

Social behaviour and personality profiles of breeding does housed part-time in group.

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ABSTRACT

Housing breeding female rabbits in multi-litter instead of single-litter cages allows for more natural behaviour and social contact with conspecifics. Hierarchy fights among does, however, inhibit uptake on farms. Past focus on high reproductive performances in single-litter cages may have yielded rabbit breeds that are less suited to living in groups. For (part-time) multi-litter systems, it may prove beneficial to identify does with personality traits that are desirable for group-living and that promote the rapid formation and maintenance of a stable social hierarchy without grave injuries and prolonged stress. In this trial, we aimed to profile the personality of does by investigating the consistency of their social behavioural strategy when mixed in different groups. We further tested if strategy and personality of does were linked with skin injuries in the groups and if skin injuries could serve as a proxy to identify doe strategies and profiles. During three consecutive reproduction cycles, three or four does and their 22-day-old kits were housed in multi-litter cages for a period of 13 days ($N = 51$ does in total). Doe agonistic behaviour was recorded during the first 24 h (cycle 1 and 2) and the first 8 h (cycle 3) after grouping. Cluster analysis revealed two social behavioural strategies does adopted when a new group was formed: 'offensive' (36.8%) versus 'submissive/avoider' (63.2%). From all does that participated in the study for all three reproduction cycles ($N = 32$), 46.9% changed strategy at least once between cycles and were identified as an 'all-rounder' personality profile. Two other profiles were identified for does that did not change between cycles: 'consistently submissive' (40.6%) and 'consistently offensive' (12.5%). The presence of both 'stable' and 'unstable' does suggests that some does adjust their behaviour in response to their social environment. No significant correlations were found between injuries at both individual and group level and doe strategy or profile. Likewise, results could not confirm if skin injuries were a good proxy to identify doe strategy or profile. Future investigations could explore alternatives to identify 'sociable' does without relying on intensive behavioural studies (e.g. ano-genital distance of female kits at birth). Additionally, it needs to be ascertained whether removing offensive behaving does would indeed lead to reduced aggression and stress in group housing systems. **Implications:** Breeding female rabbits may benefit from group housing but aggressive behaviour compromises animal welfare and commercial uptake. To gain knowledge on the social dynamics between does, we investigated whether problematic agonistic behaviour could be a stable personality trait. This could facilitate selection towards 'sociable' on-farm doe groups. Results showed that social behaviour strategies (offensive or submissive/avoider) were stable across three successive production rounds in half of the does. Other does showed more flexibility, possibly depending on group composition. Links between doe behaviour and skin injuries (including those of group mates), however, are missing which makes identification and practical uptake challenging.

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1. Introduction

Breeding does nursing their litter from birth until weaning in single-litter cages is the most common practice on commercial rabbit farms. Single-litter cages, however, restrict movement and doe social contact is limited to interactions with neighbouring does through wire walls separating adjacent cages. Yet, social interaction is important. Wild European rabbits live in group, usually with 2–3 adult males and 3–5 females (von Holst et al., 2002). Laboratory female rabbits are as motivated to interact with conspecifics as they are for food (Seaman et al., 2008). In husbandry conditions, however, aggression among does housed in multi-litter cages has negative effects on reproductive performance (Machado et al., 2019; Mugnai et al., 2009) and animal welfare (Munari et al., 2020; Rommers et al., 2006). The presence of kits seems to have an important effect on doe social behaviour. Indeed, studies have shown that female rabbits seek seclusion when kindling and nursing their litters (Gerencsér et al., 2021; Rödel et al., 2007). In part-time group housing, however, does remain housed in single-litter cages during the first part of the reproductive cycle and are housed in small groups when protective behaviour towards their kits has decreased (Maertens and Buijs, 2013). Nevertheless, aggression related to doe hierarchy formation may cause considerable stress and injuries.

Several studies have been conducted to reduce the negative consequences of aggressive doe behaviour by providing hiding places (Rommers et al., 2014), altering group size (Buijs et al., 2016; Zomeño et al., 2017), postponing the timing of grouping (Braconnier et al., 2020; Trocino et al., 2021; Van Damme et al., 2022) or by providing both communal and individual zones within the housing system (Gerencsér et al., 2021). An alternative approach, which is the topic of the present study, is to use breeding does that are more suited for living in group. The environment of part-time group-housed breeding does changes multiple times. Within a reproduction cycle, does need to adapt to a sudden change in their physical and social environment when they switch from single- to multi-litter housing. Between cycles, group composition rarely remains stable in commercial management procedures. Non-pregnant does are routinely separated from the main batch of pregnant does while new pregnant does are introduced. This implies that many does are unacquainted at the start of a new group-housing period such that dominance relations need to be formed from scratch. The entire group would benefit if the social hierarchy is established smoothly without escalating or prolonged aggression. On-farm selection for less aggressive ‘amicable’ does may be a promising, but as yet unexplored, strategy to choose does with personality traits that are desirable for group-living and promote the rapid formation of a stable hierarchy.

Animals respond to socially challenging situations by displaying a specific collection of behaviours (Mendl and Deag, 1995) which could be identified as a social behavioural strategy. The strategy consistency of an individual over time and in various environments determines if a personality trait can be identified (Finkemeier et al., 2018). Social behavioural strategies and personality traits have been researched in some group-housed farm animals (Müllender et al., 2003). For example, group-housed goats were classified for adopting aggressive, affiliative, passive and avoider social behavioural strategies (Miranda-de la Lama et al., 2011). These strategies assumingly helped the animals adapt to social environments encountered under intensive husbandry conditions. Although social behaviour and hierarchy dynamics have been studied previously (Bill et al., 2020; Vervaecke et al., 2010), in-depth scientific knowledge on rabbit social behavioural strategies and their relevance in commercial settings is currently lacking. Additionally, it needs confirmation whether or not rabbit social behavioural strategies are stable between variable environments. If so and if certain personalities can be identified that consistently cause a lot of unrest and lesions amongst their group mates, it may prove useful for farmers/breeders to remove these does from the breeding stock and keep the more sociable rabbits instead.

In this study, we evaluated social doe behaviour in a part-time multi-

litter housing system shortly after grouping during three consecutive reproduction cycles. First, we characterized the social behavioural strategy of each doe within each cycle. Secondly, we aimed to identify a personality profile for each doe based on the consistency of their behaviour strategies between cycles. Thirdly, we tested whether the likelihood of doe skin injuries were linked to doe behaviour, social behaviour strategies or personality profiles present in the group. With these three objectives, we aimed to identify if there are does that consistently have a negative effect on their group and whether these does can be identified by their skin injuries instead of time-consuming behavioural observations.

2. Materials and methods

All protocols and procedures were approved by the Ethics Committee for the Use of Animals in Research (EC 2020/378) of the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO).

2.1. Animals and experimental design

A total of 66 nulliparous Hycole (Marcoing, France) female rabbits (16 weeks old at the start) were housed at ILVO (Melle, Belgium) from August 2020 until February 2021. Forty-two does were housed in single-litter cages (50 × 102 cm with a plastic slatted floor, open roof and elevated platform of 50 × 30 cm) in one compartment of the barn. The remaining 24 does were housed in slightly different single-litter cages (38 × 103 × 63 cm, wire slatted floor with a plastic comfort mat of 25 × 40 cm and elevated platform of 38 × 28 cm) in the same compartment and served as spare does. At 19 weeks of age, all does received artificial insemination (AI) for the first time. The birth of their first litter marked the start of the first reproduction cycle. AI was then repeated 17 days after parturition each time for a total of five reproduction cycles. In each cycle at day one post-partum (pp), kits were cross-fostered based on their body size and litter size. Each doe was assigned 9 kits in the first cycle and 10 kits in the subsequent cycles. The surplus of kits were euthanized ($N = 335$) with a lethal blow to the head.

During the first four reproduction cycles, groups of three or four does with their kits were housed in multi-litter cages between day 22 and 35 pp (Fig. 1). Twelve multi-litter cages were randomly assigned one of the following four treatments in each cycle (randomized block design): group of four does with no additional enrichment, four does with



Fig. 1. Multi-litter cages created 22 days post-partum from four adjacent single-litter cages by removing three wire walls. Picture shows top-view of a cage with three does (one on the right side and two on the left side of the pen). Three panels underneath the lowest elevated platform, feeders and water nipples at the front were present in all cages. Half of the groups had additional enrichment (higher elevated platforms in the back corners and PVC pipes underneath the first level platform). See Van Damme et al. (2023) for more information on the multi-litter cage design.

additional enrichment (higher elevated platform and plastic pipes), three does with no additional enrichment and three does with additional enrichment. Treatment effects of this 2×2 factorial study were reported in Van Damme et al. (2023) but will not be discussed further in the present paper. Group housing was realised by removing walls between four adjacent single-litter cages, creating a larger group multi-litter cage. In groups of three does, the fourth cage remained empty during the single-litter housing period. As cage size remained constant, a change in group size also implied a proportional change in stocking density. Does never received the same treatment nor were housed in the same cage twice. In each cycle, does were housed in multi-litter cages with unacquainted does. Sick, injured, deceased or non-pregnant does were replaced by pregnant does from the spare group between cycles ($N = 9$). As such, a total of 51 does were used for the experiment. On day 35 pp, does and kits were moved to another compartment and housed in small groups but this was not part of the experimental group housing phase. Four days later, 39 days pp, does were returned to the first compartment to prepare for their next litter. Kits remained in group and were sold to a slaughterhouse at 10–11 weeks of age.

Fresh hay was provided during the first three weeks of each reproduction cycle. All animals were given a commercial pellet rabbit feed (Country's Best CUNI TOP pure, Versele-Laga, Deinze, Belgium) and water ad libitum. Non-pregnant and non-lactating does were restricted to a daily ration of 150 g of feed. Kits were given the same feed with an added coccidiostat (Country's Best CUNI TOP plus, Versele-Laga, Deinze, Belgium) three days prior to weaning until one week before slaughter. Artificial light was provided at a cycle of 12 L:12 D, except for 7 days prior to AI when the light cycle was changed to 16 L:8 D to stimulate doe receptivity. Air temperature was set at 20–21 °C and relative air humidity was between 60% and 75%. In the second reproduction cycle, one week after parturition, all does received a *Pasteurella* vaccine. With the cooperation of accredited Belgian animal shelters, does were rehomed after nursing their last litter in the fifth reproduction cycle.

2.2. Data collection

Skin injuries of does and kits were checked just before group housing on day 22 pp. Ten different body parts were checked for injuries: ears, eyes, nose, head, trunk, front paws, hind paws, tail, abdomen and genitals. For each skin injury observed, the severity and location on the body were noted and kept as reference for future scoring to prevent scoring injuries sustained prior to the onset of the group housing phase. Injury severity was scored using a tagged visual analogue scale (t-VAS) ranging from 0 to 10 (with higher scores corresponding to more severe injuries), following Van Damme et al. (2022). Scores of skin injuries on sensitive body areas (eyes, nose and genitals) were multiplied by two. New injuries (defined as injuries that were not present before the rabbits were grouped) were scored again on day 1 and 13 after grouping, independently from each other. On both observation days, skin injuries present before grouping (see above) were ignored. Severity scores of individual injuries were added to acquire a total sum for each rabbit (total score). As three observers were involved for scoring injuries, an inter-rater reliability test was conducted prior to the experiment. An intraclass correlation coefficient (calculated in R 3.6.0 with the ICC package) of 0.82 (95% confidence interval 0.76–0.87) was obtained and this is considered good reliability between observers (Koo and Li, 2016).

Prior to grouping does and their kits, infrared cameras were installed above all multi-litter cages. All does were sprayed with a unique mark with animal-friendly black paint for individual recognition. Doe agonistic behaviour was expected to occur directly after grouping (Munari et al., 2020; Trocino et al., 2016). Recordings from all cages were scored continuously for doe behaviour during the first 24 h after grouping in the first and second reproduction cycle and for the first 8 h in the third cycle using Observer XT14 software (Noldus, The Netherlands). Eleven mutually exclusive social behaviours were scored

Table 1

Ethogram used for behavioural observations of does. For all behaviours, the frequency of behaviours (mutually exclusive) were noted. If less than two seconds elapsed between two continuous displays of the same behaviour, it was counted as only one occurrence of the corresponding behaviour. The duration of non-aggressive social contact was tracked.

Behaviour	Description
Threat	Quick movement towards other doe, ears flattened but no physical contact is made
Approach	Slow movement towards other doe, ears flattened or standing, can include physical contact
Attack	Quick movement towards other doe, neck stretched out, ears flattened, physical contact is made
Fight	Two does grip each other with their teeth and/or rip with the hind paws
Chase	Aggressive pursuing of other doe attempting to escape from the aggressor
Mount	Doe climbs on other doe and makes quick thrusting movements with the hind back
Counter attack	Doe reacts with attack or fight towards attacking doe
Submit/freeze	Doe is immobile and/or presses head and shoulders against floor, ears flattened, might drop nose below nose of other doe, immobile to approaching doe or being mounted by other doe
Flee	Running away from other doe, may involve jumping over approaching/attacking doe
Retreat	Moving away slowly from approaching/attacking doe
Non-aggressive social contact	Allo-grooming and/or laying or sitting together in physical contact with at least one other doe

(Table 1). For all behaviours, the initiator, the receiver and the frequency of the behaviours was noted. A behaviour was considered to have ended if more than two seconds elapsed between two consecutive displays of the respective behaviour or if another behaviour was initiated. Additionally, the duration of non-aggressive social behaviour was tracked.

2.3. Statistical analysis

All analyses were conducted with the statistical software R 4.1.2 (The R Foundation for Statistical Computing). Data was assumed to be sufficiently normally distributed based on visual inspection of the residuals of the models (Q-Q plots and histograms). For the skin injury data (total sum of injury severity scores per doe), a $\log(x + 1)$ transformation was necessary to acquire normally distributed residuals.

2.3.1. Links between doe post-grouping behaviour and skin injuries

Spearman's rank correlation was computed to assess the relationship between individual doe behaviour (frequency of each behaviour within the observation time) and total injury score of the same individual acquired on day 1 and day 13 after grouping. The same correlations were repeated between individual doe behaviour and the averaged total scores of her group mates and of the whole group.

2.3.2. Social behavioural strategy and personality profiles

Cluster analysis was used to group individual does together based on similarities of their social behaviour after grouping. Clusters were identified as social behaviour strategies so that for each doe within each reproduction cycle a social strategy could be identified. Behaviour data of 51 does (who participated for at least one cycle) were included in the analysis. The squared Euclidian distance measure was applied to compute the dissimilarity matrix and an iterative partitioning method (K-means cluster analysis) was used to create the clusters. Both the Hubert and D index proposed two clusters according to the majority rule. Once each doe was characterised with a social behavioural strategy (cluster) within each reproduction cycle, we identified personality profiles for each doe based on the consistency of their behavioural strategies during three consecutive cycles. Only does who participated for three reproduction cycles were retained for personality profiling

(62.7% of all does, $N = 32$).

2.3.3. Effects of social behavioural strategy and personality profile on skin injuries

We tested if the social behavioural strategy and personality profile of a doe were linked with skin injuries newly acquired on day 1 and 13 after grouping. The effect of strategy and profile were tested separately on the following outcome variables: doe's own total injury score, averaged total scores of her group mates and of the whole group. Each variable was analysed with a linear mixed model with doe social behavioural strategy or personality profile as fixed factor. Treatment (three or four does with or without enrichment) was added as an additional fixed factor. Reproduction cycle, multi-litter cage and doe ID were added as random factors to the models.

For each group, the group composition was expressed as either 'one offensive doe present in the group' ($N = 27$ groups) or 'multiple offensive does present in the group' ($N = 9$ groups). Averaged total scores of groups (outcome variable) were analysed with linear mixed models with group composition (proportion of offensive does) and treatment as fixed factors. Reproduction cycle was added as a random factor.

2.3.4. Skin injuries as proxy for typifying doe social behavioural strategy and personality profile

We tested whether skin injuries acquired on day 1 and 13 after grouping were predictor variables of the social behaviour strategy (outcome variable) adopted by individual does. For each doe, a generalized linear mixed model (logit link) was applied with her own total injury score as fixed factor. Treatment was added as an additional fixed factor. Reproduction cycle, multi-litter cage and doe ID were added as random factors to the models. The same models were repeated but with the averaged total scores of her group mates or of the whole group as predictor variables.

A linear discriminant analysis (LDA) was applied to predict if does belonged to a certain personality profile based on her own total injury score, those of her group mates or those of the whole group. LDA was applied as the independent variable was continuous (skin injuries) and the dependant variable categorical with three levels (three personality profiles). Data was split into a training and testing dataset using a 80:20 ratio, which is a common approach for LDA (Muraina, 2021).

3. Results

3.1. Links between doe post-grouping behaviour and skin injuries

The frequency of fights and counter attacks by a doe were positively

and significantly correlated with her own total injury scores on day 1 after grouping (Table 2). This indicates that does who displayed these behaviours were marked by higher skin injury scores. In contrast, does engaging in non-aggressive social contact had low skin injury scores (significant negative correlation). On day 13, only a positive significant correlation was found between fleeing behaviour and the own total injury score.

If does displayed attacking behaviour on day 1 after grouping, this increased the averaged injury score of her group mates (Table 2). The same relation was observed for both attacking and fighting behaviour on the averaged injury score on group level (including the doe herself) on day 1 after grouping. On the same day the frequency of non-aggressive social contact showed a negative correlation with the injury score on group level, whereas attacking and fighting were correlated positively. On day 13 after grouping, both the frequency and duration of non-aggressive social contact showed a negative correlation with the averaged skin injury score on group level (Table 2).

3.2. Social behavioural strategies

The cluster analysis revealed that does adopted two types of behavioural strategies after being mixed with other does (and their litters): 'offensive' or 'submissive/avoider' (Fig. 2A). The offensive behavioural strategy was characterized by a high frequency of approach, attack, chase, counter attack, fight, mount and threat behaviours towards other does, and a low frequency of flee, retreat and submit/freeze displays (Supplementary figure 1). The submissive/avoider strategy was characterized by higher frequencies of flee, retreat and submit/freeze behaviours (Supplementary figure 1). For all three reproduction cycles combined, the submissive/avoider behavioural strategy was more common than the offensive strategy (63.2 vs 36.8%, Fig. 2A). The majority of groups were composed of one offensive doe with two or three submissive/avoider does (75.0%). In the other groups (25.0%), more than one offensive doe was present.

3.3. Personality profiles

Of the 32 does that participated for all three reproduction cycles, three personality profiles were identified: 'consistently submissive' (40.6%), 'consistently offensive' (12.5%) and 'all-rounder' does (46.9%, Fig. 2B). Consistently submissive does adopted a submissive behavioural strategy in all three reproduction cycles (Fig. 2C). Similarly, consistently offensive does adopted an offensive behavioural strategy in all three cycles (Fig. 2D). All other does were profiled as 'all-rounder' as their behavioural strategy differed between cycles (Fig. 2E). See

Table 2

Spearman's rank correlation between individual doe behaviour ($N = 51$ does) and her own total skin injury score, the averaged total scores of her group mates (excluding herself) or on group level (including herself) acquired on the first (d1) and last day (d13) after grouping.

	Own injury score				Injury score of group mates (excluding doe)				Injury score on group level (including doe)			
	d1		d13		d1		d13		d1		d13	
	<i>r</i>	<i>P-value</i>	<i>r</i>	<i>P-value</i>	<i>r</i>	<i>P-value</i>	<i>r</i>	<i>P-value</i>	<i>r</i>	<i>P-value</i>	<i>r</i>	<i>P-value</i>
Threat (n)	-0.03	0.77	0.10	0.27	0.17	0.07	0.19	0.05	0.12	0.21	0.19	0.05
Approach (n)	-0.07	0.40	-0.06	0.49	0.16	0.09	-0.08	0.39	0.10	0.27	-0.10	0.30
Attack (n)	0.16	0.07	0.02	0.80	0.19	0.04	0.07	0.47	0.20	0.04	0.08	0.38
Fight (n)	0.20	0.02	0.003	0.97	0.18	0.05	0.05	0.61	0.19	0.04	0.10	0.31
Chase (n)	-0.02	0.85	-0.02	0.82	0.06	0.54	0.04	0.69	0.01	0.96	0.003	0.98
Mount (n)	-0.06	0.52	-0.01	0.92	0.05	0.57	-0.06	0.51	0.06	0.54	-0.06	0.53
Counter attack (n)	0.26	0.003	0.13	0.16	0.15	0.13	0.002	0.98	0.18	0.05	0.06	0.56
Submit/freeze (n)	0.13	0.14	0.12	0.20	-0.02	0.87	-0.01	0.93	0.08	0.42	0.01	0.91
Flee (n)	0.13	0.14	0.19	0.03	0.05	0.63	0.06	0.50	0.13	0.16	0.10	0.30
Retreat (n)	0.12	0.17	0.11	0.22	0.09	0.35	0.05	0.57	0.14	0.14	0.04	0.67
Non-aggressive social contact (n)	-0.19	0.03	-0.14	0.13	-0.13	0.16	-0.19	0.05	-0.20	0.03	-0.25	0.008
Non-aggressive social contact (duration)	-0.11	0.24	-0.16	0.08	-0.03	0.72	-0.18	0.06	-0.08	0.41	-0.26	0.007

n = frequency of behaviour; *r* = Spearman's rank correlation coefficient (0.0 – 1.9: very weak; 0.20 – 0.39: weak; 0.40 – 0.59: moderate; 0.60 – 0.79: strong; 0.80 – 1.0: very strong correlation)

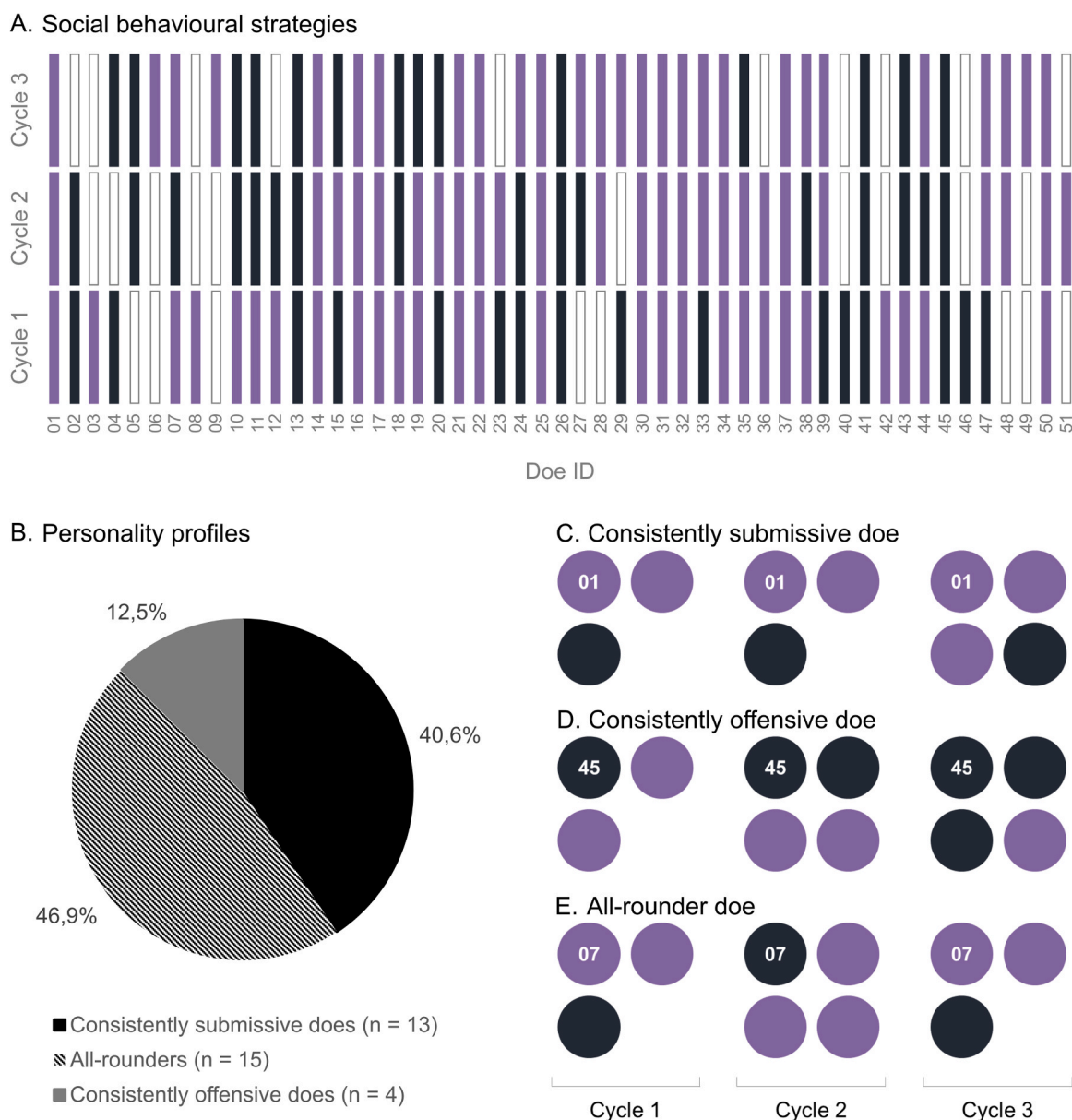


Fig. 2. A) Membership of individual does ($N = 51$) to a social behavioural strategy for each reproductive cycle as identified by cluster analysis: offensive (black) or submissive/avoider (purple). Lower, middle and upper bars represent the first, second and third reproduction cycle, respectively. White bars represent missing data (doe not participating in respective reproduction cycle). B) Frequency personality profiles of does ($N = 32$) based on their social behavioural strategies during three consecutive reproduction cycles. C) Example of a consistently submissive doe (ID 01). D) Example of a consistently offensive doe (ID 45). E) Example of an all-rounder doe (ID 07). Circles without a doe ID represent other does in the same group pen. Black and purple colours represent offensive and submissive/avoider does, respectively. Does who only participated for one or two reproduction cycles were excluded from personality profiling. See [Supplementary Figure 1](#) for a full overview of all does and their personality profiles.

[Supplementary figure 2](#) for a detailed overview of all does and their personality profile. Compared to the theoretical chance that a doe was consistently submissive, the actual occurrence of this personality profile was higher than expected (40.6 vs. 25.0%). Similarly, the occurrence of consistently offensive does was also higher than expected (12.5% vs. 5.1%).

3.4. Effects of social behavioural strategy and personality profile on skin injuries

No significant effects of individual doe behavioural social strategy or personality profile were found on doe skin injury scores during the first or last day after grouping. Strategy and profile also did not affect the averaged skin injury scores acquired by her group mates or skin injury

scores on group level on day 1 and 13 after grouping. Similarly, for the group composition (one or more than one offensive doe in the group), a significant effect on the averaged injury score in the group was absent. In all statistical models, a significant treatment effect (three or four does with or without enrichment) was absent.

3.5. Skin injuries as proxy for typifying social behavioural strategies

On both day 1 and 13 after grouping, there was no significant effect of the total injury score of does on their own social behavioural strategy. Similarly, significant links of averaged total injury scores of group mates with doe strategy were not present.

Also no significant effects of injury scores on group level with strategy or profile were found. A link between averaged total scores on

group level with group composition was also absent. In all statistical models, a significant treatment effect (three or four does with or without enrichment) was absent.

Based on the results of the LDA, higher total injury scores of the doe herself corresponded with consistently offensive or submissive personality profiles whereas lower scores correspond with all-rounder profiles on day 1 and 13 after grouping (Table 3). Similar trends were observed for the injury scores of group mates and on group level on both day 1 and 13 after grouping. Absolute differences between group means of skin injuries, however, were small and the accuracies for the linear discrimination analysis models were low (≤ 0.44 , Table 3).

4. Discussion

To our knowledge, social behavioural strategies of breeding female rabbits (relating to agonistic behaviour) have not yet been researched previously. In this study, two doe social behavioural strategies were typified with cluster analysis based on agonistic behaviour displayed by groups of three or four does housed in multi-litter cages. Does either showed an offensive behavioural strategy (characterised by a high frequency of aggressive displays) or a submissive/avoider strategy (high frequency of submissive displays and/or evasion attempts from other does). In the majority of the groups, one offensive and multiple submissive/avoider does were present (75.0%). This finding is similar to observations on wild rabbit colonies: some rabbits display relatively more offensive (including aggressive) behaviour whereas their group mates show more submission or retreats (von Holst et al., 2002). Assumingly, higher-ranked rabbits require these submissive acts from lower-ranked animals as confirmation of their social rank in the group (Mykytowycz, 1968; von Holst et al., 2002).

Nearly half of the does in the current study changed social behavioural strategy between reproduction cycles (46.9%). It is possible that does altered their strategy depending on those of their pen mates. A similar observation was discussed in a study on group-housed dairy cattle (Foris et al., 2018). The authors proposed that individual cow behaviour is subject to different (social) contexts and thus less fixed as previously assumed. In the current study, does were always housed with group companions they had not met beforehand. This may have influenced how they coped with hierarchy formation and which behavioural strategy they adopted in a specific social environment. Other does, however, did not change strategy between cycles (53.1%). The majority of these 'stable' does showed consistently submissive behaviour in each cycle and only a small proportion showed consistently offensive behaviour. The actual occurrence of consistently submissive or offensive personality profiles were higher than expected compared to the theoretical change, indicating that the occurrence of these profiles was no coincidence but was an intrinsic trait of the animals. Remarkably, consistently offensive does were also found in groups with other

offensive does (25% of all groups). This did not result in an increase in the skin injury score of the corresponding group which is contrary to our expectations. In this study, however, the sample size of groups with more than one offensive doe was limited which may have influenced the probability of finding such an effect.

Behavioural observations were limited in this study to no more than 24 h after grouping as the highest rate of agonistic behaviour was expected to occur directly after grouping (Munari et al., 2020; Trocino et al., 2016). Displays of agonistic behaviour to establish a hierarchy is part of rabbits' natural behaviour and is therefore hard to avoid when housing rabbits in group. It is, however, preferable that hierarchy is established quickly without severe injuries and prolonged unrest in the group. Possibly, adaptations to multi-litter cages (e.g. hiding and fleeing options) may help reduce severe aggression and skin injuries without inhibiting hierarchy formation; e.g. by using plastic floors in the cages instead of plastic comfort zones (Zomeño et al., 2018), providing digging opportunities (Krunz et al., 2023) or mixing does of different parities (Huang et al., 2021). For future research, it may be interesting to explore doe social strategies and personalities in relation to skin injuries once a stable hierarchy has been established.

Identification of breeding does that have a consistently negative impact on the group (based on injuries) could be useful for farmers to choose for more sociable does. Unfortunately, relying on extensive behavioural observations to identify such does is time consuming. Alternative methods, easier and less time intensive, are needed to identify does more likely to express non-aggressive behaviour or to form a stable hierarchy quickly and smoothly. Although the present study attempted to identify doe personalities based on skin injuries on individual and group level, strong links were not found. A few correlations between doe agonistic behaviour and skin injuries were observed but no links between social strategy or personality profile and skin injuries were present. Other proxy traits to identify sociable and antisocial does could be explored further. For example, Buijs et al. (2016) found that a greater ano-genital distance of female kits at birth was an indicator for a higher frequency of adult offensive behaviour.

If antisocial does could be identified, removing such does from the group, however, may not necessarily lead to an improvement as other does may take up its role. This phenomenon has been observed in wild rabbit populations (von Holst et al., 2002) and group-housed rabbits in captivity (Bill et al., 2020). Hierarchies within groups are often characterized by one dominant animal exerting control over its group members. Dominant rabbits typically display a higher frequency of offensive behaviours and removing such individuals from the group can lead to increased unrest compared to removing lower-ranked animals that primarily engage in submissive behaviours. Also our own results seem to confirm this: at least one offensive doe was present in all groups. Further investigation is required to determine if removing offensive does would result in reduced aggression rates and a decrease in skin injuries within group housing systems.

5. Conclusion

After housing three or four does in multi-litter cages during three reproduction cycles, two social behavioural strategies were identified based on doe post-grouping social behaviour: an offensive behavioural strategy or a submissive/avoider strategy. Based on social behavioural strategy between cycles, does were either marked with an 'all-rounder', 'consistently offensive' or 'consistently submissive' personality profile. Results could not confirm if skin injuries were correlated with doe strategy or profile or if injuries were a good proxy to identify doe strategy or profile. Future investigations could explore alternative traits (e.g. ano-genital distance at birth) that can serve as proxy indicators to identify 'sociable' does. It remains essential, however, to ascertain whether removing offensive does would indeed lead to reduced rates of aggression and fewer skin injuries in group housing systems for breeding does. Considering the importance of social interaction for rabbits and

Table 3

Output linear discrimination analysis: skin injuries acquired on day (d) 1 or 13 after grouping as predictor for doe personality profile. Skin injuries were divided in the total skin injury score acquired by the doe herself, the averaged skin injury score of her group mates (excluding herself) or on group level (including herself). Values represent the group means (of skin injuries) for each personality profile. Skin injury data was log-transformed prior to analysis.

	Own injury score ¹		Injury score of group mates ²		Injury score on group level ³	
	d1	d13	d1	d13	d1	d13
Consistently offensive	0.20	0.20	0.14	0.37	0.07	0.11
All-rounder	-0.07	-0.19	-0.10	-0.17	-0.09	-0.01
Consistently submissive	0.02	0.16	0.07	0.09	0.08	0.19

¹ model accuracy: 0.44 and 0.5 for d1 and 13 respectively

² model accuracy: 0.29 and 0.35 for d1 and 13 respectively

³ model accuracy: 0.24 and 0.18 for d1 and 13 respectively

the detrimental effects of severe skin injuries and stress on animal welfare, it is crucial to explore novel approaches that accommodate the social and behavioural needs of breeding does.

CRediT authorship contribution statement

L.G.W. Van Damme: methodology, investigation, validation, statistical analysis, visualisation, writing original draft of manuscript. **B. Ampe:** methodology, statistical analysis, visualisation, review and editing manuscript draft. **E. Delezie:** methodology, review and editing manuscript draft, supervision, funding acquisition. **J. Rommers:** review and editing manuscript draft. **F.A.M. Tuytens:** methodology, review and editing manuscript draft, supervision, funding acquisition.

Declaration of Competing Interest

None of the data were deposited in an official repository. The data/models that support the study findings are available from the authors upon request.

Data Availability

No datasets were published in an official repository.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.applanim.2023.106064](https://doi.org/10.1016/j.applanim.2023.106064).

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