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ANIMAL WELFARE IN REARED RABBITS: A REVIEW WITH EMPHASIS ON HOUSING SYSTEMS

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Abstract: Research on rabbit welfare has been fragmentary and to date has been performed by only a few European teams who have often neglected the productive and commercial aims of rabbit rearing. With European Project COST Action 848 (Multi-facetted research in rabbits: a model to develop healthy and safe production in respect with animal welfare), rabbit welfare began to be considered in European research projects with the focus mainly on ethology, welfare evaluation methods, doe-litter relationships, man-animal relationships, and reproducing and fattening housing systems. As regards legislation, since 1996 the Standing Committee for the protection of animals kept for farming purposes established in the European Council by the Convention on the Protection of farm animals (ETS 87/1976) has been preparing specific recommendations to ensure improved welfare of domestic rabbits kept for commercial purposes, which should provide the basis for future European and national regulations. The European Commission asked the European Food and Safety Authority (EFSA) for its opinion on "The impact of the current housing and husbandry systems on the health and welfare of farmed domestic rabbits". The present paper provides a critical review of the existing literature on rabbit welfare with special emphasis on housing conditions.

Key words: rabbit, ethology, welfare, housing conditions

RESEARCH ON RABBIT WELFARE

It is not easy to find a satisfactory universal definition of animal welfare under differing environmental and rearing conditions (Sainsbury, 1986; Broom, 1993; Verga, 2000). In recent years, several definitions of "animal welfare" have been proposed, following the first provided by Hughes (1976), according to whom welfare is "a condition of perfect physical and mental integrity in which the animal is in complete harmony with the surrounding environment". The concept evolved further with Broom's definition (1986), for whom the condition of "welfare of an organism is measurable in relation to its attempts of adaptation to the environment". In other words, if the animal adapts to the environment rapidly, it is in a welfare status, whereas if adaptation attempts are numerous and consume too much energy, the animal is not in a welfare condition.

The most comprehensible definition however is offered by the Farm Animal Welfare Council (1991) and known as the "five freedoms", according to which animals are in welfare when protected and free from 1) hunger and thirst, 2) unsuitable housing and inclement weather, 3) illness and injury, 4) fear and anxiety, and, finally, 5) can freely express the behavioural pattern typical of their species. The first three freedoms are easily identified and measured, and generally pursued by farmers thanks to their positive effects on productivity. On the other hand, there is no guarantee that rabbits are not afraid of men or the environment and are able to freely express their specific behavioural repertoire,

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due to lack of the scientific information and objective methods required to measure these latter two "freedoms".

The research on rabbit welfare conducted up to the present has been fragmentary and limited to only a few European research groups and has often neglected the productive aspects and commercial aims of rabbit rearing. On the other hand, the wide-scale utilization of rabbits as laboratory animals has led to the production of a great deal of literature on neuro-endocrine, physiological and behavioural aspects and the effect of housing systems under laboratory conditions that also offers useful information on rabbits reared for meat production.

With European Project COST Action 848 (Multi-facetted research in rabbits: a model to develop a healthy and safe production in respect with animal welfare) initiated in 2000 under the scientific coordination of Luc Maertens (Belgium) and concluded in 2005, rabbit welfare became fully included among the research programs conducted by those European nations most involved in rabbit production. This Project was structured in five Working Groups (Reproduction, Pathology, Nutrition, Meat Quality and Welfare) acting in close conjunction (López, 2002; COST 848, 2005); the Welfare Group worked with the Reproduction Group on the consequences of the management of reproducing animals in terms of welfare, with the Quality Group on the effects of housing on final product quality, and with the Pathology Group on the consequences of stressing situations on immune status and consequent susceptibility to illness.

The main research lines of the COST Project and other national rabbit welfare programs are: ethology, welfare evaluation methods, doe-litter relationships, man-animal relationships, and reproducing and fattening rabbit housing systems (López, 2002).

To date, specific regulations on the defence of the welfare of rabbits reared for farming purposes have not been developed (Porfiri, 2002). The Standing Committee for the protection of animals kept for farming purposes established in the European Council by the Convention on the Protection of farm animals (ETS 87/1976) has been preparing since 1996 specific recommendations to ensure the improved welfare of meat rabbits which should provide the basis for future European and national regulations (Morisse, 1998). Because of fragmentary scientific information on the welfare of rabbits kept for farming purposes, in March 2004 the European Commission asked the European Food and Safety Authority (EFSA) for a report on "The impact of the current housing and husbandry systems on the health and welfare of farmed domestic rabbits" (EFSA, 2005a). On the basis of this report, a scientific opinion (EFSA, 2005b) reporting conclusions, recommendations and future research was presented to the Standing Committee at the end of 2005. As reviewed by EFSA (2005a), the current production techniques, and in particular housing systems, do not respect certain of the rabbit's fundamental biological characteristics.

BIOLOGICAL CHARACTERISTICS AND ETHOLOGY OF RABBITS

The study of rabbit behaviour is fundamental to an understanding of species requirements and the consequent adaptation of intensive rearing housing conditions. Rabbits differ from other livestock as the only domestic animal whose behaviour is assessed on the basis of the behaviour of the wild animal (Morisse, 1998; Verga, 1992, 1997 and 2000; Chu *et al*., 2004). Rabbit domestication is, in fact, quite recent and has not produced any substantial changes in behaviour compared with wild rabbits, but only in the intensity and frequency of some types of behaviour, such as higher daily activity in domestic rabbits.

Under natural conditions, rabbits prefer grassland with soil in which burrows can be easily dug that is also rich in vegetation for shelter when threatened by predators. Rabbits are herbivorous and characterized by caecotrophy; in semi-wild conditions, they spend from 30 to 70% of the day, depending on the season, searching for food and eating. Rabbits spend most of their resting time in groups and in close contact, demonstrating complex social activity that cannot be duplicated under some commercial rearing conditions, such as in individual or bicellular cages. The social unit is composed of from one to four males and one to nine females. Fights are not frequent because hierarchies are clearly defined. Bucks are tolerant towards females and young, whereas competition is sometimes observed among females choosing nesting sites.

Rabbits perform various comfort activities on their own bodies (self-grooming) and those of others (allo-grooming), and locomotory activities. The latter are highly typical of rabbits with hopping as the main expression. Rabbits usually move in small hops and make longer hops to overcome obstacles and reach elevated positions. Rabbit exploratory activity is mainly evident in digging and sniffing the surrounding environment, and sometimes associated with gnawing. Among the anti-predator responses, the positions of alert, high-speed running towards a shelter and immobility may be mentioned. As regards the latter behaviour, rabbits use freezing to confuse and escape from aggressors. Moreover, one rabbit is often found guarding the access to the common burrow and alerting the others in case of danger by thumping its foot on the soil.

As regards sexual behaviour, wild rabbits mate almost exclusively in the first hours after kindling and reproductive activity usually increases with increasing daylight in spring. In commercial farms, semi-intensive reproductive rhythms are used with mating 10-18 days *post-partum* rather than just a few days *post-partum* to avoid excessive doe exploitation. Reproductive performance remains high all-year round thanks to a constant photoperiod of 14-16 hours of light, while the use of artificial insemination prevents the expression of pre-mating behaviour, a characteristic of wild rabbits still present in domestic rabbits.

The maternal behaviour of rabbits differs from that of other mammals in the minimum parental care provided towards litters. In the wild, the doe leaves the common burrow 3 to 4 days before kindling and finds a new place to dig her nest, which she prepares with grass and, just before kindling, the fur she tears from her abdomen and chest. After kindling and attending to the new-born kits, the doe leaves the nest, closes it up, and comes back only to suckle the kits. Suckling takes place only once a day, usually after sunset, and lasts a few minutes (2 to 5), during which the kits ingest a high quantity of nutritive substance and energy sufficient for rapid development and growth thanks to the high milk protein and fat concentration. The doe opens the nest when the kits are around 18-20 days of age, in which period they begin ingesting doe faecal pellets and other solid material left in the nest, thus triggering caecal fermentative activity. In the wild, with the frequent mating of the doe soon after kindling, milk production drastically drops from the 20th day of lactation, and 24-25 days after kindling, the doe leaves the nest and litter definitively to prepare for her next kindling. If the doe is not pregnant, litter weaning is completed within the 5th and the 6th weeks of age.

RABBIT WELFARE EVALUATION METHODS

Although not always easy to perform, an objective evaluation of welfare conditions is essential in correctly assessing and comparing different commercial rearing conditions. In rabbits, as in other species, welfare conditions may be measured using either single or preferably groups of indicators, such as behavioural, physiological, pathological and productive indicators (Broom, 1993).

As mentioned above, even if there is still no animal model for the evaluation of domestic rabbit behavioural indicators, the observation of behaviour may be used positively to compare different management conditions and identify the possible occurrence of deviant behaviours (Koolhaas *et* *al*., 1993). Among these latter, kit scattering and cannibalism are frequently observed in rabbit does as well as aggressiveness. Both in growing and adult animals, stereotypes, that is abnormal behaviour repeated obsessively without apparent aim, have often been described (Verga and Carenzi, 1981; Lawrence and Rushen, 1993). The efficacy of direct observation is limited by the disturbance caused by the observer to the animal and the necessarily short observation time. Continuous or short-time interval video-recording permits this problem to be overcome and to obtain complete information on the rabbit ethogram over a 24-hour period. Bearing in mind the importance of rabbit nocturnal activity, video-recording with infra-red systems or low-voltage (10-15 V) lamps is necessary to avoid disturbance (Hoy, 2000).

By means of the "preference tests", that is giving the opportunity of choosing between different environments, the rabbits may be directly consulted about the "way they view the world" and feel in a welfare condition (Sainsbury, 1986; Koolhaas *et al.*, 1993, Morisse *et al*., 1999; Matics *et al*., 2004; Orova *et al*., 2004).

Useful information on rabbit adaptation and behaviour may be obtained by observing their response during so-called "reactivity tests" in which the reaction and fear towards man or a new environmental condition are assessed. The tonic immobility test is used to evaluate the reaction towards a man considered as predator (Carli, 1982; Bilèík *et al.*, 1998). The rabbit, held on its back in the operator's hands, enters a condition of tonic immobility of a duration that is considered positively correlated with the fear level. The condition of tonic immobility corresponds to precise physiological variations and its duration may also be conditioned by genetic factors. The open-field test measures animal reaction (exploration, movement, freezing, etc.) to an unknown environment consisting of a pen closed by wooden walls (Meijsser *et al.*, 1989; Ferrante *et al.*, 1992; de Passillé *et al.*, 1995).

Interpretations of animal behaviour during reactivity tests do not always agree because the reasons for similar behaviour may differ (de Passillé *et al.*, 1995; Rushen, 2000). For example, the locomotory activity of a rabbit during the open-field test may depend on the need to explore the new environment looking for food and shelter (a positive behaviour of adaptation) or be derived from the instinct of escaping a predator (a negative behaviour of fear). In any case, a high locomotory and explorative activity during the test is considered a sign of good adaptation, whereas longer freezing and immobility represent a reaction of passive adaptation considered negatively.

As is well known and has been widely described in many species, a prolonged stress condition implies a series of alterations in homeostatic equilibrium that leads to changes in physiological assets (Broom, 1993). Therefore, the measurement of some hemato-chemical variables (e.g. corticosteroid hormones, leukocyte number) may provide objective indications on the animal's stress condition (Koolhaas *et al.*, 1993). Blood sampling itself, however, causes stress to the animal and affects the level of these variables, especially the acute stress indicators. Among the physiological indicators, although heartbeat measurement has often been used in different species, few data are available for rabbits (Broom, 1993; Canali *et al.*, 2000).

The indicators of pathological conditions and productive performance are the most easily perceptible but must be interpreted with caution. Unsuitable sanitary conditions decrease welfare, whereas on the other hand, prolonged chronic stress causes a higher susceptibility to pathologies due to reduced immune response (Broom, 1993; Koolhaas *et al.*, 1993; Napolitano and De Rosa, 1997). Conversely, low productive and reproductive performance are not necessarily associated to lower animal welfare conditions (e.g. under extensive rearing conditions), while on the other hand, high performance may be obtained under intensive conditions that optimize productive factors but do not fulfil animal biological requirements.

DOE-LITTER RELATIONSHIPS IN COMMERCIAL FARMS

The characteristics of doe-litter relationships in the wild mentioned above and amply described by Hudson *et al.* (1996 and 2000) are substantially unchanged under intensive commercial conditions: the doe may enter the nest 2 to 3 days before kindling; soon after giving birth, the nest is often closed by the farmer for 7 to 18 days to perform controlled lactation, i.e. allowing the doe to enter the nest only once a day to suckle the litter for a few minutes. The advantages of controlled lactation have also been demonstrated for the litter, in terms of higher kit weight homogeneity and lower mortality, especially in the first days of life (Coureaud *et al.*, 1998).

Unlike in the wild, however, the doe, kept in the same cage with its litter, is not free to leave and close the nest at her own discretion after suckling. Under current breeding conditions, the separation of the doe from the litter is possible with minor nest adaptation for the first 12 to 15 days of lactation when the kits stay in the closed nest, whereas after the definitive opening of the nest, the doe never stays separate from her litter. Alternative cages with completely separated sectors or elevated platforms could be used to permit does to isolate themselves from their litters. According to Baumann *et al.* (2005), however, these latter modifications would not allow a nearer approximation to natural maternal behaviour: does should be provided with suitable material to close the nest, and the nest should be separated from the maternal cage by a distance sufficient to permit does to get away from the nest without perceiving kit odour.

Some authors affirm that does in the wild suckle more than once a day. Only 56% of the does free to enter cages at will, in fact, suckled only once a day, whereas 40% suckled twice or more often during the day and 4% did not suckle at all (Hoy *et al.*, 2000). The highest percentage of suckling was observed in the first hours of darkness, confirming the doe's preference for suckling during nocturnal hours (84-86%), even if some differences were observed between domestic and wild rabbits in the hours of preference (Hoy and Selzer, 2002). Most of the wild does did their suckling after midnight, whereas most domestic does suckled in the first two hours of darkness. The confirmation of these findings by further investigation could lead to substantial modifications in current lactation management.

MAN-RABBIT RELATIONSHIP

The man-animal relationship plays a key role in the commercial rearing of all species, but assumes particular importance in rabbits, due to their shyness and diffidence towards man (Rushen *et al.*, 1999; Verga, 2000). In rabbit farms, contacts between animal and man begin soon after birth and continue to be frequent, so usually a positive relationship free from fear of man is developed. In fact, fear levels fall when animals become accustomed to human presence and contact, and this improves their general welfare with positive effects on productive performance and health (Kersten *et al.*, 1989; Duperray, 1996; Jiezierski and Koneca, 1996). Among the actions that may be adopted to improve man-animal relationships, early manipulation has been shown to provide positive results and reduce levels of fear in rabbits and other species (Markowitz *et al.*, 1998; Jones, 2003; Csatádi *et al.*, 2005). Csatádi *et al.* (2005) observed reduced fear levels in kits handled for five minutes a day by the same operator for the first week of age. The effects of praecox litter manipulation on fear reduction in kits and its consequences on their future productive early reproductive performance are under study (Verga *et al.*, 2004a). Despite the possible advantages, this technique does not appear feasible in commercial conditions due to the amount of labour required and would be almost unnecessary because contacts between man and animal are already praecox and frequent in commercial farms. The standardization of kit numbers performed soon after kindling and during the first week of life combined with daily nest control represents very praecox and repeated manipulation of litters by breeders.

RABBIT HOUSING CONDITIONS

Based on their highly social behaviour in the wild, both reproducing and fattening rabbits should be reared in groups. Group rearing might be acceptable for young does before beginning their reproductive career and remating does, even if this required changing the current management system. It would most likely increase health problems. Group housing appears more difficult, however, for lactating does, and would probably cause higher kit mortality and reduce sanitary control on does and kits. Research on group housing in the reproducing sector is scarce and often limited to a few animals. Stauffacher (1992) proposed a 200 x 450 cm pen for rearing 1 male and 4-5 females equipped with separate areas for feeding and nests that contained different types of environmental enrichment. Behavioural observation showed the establishment of hierarchy among females and some competition for the nesting site, but no aggressive interaction among does and kits.

More recently, Mirabito (2005a and 2005b) compared three housing systems for reproducing does: conventional individual cages, modified cages for two does, and pens with net floors for four does. Young does were housed collectively to become accustomed to the system, but the culling rate increased due to a higher incidence of wounds. Reproductive performance was similar among groups, while kit mortality was higher in collective pens than in individual or two-doe housing due to several kindling taking place in the same nest. Behavioural records showed that does in collective pens spent 30% of their time together, but only 0.8% when kept in couples; the former moved more (2.7% of observations) than the latter (1.2% in couples and 0.6% in individual cages). In any case, however, the results of two-doe and collective housing experiments were not positive enough to demonstrate better doe and litter welfare than in individual housing. The installation of electronic devices for limiting the access of does exclusively to their respective nests (Ruis and Coenen, 2004), moreover, is unrealistic in a commercial context due to the high cost and difficult management. Preliminary results by Dal Bosco *et al.* (2004) show that a collective cage system (76 × 150 × 60 cm high with 4 females and 4 nests) may work efficiently if the doe is trained to recognise her own nest as follows: five days before kindling, each doe is put into an assigned nest, which is still closed, once a day for two days. When the nests are opened (three days before kindling), each doe returns to the nest she has recognised as her own for kindling. Even if these latter results have to be considered with prudence, because they were based on a low number of experimental units, this technique offers one possible solution to the problem of multiple kindling in the same nest. The same study showed that productive performance was unaffected by the housing system (Table 1), which clearly influenced doe behaviour, however (Table 2).

As regards housing conditions, Dresher (1996) showed that current reproducing rabbit cage dimensions promoted abnormal skeletal development (Table 3). The high rate of deformation in multiparous does was explained by the scarce possibility for locomotion and the low height of conventional cages that led to a prolonged flat-sitting position, systemic hypoplasia of bone tissue, and a caudal dislocation of body gravity centre due to the weight of the pregnant uterus. When does were kept in wider cages (6000 *vs.* 3000 cm^2), the time spent resting with the body completely extended increased significantly, while a greater cage height (50 *vs.* 30 cm) also allowed does to stand up (Rommers and Mejierhof, 1998a). However, these variations in cage dimensions did not affect productive performance. Mirabito *et al*. (2005c) did not observe any significant difference in reproductive time or budget time of reproducing does kept in cages with different available surfaces (about 3400, 4500 and 5900 cm^2).

Cage dimensions occupy the main point of discussion from a technical and economical point of view. The present situation for the reproductive sector in the main producing countries is represented in Table 4: for a lactating doe with its litter, cage width does not exceed 40 cm, depth varies from 85 to 100 cm, while height does not exceed 35 cm. Available surface ranges from 1200 to 1600 cm^2 , for

Table 1: Reproductive performance of does kept under different housing conditions (Dal Bosco *et al.*, 2004).

	Housing system	
	1 doe/cage	4 does/cage
Sexual receptivity, %	80.9	79.8
Fertility, %	73.6	70.4
Kits born alive, no.	7.5	6.9
Kits born dead, no.	0.7	0.9
Milk production (0-16 d), g	2321	2266
Milk production/kit, g/d	19.3	20.5
Weaned kits, no.	6.8	6.2
Live weight of weaned kit, g	575	601
Mortality until weaning, %	9.3	10.1

young or non-pregnant females and from 3400 to 4000 cm^2 for lactating does with litters. According to EFSA opinion (2005b), a breeding rabbit towards the end of pregnancy (4-5 kg live weight) would need a cage with a minimum 65-75 cm length, 38 cm width and 3500 cm^2 area, without considering the space of the nest. Moreover, height should be 38-40 cm minimum, at least in a part of the cage, to permit the rabbit to sit up with its ears erect. Both for practical purposes and welfare reasons, EFSA recommends a standard cage depth of 75-80 cm for both growing and reproducing animals.

The introduction of enrichment structures in breeding cages is not sufficiently supported by scientific evidence, in addition to being hard to accomplish from a technical point of view. Unlike in the wild, domestic rabbits do not hide when disturbed, even when suitable structures are present. When cages contain boxes for hiding, the rabbits spend most of their time above the box than inside (>800 *vs*. < 20 min during 24 h; Hansen and Berthelsen, 2000). When various types of enrichment were

Table 2: Behavioural pattern during direct observation (% of total activities) (Dal Bosco *et al.*, 2004).

	Housing system	
	1 doe/cage	4 does/cage
Moving	22.3[a]	26.8[b]
Feeding and drinking	4.9[b]	3.5[a]
Biting bars	8.2[b]	1.4[a]
Comfort (licking and scratching)	7.5[a]	11.1[b]
Smelling	15.4[b]	9.1[a]
Lying down	6.2[a]	18.2[b]
Crouching	9.1[b]	3.8[a]
Sitting in a hunched posture	4.2[b]	0.0[a]
Standing alert	1.9[b]	0.6[a]
Standing up on hind legs	1.2[a]	8.6[b]
Nesting	12.5[b]	1.3[b]
Social relationship	0.0[a]	6.9[b]

[a,b]: $P<0.05$

Table 3: Deformations of vertebral column in reproducing rabbits (Dresher, 1996).

Group	Rabbits (No.)	Sex	Cage type (width x depth x height)	Age at radiological investigation	Rabbits with deformations
1	20	Males	50 x 70 x 40 cm	12 months	0%
2	10	Females	50 x 60 x 40 cm	9-16.5 months	40%
3	20	Females	60 x 40 x 32 cm	2-4 years	70%
4	12	Females	50 x 70 x 40 cm (1-3 months) and then alternative cages[1]	3, 18, 22, 26 and 33 months	17%

[1]Cages with separate compartments for does, adults and young rabbits and litter boxes.

compared in adult males kept in individual cages, the least interaction was observed with the box (Lidford, 1997). Enrichment with hay or grass cubes decreased the frequency of abnormal behaviour (licking, gnawing or nibbling at cages) in laboratory animals (Lidford, 1997; Hansen and Berthelsen, 2000). The redirection of interest towards this type of enrichment may be explained, however, by the restricted feeding regime used for these animals (EFSA, 2005a). In farmed animals, research performed until now has not always clearly proven an improvement of rabbit welfare, even if stereotypes were sometimes reduced (Verga *et al.*, 2005). The rabbit's preference for some particular object of enrichment (straw, wooden objects) was also observed (López and Gomez Arciniega, 2003; López *et al.*, 2004: Carrilho *et al.*, 2005; María *et al.*, 2005).

Enriching the cage by putting raised platforms over the floor aims at satisfying the doe's need for isolation from her litter rather than stimulating exercise. Finzi *et al.* (1996) proposed this solution to increase the available surface per doe and observed that both the lower and upper parts of the cage were utilised basically to the same degree (45% and 55% respectively). Does in the second half of lactation spent more time (35%) on the platform than those in the first stage (20%) (Mirabito *et al.*, 1999a), even if it is not clear whether they were trying to escape from the litter (which also occupied the platform) or if they were looking for more space (Mirabito, 2003; Mirabito *et al.*, 2005c). Raised

Table 4: Dimensions of cages used in Europe for rearing of young females or lactating does with their litters and EFSA opinion (2005b).

Country Type of cage	Width (cm)	Depth (cm)	Height (cm)	Available surface (cm^2)
France/Belgium				
Young or not-pregnant female	26-30	45-50	29-30	1200-1500
Lactating doe with litter	40	90-100	29-30	3600-4000
Italy/Hungary				
Young or not-pregnant female	38	43	35	1600
Lactating doe with litter	38	95	35	3600
Spain				
Young or not-pregnant female	30	40	33	1200
Lactating doe with litter	40	85	33	3400
EFSA				
Breeding males and females[1]	38	65-75	38-40	3500

[1]Excluded nest dimension.

Table 5: Dimensions of cages and stocking density used in Europe for rearing of fattening rabbits and EFSA opinion (2005b).

Country Type of cage	Width (cm)	Depth (cm)	Height (cm)	Total surface (cm^2)	Rabbits per cage	Individual surface (cm^2)	Stocking density (rabbits/m^2)	Slaughter weight[1] (kg/m^2)
France/Belgium								
Multi-function	40	90-100	29-30	3600-4000	6-7	515-570	17.5-19.4	40.3-46.6
Italy/Hungary								
Fattening in pair	28	43	35	1200	2	600	16.7	41.8-41.5
Multi-function	38	95	35	3600	5-6	720-600	13.9-16.71	34.8-45.0
Spain								
Multi-function	40	85	33	3400	7-8	485-425	20.6-23.5	45.3-51.7
EFSA								
Multi-function	35-40	75-70	38-40	-	-	625	-	40

[1]Average slaughter weight: France, 2.3-2.4 kg; Hungary, 2.5-2.7 kg; Italy, 2.5-2.7 kg; Spain, 2.2 kg.

platforms also lead to important and still unsolved hygiene problems caused by the defecation and urination of the animals above on those below.

Also for growing rabbits, cage dimensions is under discussion in view of the European legislation now in preparation. The current commercial situation is represented in Table 5: in multi-function cages (reproduction and fattening) for group reared rabbits, width is 38-40 cm, depth varies from 85 to 100 cm and height from 29 to 35 cm. Available surface widely ranges from 425 to 720 cm^2 per rabbit, corresponding to stocking densities of 23 to 14 rabbits/m^2. In Italy and Hungary, fattening rabbits are usually kept in pairs in the so-called "bicellular" cages of about 1200 cm^2 at a stocking density of 16-17 rabbits/m^2. According to EFSA (2005b), fattening rabbits should be kept in collective cages with minimum 75-80 cm depth, 35-40 cm width and 38-40 cm height. Minimum individual surface should be 625 cm^2 and maximum slaughter weight 40 kg/m^2.

A great increase of available surface in comparison with the current commercial situation does not appear sufficiently justified by experimental evidence in rabbits kept either in individual cages or in collective cages or pens (Combes and Lebas, 2003; Mirabito, 2003; Maertens, 2004).

In fattening rabbits kept at two stocking densities (12 *vs.* 16 rabbits/m^2), both in individual cages or in collective cages with three animals, Xiccato *et al.* (1999) did not observe any significant differences in growth performance, open-field reactivity, immobility tests or skeletal development, and only a slight difference in tibia diameter ($P<0.10$) (Table 6).

On the basis of productive performance, Maertens and De Groote (1984) indicated that animals are in a critical situation above 15 rabbits/m^2 and/or 40 kg/m^2, while Aubret and Duperray (1992) considered a stocking density above 20 rabbits/m^2 corresponding to a slaughter weight above 46-47 kg/m^2 as critical (Table 7). The latter critical value was confirmed by Morisse and Maurice (1997), who investigated the effects of increasing stocking density on the behaviour of rabbits at 10 weeks of age, showing a longer resting time and shorter feeding and other activity times at stocking densities higher than 20 rabbits/m^2 and final weights higher than 40 kg/m^2 (Figure 1). The lower surface available for movement may explain the increase in resting, which increases with age, however, and the reduction of feeding due to a difficult access to feeders. Among the other behaviours, the increase of resting and exploration and the reduction of social activities were interpreted negatively by the authors as a

Table 6: Effect of stocking density in rabbits in individual and group (3 rabbits) cages (average data) (Xiccato *et al.*, 1999).

	Stocking density	
	12 rabbits/m^2 (830 cm^2/rabbit)	16 rabbits/m^2 (625 cm^2/rabbit)
Live weight at 35 day, g	924	920
Live weight at 80 day, g	2762	2747
Daily weight gain, g/d	43.7	43.7
Daily feed intake, g/d	127	124
Tibia length, mm	93.6	94.7
Tibia minimum diameter, mm	5.24^b	5.15^a
Tibia fracture resistance, kg	35.7	36.2

a,b: P<0.10

redirection of the animal's attention on its own body care and surrounding structures (cages or equipment). On the base of these results, a maximum weight at slaughter of 40 kg/m^2 was indicated as also being compatible with the correct behavioural expressions. When stocking density was increased in rabbits reared in pens on the ground, productive performance was impaired (Lambertini *et al.*, 2001) and the results of the open-field test showed increased freezing and reduced exploration (Ferrante *et al.*, 1997) (Table 8), both of which are passive reactions to a new environment and considered indicators of stress.

The growth performance of rabbits kept in collective cages (8 rabbits/cage) at two stocking densities (12 *vs*. 16 rabbits/m^2) until slaughter (70 days) was very high and comparable to the data obtained with individual cages (Trocino *et al.*, 2004). A reduction in feed intake was recorded only in the last two weeks before slaughter at the highest stocking density (185 g/d with 12 rabbits/m^2 and 179 g/d with 16 rabbits/m^2, P=0.06). Behaviour pattern recorded at 57 and 68 days of age was unaffected by the housing system, while the longer time dedicated to exploration during the open-field test in rabbits reared at the highest density (16 rabbits/m^2) should not be interpreted as a sign of higher stress (Table 9).

In accordance with the above results, Matics *et al.* (2004) observed that young rabbits free to move from one cage to another in a system of four connected cages of different sizes prefer to stay together in the same cage at very high density during the first weeks after weaning (until 60-70 rabbits/m^2). Thereafter, animals distribute themselves more homogeneously in the four differently-sized cages in such way as to achieve a similar stocking density in each one, even if they continued to prefer the smaller cages to the larger.

Table 7: Effect of stocking density on productive performance in growing rabbits from 32 to 68 days of age (Aubert and Duperray, 1992).

Number of rabbits/cage	6	7	8	9	10
Stocking density, rabbits/m^2	16.9	19.8	22.6	25.4	28.2
Daily weight gain, g/d	43.6^c	44.1^c	42.9^{bc}	42.1^b	40.3^a
Daily feed intake, g/d	132^c	130^{bc}	129^{bc}	126^{ab}	122^a
Mortality, %	0	3.6	1.6	0	0
Weight at 68 days, kg/m^2	39.7	46.6	52.4	58.1	62.8

a,b,c: P<0.05

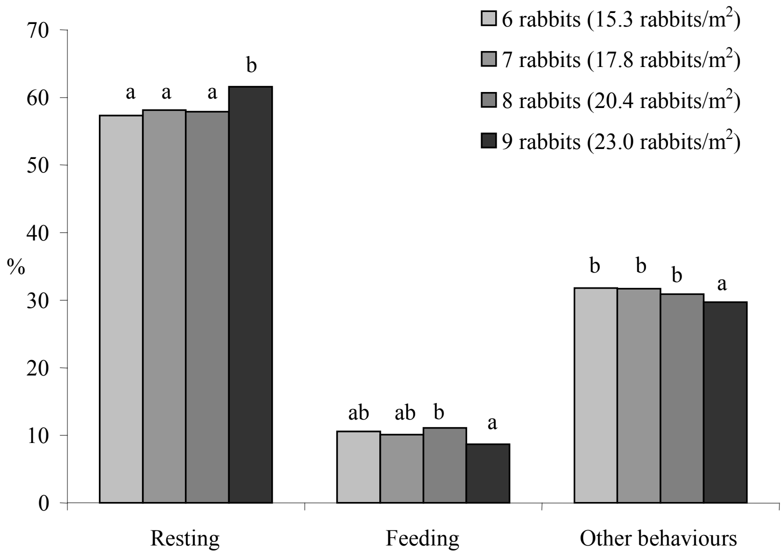

Figure 1: Distribution of behaviours (% of observations) in fattening rabbits at 10 weeks of age according to group size and stocking density (Morisse and Maurice, 1997). a,b: $P<0.05$.

Few experimental data are available on the effect of cage height on growing rabbits: Szendro *et al.* (2005) found that rabbits did not prefer high cages (20 *vs.* 30 and 40 cm), while they clearly disliked open-top cages. On this basis the authors concluded that the present commercial cages with 30-35 cm height do not impair the welfare of growing rabbits.

No one challenges the assertions that rabbits are highly social animals and that group housing is recommended to permit the complete expression of the species behavioural pattern. Unlike reproducing females, group housing poses no particular management problems for fattening rabbits, apart from a possibly higher spread of disease and the occurrence of aggressive behaviour. Fattening rabbits in medium-sized groups (7-10 rabbits) is common practice in all commercial rabbit production countries except Italy and Hungary, where rabbits are usually kept two per cage from weaning until slaughter. The higher slaughter age (80-90 days) necessary to reach the high market weight requested by consumers (2.5-2.6 kg on average) compared to France (2.3-2.4 kg) and Spain (2.0-2.2 kg), and the consequent possibility of increased aggressive behaviour and wounds are the two main reasons for this housing system.

Table 8: Effect of stocking density on performance and reactivity during the open-field test in fattening rabbits kept in pens on the ground (Ferrante *et al.*, 1997).

	Stocking density	
	12 rabbits/m^2	17 rabbits/m^2
Live weight at 90 days, g	2398^b	2232^a
Feed conversion index	3.85	3.86
Mortality, %	4.0	8.7
Freezing, sec	46.5^a	86.3^b
Exploration, sec	121.1^b	91.7^a

a, b: $P<0.01$

Table 9: Behavioural pattern (% of observations) and reactivity during the open-field test in group-reared rabbits (Trocino *et al.*, 2004).

	Stocking density	
	12 rabbits/m^2	16 rabbits/m^2
Behavioural pattern		
Feeding, %	11.1	10.3
Comfort, %	18.3	17.3
Resting, %	64.5	66.7
Moving, %	2.5	1.9
Reactivity during the open field test		
Moving, sec	59.0^a	69.8^b
Exploration, sec	401	411

a,b: $P<0.05$

Research has also shown behavioural patterns to be wider when rabbits are kept in groups, with the disappearance of stereotypes, reduced time spent in feeding and resting, and increased social activities, exploration, and occasional aggressiveness (Podberschek *et al.*, 1991) (Figure 2).

Several references document the effect of group size on productive performance and behaviour. Results often differ and may be confused by other factors of variability, such as stocking density, housing system, and slaughter age, etc. With small-sized groups (from 2 to 4-6 rabbits) kept in conventional cages, growth performance either improved by increasing group size (Mirabito *et al.*, 1999b) or remained unaffected (Verga *et al.*, 2004b), while behaviour significantly changes (Mirabito *et al.*, 1999c). Conversely, when comparing rabbits housed in conventional cages and in alternative pens on the ground (8-16 rabbits/pen), productive performance of the latter was impaired by the occurrence of unfavourable hygiene conditions and health status in pens (Dal Bosco *et al.*, 2000;

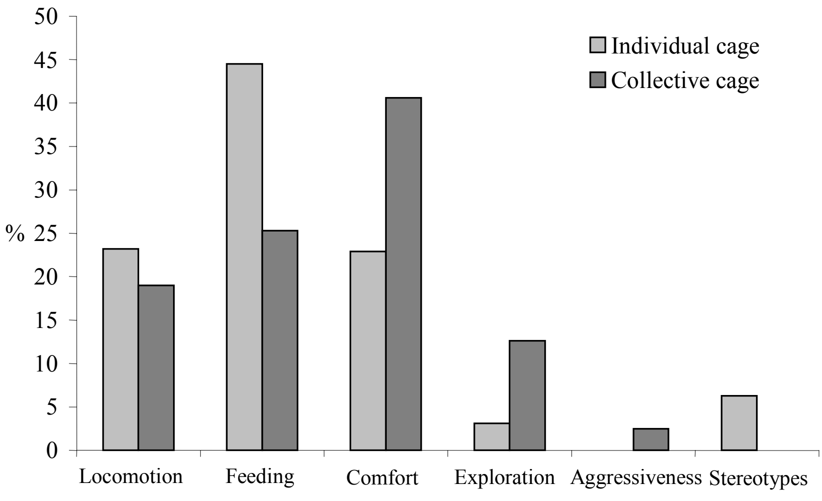

Figure 2: Behaviours recorded in fattening rabbits according to the housing system (Podberschek *et al.*, 1991).

Table 10: Growth performance, mortality and behaviour (% of observations) in fattening rabbits according to housing system (Dal Bosco *et al.*, 2002).

	Bicellular cage	Pen with straw	Pen with wire net
Final weight, g	2785^{B}	2428^{Aa}	2517^{Ab}
Daily weight gain, g/d	40.1^{B}	33.0^{Aa}	34.7^{Ab}
Mortality, %	3.5^{A}	13.2^{Bb}	9.8^{Ba}
Resting, %	60^{b}	50^{a}	54^{ab}
Ingestion, %	16^{b}	12^{a}	11^{a}
Comfort, %	7^{a}	11^{c}	9^{b}
Locomotion, %	13^{a}	18^{c}	16^{b}
Social activity, %	4^{a}	9^{b}	10^{b}

a,b,c: P<0.05; A, B: P<0.01

Lambertini *et al.*, 2001). Locomotory activity (hopping) and resting were different in rabbits housed 6 per cage compared to 24 per pen, while the frequency of abnormal behaviour was unaffected (Martrenchar *et al.*, 2001).

The possible occurrence of aggressiveness and the existence of a hierarchy seem to place limits on group size. According to Bigler and Oester (1996), when using a low stocking density (6.2 rabbits/m^2 on average) in groups with less than 10 rabbits, 75% of animals did not show wounds, 18% showed minor wounds, and 7% medium wounds; in groups with 10-15 rabbits, 23% had minor wounds, 4% medium-entity wounds, and 2.5% had severe wounds. Lastly, in groups with more than 40 rabbits, 38% showed minor wounds, 16% medium-entity wounds, and 5% severe wounds. Although obtained in the 60-80 day period, these results were unaffected by the sexual composition of groups. When rabbits were slaughtered at 72 d, Postollec *et al.* (2003) did not observe pathologies or lesions in rabbits housed at the same stocking density (15 animals/m^2) in conventional collective cages (6 rabbits/cage), small pens (10 rabbits/pen) or large pens (60 rabbits/pen). Rommers and Meijerhof (1998b) reported that wound frequency increased with age and regardless of group size. On the basis of these latter results, a maximum limit of 80 days has been recommended for the group rearing of fattening rabbits, even if the sexual precocity and growth rate of specific breeds or hybrids should also be taken into account.

As for reproducing rabbits, cage enrichment is also proposed for fattening rabbits, in this way stimulating hiding, rest and exercise. A part of the floor of pens and cages could be bedded with suitable litter: rearing on wire net floors is considered unsuitable for animal welfare, because it does not permit the expression of certain behaviour shown by wild animals, like scratching or digging. The wire net floor, however, is the best technical and hygienic solution and although reproducing rabbits more frequently suffer foot pad injuries, fattening rabbits do not, due to the shorter production cycle. In addition, despite the increased animal welfare claimed, the choice of providing litter on the floor is not justified by experimental results. In fact, when rabbits reared in collective cages with wire net floor were given free access to an area bedded with straw, they preferred the floor without straw (Morisse *et al.*, 1999; Orova *et al.*, 2004). The animals kept in groups in pens bedded with straw dedicated more time to cleaning their dirty fur and moving around in search of a more comfortable place inside the cage, thus expressing a lower welfare status (Table 10) (Dal Bosco *et al.*, 2002). The straw also impaired the growth rate of the animals, who ate it, and facilitated the transmission of diseases (Morisse *et al.*, 1999; Dal Bosco *et al.*, 2002).

Table 11: Growth performance of rabbits in enriched pens (Maertens and Van Oeckel, 2001).

	Enrichment		
	Absent	Straw	Wooden object
Live weight at 78 days, g	2490	2497	2533
Daily weight gain, g/d	37.6	37.6	37.9
Feed intake, g/d	113	110	114
Mortality and elimination, %	21.7	20.8	21.7
Non-vendible rabbits, %	6.7	4.6	3.8

Rather than satisfying an ethological need of rabbits, the presence of straw might represent an environmental enrichment that limits aggressive interactions in group-housed rabbits. Other enrichments have been proposed with the same aim, such as wooden or metal objects on the floor or hanging from the ceiling. In most cases, growth performance was unaffected by the presence or type of enrichment (Mirabito *et al.*, 2000; Maertens and Van Oeckel, 2001; Verga *et al.*, 2004b), whereas the number of rabbits with serious wounds or with final live weight lower than market demand seemed to decrease in enriched pens (Table 11).

On the other hand, animal behaviour is significantly affected by the presence or type of enrichment in both pens (Dal Bosco *et al.*, 2002) and collective cages (Verga *et al.*, 2004b). In particular, the presence of a wooden stick suspended from the cage ceiling to limit faecal contamination stimulated the activity of fattening rabbits by increasing the frequency of hopping and social interaction and reduced aggressiveness and stereotype frequency (Figure 3). Research on the subject is still insufficient to provide definitive results, however.

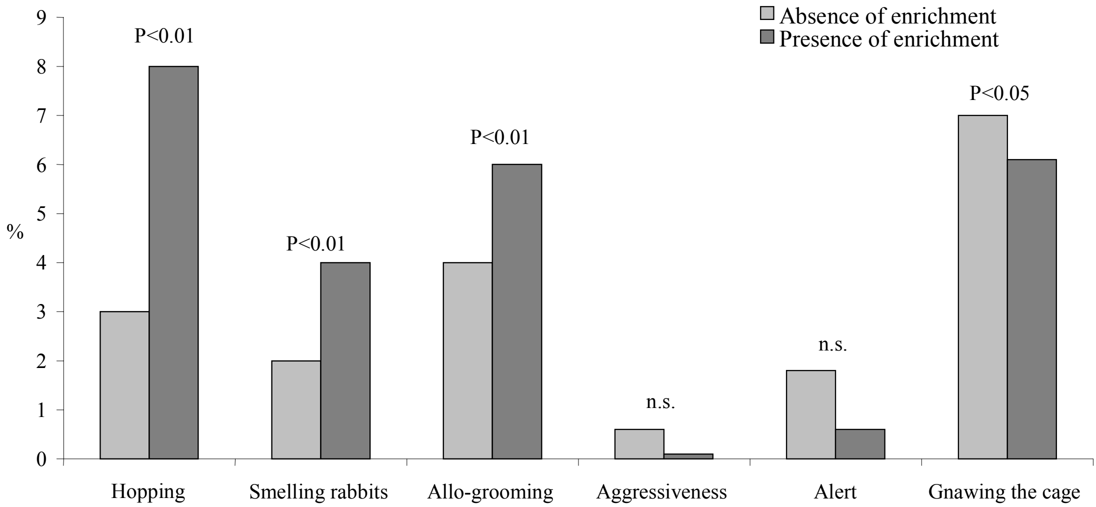

Figure 3: Behaviour of rabbits in collective cages according to environmental enrichment (Verga *et al.*, 2004b)

CONCLUSIONS

Research on the effect of the housing system on animal welfare is not yet sufficient to reach definitive conclusions on the best rabbit accommodation. As far as fattening rabbits are concerned, group rearing is surely the best choice to satisfy rabbit social behaviour, even if optimal available surface and group size need to be further evaluated, also with a view to maintaining high final product quality. In reproducing animals, alternative housing systems, that permit does to separate themselves from their litters, should be developed as well as group rearing systems which prevent abnormal reproductive behaviour and guarantee kit welfare and survival. Further investigation is also necessary on cage dimensions, equipment and floor types, to avoid abnormal behaviour and poor hygiene and health of kits and growing and reproducing rabbits.

Although several aspects of housing and rearing systems appear easily modified in commercial breeding without serious effects on commercial results and offer guaranteed advantages for both rabbit and farmer in terms of improved welfare, health conditions and productivity, other changes could or should be applied with proven benefit to animal welfare at costs that might be repaid in terms of an improvement in the image rabbit meat offers to consumers. Lastly, dramatic changes in individual space allowance, cage equipment, or in management and housing systems that have been proposed only at an experimental level will prove extremely difficult to apply in the current European production system, do not even offer a scientifically proven improvement in rabbit welfare and, if made compulsory by European or national law, could lead to a great rise in meat production costs.

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