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ABSTRACT

Collective housing is perceived as a possible way to improve rabbit welfare, especially among adult females, which are normally individually housed. Part-time group housing seems to allow a better balance between welfare and health than continuous group housing, but practical implementation and consequences for reproductive performance have not been extensively studied. The aim of this work was to compare weight, feed intake, litter size, injury occurrence, body integrity, and spatial location of female rabbits housed part-time in group housing (**PGH** group, $n = 32$) or housed individually (**IH** group, $n = 8$). Females were grouped by opening connecting hatches between four individual enriched cages (platform, wood stick and gnawing block). Collective housing started 12 days after artificial insemination and was interrupted at the 10th day (instead of the 15th day later as originally planned) due to high injury rates and severe injuries caused by fighting. The proportion of injured females increased from 25% on the first day of grouping to 63% on the 10th day. Female weight gain during the experiment was similar in the two groups. Litter size at weaning was 9% lower in the PGH group than in the IH group (9.2 vs 10.0, $P < 0.01$). Platform use was recorded in 32% of the observations and was the highest during the 2 weeks before weaning (46% and 47% of total observations, $P < 0.05$). During the grouping period, there were at least two females in the same housing unit in 59.4% of the cases, at least two females were located on the same level in 31.3% of the cases. In conclusion, connecting individual cages is an ergonomic solution for part-time group housing, but does not prevent fights for the establishment of a social hierarchy. This is detrimental to the health and body integrity of female rabbits.

Implications

Housing rabbit females in individual wire cages is considered to be detrimental to rabbit welfare. Part-time group housing could improve their welfare by allowing social interactions. We evaluated a part-time group housing system that consists of connecting individual enriched cages. This system provides a large split habitat aiming to mimic a residual territory. It is easy to implement on the farm and is modular, and sick or injured females can be isolated if necessary. However, the system did not prevent fighting between females and led to frequent injuries. We observed that enrichments were attractive to rabbits and could improve their welfare.

Introduction

The rabbit is a gregarious animal with a diverse behavioural repertoire including jumping, running, and gnawing as well as positive social behaviours such as allogrooming or resting side-by-side (Coureaud et al., 2015). In current rabbit farming systems, reproductive rabbit females are individually housed in a wire cage with their litter until weaning. The small space available and the absence of any enrichment in the living area are considered to have an impact on rabbit welfare (Buijs et al., 2011). Collective housing of rabbits is believed to improve their welfare by allowing social interactions between adult females. However, continuous group housing of reproducing female rabbits has not produced acceptable results concerning either the health (body integrity and injuries) of the females and their kits or productive performance. Indeed, the reproductive performance of collectively housed females decreased due to pseudo-pregnancy, competition among females for nests and aggressive behaviour towards kits when two or three females shared the same nest box (Mirabito et al., 2005; Szendrö et al., 2019).

Attention has thus recently shifted to part-time group housing systems (Szendrö et al., 2019). In such systems, females are collectively housed for several weeks while gestating and placed in individual cages a few days before parturition (Maertens and Buijs,

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2016). Compared to permanent group housing, part-time group housing avoids pseudo-pregnancy and competition for the nest or collective littering (Szendrö et al., 2016). Acceptable reproductive results can be achieved in the part-time group housing system (Maertens and Buijs, 2016; Zomeño et al., 2018). However, aggressive behaviours, and injuries to rabbits after grouping, remain problematic (Andrist et al., 2013; Buijs et al., 2015). These housing systems, as used in previous studies (parks or elevated pens, Andrist et al., 2013; Buijs et al., 2015), could also have the disadvantage of increasing the time and work required by the breeder to install or remove the partitions that allow separation or grouping of the females. In addition, enrichments may be required to reduce aggressiveness of females in the group housing system. Some strategies, such as providing hiding spaces, have been proposed (Rommers et al., 2014), but the benefits remain to be investigated.

We therefore designed, together with various players of the French rabbit production sector (breeders, farmers, feed mills) and two welfare non-governmental organisations, a housing system (enriched with platforms, gnawing material and burrows) that allows part-time grouping of female rabbits. It was also designed to require little handling by connecting four individual housing units via hatches placed at the platform level to create a split habitat and residual territory. The housing system was designed to allow the expression of specific behaviours and social interactions, and to favour locomotion, while at the same time, maintaining an acceptable level of production. It further requires minimal labour of the farmer as it is easy to connect cages, easy to clean, and easy to handle animals after grouping.

The aim of the experiment was to investigate the effect of part-time grouping before parturition in this enriched housing system on body integrity (injuries) and reproductive performance, to describe the use of enrichments, and the spatial distribution of animals.

Material and methods

Animals and housing

This study was conducted at the INRAE GenPhySE rabbit experimental station (Centre Occitanie Toulouse) between November 2018 and January 2019.

The individual housing units were made of wire mesh (102 × 47 × 60 cm, w × l × h) and contained a series of enrichments. A platform (38 × 45 cm, w × l, including a corridor 21.5 × 62 cm, w × l) made of plastic mesh was fixed at a height of 30 cm from the ground. A compact forage block (more than 50% composed by dehydrated alfalfa, Lapety bloc, Inzo, 02400 Chierry, France) and a 20 cm wood stick were both provided as gnawing material. All animals had at their disposition a wooden burrow (28 × 45 × 32 cm, w × l × h, closed on four sides and with small opening on the front) located on the front of each cage and evenly spaced among them. This burrow had a double purpose, be used as a nest box in the presence of a litter (after changing the floor to accommodate a plastic next box), or as a refuge (similar function as a burrow) in the absence of a litter. The ground floor consisted partly of a wire mesh (64 × 47 cm) and partly of a plastic mesh (38 × 45 cm). The total floor area was 4 794 cm^2 (of which 35.7% was plastic mesh) and the total available area (including the platform, corridor and wooden box) was 9,097 cm2 (52.2% of the total surface was plastic mesh).

A total of 40 rabbit does (crossbred female Hyplus PS 19 rabbits, Hypharm, France), including 29 primiparous and 11 multiparous (average parity 7.6), were used. Primiparous rabbit does were transferred to our experimental station at 70 days old, and multiparous rabbit does were the remaining animals of a previous study (Savietto et al., 2020).

The experiment started at artificial insemination (**AI**: D1, when housing the does in the experimental cages) and ended at weaning of litters (35 days of age; D67). All the females were in good health at the beginning of the experiment. All the animals had *ad libitum* access to a commercial pelleted diet (STABIMAT by Terrya, Rignac, France: 16.4 MJ GE/kg, 172 g of CP/kg, 150 g/kg of crude fibre, and 25 g/kg of ether extract on a DM basis) and freshwater. Female rabbits were assigned to one of the two groups by stratified randomisation based on female parity order and weight at AI (averaged 4 332 ± 470 g):

i. The individual housing system (**IH** group): 8 cage units for females and their litters (3 multiparous and 5 primiparous) from D1 to D67.
ii. The part-time group housing system (**PGH** group): 32 cage units connected via hatches located at the platform level to form eight part-time group housing pens (total available area was about 3.64 m^2) each containing four females (Fig. 1). The pen allowed therefore a maximum length of 4 m at least for one side of the housing (longer than the minimum length of 1.8 m recommended by Federation of Veterinarians of Europe, 2017) to permit the locomotion of rabbits. In this group, multiparous (n = 8) and primiparous (n = 24) females were mixed. The grouping period was initially planned to start at the D13 and end at the D27 but was interrupted at D22 (Fig. 2) due to the number of injuries caused by fighting between females.

Female rabbits were weighed at artificial insemination (D1), at the separation of the group (D22), at parturition (D32) and at weaning (D67). Feed intake was measured in each housing unit from D13 to D67. It corresponded to one female rabbit and its kits when in isolation, or to the average of several females in the PGH group (total intake of all feeders divided by the number of females collectively housed). Each compacted forage block was weighed at the beginning of grouping (D13) and at the end of experiment to

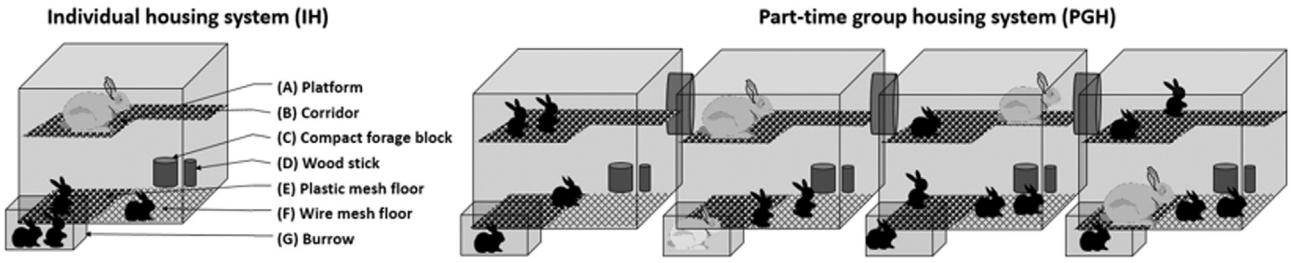

Fig. 1. The two housing systems for rabbits. Each individual cage unit was enriched with a platform (A, including a corridor B), gnawing material in the form of a compact forage block (C) or a wood stick (D), floor area made of plastic mesh (E) or wire mesh (F) and a permanent wooden box forming a burrow (G). In the PGH (part-time group housing) group, individual cage units were connected by mean of hatches from D13 to D22 (instead of until D27 as originally planned).

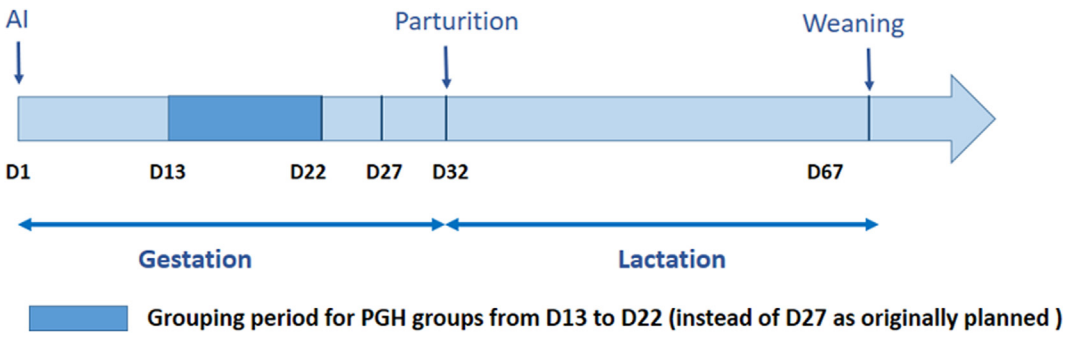

Fig. 2. Experiment timeline events. The experiment started at artificial insemination (AI, D1) and lasted until the weaning of litters (D67). Female rabbits assigned to the PGH (part-time housing system) group shared four cage units (eight groups of four females) from D13 to 22.

quantify use. A new block was added whenever necessary. The use of the wood stick was evaluated using a 4-point scale (0: not gnawed; 1: less than 1/3 gnawed; 2: 1/3 to 2/3 gnawed; 3: more than 2/3 gnawed) at the end of the experiment. At birth, the litter size was measured and then set to eight kits for primiparous and 12 kits for multiparous does by adoption (introduction into the litter of a kit from another mother female) or culling non-viable kits (< 35 g at birth). It was evaluated again at weaning.

Each animal was inspected for injuries daily and evaluated using a 4-point severity scale (0: no damage; 1: minor injury with scratching on the ear or torn hairs; 2: moderate injury – i.e. torn nail, or scratch on the eye or on the back, or damaged epidermis, or fur torn off; 3: serious injury with damaged dermis, raw flesh, or rapid evolution of a wound that passes from severity one to two in 24 h). Injured animals were observed every day to monitor their physical integrity. Severely injured animals were immediately isolated in one part of the four-cage unit by closing the connecting hatch. The remaining hatches were kept open to continue group housing. In addition, animal mortality was recorded daily.

The spatial distribution of female rabbits and the number of kits in each area of each cage unit (wire mesh floor, plastic mesh floor, platform or burrow) were recorded by direct observation twice a day (at 1 000 and 1 500 h), two days a week, for nine consecutive weeks. In total, 36 observations were done for each of 40 female rabbits and their litter.

Statistical analysis

All analyses were performed in R statistical software (version 3.4.0). A dummy variable 'Injury' (presence or absence of injury) was calculated and analysed according to the housing system, parity, and the live weight of the rabbit at artificial insemination using a logistic regression.

The live weight of the female rabbits was analysed using a linear mixed effect model including housing system (IH or PGH) and female parity order (primiparous or multiparous) as fixed effect and female as random effect. The live weight of female rabbits at artificial insemination was added as a co-variable. The number of kits born and weaned, and the live weight of kits at weaning were also analysed using a linear mixed effect model including the housing system and parity order of female rabbits as fixed effect and female as random effect.

The daily feed intake at each feeder was calculated for six periods (from experimental days 13 to 22, 22 to 34, 34 to 43, 43 to 50, 50 to 55 and 55 to 67). The daily intake in each period, the average throughout the cycle, and the consumption of the compact forage block were analysed using a mixed model with the housing system as fixed effect and female as random effect. To avoid errors due to absence of intake (or use) by kits, only in the presence of lactating rabbit females were taken into consideration for these analyses (n = 28 out of 40). The influence of the housing system on the scoring of the wood sticks, fertility of female rabbits was analysed using a chi-square test when appropriate (i.e., when the number of repetitions was sufficient) or by descriptive statistics only (when the number of repetitions was low).

To analyse the use of space by the does in the housing, two qualitative variables were created: 'type of floor' (two classes: plastic mesh vs wire mesh) and 'platform' (in which corridor was considered as a part of platform). The influence of the housing system, parity, observation time (morning vs afternoon) and week of observation on these two variables was analysed using a logistic regression model. The percentage of kits on the platform was calculated for each housing unit at each observation to evaluate their choice. The influence of housing system, parity of female rabbits, the observation time (morning vs afternoon) and the week of observation on these two variables was analysed using a mixed model with the litter as random effect.

Statistical differences were declared at an alpha value below 0.05 (type-II analysis-of-variance, F-test for generalised linear models and for logit models; Anova function of the car package; Fox and Weisberg; 2019).

Results

Injury rate of female rabbits during the part-time grouping period

Fig. 3 shows the percentage of injuries according to the experimental day. 2 days after grouping, 25% of females were injured (mostly severity rate 1). The number of injured animals and the severity of the injuries increased rapidly. One week after grouping (D19), 50% of females were injured (severity rates 2 or 3 representing 44% of the observed injuries). By the tenth day of grouping (D22), 62.5% of animals were injured (severity 3: 28.1%, severity 2: 9.4% and severity 1: 25.0%). This situation was intolerable and, for ethical reasons, we chose to end the group housing period 5 days earlier than planned (originally planned to occur 15 days after group housing, D27). Most of the injuries were on the face and hindquarters. No injury was found on females in the IH group (P < 0.001), confirming that injuries were due to fights between females. The parity order of females also influenced the injury rate (P < 0.05). Primiparous rabbit females had a higher incidence of injuries (75% of 24) than multiparous does (25% of 8). The live weight of the female rabbits at artificial insemination did not influence the injury rate (P = 0.419).

Performance of female rabbits and their litters

No females died during the experimental period. However, three females in the PGH group (10.3%) were culled due to general poor health at D28, D39 and D40. Of these three females, one had

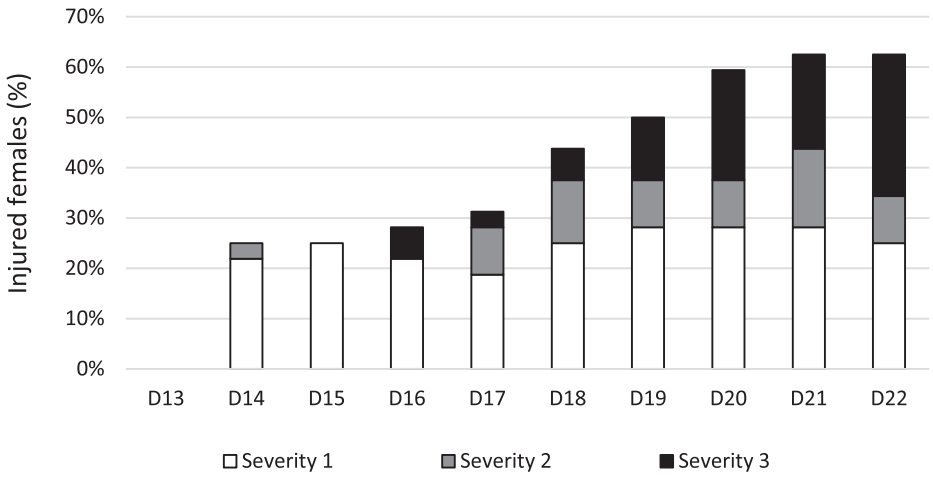

Fig. 3. Percentage of injured female rabbits based on severity at D13 to D22 in the part-time group housing group (n = 32 female rabbits).

no injury at all and the other two had minor injuries (with scratching on the ear or torn hairs) at the end of the grouping period. There was no culling in the IH group.

At the end of grouping (D22), the live weight of rabbit females in the PGH group (4 284 g) was 10% lower than those in the IH group (4 662 g, $P < 0.001$, $F_{1,35} = 13.21$); this difference between groups was also found at parturition (4 176 vs 4 509 g, $P < 0.001$, $F_{1,34} = 19.65$) and at weaning (4 500 vs 4 728 g, $P < 0.05$, $F_{1,32} = 7.18$). The live weight gain at different periods was not affected by housing system (Table 1). Fertility rate of females was 68.8% in the PGH group and 75.0% in the IH group (no statistical analyses performed). Litter size at birth was similar between IGH and IG (9.3 vs 10.3 kits, respectively, $P = 0.431$, $F_{1, 24} = 0.64$). Although mortality of kits at weaning did not seem to differ (PGH = 10.3 and IH = 0.0%, $P = 0.368$, $F_{1, 24} = 2.40$), litter size at weaning was 9% lower in the PGH group than in the IH group (9.2 vs 10.0 kits, $P = 0.019$, $F_{1, 24} = 9.1$).

Daily feed intake (averaged for all rabbits in PHG, on individual basis in IH) was not affected by the housing system (Table 2). However, in the PGH group, we observed uneven feed consumption among feeders in the same collective unit. In 12 out of the 32 housing units in the PGH group, the feed intake was 50% lower (averaged 59 g/d; $P < 0.01$, $F_{1, 30} = 51.3$) than in other housing units (averaged 153 g/d, results not shown).

The daily feed intake between D34 and D43 was 20% lower by injured females compared to healthy females (252 vs 325 g/day, P <0.05, $F_{1, 27} = 4.8$). The live weight of injured females was 7.6% lower at AI (D1: 4 151 vs 4 494 g, $P < 0.05$, $F_{3,36} = 2.9$), 6.9% lower at separation (D22: 4 124 vs 4 558 g, $P < 0.05$, $F_{3,36} = 3.2$), 11.1% lower at parturition (D32: 3 984 vs 4 480 g, $P < 0.01$, $F_{3,35} = 6.0$) and 8.5% lower at weaning (D67: 4 347 vs 4 752 g, $P < 0.01$, $F_{3,33} = 3.7$). There was no difference in the size of the litter between injured and not injured animals in the PGH group (Table 3). The fertility rate was 65.0% for injured and 75% for not injured females in PGH group, respectively (descriptive statistics only).

Use of enrichments by rabbits

The use of the compact forage block during the experiment was similar for females in the PGH and IH groups (Table 2). The use of wood sticks was similar for all treatments at parturition (Table 4) but was lower in the PGH group than in the IH group at weaning (2 vs 3, $P < 0.001$, Table 4).

Animals were observed on the platform (the corridor was considered as a part of platform) in 32% of observations. Primiparous females were observed more often on the platform (35%) than multiparous (23%, $P < 0.001$).

The frequency of the presence of rabbit females on the platforms increased ($P < 0.001$) from week 1 (28.1%) to week 9 (46.6%). This frequency was not influenced by the housing system ($P = 0.960$) or by the time of observation ($P = 0.280$). During the grouping period, females in the PGH group were found in their

Table 1
Reproductive performances and live weight of female rabbits and their kits reared either in part-time group housing (PGH group) or in individual housing (IH group).

	Housing		SEM	*P*-value	
	PGH n = 32	IH n = 8		Housing	Parity
Live weight of female rabbits (g) at:					
End of grouping (D22)	4 287	4 662	89	<0.001	<0.001
Parturition (D32)	4 176	4 509	73	<0.001	<0.001
Weaning (D67)	4 500	4 728	66	0.012	<0.001
Live weight gain (g):					
D1 to D22	7	123	41	0.271	0.264
D22 to D32	−129	−153	43	0.806	0.296
D32 to D67	298	219	27	0.222	0.067
Litter size (n)					
at birth (D32)	9.3	10.3	0.5	0.431	0.215
at weaning (D67)	9.2	10.0	0.1	0.006	0.019
Weaning weight of kits (g)	991	966	11	0.629	<0.001

Table 2
Daily feed intake (g/day, as fed basis, 90.4% of DM), use of compact forage block by female rabbits (only lactating females) and their litters reared either in part-time group housing (PGH group) or in individual housing (IH group).

	Housing		SEM	*P*-value
	PGH n = 22	IH n = 6		
Daily feed intake (g/day)				
D13 to D22*	118	160	11	0.130
D22 to D34	139	141	8	0.887
D34 to D43	316	291	14	0.454
D43 to D50	373	355	10	0.469
D50 to D55	401	380	15	0.568
D55 to D67	765	777	22	0.831
D13 to D67	352	351	11	0.960
Use of compact forage block				
Total use (D13 to D67, g)	2 263	2 438	145	0.636
Daily use (D13 to D67, g/day)	42	44	3	0.719

* Period of group housing in the part-time group housing system.

Table 3
Daily feed intake (g/day as fed basis, 90.4% of DM), live weight, and performance of female rabbits in part-time group housing system (PGH) according to their injury status (injured or not).

	Injured females (n = 20)	Female with no injuries (n = 12)	P-value
Daily feed intake (g/d)			
D22 to D34	126	155	0.066
D34 to D43	252	325	0.033
D43 to D50	304	352	0.220
D50 to D55	470	514	0.656
D55 to D67	580	679	0.375
D 22 to D67	284	342	0.099
Live weight at (g)			
Artificial insemination (D1)	4 151	4 494	0.019
Separation (D22)	4 124	4 558	0.016
Parturition (D32)	3 984	4 480	0.002
Weaning (D67)	4 347	4 752	0.005
Live weight gain (g)			
AI to separation	−27	64	0.369
Separation to parturition	−161	−78	0.399
Parturition to weaning	341	228	0.062
Reproductive performance			
Litter size at birth	8.8	10.0	0.369
Litter size at weaning	9.1	9.3	0.433
Weaning weight of kits (g)	943 (n = 118)	1 058 (n = 85)	0.313

Table 4
Use of wood gnawing sticks (score) by female rabbits and their litters reared either in part-time group housing (PGH group) or in individual housing (IH group).

	Housing		P-value
	PGH n = 32	IH n = 8	
Median note at parturition (D32)	2	2	1
Median note at weaning (D67)	2	3	<0.001

original cage unit (i.e. the unit where they had been alone before D13) in 50% of observations. In 59.4% of the observations (n = 32), there were at least two does in the same housing unit; and in 31.3% of the cases, there were at least two does on the same level (on the ground or on the platform) of the same cage unit. Females were rarely observed in the burrow either in the PGH or the IH group (3.1% of observations during the grouping period).

Only in the ground floor (which was composed of 36% of plastic mesh and 64% of wire mesh), the females were observed over the plastic mesh in 46% of the observations (data not shown). The does in the PGH group were more frequently observed on the plastic mesh than the does in the IH group (48% and 38%, respectively, P < 0.05). Additionally, multiparous does were more frequently observed on the plastic mesh (54%) than primiparous (43%, P < 0.01). This frequency was not influenced by time (P = 0.21) or by the week of observation (P = 0.33).

Discussion

Group housing and aggressive conflicts

In current rabbit farming systems, reproductive rabbit females are housed individually in a wire cage with their litter until weaning. Previous studies showed a notable decline in reproductive performance in permanent group housing systems (Mirabito et al., 2005; Szendrö et al., 2019), making their use impracticable. Part-time group housing system is an attempt to reduce the reproductive problems while responding to the welfare concern of lack of socialisation. Aggression between females housed in groups for a short period has already been reported (Rommers et al., 2014; Buijs et al., 2015; Rommers and De Greef 2018). Our results confirmed that aggressive interactions between female rabbits during grouping. In fact, aggressive conflicts are part of the natural social behaviour of rabbits, especially during the period of reproduction since social hierarchies are established through agonistic interactions (von Holst et al., 2002; Szendrö et al., 2016), but a high frequency of aggressive interactions in group housing leads to injuries and has a significant negative effect on the welfare of does (Andrist et al., 2013).

Some studies focused on reducing aggression between females housed in groups. According to Rommers et al. (2014), the presence of hiding places (platform and PVC pipes) slightly reduced the aggression, the number of injured animals and the culling rate. In the present study, we designed a housing system enriched with platforms, gnawing material and burrows to allow part-time grouping of females by connecting four individual housing units, which offered a split habitat to mimic residual territory with a burrow at floor level (connection was made at the platform level). Animals were housed in modular cages that could be configured either in four dual purpose housing units (for one female and her litter) or in larger pens (for two, three or four females and their litters) by simply opening or closing the hatch between two cages. However, even with a modular habitat that aimed to mimic a residual territory, the part-time group housing of females before parturition still led to a high injury rate.

Unbalanced social hierarchy could explain the degree of severe aggression we observed; most of the injured females were primiparous, in agreement with Mikó et al. (2013) who observed that the oldest females mostly attacked the younger ones (in group of four females and a buck, the aggressive female was older than the others). Generally, young rabbits are subdominant towards older rabbits (Lehmann, 1991, Rödel et al., 2004). If there is an older female in the group, a hierarchy is established within a short period, thereby reducing the frequency of aggressive behaviour with time. Rommers and De Greef (2018) reported that mixing young females with older females resulted in fewer skin injuries compared to systems with mixed animals of similar age. However, Gerencsér et al. (2019) showed that introducing an older female into the group increased aggressive interactions in the first week. In fact, the older females were not always ranked in the first position before grouping. According to von Holst et al. (2002), in wild rabbits, 8% of females gained the dominant position in the first season. The age and parity are not the only factors that determine social hierarchies. Rommers et al. (2014) reported that familiarity with the cage before grouping could affect the females' behaviour during the group housing period.

The stability of the group could also influence the aggressions. Here, the number and the severity of injuries continued to increase for 10 consecutive days after grouping. Andrist et al. (2012), however, reported fewer lesions and lower stress levels in stable-groups compared to mixed-groups of animals not familiar with each other, and noted a reduction in the level of aggression 5 days after regrouping. The same authors also identified differences between seasons in the lesion score, with more lesions in summer than in spring. In addition, aggression among female rabbits could also be affected by the size of the group, the characteristics of the pen and the moment when the group was formed (Zomeño et al., 2017). In the present study, rabbit females were individually housed after reaching 70 days of age. The abrupt change in group housing may frighten the rabbit of the novel stimuli (new space, noises, smells etc.; Morton et al., 1993) as well as to the presence of a potential rival. All these factors may explain the frequency, the duration and severity of the agonistic interactions we observed. In addition, the space provided might be not sufficient to allow the subordinate female to show her submission to the dominant

female. In the wild, an adult female rabbit would not tolerate younger rabbits within a radius of several metres from their burrows or sitting-out places (Southern, 1948) and at least 1 m between two male rabbits is required (Lockley, 1961). Additionally, in experimental conditions with access to a meadow enclosure of 20 areas, Vastrade (1987) observed that the average distance between two females was about 21 m. Although the present housing system allowed a maximum length of 4 m between two females placed opposite each other, longer than that used by Andrist et al. (2013) and that by Buijs et al. (2015), it might be not long enough to demonstrate submission when four animals group together. Moreover, the spatial configuration in a row (adjoining individual housing) may have stimulated agonistic behaviour between animals that were not in direct contact to each other before grouping. The presence of a neutral area, as proposed by Braconnier et al. (2020), may have reduced the aggression levels observed. However, the limited space provided under farming conditions remains the limiting factor (Vastrade, 1987). Housing females in compatible pairs in an enriched environment, as suggested by Morton et al (1993), could be an alternative strategy compatible with the present housing system. However, the identified limits will remain (lack of a neutral area and reduced space).

Most authors reported a decline in reproductive performance in part-time group housing. Maertens and Buijs (2016) reported higher performance in individual cages than in part-time group housing (+3.3% weaned, +8% weaning weight). Dal Bosco et al. (2019) also observed a slight decrease in the litter sizes at birth (from 8.90 to 7.95) and at weaning (from 7.85 to 7.20) in part-time group housing (group of four does, separation between 4 days before and 7 days after parturition) compared to an individual housing system. Zomeño et al. (2018) reported that the doe feed intake (+17.3 g/d) and the milk production (+11.5 g/d) were higher in collective pens than in individual modules, but kit weaning weight was slightly lower (−20.4 g). Here, the aggressions did not impair the overall reproductive performance, except for the litter size at weaning which was lower among females in the part-time group housing system. Despite severe injuries, the grouping period of our study might not have been long enough to influence reproductive performance. The modular organisation of our part-time group housing system allowed the injured animals to be isolated as soon as necessary. This rapid response to a negative interaction might have limited the negative impact of aggressive conflicts on reproductive performances we observed.

Use of space and enrichments by rabbit does

Our results showed that although the enrichments did not prevent continuous aggressive conflicts, they remained attractive for rabbits and therefore confirm their usefulness to improve welfare. The platform provides more opportunities for movement and exercise thanks to the increased functional area. The frequency of rabbit females observed on platforms we observed (32%) was much higher than in our previous study (4% of observations in housing equipped with a platform, Huang et al., unpublished results). The difference could be explained by improvement of platform design (better position and a larger area) and the females' age in this study (parity averaged 3.3 in current study vs 6.4 in our previous study) as primiparous females were found on the platform more frequently than multiparous. In addition, female rabbits were observed on the platform more frequently during the last 2 weeks of lactation, just before weaning. This confirmed that the platform offered animals the possibility to escape from their progeny once they have left the nest box (Mikó et al., 2012). Since kits stayed in the nest during the first 2 weeks of lactation, the proportion of kits on the platform was low (9.5%) but increased strongly over the course of the experiment. The more frequent presence of kits originating from multiparous females on the platform could be related to the less frequent presence of multiparous females on the platform.

Placing a plastic mesh on top of the wire floor of the nest is recommended to provide a comfortable resting area and to avoid injuries to footpads (Rosell and de la Fuente, 2009 and 2013). In the present study, females were observed on the plastic mesh floor more frequently than on the wire mesh floor (based on counts, not on time budgets). This preference could be explained by the more comfortable plastic mesh. This observation is in agreement with that of Mikó et al. (2014) who observed a female preference for plastic mesh platform over a wire mesh platform (56.9% chose plastic, 31.7% chose wire). In present study, multiparous females were more often observed on the plastic mesh than primiparous, suggesting that the comfort provided by the plastic mesh increased with an increase in the weight of the females.

Females in the PGH group were observed outside their original housing in 50% of the observations. This result suggests frequent movements in the large pens. Considering the surface area of the whole housing, it also reflects territorial ownership (Graf et al., 2011). However, according to Rommers et al. (2014), female rabbits do not defend a territory within a group pen. Females were quite frequently observed in the same cage unit during the grouping period, suggesting a need for social contact during this period. The uneven feed consumption between the feeders in the original cage units in larger pens during the grouping period suggested a form of functionalisation of space.

Contrary to our expectations, the frequency of female rabbits in the burrow area remained very low during the group housing period in agreement with the results of a previous study (Huang et al., 2021). However, the frequency might have been underestimated as direct observations were only made during daytime.

In conclusion, the part-time group housing system was easy to install, as it did not require the removal of individual cages, but only connecting them through hatches. It was modular since a female could be easily isolated through closing the hatches. This system offered a large split habitat mimicking a residual territory, which meant injured females could be isolated as soon as necessary which might have limited the negative impact of aggressive conflicts on reproductive performance. However, the frequency of injuries due to fighting between females of different parities and that had previously been housed individually for a long period before being placed in a group was very high. Raising young females together before puberty could allow the progressive establishment of the social hierarchy before grouping. The effects of such a strategy on performance, health and welfare of females will be investigated in a future study. The provision of gnawing material, a plastic mesh and a platform remained attractive for the animals. Although these enrichments did not avoid the continuing aggressive conflicts during the group housing period, they seem to have the potential to improve the welfare of female rabbits.

Ethics approval

Animals were handled in accordance with the recommendations of the European Union (2010) and French legislation on the protection of animals used for scientific purposes (EU Directive 2010/63 / EU, Official Journal of the French Republic (Decree No. 2013-118)). All the protocols were approved by the Ethics Committee n° 115 of the Ministry of National Education, Higher Education and Research (approval number 16330-2018072716211212).

Data and model availability statement.

None of the data were deposited in an official repository.

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Declaration of interest

The authors have no potential conflict of interest to declare.

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References

Andrist, C.A., Bigler, L.M., Würbel, H., Roth, B.A., 2012. Effects of group stability on aggression, stress and injuries in breeding rabbits. Applied Animal Behaviour Science 142, 182–188.
Andrist, C.A., van den Borne, B.H., Bigler, L.M., Buchwalder, T., Roth, B.A., 2013. Epidemiologic survey in Swiss group-housed breeding rabbits: extent of lesions and potential risk factors. Preventive Veterinary Medicine 108, 218–224.
Braconnier, M., Gómez, Y., Gebhardt-Henrich, S.G., 2020. Different regrouping schedules in semi group-housed rabbit does: effects on agonistic behaviour, stress and lesions. Applied Animal Behaviour Science 228, 105024.
Buijs, S., Keeling, L.J., Tuyttens, F.A., 2011. Behaviour and use of space in fattening rabbits as influenced by cage size and enrichment. Applied Animal Behaviour Science 134, 229–238.
Buijs, S., Maertens, L., Hermans, K., Vangeyte, J., Tuyttens, F.A.M., 2015. Behaviour, wounds, weight loss and adrenal weight of rabbit does as affected by semi-group housing. Applied Animal Behaviour Science 172, 44–51.
Coureaud, G., Rödel, H.G., Le Normand, B., Fortun-lamothe, L., 2015. Habitat et Comportement. In: Gidenne, T. (Ed.), Le lapin de la biologie à l'élevage. Editions Quae, Versailles, France, pp. 107–136.
Dal Bosco, A., Mugnai, C., Martino, M., Szendrö, Z., Mattioli, S., Cambiotti, V., Cartoni, M.A., Moscati, L., Castellini, C., 2019. Housing rabbit does in a combi system with removable walls: effect on behaviour and reproductive performance. Animals 9, 528.
Federation of Veterinarians of Europe, 2017. FVE comments on farmed rabbits Retrieved on 23 July 2021, from https://fve.org/publications/fve-comments-on-farmed-rabbits/, .
Fox, J., Weisberg, S., 2019. An R Companion to Applied Regression. Sage, Thousand Oaks, CA, USA.
Gerencsér, Z., Matics, Z., Szabó, R.T., Kustos, K., Mikó, A., Nagy, I., Odermatt, M., Atkari, T., Szendrö, Z., 2019. Aggressiveness, mating behaviour and lifespan of group housed rabbit does. Animals 9, 708.
Graf, S., Bigler, L., Failing, K., Würbel, H., Buchwalder, T., 2011. Regrouping rabbit does in a familiar or novel pen: Effects on agonistic behaviour, injuries and core body temperature. Applied Animal Behaviour Science 135, 121–127.
Huang, Y., Breda, J., Savietto, D., Labatut, D., Pujol, S., Combes, S., Gidenne, T., Warin, L., Fortun-Lamothe, L., 2021. Effect of housing enrichment on behaviour of growing and reproductive rabbits. in press, Nantes, France.
Lehmann, M., 1991. Social behaviour in young domestic rabbits under semi-natural conditions. Applied Animal Behaviour Science 32, 269–292.
Lockley, R.M., 1961. Social structure and stress in the rabbit warren. Journal of Animal Ecology 30, 385–423.
Maertens, L., Buijs, S. Production performances of rabbit does in a part-time group housing system. In: 2016. Paper presented at the 11th World Rabbit Congress, 15-18 June 2016, Qingdao, China, pp. 711–714.
Mikó, A., Matics, Z., Gerencsér, Z., Odermatt, M., Radnai, I., Nagy, I., Szendrö, K., Szendrö, Z., 2014. Performance and welfare of rabbit does in various caging systems. Animal 8, 1146–1152.
Mikó, A., Szendrö, Z., Matics, Z., Radnai, I., Odermatt, M., Nagy, I., Gerencser, Z., 2012. Location preference of lactating rabbit does and their kits in pens with elevated platform. In: Paper presented at the 10th World Rabbit Congress, 3-6 September 2012, Sharm El-Sheikh, Egypt, pp. 1029–1032.
Mikó, A., Szendrö, Z., Odermatt, M., Gerencsér, Z., Radnai, I., Nagy, I., Matics, Z., 2013. Aggressive behaviour of group-housed rabbit does after establishing the group. Animal Welfare, Ethology and Housing Systems 9, 244–249.
Mirabito, L., Galliot, P., Souchet, C., Dumont, F., Thomeret, F., 2005. Logement collectif des lapines reproductrices: Conséquences zootechniques. In: Paper presented at 11émes Journées de la Recherche Cunicole, 29-30 November 2005, Paris, France, pp. 53–56.
Morton, D.B., Jennings, M., Batchelor, G.R., Bell, D., Birke, L., Davies, K., Eveleigh, J.R., Gunn, D., Heath, M., Howard, B., Koder, P., Phillips, J., Poole, T., Sainsbury, A.W., Sales, G.D., Smith, D.J.A., Stauffacher, M., Turner, R.J., 1993. Refinements in rabbit husbandry. Second report of the BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement. Laboratory Animals 27, 301–329.
Rödel, H.G., Bora, A., Kaiser, J., Kaetzke, P., Khaschei, M., Von Holst, D., 2004. Density-dependent reproduction in the European rabbit: a consequence of individual response and age-dependent reproductive performance. Oikos 104, 529–539.
Rommers, J.M., Reuvekamp, B.J., Gunnink, H., de Jong, I.C., 2014. Effect of hiding places, straw and territory on aggression in group-housed rabbit does. Applied Animal Behaviour Science 157, 117–126.
Rommers, J., de Greef, K.H., 2018. Are combi parks just as useful as regular parks for fatteners for part-time group housing of rabbit does? World Rabbit Science 26, 299–305.
Rosell, J.M., De la Fuente, L.F., 2009. Effect of footrests on the incidence of ulcerative pododermatitis in domestic rabbit does. Animal Welfare 18, 199–204.
Rosell, J.M. De, la Fuente, L.F., 2013. Assessing ulcerative pododermatitis of breeding rabbits. Animals 3, 318–326.
Savietto, D., Paës, C., Cauquil, L., Fortun-Lamothe, L., Combes, S., 2020. Evolution of gut microbial community through reproductive life in female rabbits and investigation of the link with offspring survival. Animal 14, 2253–2261.
Southern, H.N., 1948. Sexual and aggressive behaviour in the wild rabbit. Behaviour 1, 173–194.
Szendrö, Z., McNitt, J.I., Matics, Z., Mikó, A., Gerencsér, Z., 2016. Alternative and enriched housing systems for breeding does: a review. World Rabbit Science 24, 1–14.
Szendrö, Z., Trocino, A., Hoy, S., Xiccato, G., Villagrá, A., Maertens, L., 2019. A review of recent research outcomes on the housing of farmed domestic rabbits: reproducing does. World Rabbit Science 27, 1–14.
Vastrade, F.M., 1987. Spacing behaviour of free-ranging domestic rabbits, Oryctolagus cuniculus L. Applied Animal Behaviour Science 18, 185–195.
von Holst, D., Hutzelmeyer, H., Kaetzke, P., Khaschei, M., Rödel, H.G., Schrutka, H., 2002. Social rank, fecundity and lifetime reproductive success in wild European rabbits (Oryctolagus cuniculus). Behavioral Ecology and Sociobiology 51, 245–254.
Zomeño, C., Birolo, M., Zuffellato, A., Xiccato, G., Trocino, A., 2017. Aggressiveness in group-housed rabbit does: influence of group size and pen characteristics. Applied Animal Behaviour Science 194, 79–85.
Zomeño, C., Birolo, M., Gratta, F., Zuffellato, A., Xiccato, G., Trocino, A., 2018. Effects of group housing system, pen floor type, and lactation management on performance and behaviour in rabbit does. Applied Animal Behaviour Science 203, 55–63.