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EFFECT OF HOUSING ENRICHMENT AND TYPE OF FLOORING ON THE PERFORMANCE AND BEHAVIOUR OF FEMALE RABBITS

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Abstract: This study investigated the effect of housing enrichments (scratching card, gnawing material and a platform), of a change in height and in the type of flooring on the live weight, reproductive performance and behaviour of female rabbits, as well as on the feed intake and spatial distribution of females and their kits. A total of 40 multiparous female rabbits were monitored in three consecutive reproductive cycles (48-d intervals). Four days before parturition in each reproductive cycle, the females were randomly assigned to one of the five types of housing: Control (CNT: 102×47×30 cm, L×W× H); Scratching card (SCT: containing a scratching card); Gnawing materials (GNW: CNT dimensions plus a compressed lucerne hay block and a wooden stick); Platform (PLT: 102×47×60 cm, including a platform with a plastic floor) and Combination (CBN: PLT dimensions with the scratching card, the gnawing materials and a platform). Data were only recorded during the first and third reproductive cycles. The living conditions did not significantly alter the females' live weight (4889 g at housing; 4890 g at mid-lactation; 4867 g at weaning), reproductive performance (9.0 kits born alive), survival of the kits (90%), nor the feed intake of females and their litters (542 g/day). Providing animals with a gnawing block stimulated *Gnawing* behaviour (median frequency per group: CTL=0.00, SCT=0.00, GNW=4.69, PLT=0.00, and CBN=2.34; $P<0.001$). Providing housing 60 cm in height appeared to stimulate the *Rearing up* behaviour (median frequencies per group: CTL=0.00, SCT=0.00, GNW=0.00, PLT=2.08, and CBN=3.12; $P=0.06$), and when a platform was present, the rabbits used it (mean values per group: CTL=0.00, SCT=0.00, GNW=0.00, PLT=1.79, and CBN=4.91; $P=0.003$). Regarding the type of floor, females appeared to prefer the plastic mesh flooring (31.2%) to the wire mesh flooring (18.8%). To sum up, providing female rabbits with simple enrichments appears to stimulate specific behaviours like *Gnawing* and *Rearing up* and may contribute to their wellbeing.

Key Words: *Oryctolagus cuniculus*, housing enrichment, specific behaviour, reproductive performance, rabbit.

INTRODUCTION

The rabbit is a gregarious animal that has a diverse behavioural repertoire including jumping, running, gnawing and positive social behaviours such as allogrooming or resting side by side (Coureaud *et al.*, 2015). On rabbit farms, adult rabbits are individually housed in wire cages. Cages are generally 30 to 39 cm high, 38 to 46 cm wide and 87 to 102 cm long, equipped only with a feeder, a drinker and a nest area (EFSA, 2020). In general, the living conditions provide few or no enrichments, and the limited height of *"conventional"* cages limits the rabbits' freedom to express their normal behaviour, thereby neglecting one of their *"five freedoms"* (Animal Welfare Committee, 2009). *"Structurally enriched cages"* (EFSA, 2020) are higher (60 cm high) and provide a few enrichments, such as a plastic footrest (usually 25×36 cm).

Animal welfare is an evolving concept. One of the most recent definitions was proposed by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES, 2018). For ANSES, *"The welfare of an animal is a*

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positive mental and physical state as related to the fulfilment of its physiological and behaviour needs in addition to its expectations…" This definition introduces the notion that an animal should have access to a series of environmental stimuli to fulfil its needs, in addition to the mere presence of a plastic footrest or a platform.

In the opinion of Baumans (2005), the environment of a captive rabbit should be designed to accommodate its needs. Drinking, eating and sleeping are basic physiological needs, while social contact, exploring, foraging, grooming, digging, nest building and hiding can be considered as essential innate behaviours (Baumans, 2005). To fulfil these needs, the living environment of captive animals should be designed to provide additional features for the animals that enable them to express their natural behaviours. These features, called environmental enrichments, should focus on behaviours that are strongly motivated. Baumans (2005) classifies enrichments in two main categories: social and physical. Social enrichments can be achieved by direct or indirect conspecific contact and/or contraspecific contact, including with humans. Collective housing of rabbits is believed to improve welfare by allowing social interactions between adult females. However, aggressions and the incidence of injured rabbits after grouping remain an unsolved problem (Buijs *et al.,* 2015; Rommers and De Greef, 2018; Huang *et al.*, in press). When group housing is not possible, social noncontact enrichments such as visual, auditory and olfactory communication with other individuals should be allowed. Physical enrichments include complexity (how the space is structured), nesting materials and sensory and nutritional enrichments. Baumans (2005) states that "suitable enrichment for rabbits includes at minimum roughage, hay blocks or chew sticks, as well as an area for withdrawal and lookout (e.g. a platform)".

When housed in "conventional cages", adult rabbits cannot run, jump, rear up, gnaw or scratch (Hawkins *et al.*, 2008; Leach *et al.*, 2009), and in the absence of environmental enrichment, stereotypic behaviours may occur (Verga *et al.,* 2007). Additionally, wire-mesh floors are responsible for a high incidence of pododermatitis - "sore hocks" - (Rosell and De la Fuente, 2009). It is therefore necessary to provide alternative housing that respects rabbits' physiological and behavioural needs. The alternatives may also help maintain the health and productivity of animals, thereby ensuring the economic sustainability of rabbit farming (Szendrő *et al.,* 2019).

The aim of the present study was to investigate to what extent the provision a series of simple enrichments of the *"conventional cage"* provide rabbits with the opportunity to express some of their natural behaviours like *Scratching*, *Gnawing*, *Rearing up*, *Jumping* or *Hiding*. We also studied the rabbits' use of space when they had access to a plastic-mesh floor area, intended to provide a more comfortable flooring for adult animals. The overall health status and reproductive performances of females were also assessed.

MATERIAL AND METHODS

This study was conducted in strict accordance with European Union (2010) recommendations and with French legislation on the protection of animals used for scientific purposes (EU Directive 2010/63/EU, Official Journal of the French Republic; Decree N°. 2013-118) at the rabbit experimental unit of INRAE GenPhySE lab. All the protocols were approved by ethics committee N° 115 of the Ministry of National Education, Higher Education and Research (approval number 16330-2018072716211212).

Animals and farming practices

We monitored 40 multiparous (average parturitions: 6.4) crossbreed rabbit females (PS19; Hypharm, Roussay, 49450 Sèvremoine, France) in two out of three consecutive reproductive cycles. Each cycle started at the birth of a litter (day 0) and ended when the litter was weaned (day 35). In each cycle, females were re-inseminated 17 d after parturition using the semen of males of the INRA1001 breed, INRAE Occitanie Toulouse, France), following a 49-d interval between two kindlings. The first cycle started in May 2018 and the third cycle ended in September 2018. Data were only recorded in the first and third reproductive cycles. During the second reproductive cycle, only normal animal care was provided, in addition to checking their health status.

Four days before parturition, a plastic nest box filled with wood chips was placed in each cage. From then until weaning, females had free access to their nest at all times. At birth, the size of litters was set at 8-9 rabbit kits in cycle 1, and 10 rabbit kits in cycle 3 using culling and cross-fostering.

Animals had permanent access to water and commercial pelleted feed for reproducing females (16.4 MJ of gross energy and 172 g of crude protein per kg of dry matter). The photoperiod was set at 16 h light and 8 h dark and the regulation of ambient temperature was set to between 15°C and 28°C.

Housing conditions and experimental groups

To investigate how a series of simple adjustments of the "*conventional cage*" provides rabbits with the opportunity to express some of their natural behaviours like *Scratching*, *Gnawing*, *Rearing up*, *Jumping* or *Hiding*, we adapted 32 conventional cages into 4 experimental housing systems (Scratching: SCT; Gnawing: GNW; Platform: PLT and Combination: CBN) and compared them with eight unchanged conventional ones (Control: CTL). The sizes of the cages and the physical enrichments provided are reported in Table 1 and Figure 1 shows the spatial organisation of CTL and CBN housing systems. In the SCT group, a black scratching card (which shows a trace of colour when scratched) was fixed inside the housing using a 15×15 cm PVC frame. In the PLT group, a plastic mesh platform (25×45 cm, width×length) placed 30 cm above the cage floor in the middle of the cage (two sides of the platform touching the sides of the housing). In the GNW group, the housing was enriched with organic gnawing materials: a compacted forage block (80% lucerne, length 20 cm weight 1 kg) and two 20 cm long untreated hard- (beech) and soft- (pine) wood sticks. In the CBN group, the cage was enriched with organic gnawing materials, a black scratching card and a plastic mesh platform (25×45 cm, width×length) placed 30 cm above the cage floor in the middle of the cage.

The use of space in the presence of a plastic mesh floor (assumed to be more comfortable) was assessed by dividing the floor area (outside the nest box) in half (½ covered with wire mesh and ½ with plastic mesh). The plastic floor was placed on one side of the nest box in half the cages, and on the other side in the other half. To avoid any confounding effect between floor type preference and enrichment use, the scratching cards and/or the gnawing material were always placed in the same position. In this way, in half the cages the enrichments were located on a plastic-mesh floor and in the other half, on a wire-mesh floor.

As animals do become familiar with their environment, we randomly assigned each female to a new environment four days before parturition. This meant that each housing condition was used and explored by 16 female rabbits (hereafter referred to as statistical units).

Performance evaluation

The live weight and health status of the female rabbits. Each female was weighed on six occasions: upon housing (four days before parturition), at artificial insemination and at weaning in the first and third cycles. The health status of each rabbit was assessed visually just before weighing.

Female feed intake during lactation. Feed intake was monitored every week starting 11 d after birth and continued for three consecutive weeks (from 11 to 32 d). As rabbit kits start to ingest solid feed around 18 d old, feed intake during the last two weeks of lactation represented the joint intake of a female and her litter.

Table 1: Size and physical enrichments in each of the five housing conditions.

Housing condition	No.	Size (width×length×heigth)	Scratching card[1]	Gnawing material[2]	Platform[3]
Control	8	47×102×30 cm			
Scratching	8	47×102×30 cm	Yes		
Gnawing	8	47×102×30 cm		Yes	
Platform	8	47×102×60 cm			Yes
Combination	8	47×102×60 cm	Yes	Yes	Yes

[1]Scratching card: a black scratching card (which shows a trace of colour when scratched) was fixed inside the housing using a 15×15 cm PVC frame.

[2]Organic gnawing material: three options; a compacted forage block (80% lucerne, length 20 cm weight 1 kg) and two 20 cm long untreated hard- (beech) and soft- (pine) wood sticks.

[3]Platform: a plastic mesh platform (25×45 cm, width×length) placed 30 cm above the cage floor in the middle of the cage (two sides of the platform touching the sides of the housing).

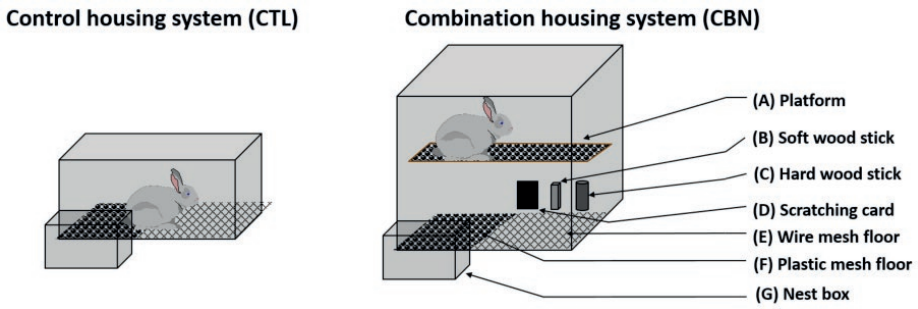

Figure 1: Spatial organisation of control (CTL) and combination (CBN) housing systems.

Female reproductive performance. The litter size was evaluated at birth (number of total born and born alive), after cross-fostering and at weaning. The survival rate of the kits during lactation is expressed as the ratio of live kits at weaning to the number of live kits after cross-fostering.

Ethogram and behaviour observations

We adapted the ethogram for cage rabbits proposed by Podberscek *et al.* (1991), and recorded 13 behaviours previously described for the rabbit by Morton *et al.* (1993), Leach *et al.* (2009), and Dixon *et al.* (2010). Each behaviour was sub-classified with respect to *Maintenance*, *Comfort*, *Investigatory*, *Locomotory*, *Maternal* or *Stereotypic* behaviours. *Eating*, *Drinking*, *Sitting* (in upright stationary position, with hind limbs tucked under the rump both active or inactive) and *Resting* (lying on the left or right hand side of the body, or with hind limbs tucked under the rump and fore limbs extended horizontally but inactive, without the head raised or nose moving or ear moving) were all classified as *Maintenance* behaviours. *Grooming*, *Gnawing* (gnawing material) were classified as *Comfort* behaviours. Since *lying active* (with the head raised or nose moving or ear moving) could be considered as subtle vigilance which is directed towards a member of the group in social contexts (Monclús and Rödel, 2008), it was also classified as *Comfort* behaviour. *Rearing up* (both forepaws off the ground, with or without the forelimbs placed on the side of the cage or on another object for support) were all classified as *Investigatory* behaviour. *Hopping* (hops, including horizontal jumps) and *Jumping* (vertical movement up onto the platforms) were classified a *Locomotory* behaviours. *Maternal* behaviours included any interaction of a female with her kits (e.g. lactation, sniffing, allogrooming). Finally, *Stereotypic* behaviours included *Biting cage bars or feeders* and *Clawing at cage walls or corners*.

Observations were performed using the scan sampling method (Altmann, 1974). The behaviour of each female rabbit and the spatial position of a female and her kits were evaluated by direct observation twice a day (mornings: between 8:00 and 10:00 and afternoons: between 15:00 and 17:00) two days a week starting at week 2 of lactation and continuing for four consecutive weeks (giving a total of 32 direct observations per animal and cycle).

The day before the observations, the observer spent about 30 min in the room to simulate direct observation and to allow the rabbits to become accustomed to his presence. On the observation day, he entered the room and walked around calmly for about ten minutes before starting to record his observations. To reduce visual stress, the dress code and the pattern of movements inside the room were the same throughout the experiment. The observer always positioned himself between two cages to limit the influence of his presence on the female rabbits' behaviour. Each direct observation lasted two minutes. Each rabbit female was observed individually and the behavioural event (yes/no) was recorded at 20-s intervals, giving a total of six independent behavioural events recorded in the two-minute period. The spatial location of each female rabbit in its cage and the number of kits located in the different parts of the cage (on the wire-mesh floor, plastic-mesh floor, platform or nest) were also recorded.

Use of gnawing material and scratching cards

Compacted forage blocks were weighed individually at the beginning and end of reproductive cycles 1 and 3 to quantify their use by the rabbits. A new block was added when necessary. The use of wooden sticks (hard and soft) and the use of scratching cards were evaluated on a four-point scale (Figure 2). For wood sticks: score 0: not used; score 1: little damage and regular edges, score 2: damaged stick and hollowed edges; score 3: badly damaged stick and faces attacks. For scratching cards, score 0: not used; score 1: less than 50% used; score 2: between 50 and 75% used; score 3: more than 75% used) at the end of cycles 1 and 3. A new scratching card or wooden stick was placed in the cage at the beginning of each reproductive cycle.

Statistical analyses

All analyses were performed in R version 4.0.0 (R Core Team, 2020).

Live weight of female rabbits upon housing, at mid-lactation and at weaning. These three variables were analysed using a linear model (*lm* function in the R *stats* package). The initial models included *Housing* (5 levels: CTL, SCT, GNW, PLT and CBN), the *Reproductive Cycle* (1 or 3) and their interaction. The age of each female (*i*) was used as a covariate in the model. Among the three variables studied, the *Reproductive Cycle* and its interaction with *Housing* were not significant, and thus were excluded from the final model. The final model was:

$$LW_i = Housing_i + Age_i + e_i \quad (1)$$

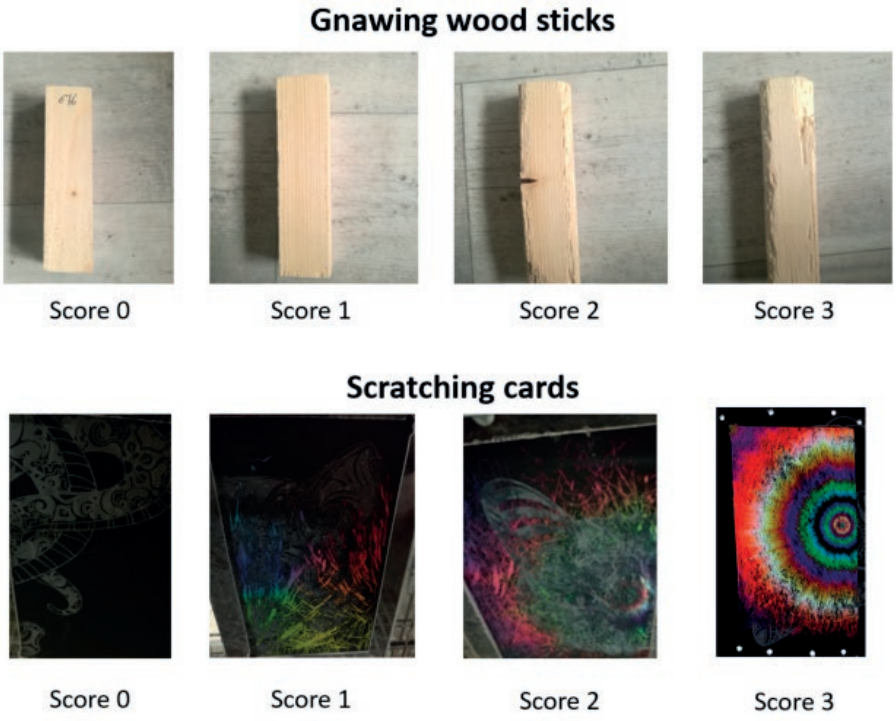

Figure 2: Use of gnawing wood sticks and scratching cards. The use was evaluated on a four-point scale (score 0: not used to score 4: deeply used). The photo of score 3 of scratching card shows the picture that can only be seen when the card is completely used.

Litter sizes at birth, after cross-fostering and at weaning, and survival of the kits during lactation. These four variables were analysed using a linear model (*lm* function in the R *stats* package). The initial models included *Housing* (5 levels: CTL, SCT, GNW, PLT and CBN), the *Reproductive Cycle* (1 or 3) and their interaction. The age of each female (*i*) was used as a covariate in the model. Interaction among the four variables studied was not significant, and was thus excluded from the final model. The final model was:

$$\text{Litter sizes}=\text{Housing}_i+\text{Reproductive cycle}_i+\text{Age}_i+e_i \quad (2)$$

Feed intake. This variable was analysed using a linear model (*lm* function in the R *stats* package). The initial models included *Housing* (5 levels: CTL, SCT, GNW, PLT and CBN), the *Reproductive Cycle* (1 or 3) and their interaction. Litter size at weaning of each female (*i*) was used as a covariate in the model. Interaction among the four variables studied was not significant, and was thus excluded from the final model. The final model was:

$$\text{Intake}_i=\text{Housing}_i+\text{Reproductive cycle}_i+\text{Litter size at weaning}_i+e_i \quad (3)$$

Use of compact lucerne forage blocks. Only two housing conditions (CBN and GNW) received a compact forage block. This variable was analysed using a linear model (*lm* function in the R *stats* package). The initial model included *Housing* (2 levels: CBN and GNW) and the *Reproductive Cycle* (2 levels: 1 and 3). Interaction was not significant, and was thus excluded from the final model:

$$\text{Intake of Lucerne Block}_i=\text{Housing}_i+\text{Reproductive cycle}_i+e_i \quad (4)$$

Use of scratching cards and wood sticks. Use of scratching cards and wood sticks was scored on a scale from 0 to 4. These variables were analysed using two complementary tests: the independence test and Mood's median test (both included in the R *coin* package). The model only included *Housing*. For the scratching card, only two groups (CBN and SCT) were compared. For the use of wooden sticks, the groups compared were CBN and GNW.

Behaviour (number of events counted in a two-minute period) and spatial distribution of female rabbits. Each behaviour and the spatial distribution of the females on the wire-mesh floor, on the plastic-mesh floor, straddling the two types of flooring, and on the platform were analysed using two complimentary tests: the independence test and Mood's median test (both included in the R *coin* package). When a statistical significance was observed ($P<0.05$) a pairwise *post-hoc* Mood's median test was performed to identify which groups differed from the others. The data presented represent the median value of percentages. Reproductive cycle was significant for *Sitting* ($P<0.001$ in both tests), *Resting* ($P<0.001$ in both tests) and *Hopping* ($P<0.005$ in both tests). For these three variables two independent models were retained, one for *Reproductive Cycle* and one for *Housing*. For the remaining variables (behaviour and spatial distribution) only the model including the *Housing condition* was kept because *Reproductive cycle* was not significant in either test. For behaviour, data were aggregated for weeks 2 to 5 (including both morning and afternoon observations).

Spatial distribution of rabbit kits. The percentage of kits located on the plastic-mesh floor (number of kits on the plastic-mesh / total number of kits on the floor×100%) was calculated for each type of housing at each observation to evaluate their choice (giving a total of 1352 records). One sample t-test was carried out to determine if more kits were located on the plastic-mesh floor or on the wire-mesh floor. The influence of the housing group, the presence of females on the plastic-mesh floor (yes or no), parity of females, reproductive cycle, observation time and week of observation on the percentage of kits on plastic-mesh was analysed using a mixed model (female was considered as random effect).

RESULTS

Live weight of female rabbits

The live weights of the female rabbits recorded upon housing, at mid-lactation and at weaning are listed in Table 2. Housing did not affect the live weight of the females. On average, the live weight of the females upon housing was 4889 (±44.9) g, and no change was observed at mid-lactation (4890±45.5 g) or upon weaning (4867±46.4 g).

Table 2: Average live weight (in g) of female rabbits upon housing, at mid-lactation and at weaning according to the housing condition. Data aggregated from reproductive cycles 1 and 3. Numbers in brackets are the standard error of each estimated marginal mean. *P*-values for the main effect *Housing condition*.

	Housing condition[1]					
Live weight	CTL	SCT	GNW	PLT	CBN	*P*-value[2]
Upon housing (4 d before partum)	4907 (83)	4749 (86)	4958 (77)	4912 (80)	4860 (80)	0.312
At mid lactation (15 d post-partum)	4955 (90)	4660 (93)	4924 (97)	4949 (90)	4914 (84)	0.092
At weaning (35 d post-partum)	5136 (117)	4700 (105)	4885 (114)	4918 (117)	4915 (105)	0.905

[1]Housing conditions: Control (CTL), Scratching card (SCT), Gnawing material (GNW), Platform (PLT) and Combination (CBN).

[2]The interaction between Housing and Reproductive cycle and the Reproductive Cycle effect were not significantly different from zero (all variables).

Reproductive performance (litter size)

The housing system seemed to have no significantly affected on the number of kits born alive (9.00±0.18), the number alive at weaning (8.16±0.25) and survival of the kits during lactation (90.4±1.9%). The presence of housing enrichments (scratching card, gnawing blocks, platform and their combination) did not influence kit survival during lactation compared to the CTL group.

The number of kits after cross-fostering differed in cycle 1 (8.23 ±0.095) and in 3 (10.00 ±0.093), and a difference was also observed in the number of weaned kits (cycle 1: 7.18±0.574 *vs.* cycle 3: 9.05±0.560; $P<0.001$). However, the differences caused by the cross-fostering practice did not affect kit survival during lactation (88.0±4.7 % in cycle 1 and 93.0±4.7 % in cycle 3; $P=0.190$).

Feed intake during lactation (females and kits)

Housing conditions did not influence the feed intake of the females and their litters; the daily intake averaged 487±14 g. However, the joint intakes of females and their kits differed between reproductive cycles. Even though the number of kits raised by females in reproductive cycle 3 was higher (10.0 *vs.* 8.2 kits), joint feed intake was higher in reproductive cycle 1 in lactation week 2 (475±11 *vs.* 380±11; $P<0.01$), in lactation week 3 (538±9.9 *vs.* 464±9.7; $P<0.01$) and lactation week 4 (741±23 *vs.* 684±22; $P=0.034$) compared to those in reproductive cycle 3.

Use of scratching cards, hard and soft wood sticks and forage blocks

Scratch cards were used equally by females in the SCT and CBN groups (median use score: 3.0 *vs.* 2.0, respectively; Mood's median test: $P=0.86$ and the independence test: $P=0.13$). Hard wood sticks were not used. Score for the use of soft wood stick did not differ between females in the GNW and CBN group (median values: 2.0 *vs.* 1.0, respectively; Mood's median test: $P=0.37$ and the independence test: $P=0.53$). Use of lucerne forage blocks did not differ between females in the GNW and CBN groups (25.3±2.97 *vs.* 22.6 ±3.18 g/d, respectively; $P=0.53$). However, the use of the lucerne blocks differed between the reproductive cycles 1 and 3 (14.5 g/d *vs.* 33.4 g/d; $P<0.001$).

Specific behaviours of female rabbits

The specific behaviours of the females are summarised in Table 3. *Gnawing* behaviour was the only behaviour that statistically differed among groups ($P<0.001$). This behaviour was observed only among females in the GNW (median frequency 4.69) and CBN (median frequency 2.34) groups. Although not statistically significant ($P=0.06$), when given the opportunity (cage height 60 cm), females in the PLT (median frequency 2.08) and in the CBN (median frequency 3.12) groups did *Rear up*. No scratching was observed, so statistical analysis was not performed.

Spatial distribution of female rabbits

The spatial distribution of females on the different types of flooring and on the platforms is reported in Table 4. Independently of the housing condition, females were more frequently observed straddling the mesh and plastic floors

Table 3: Median values of female rabbits' behaviours (%) housed in five different cages (CTL: Control, SCT: Scratching paper, GNW: Gnawing material, PLT: Platform and CBN: Combination of SCT, GNW and PLT).

	CBN	SCT	PLT	GNW	CTL	Sum
No. of tests (six points per test)	256	240	240	228	232	1196
Females (n)	14	14	14	15	15	72
Maintenance behaviours (%)						*P*-value
Eating	6.25	7.29	4.69	7.29	8.33	0.61
Drinking	1.82	2.34	2.04	2.08	2.08	0.75
Sitting (active)	12.24	9.38	9.90	13.54	11.46	0.54
Resting (sitting or lying down inactive)	6.77	2.08	4.69	0	2.08	0.29
Comfort behaviours (%)						
Grooming	8.56	10.94	15.62	12.50	10.42	0.24
Gnawing	2.34[a]	0[b]	0[b]	4.69[a]	0[b]	<0.001
Lying down (active)	45.83	50.00	51.56	47.92	53.12	0.3319
Investigatory behaviour (%)						
Rearing up	3.12	0	2.08	0	0	0.06
Locomotory behaviours (%)						
Hopping	1.04	0.52	0	0	1.04	0.43
Jumping	0	0	0	0	0	0.42
Maternal behaviour (%)						
Interaction with kits	0.52	1.04	1.04	1.04	1.04	0.86
Stereotypic behaviours (%)						
Biting cage bars or feeders	0	1.04	0.52	0	1.04	0.67
Clawing at cage walls or corners	0	0	0	0	0	0.41

[a,b]Means in a row not sharing superscript were significantly different at $P<0.05$.

(median=43.8%), followed by on the plastic mesh (31.2%) and on the wire mesh (18.8%). Obviously, the use of a platform was only counted in housing containing this enrichment (mean values for PLT=1.75% and CBN=4.91%; the median value for CTL, SCT and GNW groups was zero).

Spatial distribution of rabbit kits (weeks 4 and 5)

Rabbit kits were observed only 22 times on the platform. Among the 471 records of kits located on the floor, they were more often observed on plastic-mesh flooring (64.7%) than on wire mesh flooring (35.3%; $P<0.001$). The percentage of kits on plastic-mesh flooring was influenced by the housing group ($P<0.05$), being higher in CTL (73.7%) than

Table 4: Median values of female rabbits' spatial distribution (frequency) according to the housing system. Data aggregated from lactation weeks 2 to 5 and reproductive cycles 1 and 3.

	Housing condition[1]					*P*-value[2]	
Spatial distribution	CTL	SCT	GNW	PLT	CBN	Independence	Mood's
Wire mesh floor	16.3	31.2	25.0	21.9	18.8	0.281	0.156
Plastic mesh floor	37.5	22.3	31.2	31.2	34.4	0.102	0.741
Between wire and plastic floors	50.0	50.0	43.8	50.0	37.5	0.758	0.221
On the platform[3]	0[b]	0[b]	0[b]	0[ab]	0[a]	0.003	<0.001

[1]Housing conditions: Control (CTL), Scratching card (SCT), Gnawing material (GNW), Platform (PLT) and Combination (CBN).

[2]Reproductive cycle: *P*-values for independence test (Wire mesh floor=0.122; Plastic mesh floor=0.956; Between wired and plastic floors=0.095; On the platform=0.405) and Mood's median test (Wired mesh floor=0.746; Plastic floor=0.933; Between the wire and plastic floors = 0.126; On the platform = 1.0).

[3]Median values. The mean (±standard deviation) percentage values were: CNT=0.0 (±0.0), SCT=0.0 (±0.0), GNW=0.0 (±0.0), PLT=1.79 (±5.16) and CBN=4.91 (±7.43).

[a,b]Means in a row not sharing superscript were significantly different at $P<0.05$.

other groups (61.2, 61.6, 62.5 and 63.8% for SCT, PLT, GNW and CBN groups, respectively). It was also influenced by the week of observation (83.1, 68.7 and 56.3%, for week 3, 4 and 5, respectively; $P<0.001$).

The percentage of kits observed on the plastic-mesh flooring was influenced by the reproductive cycle (61.7 *vs.* 69.7% for cycle 1 and 3, respectively; $P<0.05$), and the week of observation (83.1, 68.7 and 56.3% for week 3, 4 and 5, respectively; $P<0.001$). The presence of female rabbits on the plastic mesh did not significantly influence the percentage of kits located on the plastic mesh ($P=0.166$).

DISCUSSION

Feed intake and performance

In agreement with most other published studies, the production performance of females was not influenced by provision of gnawing blocks (Verga *et al.,* 2004; Jordan *et al.,* 2008; Rommers *et al.,* 2014) or of a platform (Farkas *et al.,* 2016; Matics *et al.,* 2018; Trocino *et al.,* 2019). However, Barge *et al.* (2008) reported increased feed intake by females from day 1 to day 19 (+556 g) and an increase in litter size at day 19 (+0.75) in a two-floor platform system compared to standard housing. On the contrary, Mirabito *et al.* (2000) observed increased mortality (+6.8%) in fattening rabbits in housing enriched with a wood stick compared to those in non-enriched housing.

Behaviour

Enrichment succeeded in increasing the expression of targeted behaviours. Thus, as expected, *Gnawing* behaviour was observed in female rabbits supplied with gnawing material (soft wood sticks and forage blocks), as confirmed by consumption of the block. Although rarely recorded during direct observations, when provided, the soft wood sticks were used by the females. Additionally, in line with the results of Princz *et al.* (2007), the present study confirmed that the rabbits preferred soft wood to hard wood, as hard wood sticks were not used at all.

The presence of a platform offers more opportunities for movement (standing up and jumping) and exercise thanks to the increased functional area. It also offers females the possibility of escaping from their offspring once the kits leave the nest box (Mirabito *et al.,* 1999; Mikó *et al.,* 2014). In our study, both standing up and jumping behaviour were observed in the groups whose housing included a platform, but rarely. When enrichments were combined, their use was no different from when each enrichment was provided alone. This result suggests there was no compensation, reorientation or overuse of enrichment in single-enriched housing.

The frequency of females observed on the platform was also low compared to that reported in the literature (55.9-67.1% according to Mikó *et al.,* 2014). In fact, the period when females need to escape from their kits is relatively short, as it is only after the kits reach 15-18 d of age that they are more often outside the nest than inside (Coureaud *et al.,* 2008) and the nest box is usually removed after 21 d of lactation. Some authors found that females spend more time on the platform when their kits begin to leave the nest box, and more time on the bottom level when the kits themselves started jumping up onto the platform (Mirabito *et al.,* 1999; Mikó *et al.,* 2014). The low occupancy of platform in the present study could be explained by the position of the platform in the cage. As it was placed in the middle of the housing, only two edges were in contact with the sides of the housing rather than three. This could trigger a fear of emptiness in the females and hence limit their use. However, the use of a platform could also create hygiene problems from faeces and urine possibly falling onto animals located underneath it. In growing rabbits, Gerencsér *et al.,* (2016) reported higher animal density in front of the platforms than underneath them (13.3 *vs.* 8.3 rabbits/m^2). They also observed a clear preference for the second level of platforms compared to the first one. Szendrő *et al.* (2012) used drip trays below each platform to collect urine and faeces which resulted in the rabbits spreading out more evenly in the pen. No sign of rabbits being dirty from the urine or faeces was observed in our study. This is not surprising, as the platform was rarely used.

In the experimental conditions used in the present study, the expected species-specific behavioural traits of rabbits such as gnawing, rearing up, hopping, jumping, and clawing were rarely observed during direct recording. This is in line with Rommers *et al.* (2014), who observed few animals occupied with the enriched materials, and no effect of gnawing stick on abnormal behaviour was observed. The use of housing enrichment by rabbits in the present study

may be underestimated due to the method of observation used (direct observation), which took place for a short period in daytime. According to Jordan *et al.* (2011), the difference in the daily rhythm and duration of individual behavioural patterns in rabbits in enriched and non-enriched housing was mostly expressed around the time the light changes. Mikó *et al.* (2014) also observed that females spent more time on the platform during the active period (23:00-4:30) than during the light period (6:00-17:00). Similarly, Lang and Hoy (2011) also found growing rabbits spent more time on the platform at night than during the day. Dynamic observations using video recording are needed to complete longitudinal static observations. However, by presenting enrichments to the rabbits we enabled them to choose to use the enrichments or not. To give them the opportunity to perform this behaviours, although it is not observed that often, is also important from a welfare point of view.

Flooring type

Under farming conditions, rabbits are kept on wire-mesh flooring most of the time, which ensures good hygienic conditions as they are separated from their droppings. However, pododermatitis is frequently observed in females (Rosell and de la Fuente, 2013). The provision of a plastic footrest placed on the wire mesh floor is recommended to provide a comfortable resting area and avoid footpad injuries (Rosell and de la Fuente, 2009 and 2013). In the present study, both females and kits were observed more frequently on the plastic-mesh flooring, suggesting that it is more comfortable for the animals than wire. This is in line with the results of Mikó *et al.* (2014), who observed a preference of females for a plastic-mesh platform over a wire-mesh platform.

CONCLUSION

Providing female rabbits with simple enrichments appeared to stimulate specific behaviours like *gnawing*, *rearing up* and *scratching*. These targeted behaviours are sometimes difficult to measure using direct observations made during the day. Farmers' working conditions and work time as well as their income should be evaluated in further studies to assess the sustainability of such housing modifications.

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