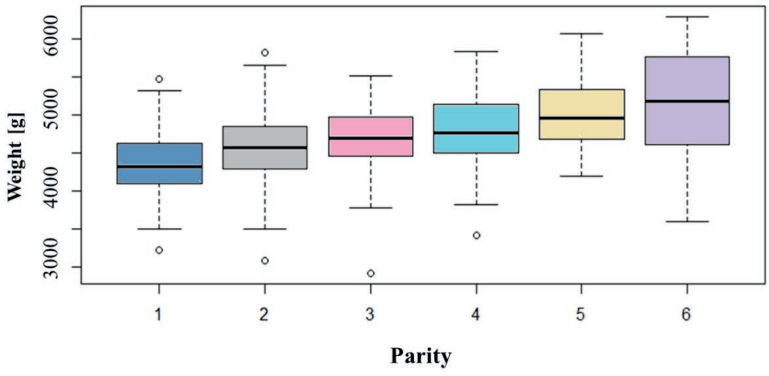

Figure 6: Body weight of rabbit does at day 30 *postpartum* according to their parity.

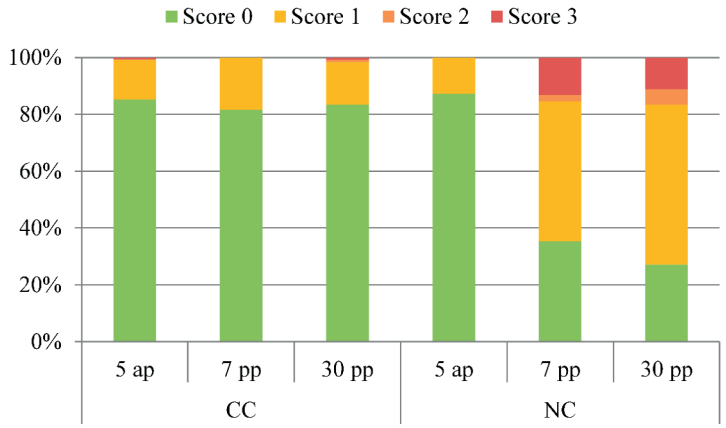

Figure 7: Percentage of rabbit does' hind feet assessed with soiling scores 0-3 (Table 1) in conventional (CC) and new housing conditions (NC) at 5 d *antepartum* (ap) and 7 d and 30 d *postpartum* (pp).

difference between does of the first and second parity. Figure 9 shows average kit weight at 30 d pp according to the parity of the nursing doe. The batch only affected the average kit weight at day 7 pp ($P<0.001$).

The mean number of weaned kits did not differ between the housing systems ($P=0.970$, Table 3) and was also not affected by the batch ($P=0.618$).

DISCUSSION

There are different approaches to keeping rabbit does and their kits under alternative housing conditions instead of in conventional cages, which may restrict normal rabbit behaviour (Szendrő *et al.*, 2016; Saxmose Nielsen *et al.*, 2020). In the present study, an alternative housing system similar to structurally enriched elevated pens providing an open top and slatted flooring as described by Saxmose Nielsen *et al.* (2020) was investigated for rabbit does and their kits. The system was compared to conventional wire mesh cages that were only equipped with a feeder, a drinker, a nest and one gnawing stick. Providing an increased floor area, a platform with a 15% degree of perforation and slatted plastic flooring with 11 mm gaps and slats, the new system additionally complied with new legal requirements in Germany (TierSchNutztV, 2014). Whereas a greater floor area and height were observed not only to improve welfare concerning animal behaviour (Hansen and Berthelsen, 2000), but also the performance of kits (Rommers and Meijerhof, 1997; Miko *et al.*, 2014), in the new housing system studied, doe performance was lower than that of does

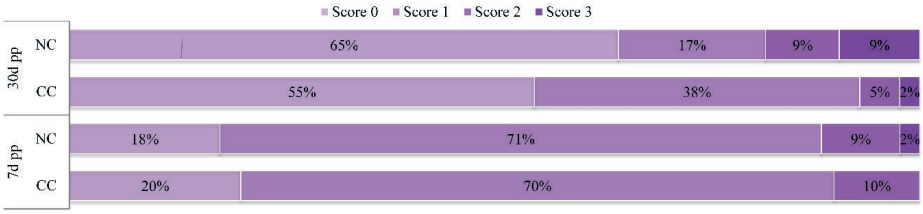

Figure 8: Percentage of litters assessed with scores 0–3 for skin lesions (Table 1) from conventional (CC) and new housing conditions (NC) at 7 d and 30 d (d) *postpartum* (pp).

Table 3: Mean litter performance of does from new (n=135) and conventional housing conditions (n=137).

Day pp	NC	CC	SD	*P*-value
Average kit weight, g				
7	158	157	20.9	NS
30	705	713	102	NS
Average daily weight gain, g/d				
7-3	23.7	24.2	4.0	NS
Number of kits weaned per doe				
30	9.9	10	0.6	NS

pp=*postpartum*; NC=new housing conditions; CC=conventional housing conditions; SD=standard deviation, NS=not significant.

from cages, and litter performance was similar in both systems. In particular, hygiene problems were observed in the new system, which may have negatively influenced the health and performance of rabbit does.

The less perforated flooring and the platform with a degree of perforation of only 15% in NC housing led to an increased soiling of the housing environment, which was reflected in the soiling of the rabbits' hind feet (Leinberger *et al.*, 2019; Rauterberg *et al.*, 2019a). In the present study, soiling of all rabbit does' hind feet was similar at the start of the housing period, which was expected, as all does came from cage systems with wire mesh flooring. Already seven days pp and similarly at 30 d pp, rabbit does from NC were significantly more soiled than CC rabbit does. A high degree of soiling in the same new housing system was previously observed in fattening rabbits after weaning (Rauterberg *et al.*, 2019b) and was also expected for rabbit does, as they usually have large and soft droppings after giving birth which tend to block the slats. Thus, it had already been shown that slatted plastic floorings with a slat distance of 10 or 12 mm are less suitable for does (Schlender-Böbbis, 1999). In addition, rabbit does from NC showed an increased incidence of diarrhoea, which may again increase the degree of soiling in the pen and consequently the soiling of rabbit does' hind feet.

The present flooring met the German requirements for fattening rabbits with 11 mm slats and gaps. In a housing system only for rabbit does, the slat distance could be expanded to 14 mm (TierSchNutztV, 2014), which may have a positive effect on the degree of soiling. However, at the same time, in Germany, the slat width must correspond to the gap width. This may again affect soiling negatively, as slats of 14 mm may increase an accumulation of droppings and urine on the flooring. For practical reasons, the present housing system was intended to be used as a combi-system for rabbit does and their kits, as well as for the young after weaning in the fattening period. Therefore, the flooring should meet the German requirements for both rabbit does (max. 14 mm gaps) and fattening rabbits (max. 11 mm gaps), which was implemented by a floor with 11 mm slats and 11 mm gaps. Furthermore, an elevated platform

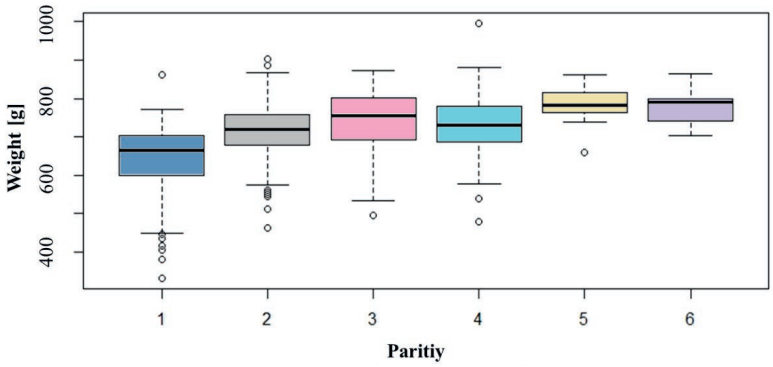

Figure 9: Average kit weight at day 30 *postpartum* according to the parity of the nursing doe.

is required, which can pose a possible risk of soiling overall (Alfonso-Carrillo *et al.*, 2014; Saxmose Nielsen *et al.*, 2020). Elevated platforms according to the German regulations are additionally required to have a maximum degree of perforation of 15% for both rabbit does and fattening rabbits, and this requirement in particular is already known to affect the soiling of rabbits negatively (Leinberger *et al.*, 2019; Rauterberg *et al.*, 2019a).

Flooring conditions should be changed in order to improve the hygienic conditions in the new housing system. However, this seems difficult when the flooring should still meet the German legal requirements for both rabbit does and fattening rabbits. Nevertheless, previous investigations on an alternative flooring complying with German welfare regulations showed an improvement in the hygienic conditions when keeping fattening rabbits in a modified system. This was equipped with a plastic floor with the same slat and gap widths, but with slats providing a rounded surface. In addition, it was fitted with a modified elevated platform with a degree of perforation of 15% (Rauterberg *et al.*, 2019a). Different implementations of the legal requirements should be analysed in future studies also for rabbit does and their kits. In addition, further research should be carried out in rabbit does with a floor design meeting the regulations for breeding rabbits, as with a slat distance of 14 mm soiling might be reduced. However, such investigations could only be carried out when separate housing systems were used for breeding and fattening rabbits or when the flooring is replaced intermediately, which could not be implemented with the present housing and management system.

On the other hand, a regular intermediate cleaning may reduce soiling and is recommended (Saxmose Nielsen *et al.*, 2020). This should be implemented in particular if a floor design like the present one is used, even if this was not usually done on the farm studied and would lead to an increased workload. The higher incidence of the investigated signs of diseases in rabbit does from NC may be related to the bad hygiene conditions of the housing environment. A relation between soiling and poor animal health also resulting in higher mortality rates had already been observed for different housing systems (Princz *et al.*, 2009; Tillmann *et al.*, 2019), as well as in the present NC housing when its impacts on fattening rabbits were studied (Rauterberg *et al.*, 2019b). Apart from a higher incidence of the recorded signs of diseases, fertility of does from NC was lower than in CC, which may also be related to poor hygiene and health. A lower reproductive performance of primiparous does was already described in previous works (Rommers *et al.*, 1999; Xiccato *et al.*, 2004) and may be related to a poor body condition (Castellini *et al.*, 2010).

While the cumulative lesion score did not differ between does at the beginning of the housing period five days ap, an increase in lesion score during the lactation period in both housing systems and a higher lesion score in NC than in CC housing at day 30 pp were observed. In particular, the number of lesions at the teats increased until day 30 pp. These lesions are probably caused by the kits during suckling. Higher lesion scores at the teats (3 and 4 for wounds and loss of tissue) were often observed along with the occurrence of mastitis. Mastitis is an infection of the mammary gland that is caused by pathogens as *Staphylococcus aureus* and may lead to skin lesions, necrosis and abscesses (Viana *et al.*, 2011). This may also be the reason why a higher teat lesion score was observed in NC than in CC housing in the present research, as in NC the incidence of mastitis was higher. Pathogens, being ubiquitous components of the soiled environment in NC, may have led to a higher incidence of mastitis in NC housing. This was the case despite the fact that does were moved to a clean and disinfected housing environment before parturition. This is common practice in duo-systems and is usually observed to reduce the prevalence of clinical mastitis due to a decrease in infection pressure (Rosell and de la Fuente, 2018).

In contrast, lesions at the tail and the body decreased until weaning. These lesions mainly affected primiparous rabbit does. As primiparous does in the present study often came from a group rearing system, these lesions may have had their origin in the previous rearing period, as tail lesions are especially associated with group rearing (Bill *et al.*, 2019). During the period of individual housing in NC and CC, the number of these lesions decreased. Overall, lesions at the ears were most commonly observed during the housing period. This was already reported for fattening rabbits and may be promoted by the lack of fur at the ears, which protects the skin and, on the other hand, makes it easier for the observer to detect all lesions no matter how small (Rauterberg *et al.*, 2019b). Even if ear lesions were mostly assessed with score one, ears also showed the highest frequency of tissue loss (score 4) in comparison to the other body parts. The fact that these severe lesions were mostly older and fully healed suggests that these lesions had occurred earlier, probably during the rearing of the does before they were moved to the current housing system.

Even if floor type and soiling have substantial effects on the severity of pododermatitis in rabbits (Rommers and Meijerhof, 1996; Masthoff and Hoy, 2019; Saxmose Nielsen *et al.*, 2020), the prevalence of pododermatitis did not

differ between the housing systems in the present study. It can be assumed that the studied housing period was too short for differences to be observed in this regard. During a longer housing period, an effect of floor type and soiling on the degree of pododermatitis may be detected. However, making a prediction as to whether it would be less severe in NC because of the smoother flooring (Rommers and Meijerhof, 1996) or even worse because of the soiled and wet environment (Zegowitz *et al.*, 2017; Masthoff and Hoy, 2019) is difficult. Overall, severe pododermatitis was found in the present study, especially in does with higher parity number, and not a single doe was found that was assessed with score 0 (skin and hair intact). This may be caused by the fact that all of them had been previously kept in cages with wire mesh flooring, which is known to promote the development of pododermatitis (Rommers and Meijerhof, 1996; Rosell and de la Fuente, 2013; Buijs *et al.*, 2014). A relation between the degree of pododermatitis and the parity was already shown in previous research (Rommers and de Jong, 2009; Rosell and de la Fuente, 2009). Apart from the time spent on the respective flooring, the body weight of does might also be a risk factor for the development of pododermatitis (Ruchti *et al.*, 2018). However, the effect of the body weight and time spent on the floor cannot be clearly separated as in most cases, both increase with increasing parity.

Even if performance of does was negatively influenced by NC housing and despite the hygienic challenges, litter performance was not negatively affected by the new system. Kit weight depended on the parity of the respective doe, with heavier kits from older rabbit does than from primiparous does, which was already observed in previous studies (Vásquez *et al.*, 1997). This effect was obvious in the present study, even if litter size was equalised to a lower number of kits per doe in primiparous than in multiparous does. An even greater reduction in the number of kits in primiparous rabbit does or a more individually adapted equalisation of the litter size adapted to the does' capacities may improve the performance of kits and does. It was also described previously that kits from primiparous rabbit does still have the lowest weights even when they get older and are examined during the fattening period (Zimmermann, 1990). In line with the present study, the highest difference was observed between parity one and two (Zimmermann, 1990; Petersen *et al.*, 1996). One reason may be the lower milk production of primiparous rabbit does (Rebollar *et al.*, 2009).

The lesion score of litters was similar in NC and CC housing and was mostly assessed with score 1 (scratches) at day 7 pp. This may be due to the fact that litters were still in the nestbox at this time where the doe came in for suckling. In this cramped situation, lesions caused by the doe may occur. After leaving the nest, scratches may have healed and score 0 was mostly observed at day 30. The number of litters assessed with score 3 (loss of tissue) increased until day 30 pp. The loss of tissue in kits might be caused by injurious maternal behaviour, which is known to occur in does (Rashwan and Marai, 2000).

Overall, it must be considered that the rabbit does had little time to become acclimatised to the new housing system. They were housed five days before parturition and left the system 31 d after parturition. This situation may induce stress and, consequently, not only the housing conditions per se but also the stress caused by an unfamiliar environment may affect the does' performance and health. Kits, on the contrary, were born in the system and litter performance was not negatively affected in comparison to the established cage system, even if the does' performance was lower.

CONCLUSIONS

The floor design of the new housing system led to a high degree of soiling compared to the established cages with wire mesh flooring. The resulting poor hygienic conditions are supposed to affect the rabbit does' health and performance.

It has to be considered that rabbit does in the present study were only kept for a short period in the new system and long term effects were not determined. However, it can be assumed that a longer housing period would have led to further deficits in animal health. From a hygienic point of view, the housing system should be improved to prevent negative effects on animal welfare. In this context, legal requirements in Germany concerning floor design in rabbit housing need to be critically examined, especially with regard to the low degree of perforation of flooring and elevated platform. These specifications are difficult to implement in common conventional rabbit husbandry without fundamental changes in management. Even then, it is questionable whether sufficient hygienic conditions can be

achieved. Further research is necessary to study the effect of different management and floor conditions to find a housing system that enables farmers to keep their rabbits economically, in good health and welfare and in accordance with the legal regulations at the same time.

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