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Effect of different rearing systems and pre-kindling handling on behaviour and performance of rabbit does

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A B S T R A C T

The aim of this study was to ascertain how collective cage and pre-kindling handling (training does to go into their own nest) practices, in comparison to standard housing (single cage rearing), modify the behaviour and the performance of rabbit does. To this aim, 40 nulliparous New Zealand White does were artificially inseminated, where the pregnant ones were assigned to three groups with the following treatments: eight does, kept in single standard cages (group S); eight does kept in two colony cages and trained to recognise their own nest (group TC); eight does kept in two colony cages, but not trained to recognise their own nest (group UC). Performance and behaviour, with particular attention to the social relationships of animals, were evaluated for one year. The housing system and training practice affected the behaviour of animals. Does kept in colony cages showed a wider behavioural repertoire, as well as fewer stereotyped and social behaviours. However, the interactions between animals were not always friendly; in particular, the UC group showed the highest incidence of aggressiveness: attack (26.61% *vs.* 13.55%) and dominance (12.98% *vs.* 8.81%) and lower allo-grooming (4.16% *vs.* 19.56%) in comparison to TC does. Negative correlation values between feeding and moving behaviours were obtained (—0.37 and —0.28) for TC and UC does, respectively. UC does showed significant correlation coefficients between stereotyped, moving and static behaviours (0.50 and —0.61, respectively). Different correlation values between moving and social interactions were shown for TC (—0.44) and UC does (0.48). In UC does, stereotypies were also correlated with social relationships (0.40) and, in particular, with attack (0.57; data not shown). Smelling one other was one of the major social activities, but while animals in the UC group exhibited a stable trend in the days close to kindling, in the TC group, the values increased from 20% (3 days before *partum*) to 75% (3 days after *partum*). Dominant and submissive features in TC does showed the same trends and decreased to about 0% after kindling; in contrast, in the UC group, dominant behaviours were performed even after kindling (4.8%) and submissiveness reached values similar to that of the first day of observation (about 35%). Reproductive performance and productivity of colony does were lower than S does. This reduction was lessened if does were trained to recognise their own nest. In the UC group, does had very low sexual receptivity (49.8%) and fertility rates (40.8%), a higher annual replacement of does (83.3%) and low rabbits sold/year/doe (17.7), probably due to the higher social pressure and aggressiveness, as confirmed by the percentage of does replaced due to severe injury (8.3%).

In conclusion, breeding does in a colony cage, without the training to recognise their own nest, renders the animals disagreeable to social encounters, does not assure adequate welfare or a productive performance and increases the possibility of suffering from injuries caused by attacks from other does.

1. Introduction

Worldwide rabbit meat production is currently esti- mated at 1,107,025 tonnes equivalent carcasses (TEC), corresponding to 856,797,000 slaughtered animals (FAO- STAT data, 2004). Commercial rabbit production is intensive in terms of technological inputs, concentrated diets and husbandry systems. In commercial rabbit production, rabbit does are commonly housed individually in standard wire cages (in cm: 60–65W × 40–50L × 34– 38H) and inseminated 11 days *post-partum*.

Group housing of breeding does was investigated during the establishment of modern rabbit husbandry methods, as it was less time-consuming than single housing, but at the end of the 1970s this practice ceased because of behavioural and hygienic problems and consequent poor productivity (Lecerf, 1982).

Currently, housing systems have to be consistent with animal welfare regulations and not only economically satisfactory for farmers. Such economic restraints imply that the productive unit must be organized in an efficient way. Therefore, most of the housing and management systems used in commercial rabbit farms are not ideal with respect to the ethological needs of animals, and need to be reconsidered. Indeed, the single cage isolates rabbits and prevents them from physical and visual contact and social interaction, particularly in solid-walled cages (Huls et al., 1991; Gunn-Dore, 1994). Furthermore, spatial restriction precludes the expression of some basic activities (Gunn- Dore and Morton, 1993), which can lead to atypical behaviours, indicative of frustration, anxiety or boredom (Gunn-Dore, 1994), and also to skeletal anomalies (Drescher, 1996). For all these reasons, greater attention has to be focused on developing alternative housing systems. In this context, the promotion of appropriate, environmentally friendly and economically sustainable housing systems should be improved.

Several solutions have been proposed for growing rabbits (Dal Bosco et al., 2000, 2002; Trocino et al., 2004); whereas only a few studies have been carried out for does and pups (breeding group pen, Stauffacher, 1992; double height cage and two-floor cage, Finzi et al., 1996; Mirabito, 2003, 2004; colony cage, Dal Bosco et al., 2004). Unfortunately, the proposed reproductive cages and rear- ing systems involve new welfare issues (Ruis, 2006):

the entrance of does to nest boxes of other does may cause high mortality and/or lower weights in young rabbits;

the aggression that may prevail in groups of does.

Until now, only Ruis and Coenen (2004), using an individual electronic nest-box recognition system, have attained satisfactory animal welfare conditions and reproductive performance, but with an enormous increase of production costs, making the use of the system at this time unwise.

Dal Bosco et al. (2004), in a preliminary study, observed that group housing of rabbit does meets their ethological needs and allows suitable performance when does were trained to recognise their own nests before kindling. Further studies were necessary to verify the real applicability of this prototype cage in a commercial context, without training, to reduce the production costs.

Therefore, the aim of this study was to ascertain how collective cage and pre-kindling handling practices modify the behaviour and the performance of rabbit does, with respect to standard conditions (single cage rearing).

2. Materials and methods

All procedures were carried out under EU Regulations for experiments on living animals.

2.1. *Animals, housing, experimental design and diets*

The research was carried out in the experimental rabbit farm of the Department Applied Biology of Perugia University. The environmental temperature and relative humidity were conditioned and controlled daily (range:
+15 8C to +28 8C; 60–75%, respectively) and the light programme was 16L/8D. The building was artificially ventilated (0.3 m/s) (International Rabbit Reproduction Group, 2005).

The colony cages were planned in collaboration with Metac-Ellebi s.r.l. manufacturing (Fabriano, Italy) and were built for four females reared at the same density

as in the conventional system. Its dimensions were 76W × 150L × 60H cm and it was equipped with four external shut-out nest boxes (38 cm × 25 cm × 35 cm) at the two ends of the cage (Fig. 1).

Twenty-four pregnant New Zealand White nulliparous rabbit does, 5 days before kindling, were transferred to single cages (n = 8) or to colony cages (n = 4) and treated as following:

Standard group (S): eight does were housed in single standard cages (38W × 60L × 34H cm), provided with an external nest box.

Trained colony group (TC): during the first 2 days in the new location, eight does were located in two colony cages and trained to go into their own nest, putting the same doe in the same nest and holding it inside for 10 min.

Untrained colony group (UC): eight does were housed in two colony cages, but not trained to go into their own nest.

In all groups 3 days before kindling, the holes to nest boxes were left open to permit the does to nest.

Reproductive performance was checked over a period of one year, from January till December, while behavioural observations were performed for three consecutive breed- ing cycles from January until the end of June.

Does were managed according to a cycled production system, which required no identification between cage– does. Every breeding cycle, does change cages; in particular, the does of the colony groups changed without any consideration of the original group.

After 24 h from weaning (30 days), the does of all groups were moved into traditional single cages and submitted to artificial insemination (AI) (Dal Bosco et al., 2007). AI was performed in the morning by inseminating 0.3 mL of diluted fresh semen, containing about 10 million spermatozoa (Castellini and Lattaioli, 1999). No oestrus synchronisation was done. Ovulation was induced by inoculating 10 mg of GnRH (Lutal-Hoechst); if non- pregnant, does were replaced by pregnant ones of the same age and genetic strain. During the first 16 days of lactation, controlled nursing was performed by permitting the does access to the nest only once a day for 15 min. Milk output was determined by weighing the doe immediately before and after suckling (Castellini et al., 2003).

Chemical analysis of feed was performed according to AOAC procedures (1995), where the composition was: crude protein 18.7%, ether extract 4.8%, crude fiber 14.7%,
ash 9.2%, NDF 29.2%, ADF 18.5%, ADL 3.3%, cellulose 14.5%, hemicelluloses 10.6%; estimated digestible ener- gy = 10.9 MJ/kg (according to Maertens et al., 1988).

2.2. *Ethogram*

In order to establish the ethogram of does the behaviours observed and categories of behaviours are reported in Table 1. Colony-reared does were marked with a different spray colour on their back, while S does were recognised on the basis of the cage number.

The following social relationships, feasible only in colony groups, were recorded: smelling others, allo- grooming, attack, dominance and submissiveness features. A doe was considered dominant when observed to be mounting, biting and scratching another doe or sitting, with a tense body posture and with erect ears and tail, near another doe that, instead, performed a crouched posture avoiding visual contact, rolling over on the back, ears back and tail tucked (McBride, 1988).

2.3. *Behaviour observation techniques and calculations*

The behaviours were recorded by two operators in the morning (9–11 a.m.) and in the afternoon (2–4 p.m.) and reported on a designed table, using the focal animal sampling method (Martin and Bateson, 1986). Before each observation, 5 min were allowed for the animals to adapt to the presence of the operators. S group was observed for a daily mean periods of 10.0 min (5.0 min in the morning and 5.0 min in the afternoon). For colony groups, relative to social relationships, observation was extended by 3 min; the daily mean periods of observation for TC and UC groups were 10.8 min and 11.0 min, respectively.

To establish the end of a performed behaviour, 5 s were allowed to determine if the same behaviour was repeated; after this time, a new behaviour was recorded (Bornett et al., 2000). During the day of kindling no data were collected to provide a peaceful and quiet environment for does.

For each doe, the number of times a particular behaviour occurred, with reference to total observations, was converted into a percentage. Each behaviour of an individual doe was added together and divided by 8 to give a mean percentage for each observation period. Since no differences were found between the periods of the day and breeding cycles, all the data were pooled to obtain a mean value. Does from the S group were observed for a total of 1440 min (80 min/day × 6 days of observations × 3 breed- ing cycles); whereas the TC and UC groups were observed for 1555 min and 1584 min, respectively. Social beha- viours were analysed separately, calculating their fre- quency as a percentage of total social relationships. Social behaviours were observed for 190 min and 210 min, for TC and UC does, respectively.

2.4. *Reproductive performance*

The following reproductive traits were recorded: sexual receptivity (colour and turgescency of the vulva; a doe was judged receptive when its vulva was red or purple and turgid), fertility rate (kindling/inseminations × 100) and live-born pups. After three consecutive AIs, does that were never pregnant were replaced by rabbit does of the same age and genetic strain. The indices of efficiency were calculated in terms of: overall productivity (number and weight of rabbits sold/year/doe), production losses (difference between actual and theoretical production considering fertility rate = 100, mortality of the young rabbits = 0 and kindling interval = 60) and efficiency of the system (Cas- tellini et al., 2005). The percentage of does that had severe skin injuries was also calculated and the distribution of injuries over the different body parts was registered.

2.5. *Statistical analysis*

Statistical analysis of behaviour patterns and repro- ductive performance was performed using a linear model (StataCorp., 2005, proc GLM) considering the effects of rearing system, and the significance of differences were evaluated by *t*-test. Non-parametric variables (sexual receptivity, fertility, pre-weaning mortality and annual replacement of does) were analysed with x^2. Differences were assessed as significant when $P < 0.05$. The beha- vioural patterns of the does were also analysed by multivariate analysis (proc factor) to summarise variables and to detect their relationships.

Social behaviours were excluded from this analysis since they concerned only the colony groups. Such behaviours were analysed with polynomial regression to fit the effect of the day *pre-partum* to behaviours observed *post-partum*.

Correlation analysis was also performed separately for the two colony groups, to avoid spurious positives significant level was calculated according to Bonferroni adjustment.

3. Results

3.1. *Behavioural patterns*

The does of the different groups showed changed behaviours (Table 1). The moving activities of does reared in colonies were significantly higher than for control does. TC does showed the lowest percentage of feeding behaviour with respect to those of S and UC. Comfort behaviours were higher in S does, intermediate values were observed in the TC does and the lowest values were observed in UC does. Regarding biting the cage bars, the highest percentage was found in S does; between colony groups, UC does showed the highest percentage, while the lowest was found in TC does. The highest percentage of smelling bars was found in S and TC does, while the lowest percentage was found in UC does.

Static positions were the more common behaviours performed (40.29%, 47.07% and 44.82%, respectively, for S, TC and UC does; data not shown). With regard to static behaviour in the colony groups, the most frequent position was laying down with stretched legs, whereas, in single- caged does, crouching was the most performed behaviour. The does in single cages showed lower frequencies for sitting-up and standing-up on hind legs (in comparison to both colony groups).

Does reared in single cages were significantly different in terms of standing alert and nesting compared to colony does; within colony groups TC does spent less time standing alert.

Naturally, social relations were present only in colony groups. The detailed analysis of social relationships of colony groups showed a different percentage and dis- tribution from the main social behaviours. Percentages of social behaviour (Table 1) showed that TC does, in comparison to those of the UC group, performed more allo-grooming, as well as lower attack and dominance. In both groups of does, the most expressed social behaviours (Figs. 2 and 3) were smelling each other, but with different trends; in fact, in TC does, the values increased from 20% (3 days *pre-partum*) to 75% (3 days *post-partum*), while, in UC does, this increase was less marked, from about 55% (3 days *pre-partum*) to 65% (3 days *post-partum*).

Allo-grooming in TC does, more than 3 days after kindling, was still represented (about 25%), while, in UC does in the same period, it was absent.

Regarding dominant and submissive features, these two behaviours in TC does showed the same trends and were almost absent 1 day after kindling. In the UC group, dominance behaviours were performed until the third day after kindling (4.8%) and submissiveness, after a decreasing trend corresponding to kindling, reached a value similar to that of the pre-kindling period (about 35%).

In Table 2, correlation values between behaviours are presented. Negative correlation values between feeding and moving behaviours were obtained for TC and UC does, respectively. Significant correlation coefficients between stereotypy, moving and static behaviours were found but only for UC does.

Differences in the correlation between moving and social interactions were shown for TC and UC does. Significant correlation coefficients between social and eat was found only for TC does.

In UC does, stereotypies were also correlated with social relationships and in particular with attack (0.57, $P < .0001$; data not shown).

Multivariate analysis

An overview of relationships between behaviours in the three experimental groups is shown in Fig. 4a and b.

From the score plot, it is clear that does in a single cage were characterized by "stereotype" and "eat" activities, while the colony does were discriminated on the basis of their "moving" activities.

Variables "eat" and "stereotype" showed a positive association; moreover, "eat" was negatively correlated with "moving" whereas "stereotype" was correlated with "static".*Reproductive performance and productivity*

Experimental groups showed different reproductive performance and indexes of global productivity (Tables 3 and 4).

Colony groups usually showed the worst performance and, in particular, the UC group as compared to S and TC had lower sexual receptivity, fertility, live-born pups, milk production and weaned pups. In addition, TC does, with respect to S, showed lower sexual receptivity, fertility and milk production. TC does always demonstrated values of reproductive performance and indexes of global produc- tivity intermediate between S and UC.

UC does also showed lower global productivity (Table 4) as revealed by the lowest number of rabbits sold/year/doe, live weight sold/year/doe, production losses, kindling interval and annual replacement of does. In the UC group, a higher percentage of replaced does was associated with severe skin lesions on their heads, ears and backs.

4. Discussion

Housing conditions affected the does' welfare because of the possibility of performing *species*-specific behaviours. In particular housing system and training practice affected the behaviour of animals and does kept in colony cages showed a wider behavioural repertoire, as well as fewer stereotyped and social behaviours, but interactions between animals were not always friendly.

In agreement with Gunn and Morton (1995a,b), who showed that maintenance activities have a high diurnal distribution, the "static" activities were the most common activities observed in all groups of does; this result wasprobably found because observations were performed only during the light period and because rabbits are crepuscular animals (Jilge and Hudson, 2001).

The greater dimensions of the colony cage allowed does to assume positions such as lying, sitting and standing-up on hind legs, as observed by Rommers and Meijerhof (1998). Kraft (1979) demonstrated that time spent inactive (equal or more than 40% of all the daily activities) is a very important behavioural pattern and that the body posture of lying down with legs stretched out is a species-specific posture (EFSA, 2005). This finding is in agreement with both the negative correlations found in colony groups and with the multivariate analysis results between "stereo- typies" and "static" activities.

Unfortunately, in the S group, the confinement pre- vented lying down with legs stretched out as well as sitting-up on hind legs (34 cm *vs.* 60 cm were the respective maxima of standard and colony cages). These does performed a great percentage of crouching behaviour in hunched posture with the head held low in the corner of the cage, which was classed as a non-reactive state of boredom (Gunn and Morton, 1995a,b). In addition, they showed a high frequency of biting and smelling bars and standing alert. These results are in agreement with the findings of other authors (Lawrence and Rushen, 1993): animals housed in single-cages performed some stereo- typies such as repetitive jumps, smelling bars, standing alert, chewing, licking and biting the bars.

Moreover, the greater dimensions of the colony cage allowed does to perform more intense motor activity which was also "qualitatively" different; colony does walked and smelled mainly to explore the cage, whereas the S does jumped forward and backward in a repetitive way without any clear reason (65.53% *vs.* 14. 60% and 13.75% of moving, respectively, for S, TC and UC does; data not shown).

The frequency of these comfort activities among the colony does may have been due to the need for cleaning their fur from the odours of conspecifics.

The colony cage permits the does to form social relationships. These behaviours consisted of smelling, allo-grooming, attack and dominance-subordination fea- tures (Bigler and Oester, 1996); however, such relations appeared friendly only in TC does. The training to recognise their own nests probably contributed to render social encounters more friendly. Indeed, in TC does, the dominance patterns were concentrated during the first 2 days, when the colony was forming, and the main social activities were smelling and licking, functioning to increase group cohesion (Stauffacher, 1989). This situation was confirmed also by the positive correlation found between eat and socials behaviours in TC does; in fact according with Gunn and Morton (1995a,b), social behaviours include allo-grooming and group foraging activities.

Among UC does, the dominance, attack and submissive- ness patterns were shown throughout the experimental period, accompanied by a great percentage of time spent standing alert. This last behavioural pattern was attribu- table to social pressures suffered by these animals. One more confirmation of the suffering of UC does due to the social relationships could be found in the correlations of stereotypies with social relationships and, in particular, with attack. In addition, the high Pearson coefficient between "moving" and "social" could indicate that does also moved to avoid or to escape from the social encounters with other does. Moreover, the UC group presented more severe skin injuries among does, confirming that this group displayed aggressive behaviour to each other.

This aggressiveness could be ascribed to the competi- tion between UC does at the same physiological stage (pregnancy and lactation) for certain nesting sites. This hypothesis is consistent with the work of Stauffacher (1989, 1992) who reported competition between does at the same lactation stage for certain nesting sites. More- over, aggression is principally triggered when, as in our case, previously unfamiliar does are put together, when new does are introduced to the group associated with pregnancy and by competition for nesting places (Held et al., 1995; Stauffacher, 2000; Bigler, 2004). In agreement with Mirabito (1998), we found that does need their own space for all maternal behaviour (nesting, kindling and lactating). We are also in agreement with Myers and Poole (1959), who found an increase of aggressiveness in close proximity to the nest. In addition, Held et al. (1995) found that although aggressiveness was rare in a group of domesticate does, it can become relevant when living space and flight distance are limited, particularly for low- ranking animals that cannot withdraw when attacked; this aggressiveness was associated with sexual and, in our study, nesting and maternal behaviours.

Agonistic encounters constitute potent, socially rele- vant stressors (Zayan, 1991; Summers, 2002), as indicated by manifold changes in physiological and neuroendocrine processes that accompany social interaction (Blanchard et al., 2001; Sloman and Armstrong, 2002). Several authors (Creel, 2001; Abbott et al., 2003; Goymann and Wingfield, 2004) reported that the kind of social relationships might play an important role in animal stress and that fighting within new individuals may be the major cause of elevated corticosteroid concentrations. According to these findings, reproductive performance of S does, that did not have any social relationships, was higher in terms of receptivity and fertility rate as well as the numbers of live-born pups and milk production.

In colony does, receptivity, fertility and live-born pups were satisfactory only in TC does, while the UC group showed the lowest reproductive performance. These results agree with findings of other authors (Bilko and Altbacker, 2000; Verga et al., 2004), who found satisfactory reproductive performance in handled does, in particular in terms of receptivity and fertility, nest quality and number of weaned kits.

It is assumed that stress induces an increase of plasma prolactin level (Manteca, 1998), which is responsible for the hormonal antagonism that negatively affects the reproductive functions (Kermabon et al., 1995). Bench and Gonyou (2007) indicate that stress can reduce fertility by affecting the frequency and amplitude of LH pulses, ultimately depriving the ovarian follicle of adequate LH support. This will lead to reduced oestradiol production by slower growing follicles. Rommers et al. (2006) and Theau- Clement (2000), in studying colony-reared does, attributed the low reproductive performance to pseudo-pregnancy. In our study, the aggressiveness found in social relation- ships and the presumable incidence of pseudo-pregnancy, especially in the UC group, could have caused the lower reproductive performance in colony-reared does.

Regarding global productivity, S does showed good economic results while TC does showed intermediate values and UC does showed poor results. This was probably due to the higher social pressure felt by these animals; the high annual replacement was accompanied by the higher percentage of severely injured does.

5. Conclusion

Rearing does in a colony cage seemed to better satisfy the ethological needs of animals only if does were trained to recognise their own nest, otherwise the aggressiveness does not permit animals to perform their reproductive potential and produce. Breeding in single cages led to stereotypy. Breeding does in a colony cage, without the training to recognise their own nest, results in disagreeable social encounters, and does not assure adequate welfare or productive performance, as well as increasing the fre- quency of injury caused by attacks from other does.

Such problems could be solved by:

- training of rabbit does to recognise their own space to reduce the competition for nest sites at each breeding cycle, requiring great attention to doe behaviour, in particular to attacks;

- modifying the management of reproduction, rendering familiar the group of does, all sisters or reared together in a colony cage from weaning.

Naturally, both the proposed solutions increase the costs for farmers. In fact the management of rabbit farms implies the mixing of pregnant does from the previous breeding cycle with other "external" does to cover the non- pregnant ones, to render the unit productive. Thus, colony does suffer social pressure at each breeding cycle. Notably, the TC does that reached intermediate performance, exhibited partially reduced productivity.

This study of new welfare friendly housing systems could represent a contribution to the present literature considering the future and eventual development of EU Regulations. Further research is therefore needed to determine how to solve welfare problems without excessively increasing the production cost.

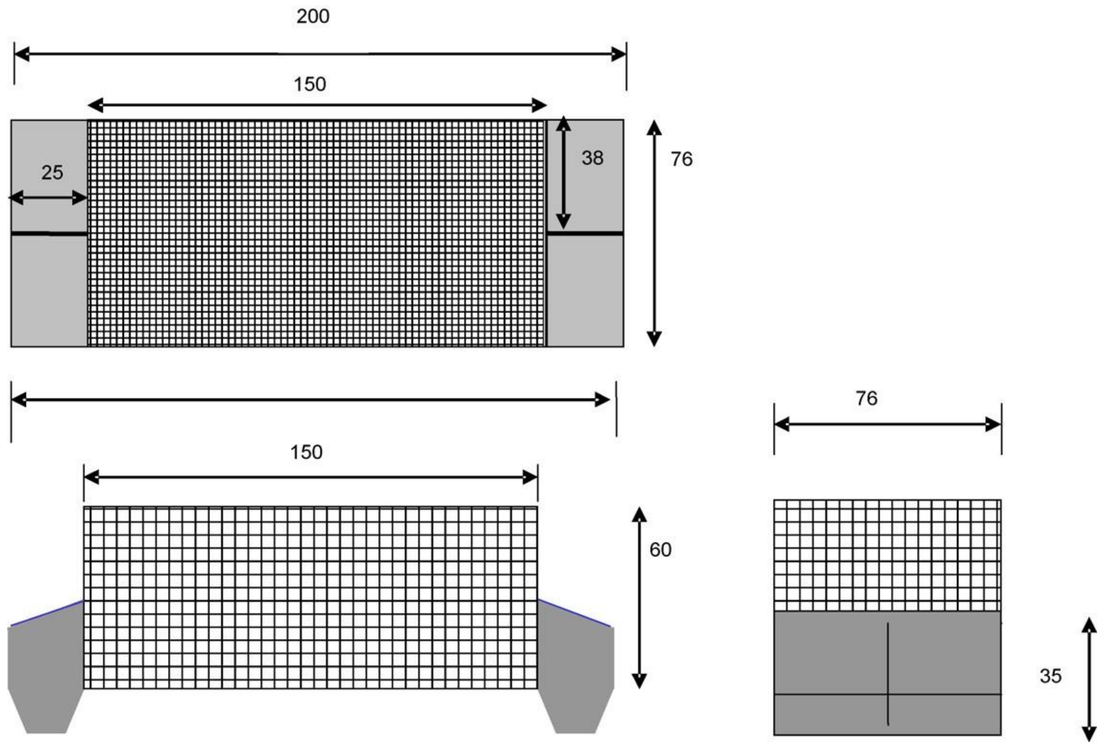

Fig. 1. Scheme of colony cage.

Table 1

Percentage of behaviours (respect total activities ± SD) and percentage of social behaviours (respect total social activities ± SD).

Behaviours observed	Categories of	S	TC	UC
Moving (walking and	Move	[illegible]	[illegible]	[illegible]
Jumping		1.92 ±	1.71 ±	0.99 ±
Feeding	Eat	10.74^{b} ±	3.58^{a} ±	9.66^{b} ±
Drinking water		3.00 ±	3.57 ±	3.68 ±
Comfort (self-licking and scratching)	Self	10.93^{b} ±	8.55^{ab} ±	6.84^{a} ±
Biting bars	Stereotypies	6.43^{b} ±	2.04^{a} ±	4.73^{ab} ±
Smelling bars		7.66^{b} ±	6.11^{b} ±	3.53^{a} ±
Lying down	Static	4.50^{a} ±	17.04^{b} ±	15.80^{b} ±
Crouching		29.15^{b} ±	11.32^{a} ±	10.33^{a} ±
Sitting-up		1.17^{a} ±	6.88^{b} ±	8.11^{b} ±
Staying		4.94 ±	5.84 ±	5.22 ±
Standing-up on hind legs		0.53^{a} ±	5.99^{b} ±	5.36^{b} ±
Standing-up on hind legs with erect ears	Standing alert	11.48^{b} ±	8.64^{a} ±	10.24^{ab}
Nesting	Others	5.74^{b} ±	3.11^{a} ±	4.06^{a} ±
Defecation, urination and coprophagy		0.80^{ab} ±	1.22^{b} ±	0.38^{a} ±
Smelling other	Social relationships	–	1.92 ±	2.04 ±
Allo-grooming (liking other)		–	0.86^{b} ±	0.20^{a} ±
Attack (chasing, biting and scratching other)		–	0.60^{a} ±	1.29^{b} ±
Dominance feature		–	0.39^{a} ±	0.63^{b} ±
Submissive feature		–	0.63 ± 0.20	0.71 ± 0.31

N = 72 (8 does × 3 groups × 3 breeding cycles). $^{a,b}P < 0.05$.

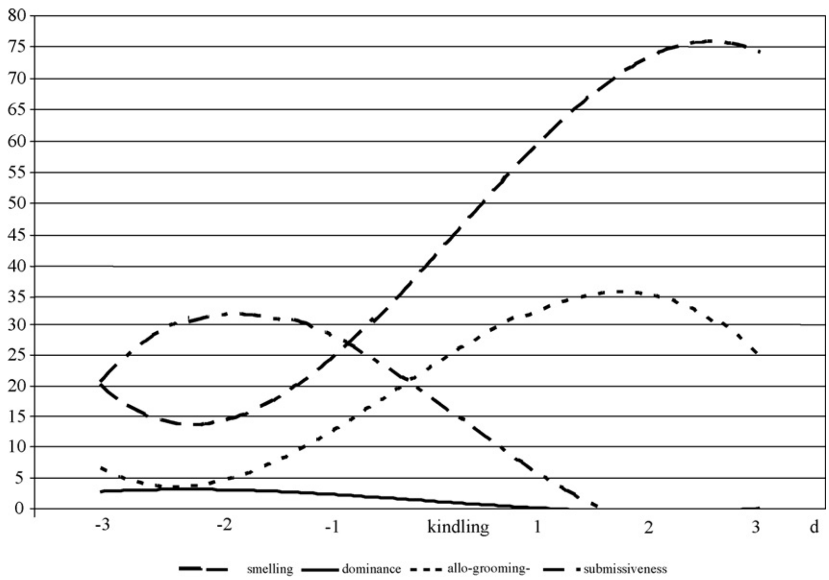

Fig. 2. Principal social relation ships of TC does (from 3 days before to 3 days after kindling). N: 48 (8 does × 2 groups × 3

cycles).

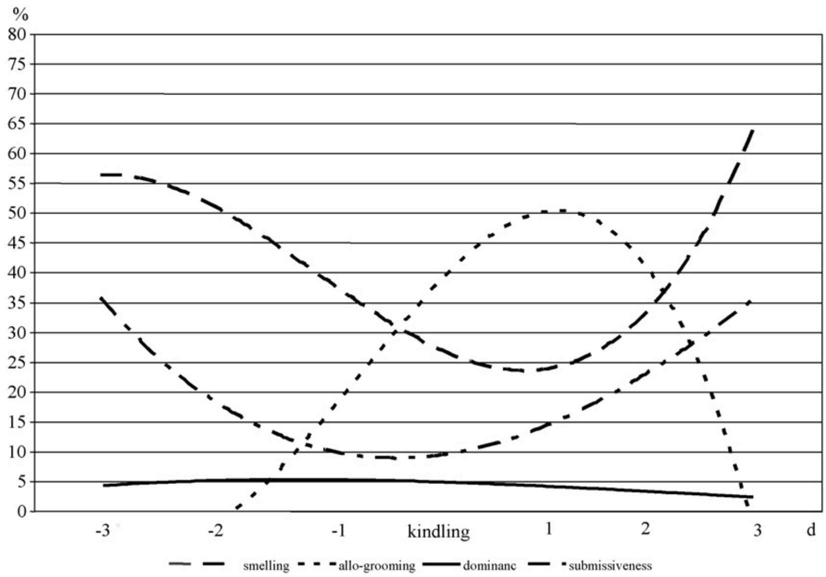

Fig. 3. Principal social relation ships of UC does (from 3 days before to 3 days after kindling). *N*: 48 (8 does × 2 groups × 3 cycles).

Table 2
Pearson correlation coefficients and probability of categories of behaviours of the two colony groups.

UC \ TC	Move	Static	Eat	Stereo-typies	Self	Socials
Move		-0.08 n.s.	**-0.37 P<.004**	-0.12 n.s.	**-0.30 P<.04**	**-0.44 P<.0001**
Static	**-0.76 P<.0001**		0.06 n.s.	**-0.18 P<.05**	-0.06 n.s.	-0.17 n.s.
Eat	**-0.28 P<.0001**	**-0.30 P<.05**		-0.08 n.s.	-0.11 n.s.	**0.41 P<.0008**.
Stereotypies	**0.50 P<.0001**	**-0.61 P<.0001**	0.21 n.s.		0.06 n.s.	-0.03 n.s.
Self	-0.05 n.s.	**-0.31 P<.05**	-0.06 n.s.	-0.03 n.s.		-0.16 n.s.
Socials	**0.48 P<.008**	**-0.60 P<.0001**	-0.05 n.s.	**0.40 P<.0001**	-0.05 n.s.	

n.s., not significant.

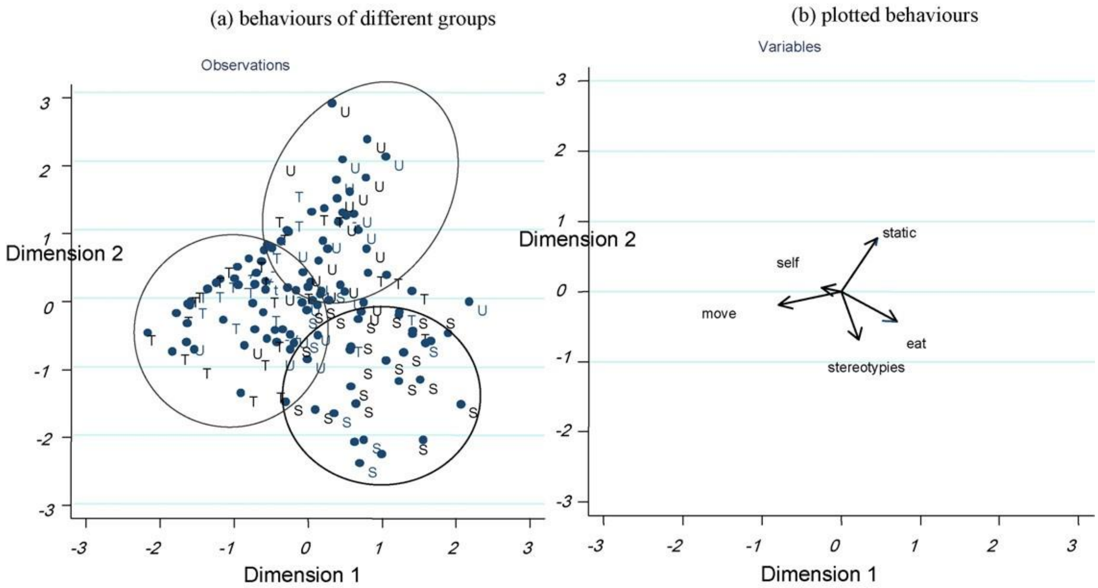

Fig. 4. Distribution of behavioural patterns of all experimental groups from multivariate factor analysis. N: 72 (8 does × 3 groups × 3 cycles).

Table 3

Reproductive performance (mean T SD).

	S	TC	U
Sexual receptivity* (%)	86.5^{c}	[illegible]	[illegible]
Fertility* (%)	75.5^{c}	61.2^{b} ± [illegible]	40.8^{a} ± 11.2
Doe weight at kindling (g)	3910 ± [illegible]	3810 ± 654	3890 ± 701
Doe weight at weaning (g)	4245 ± [illegible]	4145 ± 798	4185 ± 735
Alive-born (n)	7.5^{b} ± [illegible]	6.6^{ab} ± 1.8	5.8^{a} ± 2.0
Milk production (1–16 days) (g)	2450^{b} ± [illegible]	2220^{a} ± [illegible]	2055^{a} ± [illegible]
Milk/pup (g/day)	21.7 ± 5.4	21.8 ± 4.5	22.2 ± 6.5
Weaned pups (n)	6.6^{b} ± [illegible]	6.1^{b} ± [illegible]	5.0^{a} ± 1.7
Individual weight at weaning (g)	514 ± [illegible]	554 ± [illegible]	594 ± 36
Pre-weaning mortality* (%)	8.8 ± 1.8	9.2 ± 2.0	8.3 ± 1.6

N: 144 (8 does × 3 groups × 6 breeding cycles). *χ^2. $^{a,b,c}P < 0.05$.

Table 4

Indexes of global productivity (mean ± SD).

	S	TC	UC
Rabbits sold/year/doe	$70.8^{c} \pm 14.2$	$59.1^{b} \pm 10.1$	$40.5^{a} \pm 14.2$
Live weight sold/year/doe (kg)			
Production losses (kg)	$36.8^{a} \pm 8.7$	$47.2^{ab} \pm$	$63.8^{b} \pm 10.4$
Kindling interval (day)	$74.7^{a} \pm 2.5$	$83.3^{b} \pm 7.1$	$95.5^{c} \pm 6.2$
Kindling/year/doe (*n*)	4.9^{b}	4.4^{a}	$3.8^{a} \pm 0.8$
Annual replacement of does* (%)	62.5^{a}	75.0^{b}	83.3^{c}
Severely injured does		3.8^{a}	8.3^{b}

N: 144 (8 does × 3 groups × 6 breeding cycles). *χ^2. $^{a,b,c}P < 0.05$.

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