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A REVIEW OF RECENT RESEARCH OUTCOMES ON THE HOUSING OF FARMED DOMESTIC RABBITS: REPRODUCING DOES

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Abstract: The housing of farmed animals is increasingly scrutinised by society and thereby subject to a change towards more animal-friendly systems. For rabbits, also kept as pets, there are no EC regulations regarding their housing under farming conditions. In many countries, studies have been carried out to improve their welfare and health under current and alternative housing systems. This paper reviews and integrates the research efforts made since the EFSA report in 2005 on reproducing rabbit does and provides some conclusions, where possible, with special emphasis on animal welfare according to the principles stated by the Welfare Quality® project, i.e. good housing, good health and appropriate behaviour. The use of an elevated platform provides greater opportunities for does and their kits to move, jumping up and down. Management and housing systems (especially flooring) must guarantee good hygienic conditions (all-in, all-out) and separation of the rabbits from their excreta for proper resting places, hygiene and health. Plastic floors and footrests and environmental enrichments (e.g. gnawing material) are also recommended. Continuous group housing systems for reproducing females have been definitively proven to challenge animal welfare by increased aggression and injuries among does and to kits. Part-time group housing systems have proven to have potential, but cannot yet be recommended in farms until major problems of aggression and injuries among animals are solved.

Key Words: rabbit does, housing equipment, enrichment, welfare, group-housing.

INTRODUCTION

In most European countries, society increasingly calls for more animal-friendly housing systems and the improved welfare of farmed animals. Directives have been issued by the Council of the European Union (EU) for protection of animals kept for farming purposes (Council Directive 98/58/EC of 20 July 1998), minimum standards for the protection of laying hens (Council Directive 1999/74/EC of 19 July 1999), minimum rules for the protection of chickens kept for meat production (Council Directive 2007/43/EC of 28 June 2007), minimum standards for the protection of calves (Council Directive 2008/119/EC of 18 December 2008) and minimum standards for the protection of pigs (Council Directive 2008/120/EC of 18 December 2008). In the case of rabbits, the European Council of Strasburg has drafted a comprehensive "Draft recommendation concerning domestic rabbit – *Oryctolagus cuniculus*" (T-AP (98) 1 rev. 18) which however was never definitively published. Thus, no regulation has been issued for the protection of farmed

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rabbits which, compared to other farmed animals, are more likely to provoke strong emotional arguments in the public opinion because they are also widely used as pets.

In the absence of EU directives, some member countries have drafted their own legislation or recommendations on the housing of farmed rabbits (The Netherlands, 2006; Hungary, 2009; Hoy, 2012; Belgium, 2014; Germany, 2014). Some countries have already opted for the abolition of cage housing systems (with small group sizes) and a gradual transition is sustained towards rearing systems with larger groups of animals kept in open-top elevated pens, also called park systems, with platforms and slatted floors (Maertens, 2017). Others (Italy) have issued guidelines to guarantee welfare of rabbits kept for farming purposes (Italian Ministry of Health, 2014). Finally, in March 2017, the European Parliament approved a resolution aimed at promoting the change from conventional cage systems to alternative housing systems respectful of animal welfare (European Parliament, 2017).

However, in order to ensure the rational development of rabbit farms and the adoption of alternative animal-friendly production systems, common management practices as well as minimum standards for the housing of rabbit does and their kits during the entire reproduction and production cycle must be developed in accordance with available scientific results.

In 2005, an independent EFSA scientific opinion on the current impact of housing and husbandry on health and welfare was published, based on the latest available scientific data and literature (EFSA, 2005). Based on this detailed and multi-facetted report, EFSA recommendations for housing, management and future research were drawn up. Since then, several studies have been performed and reviews on this topic published (Trocino and Xiccato, 2006; Hoy and Verga, 2007; Szendrő and Dalle Zotte, 2011; Szendrő and McNitt, 2012; Hoy and Matics, 2016; Szendrő *et al.,* 2016a; Turner *et al.,* 2017). However, the research results available were obtained under a great variety of farming and management conditions (farm organisation, housing systems and dimensions, animal genetics, reproductive rhythms, slaughter age and weight, etc.). Nevertheless, as for other farmed species, the farm sizes are increasing and alternatives to current housing systems should be evaluated in a production context consistent with the economic sustainability of farmers.

Thus, this review integrates literature already available at the time of the first EFSA opinion (2005) with research subsequently published at scientific congresses and journals concerning the housing of rabbit does being reared in farms for meat production. Special attention has been given to factors related to the housing systems (in terms of enclosures, equipment, and individual/collective housing) which could affect animal welfare with special emphasis on good housing, good health and appropriate behaviour (consistently with three out of the four principles stated by the Welfare Quality® project; good feeding was not considered, being deemed not at risk under standard production conditions). The aim is to use available results to draw conclusions, when possible, regarding plausible alternatives beyond dispute for improving housing and management systems.

HOUSING AND EQUIPMENT

Current housing

In commercial farms, reproducing does are exclusively housed in wire cages together with their offspring until the age of weaning. In a large majority of specialised farms, cages are predominantly "dual purpose", i.e. for reproducing does and for fattening after weaning, which permits the all-in, all-out approach, as well as cleaning and disinfection for the following incoming reproduction cycle. These cages are equipped with a feeder, a nipple drinker and a nest area.

More recently, an increasing number of new or renovated farms have been using the so-called "WRSA cages", i.e. enriched cages equipped with elevated platforms and plastic footrests, sometimes provided with environmental enrichment (gnawing material). They also have a higher height than standard cages (Hoy and Matics, 2016).

Restocking does, but not pregnant does, are usually housed in small cages for a brief period before entering the batch production management system. Standard cages for reproducing does have the shortest side at 38 cm, a height of 30 cm and a minimum total surface of about 3000 cm^2 (EFSA, 2005). In some countries, cages with a width of 46 cm are also used as standard. Enriched cages and pen/park systems have a total available surface ranging from about 4400 to 6400 cm^2 per doe. An overview of dimensions for the different housing systems is presented in Table 1.

Table 1: Overview of the dimensions of the most common housing systems used in Europe for rearing of young females or lactating does with litter.

	Width (cm)	Length (cm)	Height (cm)	Total available surface (cm^2)
Young or non-pregnant female	38	45-50	35	1710-1900
Lactating doe: basic standard models	38	87-102[a,b]	32-35	3300-3900
Lactating doe: wider versions	46	95-102[b]	35	4370-4700
Lactating doe: enriched cages with wire-mesh platform (width 20 cm)	38-46	95-102[b]	60-65	4370-5600[c]
Lactating doe: enriched cages with plastic-mesh platform	46-52.5	102[b]	65-80	5600-6400[c]
Pen/Park systems (4 does) with plastic-mesh platform (width 25 cm)	180-200	95-102[b]	Open-top	Total: 21600-25400[c] Per doe: 5400-6350[c]

[a]Oldest models may be 75 cm in length.
[b]The nest area is included.
[c]The platform surface is included.

Cage dimensions

Regarding cage size for reproducing does, the 3 dimensions may affect animal welfare differently in terms of the possibility of providing good housing for movement and resting. Length and width firstly determine the available surface for rabbit movement and resting, whereas height may affect general movement possibilities and some specific behaviours of rabbits, like rearing up on their hind legs. Indeed, limitation in surface available for movement may cause mental distress such as boredom, frustration and stereotypical behaviour (Verga *et al.,* 2007), as well as developmental and skeletal abnormalities.

Initial studies on housing of reproducing does showed that housing in small and low-height cages was associated with deformation of the vertebral column in reproducing does (Drescher, 1996). In this study, according to the authors, the low height of conventional cages (<32 cm) forced the animals to adopt a prolonged flat-sitting position and was likely to provoke a systemic hypoplasia of bone tissues, as well as a caudal dislocation of the body gravity centre due to the weight of the pregnant uterus. In fact, Buijs *et al.* (2014) found no effect of dimensions of the housing system on spinal deformations occurrence in does kept in systems with little/no limitation in height, i.e. individual cages (3952 cm^2/doe, maximum roof height 63 cm) *vs.* semi-group housing system (5000 cm^2/doe, roofless). Nevertheless, to our knowledge, no welfare problem in terms of pain or decreased mobility associated with the occurrence and degree of spinal deformities has been reported in literature on farmed rabbits.

On the other hand, higher faecal corticosterone levels were measured in reproducing does kept in standard cages compared to those kept in double-size cages (83×38×32 cm *vs.* 113×46×46 cm), which could be related to differences in the stress level (Prola *et al.,* 2013). However, the results of this study cannot be conclusive regarding the effect of cage size on rabbit stress, as the large cages were also equipped with plastic foot mats, whose presence is known to increase doe health and welfare by decreasing the occurrence of ulcerative sore hocks (Rosell and de la Fuente, 2009b; Buijs *et al.,* 2014).

Few studies have investigated the budget time of reproducing does under housing systems with different available space. Effects on animal behavioural pattern, especially movement and resting, are often confounded due to other experimental factors, such as individual *vs.* group housing or physiological state or time of recording (Bignon *et al.,* 2012; Alfonso-Carrilho *et al.,* 2014; Buijs *et al.,* 2015). Moreover, to our knowledge, no studies on characterisation of the locomotion activities of reproducing does are available which could be useful to design housing systems.

Indeed, rabbit does spend most of their time in stationary behaviours (Alfonso-Carrillo *et al.,* 2014; Rommers *et al.,* 2014; Buijs *et al.,* 2015) and have been observed to hop or run for a very low amount of time both in smaller individual systems (0.11 to 0.25% of total observation time; Buijs *et al.,* 2015) and in larger semi-group systems (0.17 to 1.41% of total observation time at 12 d after group formation, Buijs *et al.,* 2015; 2% of total observation time at 4 d after group formation, Rommers *et al.,* 2014). Nevertheless, in the case of young does (from 11 wk of age until weaning of their first litter), their activity (including standing, sitting, and moving) significantly increased

(8.3 *vs.* 12.2% and 15.9%; $P<0.001$) and lying time decreased (63.8 *vs.* 57.5% and 52.0%; $P<0.05$) from standard cages (25×46×28.5 cm) to wider cages (intermediate size, 33×68.5×40 cm or large size: 38×90×60 cm with a platform of 35×25 cm at 30 cm height) (Bignon *et al.,* 2012). Locomotion also increases (until 5% of observation time) in a part-time system on the first day of group formation because of behaviour related to installation of the hierarchy among the does (Buijs *et al.,* 2015).

In wider cages, does also increased the time spent resting with the body completely extended, whereas in higher cages they were able to stand upright (Rommers and Meijerhof, 1998).

Negretti *et al.* (2010) observed that the most frequent postures adopted by adult rabbits do not require more than 40 cm height: animals stood below this height in 99.5% of observations (45000 recordings over 10 animals during 1 wk). Standing up on the hind legs is the only behaviour requiring no limitation in height, but it is an exploratory or alert behaviour. In fact, rabbits display rearing when placed in a novel environment, such as when moved from a standard cage to a flux chamber (Olivas *et al.,* 2013) or when submitted to the open field test (Meijesser *et al.,* 1989). The motivation for standing up under farming conditions may be related to an alert behaviour due to any visual stimulus (e.g. human presence) or noise.

Finally, previous research also showed that doe performance is not affected by cage size (Rommers and Meijerhof, 1998; Mirabito *et al.,* 1999).

Nest box

A nest box or nesting area in the cage should be provided for reproducing rabbit does. Most does nurse their kits only once a day during 3-4 min (Hoy *et al.,* 2000) and therefore the nest box has to be primarily comfortable for survival of the young. To our knowledge, there is no published literature concerning the optimal dimensions of the nest box or nesting area, but farm data confirm that in practice good results are obtained with standard commercial nests measuring minimal 25×35 cm.

At birth, kits are hairless and huddle together in the fur-lined nest for thermoregulation. The optimal temperatures determined in the nest are around 38°C at birth and 30°C at 14 d of age (Hull *et al.,* 1986). Proper and abundant nesting material is first required for their comfort, as the nest quality plays an important role on the survival of kits (Hamilton *et al.,* 1997). The lack of a proper nest increases mortality rates in both wild and domestic rabbits (Canali *et al.,* 1991).

Wild rabbits collect dried straw and other plant material and pluck hair from their body for nest building (Hudson *et al.,* 2000). In rabbit farms, wood shavings, hay and straw are commonly used according to the farmer's convenience and habits (Blumetto *et al.,* 2010). Based on the existing literature, all these materials comply with the health and welfare of does and kits. In fact, several nest materials have been tested (wood shavings, barley, wheat and rice straw, meadow and Tifton hay, chopped newspaper) without effects on kit mortality in most experiments (Mahmoud and Tulip, 2004; Blumetto *et al.,* 2010; Oliveira *et al.,* 2014; Farkas *et al.,* 2017). However, in preference tests, does showed preferences between the different nesting materials: straw >hay >wood shavings (Farkas *et al.,* 2018), which also deserves further investigation in terms of litter comfort, mortality and performance.

Nest boxes are usually equipped with a door (full closure) for controlled nursing (i.e. once-a-day nursing) during the first part of lactation. In fact, during the first 12 d of their life, kits only suckle and sleep (Hudson and Distel, 1982). Does may disturb their sleep when entering the nest box more frequently; moreover, a frightened doe jumping into the nest may scatter or even trample her kits, causing considerable harm. Thus, controlled nursing allows us to overcome these problems: does have access to the nest box only once a day for some minutes in the morning hours, while the remainder of the day the nest boxes are closed (Szendrő *et al.,* 1999).

Controlled nursing is not contrary to doe rabbit natural behaviour, as the large majority of wild and domesticated does nurse their kits only once a day and the nursing time is very short (Hoy *et al.,* 2000, EFSA, 2005; González-Mariscal *et al.,* 2007).

In practice, free or controlled nursing is applied in the different rabbit farms according to farmer habits, whereas controversial results about its effects on kits are available in the literature. Pizzi and Crimella (1985) found no

significant differences between the 2 systems, while Costantini *et al.* (1986) observed higher mortality of kits under controlled nursing. According to Coureaud *et al.* (1998), the controlled nursing was more favourable during the first 3-5 d after parturition, whereas free nursing was advantageous later on. On the contrary, Szendrő *et al.* (1999) found that free nursing was advantageous in the first 7 d of lactation.

Flooring

Under farming conditions, rabbits have been kept until now almost exclusively on wire-mesh flooring, which guarantees good hygienic conditions due to the separation from their droppings. Nevertheless, on wire floors, and in contrast with fattening rabbits, sore hocks (pododermatitis) are frequently observed in does (Rosell and de la Fuente, 2013). Because of the does' weight and the long-time living in cages or pens on wire-mesh floor, sore hocks could be very frequent (De Jong *et al.,* 2008; Rosell and de la Fuente, 2009b). Ulcerative pododermatitis causes chronic pain and suffering (Rosell and de la Fuente, 2013) as well as doe culling (Rosell and de la Fuente, 2009a).

The use of a plastic footrest (25×40 cm) on wire-mesh floor significantly decreases the incidence of ulcerative sore hocks in reproducing does (De Jong *et al.,* 2008; Rosell and de la Fuente, 2009b; Rommers and De Jong, 2011; Mikó *et al.,* 2014). Similarly, the presence of plastic platforms and/or plastic-slatted flooring decreases sore hock problems and improves doe welfare conditions (Rosell and de la Fuente, 2009b; Buijs *et al.,* 2014; Mikó *et al.,* 2014) (Table 2). In contrast, under alternative systems based on collective housing in parks with litter on the floor or on plastic slats combined with plastic platforms, 25% of does have ulcerative pododermatitis on at least one hind leg (Ruchti *et al.,* 2018). Both flooring materials could provoke unhygienic or more humid conditions which favour the development of sore hocks.

Table 2: Prevalence of ulcerative pododermatitis in reproducing does kept under housing systems with different flooring.

Author	Period	Animals	Prevalence (% of does)
Rosell *et al.* (2000)	1986-1996	103,968 does in commercial farms 15,987 bucks in commercial farms	ulcerative pododermatitis: 9.1% ulcerative pododermatitis: 7.5%
Rosell and de la Fuente (2013)	2001-2012	105,009 does in commercial farms	ulcerative pododermatitis 4.87±0.26 (with footrest) 13.71±0.32 (without footrest)
Rommers and De Jong (2011)	at 5th kindling	250 does in 5 commercial farms (50 per farm)	non-ulcerative and ulcerative pododermatitis 18.7% (with footrest) 86.7% (without footrest)
Rosell and De la Fuente (2009b)	until 5th kindling	224 does in 1 commercial farm	accumulated incidence of ulcerative pododermatitis: 15.1% (with footrest) 71.5% (without footrest) curative effect of footrest in 81.3% of affected does
Mikó *et al.* (2014)	at 5th kindling	108 does	ulcerative pododermatitis: 48% in wire cages without footrest 0% in wire cages with footrest 5% in pens with wire-mesh platform and footrest 0% in pens with plastic platform
Buijs *et al.* (2014)	at 5th kindling	72 does	ulcerative pododermatitis: 0% in all groups small (28.6% of all does) and large (11.4%) hyperkeratosis area and cracked callus (1.4%): 65% in wire pens with plastic mats 5% in plastic-slatted pens 68% in wire floor cages with plastic mats
Ruchti *et al.* (2018)	June-September 2016	1090 does (=30% of total Switzerland group housed does) in 17 farms that used floor pens with litter	ulcerative pododermatitis: 25% hyperkeratosis and scaling: 68%

As regards behaviour, Buijs *et al.* (2015) found no differences in the behaviour and aggression of reproducing does kept in collective pens with different flooring (wire-net with plastic mats *vs.* plastic-slatted). Differently, Zomeño *et al.* (2018) observed lower aggression with plastic-slatted floor than with wire-net floors covered with plastic mats, which was difficult to explain, as floor type did not exert any effect on does' performance and health. Similarly, other studies showed no effects of floor type on performance of does and kits kept in individual cages or in part-time collective systems across multiple reproductive cycles, when comparing wire-net with plastic mats *vs.* plastic-slatted floor (Maertens and Buijs, 2013, 2016a) or wire-net *vs.* plastic-mesh platforms (Mikó *et al.,* 2014).

Undoubtedly, the flooring design is a key factor for rabbit comfort and cage hygiene. Petersen *et al.* (2000) observed that on a slatted floor with a large distance between slats (16 mm) rabbit does avoided orientation parallel to the slat position and preferred to position themselves crosswise to the slats, and squatted significantly more frequently than when slat distance was small (10 mm).

Environmental enrichments

Environmental enrichments serve both to enrich the barren environment and to fulfil species-specific behaviours like exploring, hiding, hopping and gnawing in the case of rabbits (EFSA, 2005; Trocino and Xiccato, 2006), as well as to reduce aggression in case of animals housed collectively (Verga *et al.,* 2007; van de Weerd and Day, 2009). In this regard, compared to breeder does kept for farming purposes, more studies have researched the effect of different types of enrichment in adult rabbits housed under laboratory conditions, as well as in growing rabbits under farming conditions; these results could provide useful information.

Domestic rabbits kept in individual laboratory cages did not appear motivated to use enrichment elements allowing hiding, e.g. boxes, as they spent most of the time (more than 800 min during 1 d) above rather than inside the box (less than 20 min) (Hansen and Berthelsen, 2000). On the other hand, the presence of hiding places (such as plastic tubes or platforms) hardly reduced the frequency of severe injuries in the case of reproducing does kept in part-time collective systems (Rommers *et al.,* 2014a).

Platforms or second level

Compared to other types of enrichment, platforms in rabbit housing systems have been tested more extensively and deserve special attention. Under laboratory conditions, rabbits are motivated to gain access to a platform or any second level (Lidford, 1997; Seaman *et al.,* 2008). Under farming conditions, the inclusion of elevated platforms in high or open-top cages/pens for rabbit does increases space availability (±25%) compared to flat-deck cages, but both advantages and disadvantages are claimed.

Undoubtedly, among advantages, the platform provides more opportunities for movement and exercise (jumping up and off) due to the increased functional area (Maertens *et al.,* 2011). The rabbits can freely choose between staying on, under (safety part) or in front of the platform (highest part of the cage). It also offers mothers the possibility of escaping from their kits once they leave the nest box (Mirabito *et al.,* 1999). Nevertheless, some authors found that does spend more time on the platform when kits begin to leave the nest box (14-16 d of age), but then does spend more time on the bottom level when kits are 3 wk old and start to jump up onto the platform (Mirabito *et al.,* 1999, 2004; Mikó *et al.,* 2014).

Regarding disadvantages, daily health checking may be more difficult because animals are less visible below the platform and catching them might require more time. Moreover, according to Cervera *et al.* (2018a), in individual cages, the presence of a wire-net platform significantly impaired cage hygiene (dirty does) and animal health (higher rate of does affected by dermatophytoses and footpad injuries) compared to conventional cages. The impairment of hygiene conditions and sanitary status was confirmed by the same research group when comparing standard individual cages with part-time collective housing systems where does used the upper side of the nest box as a platform (Cervera *et al.,* 2018b). The authors reported that faeces accumulated on this type of platform, which increased animal dirtiness. These observations confirm the importance of the correct location and design of the elevated platform.

On the other hand, no effects (Mirabito, 2002, 2003; Cervera *et al.,* 2018a) or limited advantages (Barge *et al.,* 2008; Mikó *et al.,* 2014) of platform inclusion have been described on doe and kits performance. Finally, Mikó *et al.* (2014) observed that does preferred a plastic-mesh platform over a wire-mesh platform (56.9% chose plastic, 31.7% chose wire). The same trend was measured in kits at 28 d of age: more kits (33.2%) used a plastic-mesh platform than a wire-mesh platform (5.2%).

Other types of enrichments

As regards environmental enrichments allowing gnawing behaviour, once again, many studies have been performed in fatteners, whereas less information is available in adult rabbits. Generally speaking, the early research works have not clearly proven the animal preference for a particular object (straw, cans, wooden objects), nor a real improvement of animal welfare (López *et al.,* 2004; Carrilho *et al.,* 2005; María *et al.,* 2005).

However, more recently, Maertens *et al.* (2013) tested three different gnawing blocks (wood mash, wood mash+chicory pulp and wood mash+inulin syrup) as cage enrichment and feed supplement for reproducing does kept in individual cages. The presence of gnawing blocks did not affect cage manipulations such as biting on the wire walls, but significantly increased does' active behaviours (locomotion and intake) and decreased the number of visits into the nest box, which was positively considered. The block use and consumption did not decrease over time, which indicated that the blocks fulfil an animal behavioural requirement, i.e. gnawing. Wood mash blocks were more used and consumed than the other blocks. However, because of some negative effects on doe and litter performance, chicory pulp blocks should be preferred to wood mash ones.

Likewise, Rommers *et al.* (2014b) did not find significant differences in normal or abnormal behaviours when comparing rabbit does kept in barren cages or in cages enriched with different sticks (pinewood stick, straw in a plastic bin, compressed wooden block, combination of straw and pinewood stick). The does used straw and wooden blocks for gnawing and chewing, whereas they showed little interest for the pine stick (0.1% of observed time, perhaps due to its resin content).

GROUP HOUSING SYSTEMS

Group living in wild rabbits

European wild rabbits live in groups in a burrow system (Cowan, 1987) in order to reduce predation risk (many eyes, alarm signals with hind legs, running in zigzag, cooperative construction of warrens) (Cowan, 1987; Szendrő and McNitt, 2012) and this fact determines their social needs. Predation threat favours group living (König, 1997; Ebensperger and Wallem, 2002) and the group formation in rabbits has been related to defence (Villafuerte and Moreno, 1997). Nevertheless, wild rabbits have been described both as solitary and gregarious (Wheeler *et al.,* 1981; Cowan, 1987) and, in this latter case, the group size depends on how the field is covered by scrub and the extent of the predation risk (Villafuerte and Moreno, 1997). Moreover, does living in groups with more than one female have a shorter lifetime and less reproductive success than those that live with males only (Cowan, 1987). In fact, aggressive behaviour and fighting among wild rabbits are well-known (Mykytowycz, 1958; von Holst *et al.,* 1999); double kindling in the same nest and infanticides, high stress hormone levels and low productivity have been reported as a consequence (von Holst *et al.,* 2002; Rödel *et al.,* 2004, 2008).

Continuous group-housing in farms

Many studies have been performed on the housing of rabbit does in a continuous group-housing system. The so-called Stauffacher system (Stauffacher, 1992) used eight females together with a male. The results of this small scale experiment were promising, but were never confirmed either in experiments or in the field. Studies of continuous group-housing systems showed several problems and no acceptable results were obtained with respect to either welfare of does and kits or productive performance. The main reasons for the failure of this housing system are the very high rates of aggression among females and injured does and competition for nesting space (Andrist *et al.,*

2013; Szendrő *et al.,* 2013). Moreover, such a housing system is not compatible with the current batch management system, which is widely used in farmed rabbits (Maertens *et al.,* 2011; Hoy and Matics, 2016).

In collective systems, reproductive performance decreases due to high rates of pseudopregnancy (Rommers *et al.,* 2006; Mugnai *et al.,* 2009; Andrist *et al.,* 2013). Moreover, kit mortality is very high because of competition among does for nests, aggressions towards kits and kindling of 2 or 3 does in the same nest box (Mirabito *et al.,* 2005; Hoy and Matics, 2016; Szendrő *et al.,* 2016b; Hoy *et al.,* 2017). Likewise, a very high number of attacks (Szendrő *et al.,* 2016b) and mating attempts between does (Gerencsér *et al.,* 2016) have been observed. Decreased sanitary status, higher culling and shorter lifespan have also been reported (Andrist *et al.,* 2013; Szendrő *et al.,* 2013) (Table 3).

To tackle these problems, Ruis (2006) used a special individual electronic nest box recognition system, allowing a doe to have access only to her own nest box. Although survival rate of young was improved, the pseudopregnancy rate was still high, kindling rate and weaning weight remained low, and very high rates of aggression and injured does were reported (Rommers *et al.,* 2006). Buhl *et al.* (2015) tested a system which consisted of four single areas and

Table 3: Comparison of some welfare indicators of single-caged and group housed rabbit does.

Group characteristics	Individually housed females	Group housed females	Reference
Survival rate of does			
4 does and 1 buck/pen, after 200 d	71-81%	50%	Szendrő *et al.,* 2013
Aggressive interactions			
4 does and 1 buck/pen, during the 1st mo	n.a.	3.6-5.1/d	Szendrő *et al.,* 2016b
4 does/pen regrouped 8 d before kindling	n.a.	27.5 during 12 h of observation	Zomeño *et al.,* 2018
4 does/pen regrouped 2 d after kindling	n.a.	66.9 during 12 h of observation	Zomeño *et al.,* 2018
Injured does			
4 does/pen, during rearing	n.a.	32%	Mirabito *et al.,* 2005
8 does/pen	n.a.	16.8-21.0%	Rommers *et al.,* 2006
Swiss farms with different systems (generally 8 does/group)	n.a.	33% (9% severe)	Andrist *et al.,* 2013
4 does/pen regrouped 18 d after kindling	n.a.	91.7 and 75.0% of does in pens with plastic floor and wire-net, respectively, at the 4th cycle	Buijs *et al.,* 2015
4 does/pen regrouped 2 d after kindling	n.a.	34, 47, 13, 13% and 10% at 3, 10, 17, 24 and 32 d after regrouping	Zomeño *et al.,* 2018
5 does/pen regrouped 23 d after kindling	n.a.	34 and 53% at 4 d after regrouping and at weaning, respectively	Rommers and De Greef, 2018
Stress hormones level			
4 does and 1 buck/pen, corticosterone in faeces, nmol/g	54-61	175	Szendrő *et al.,* 2013
8 does/pen, progesterone concentration	100% low (0.7 ng/mL)	23.9% high (5.7 ng/mL)	Rommers *et al.,* 2006
More than 1 doe kindled into the same nest box			
4 does/pen	n.a.	31.3% (2 does) 6.3% (3 does)	Mirabito *et al.,* 2005
4 does and 1 buck/pen	n.a.	7.7% (2 does)	Szendrő *et al.,* 2013
Mortality of kits			
4 does/pen	9.7%	17.7%	Mirabito *et al.,* 2005
8 does/pen, natural mating	5.2-8.8%	12.8%	Rommers *et al.,* 2006
8 does/pen, AI	7.4%	10.1%	Rommers *et al.,* 2006
4 does and 1 buck/pen	14.0-15.2%	38.5%	Szendrő *et al.,* 2013
4 does/pen, combination of individual cage with common area	n.a.	18.1%	Hoy and Matics, 2016

n.a.: not available.

a group area using commercial "cat flaps" at the nest entrance in the individual spaces. Nevertheless, sometimes different litters used the same nest box because they were able to leave their own nest box. In each tested round, at least 1 doe did not use the group area, whereas the other 3 does used this area at very different rates of time.

Farkas *et al.* (2017) observed non-pregnant does housed in 1.83×2.00 m open-top pen containing 4 individual modules (0.5×0.91 m), which were connected to a common area (1.83×1.00 m) through a 0.25 m-long and 0.20 m-wide lockable corridor. At the beginning of the experiment, the does were placed individually in the closed modules (4 does/pen) for 3 d, to get used to their own site. After the adaptation period, the cage doors were opened to allow the does to move freely. The experiment lasted for 14 d. The frequency of mutual mating attempts was high until the end of the experiment. High frequencies of injured rabbits were also observed in the whole experimental period and in consequence this alternative group housing system failed to overcome the aforementioned problems.

Semi-group (part-time) housing in farms

More recently, semi-group (part-time) housing systems have been proposed (Maertens *et al.,* 2011) and are currently under study in different countries. In these systems, does are housed in small groups, usually from around 18 d of lactation till weaning (i.e. 3 wk of collective housing), and individually from a few days before the following kindling till around day 18 of lactation (i.e. 3 wk of individual housing). Moreover, in contrast with continuous group-housing systems, females are artificially inseminated on the same day using a batch management system (Maertens and Buijs, 2013, 2015, 2016b; Buijs *et al.,* 2014; Hoy and Matics, 2016; Cervera *et al.,* 2017; Zomeño *et al.,* 2017).

The few available studies show that under these systems the reproductive performance of does may be comparable with those under individual housing, even if litter and kit performance may be negatively affected (Maertens and Buijs, 2013, 2015, 2016b, 2016c; Maertens and Debie, 2017). Cervera *et al.* (2017) also reported lower litter size and weight at weaning in a part-time group housing system compared to individual cage housing, whereas Machado *et al.* (2016) observed an opposite trend.

Nevertheless, aggression, fighting and injured rabbits after each regrouping remain an unsolved problem. Although agonistic interactions decreased very rapidly after grouping (4 does with kits) at day 18 post parturition, Buijs *et al.* (2015) observed skin lesions in many does (58% showed slight lesions and 20% more severe lesions) on the 4th day after grouping. The loss of kits was much lower than in continuous group housing systems, whereas no loss of females was observed (Maertens and Buijs, 2016b, 2016c).

Different strategies (platform, plastic pipe, hiding place, straw, territory, dark corridor, group stability, regrouped into home or new pen, sprayed odours) have been tested without great success in reducing aggression at regrouping and consequent injuries which may affect up to 60% of does (Graf *et al.,* 2011; Rommers *et al.,* 2011, 2013, 2014a; Andrist *et al.,* 2012, 2013, 2014; Buijs *et al.,* 2015). A combined system with four individual modules and a common area has also been tested by Gerencsér *et al.* (2018): 18 d after kindling, the entrances of the individual modules were opened and a 21-d group-housing started. The ratio of injured rabbits was higher than 50%. It reached the highest peak on day 2, but remained high for many days in some pens. Indeed, aggressive interactions decreased on some days (Rommers *et al.,* 2011; Andrist *et al.,* 2012) or even a few hours after group formation (Maertens and Buijs, 2016b; Zomeño *et al.,* 2017). In fact, also in other farmed animal species, the establishing of hierarchy in a group is always a critical point (sow: Mount and Seabrook, 1993; Hoy and Bauer 2005; Elmore *et al.,* 2010; Hemsworth *et al.,* 2013; laying hen: Gvaryahu *et al.,* 1994; D'Eath and Keeling, 2003; Johannson *et al.,* 2015).

The time of group formation (first days after kindling, early or late lactation) has a great influence on the aggression level among does (Zomeño *et al.,* 2017, 2018). In the case of late lactation, does may be less stressed because more time has passed since kindling and the presence of the kits out of nest boxes may positively modulate female to female aggression (Zomeño *et al.,* 2017). Nevertheless, Rommers and De Greef (2018) found that the percentage of injured does in a part-time system with 5 does increased from 34% measured 4 d after group formation (23 d of lactation) to 53% at litter weaning (36 d) (Table 3).

The little information concerning the group size that is available also shows a significant negative effect of the increase of female group size on aggressiveness (Buijs *et al.,* 2016; Zomeño *et al.,* 2017).

CONCLUSIONS

The above literature review summarises the main scientific knowledge on the impact of housing systems on health and welfare of reproducing rabbit does in order to design reliable and feasible alternatives.

Regarding cage height, the rearing of does for their entire reproductive life in cages lower than 40 cm may challenge their skeletal development and is not advisable. Higher or roofless cages would permit does to freely stand up on hind legs, even if under standard and controlled farming conditions the motivation to display this behaviour is very low.

Plastic flooring with proper design or wire flooring partially covered with a plastic footrest or platform should be preferred to cages/pens with exclusively wire-net flooring or with full floors covered with litter.

Platforms have beneficial effects offering animals more options for movement. However, their materials (wire or plastic) and design (wire-net size and plastic slats dimensions; platform height and position inside the cage) require careful evaluation before adoption in farms on a large scale to tackle disadvantages linked to animal coat soiling and to guarantee safe hygienic conditions. Because of rabbit interest in gnawing, the presence of wooden sticks or blocks is also recommended, provided that enrichments do not deteriorate hygienic conditions within the housing system.

Research findings concerning continuous group housing of reproducing does definitively show that levels of aggression and injuries associated with continuous group housing dramatically decrease welfare and performance of does and kits. This system thus cannot be recommended under commercial conditions.

Part-time group housing systems have shown some potential, but their adoption under farming conditions cannot yet be recommended due to the aggression level and, consequently, the rate of injured does measured after each regrouping, which severely challenges animal welfare and health. Before any change can be proposed, robust research is necessary to determine the optimal strategies and management techniques, as well as pen design and equipment for a safe establishment and maintenance of hierarchies, in order to limit harmful and painful behaviours among does reared collectively in a closed environment such as a cage or pen.

European collaboration in research is urgently needed to design, jointly and based on different expertise and competences, both housing and management systems which could improve animal welfare and health of rabbits kept under farming conditions.

REFERENCES

Alfonso-Carrillo C., Martín E., De Blas C., Ibáñez M.A., García Rebollar P., García-Ruiz A.I. 2018. Effect of cage type on the behaviour pattern in rabbit does at different physiological stages. *World Rabbit Sci., 22: 59-69. https://doi.org/10.4995/wrs.2014.1396*

Andrist C.A., Bigler L.M., Würbel H., Roth B.A. 2012. Effects of group stability on aggression, stress and injuries in breeding rabbits. *Appl. Anim. Behav. Sci., 142: 182-188. https://doi.org/10.1016/j.applanim.2012.10.017*

Andrist C.A., van den Borne B.H.P., Bigler L.M., Buchwalder T., Roth B.A. 2013. Epidemiologic survey in Swiss group-housed breeding rabbits: Extent of lesions and potential risk factors. *Prev. Vet. Med., 108: 218-224. https://doi.org/10.1016/j.prevetmed.2012.07.015*

Andrist C.A., Bigler L.M., Würbel H., Roth B.A. 2014. Masking odour when regrouping rabbit does: Effect on aggression, stress and lesions. *Livest. Sci., 170: 150-157. https://doi.org/10.1016/j.livsci.2014.10.017*

Barge P., Masoero G., Chicco R. 2008. Raising rabbit does in platform cages. *In Proc.: 9th World Rabbit Congress, June 10-13, 2008. Verona, Italy,1153-1157.*

Belgium, 2014. Arrêté Royal relatif au bien-être des lapins dans les élevages, Moniteur Belge [C – 2014/24303], 60861-60864.

Bignon L., Bouchier M., Coutelet G., Galliot P., Souchet C., Fortun-Lamothe L. 2012. Individual housing of young does in different sized cages: Impact on welfare, economic costs and productive data. *In Proc.: 10th World Rabbit Congress, September 3-6, 2012. Sharm El-Sheikh, Egypt, 1045-1049.*

Blumetto O., Olivas I., Torres A.G., Villagrá A. 2010. Use of straw and wood shavings as nest material in primiparous does. *World Rabbit Sci., 18: 237-242. https://doi.org/10.4995/wrs.2010.776*

Buhl M., Damme K., Hoy St. 2015. Results of a combined housing system for rabbit does and growing rabbits. *In Proc.: 19th International Symposium on Housing and Diseases of Rabbits, Fur Providing Animals and Pet Animals, May 27-28, 2015. Celle, Germany, 58-67.*

Buijs S., Hermans K., Maertens L., Van Caelenberg A., Tuyttens F.A.M. 2014. Effects of semi-group housing and floor type on pododermatitis, spinal deformation and bone quality in rabbit does. *Animal, 8: 1728-1734. https://doi.org/10.1017/S1751731114001669*

Buijs S., Maertens L., Hermans K., Vangeyte J., Tuyttens F.A.M. 2015. Behaviour, wounds, weight loss and adrenal weight of rabbit does as affected by semi-group housing. *Appl. Anim. Behav. Sci., 172: 44-51. https://doi.org/10.1016/j.applanim.2015.09.003*

Buijs S., Vangeyte J., Tuyttens A.M.F. 2016. Effects of communal rearing and group size on breeding rabbits' post-grouping behaviour and its relation to ano-genital distance. *Appl. Anim. Behav. Sci., 182: 53-60. https://doi.org/10.1016/j.applanim.2016.06.005*

Canali E., Ferrante V., Todeschini R., Verga M., Carenzi C. 1991. Rabbit nest construction and its relationship with litter development. *Appl. Anim. Behav. Sci., 31: 259-266. https://doi.org/10.1016/0168-1591(91)90010-U*

Carrilho M.C., Gracia A.B., López M. 2005. Estudio del comportamiento de machos Gigante de España en jaula enriquecida con latas de refrescos vacías. *In Proc.: XXX Symposium de Cunicultura, May 19-20, 2005. Valladolid, Spain, 77-84.*

Cervera C., Martínez-Paredes E., Machado L., Villagrá A. 2017. Production of rabbit females in individual cages or in collective semi-group. *In Proc.: XLII Symposium de Cunicultura, May 11-12, 2017. Murcia, Spain, 130-133.*

Cervera C., Gómez E.A., Pérez Fuentes S., Villagrá A. 2018a. Bienestar y salud en conejas reproductoras (Proyecto INIA CUN2014-00001-00-00). *In Proc.: XLIII Symposium de Cunicultura, May 30-31, 2018. Calamocha, Spain, 33-42.*

Cervera C., Rodenas L., Martínez-Paredes E., 2018b. Bienestar y salud de conejas y gazapos en sistemas de alojamiento individual o colectivo en semigrupo. *In Proc.: XLIII Symposium de Cunicultura, May 30-31, 2018. Calamocha, Spain, 114-119.*

Costantini F., Panella F., Castellini C. 1986. Management of rabbit breeding. *Rivista di Coniglicoltura, 23: 44-46.*

Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes (OJ L 221, 8.8.1998, p. 23).

Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens (OJ L 203, 3.8.1999, p. 53).

Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production (OJ L 182, 12.7.2007, p. 19).

Council Directive 2008/119/EC of 18 December 2008 laying down minimum standards for the protection of calves (OJ L 10, 11.1.2009, p. 7).

Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (OJ L 47, 18.2.2009, p. 5).

Coureaud G., Schaal B., Orgeur P., Coudert P. 1998. Le contrôle de l'accès au nid chez la lapine: conséquences sur la mortalité des lapereaux. *In Proc.: 7émes Journ. Rech. Cunicole, May 12-13, 1998. Lyon, France, 245-249.*

Cowan D.P. 1987. Group living in the European rabbit (*Oryctolagus cuniculus*): mutual benefit or resource localization? *J. Anim. Ecol., 5: 779-795. https://doi.org/10.2307/4948*

D'Eath B.R., Keeling J.L. 2003. Social discrimination and aggression by laying hens in large groups: from peck orders to social tolerance. *Appl. Anim. Behav. Sci., 84: 197-212. https://doi.org/10.1016/j.applanim.2003.08.010*

De Jong I.C., Reimert H., Rommers J.M. 2008. Effect of floor type on footpad injuries in does: a pilot study. *In Proc.: 9th World Rabbit Congress, June 8-12, 2008. Verona, Italy, 1171-1175.*

Drescher B. 1996. Deformations of vertebral column in breeding rabbits. *In Proc.: 6th World Rabbit Congress, July 9-12, 1996. Toulouse, France. Vol. 2, 417-421.*

Ebensperger L.A., Wallem P.K. 2002. Grouping increased the ability of the social rodent, Octodon degus, to detect predators when using exposed microhabitats. *Oikos, 98: 491-497. https://doi.org/10.1034/j.1600-0706.2002.980313.x*

EFSA, 2005. The impact of the current housing and husbandry systems on the health and welfare of farmed domestic rabbits. *The EFSA Journal, 267: 1-140.*

Elmore P.R.M., Garner P.J., Johnson J.A., Richert T.B., Pajor A.E. 2010. A flooring comparison: The impact of rubber mats on the health, behavior, and welfare of group-housed sows at breeding. *Appl. Anim. Behav. Sci., 123: 2-15. https://doi.org/10.1016/j.applanim.2009.11.012*

European Parliament 2017. European Parliament resolution of 14 March 2017 on minimum standards for the protection of farm rabbits (2016/2077(INI)). *Available at: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2017-0077+0+DOC+XML+V0//EN&language=EN. Accessed January 2019.*

Farkas T.P., Szendrő Zs., Matics Zs., Nagy I., Odermatt M., Radnai I., Kacsala L., Kasza R., Jakab M., Gerencsér Zs. 2017. Location and behaviour of group housed rabbit does in pens include common area and individual cages. Abstracts of the 29th Hungarian Conference on rabbit production, Kaposvár, Hungary, May 31, 2017. *World Rabbit Sci., 26: 194-195. https://doi.org/10.4995/wrs.2018.9821*

Farkas T.P., Szendrő Zs., Matics Zs., Radnai I., Nagy I., Gerencsér Zs. 2018. Preference of rabbit does among different nest materials. *World Rabbit Sci., 26: 81-90. https://doi.org/10.4995/wrs.2018.7373*

Gerencsér Zs., Kustos K., Szabó R.T., Mikó A., Odermatt M., Radnai I., Matics Zs., Szendrő Zs., 2016. Mating behaviour of rabbit does and bucks in groups (preliminary results). *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 675-67.*

Gerencsér Zs., Farkas T.P., Szendrő Zs., Nagy I., Odermatt M., Radnai I., Kacsala L., Kasza R., Savanyó Zs., Matics Zs. 2018. Location preference, behaviour and performance of rabbit does in a pen system of combination of group and individual housing. *In Proc.: 30th Hung. Rabbit Prod. Conf., Kaposvár, Hungary, 107-115.*

Germany 2014. Verordnung zum Schutz landwirtschaftlicher Nutztiere und anderer zur Erzeugung tierischer Produkte gehaltener Tiere bei ihrer Haltung (Tierschutz-Nutztierhaltungsverordnung - TierSchNutztV) in der Fassung von 2014.

González-Mariscal G., McNitt J.I., Lukefahr S.D. 2007. Maternal care of rabbits in the lab and on the farm: endocrine regulation of behavior and productivity. *Horm. Behav., 52: 86-91. https://doi.org/10.1016/j.yhbeh.2007.03.028*

Graf S., Bigler L.M., Failing K., Würbel H., Buchwalder T. 2011. Regrouping rabbit does in a familiar or novel pen: Effects on agonistic behaviour, injuries and core body temperature. *Appl. Anim. Behav. Sci., 135: 121-127. https://doi.org/10.1016/j.applanim.2011.10.009*

Gvaryahu G., Ararat E., Asaf E., Lev M., Weller J.I., Robinzon B., Snapir N. 1994. An enrichment object that reduces aggressiveness and mortality in caged laying hens. *Physiol. Behav., 55, 313-316. https://doi.org/10.1016/0031-9384(94)90139-2*

Hamilton H.H., Lukefahr D.S., McNitt I.J. 1997. Maternal nest quality and its influence on litter survival and weaning performance in commercial rabbits. *J. Anim. Sci., 75: 926-933. https://doi.org/10.2527/1997.754926x*

Hansen L.H., Berthelsen H. 2000. The effect of environmental enrichment on the behaviour of caged rabbits (*Oryctolagus cuniculus*). *Appl. Anim. Behav. Sci., 68: 163-178. https://doi.org/10.1016/S0168-1591(00)00093-9*

Hemsworth H.P., Rice M., Nash J., Giri K., Butler L.K., Tilbrook J.A., Morrison S.R. 2013. Effects of group size and floor space allowance on grouped sows: Aggression, stress, skin injuries and reproductive performance. *J. Anim. Sci., 91: 4953-4964. https://doi.org/10.2527/jas.2012-5807*

Hoy St. 2012. German regulation and guidelines on rabbit housing. *In Proc.: 10th World Rabbit Congress, September 3-6, 2012. Sharm El-Sheikh, Egypt, 999-1003.*

Hoy St., Bauer J. 2005. Dominance relationships between sows dependent on the time interval between separation and reunion. *Appl. Anim. Behav. Sci. 90: 21-30. https://doi.org/10.1016/j.applanim.2004.08.003*

Hoy St., Matics Zs. 2016. Alternative housing systems for rabbit does. *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 637-651.*

Hoy St., Verga M. 2007. Welfare criteria in housing of rabbits. *In Proc.: Giornate di Coniglicoltura ASIC, September 26-27, 2007. Forlì, Italy, 31-33. Available at:* http://w*ww.asic-wrsa.it/documenti/giornate2007/03_Hoy.pdf. Accessed January 2019.*

Hoy St., Seitz K., Selzer D., Schüddemage M. 2000. Nursing behaviour of domesticated and wild rabbit does under different keeping conditions. *In Proc.: 7th World Rabbit Congress, July 4-7, 2000. Valencia, Spain, 537-543.*

Hoy St., Ruis M., Szendrő Zs. 2006. Housing of rabbits – results of an European research network. *Arch. Geflügelk., 70: 223-227.*

Hoy St., Dal Bosco A., Matics Zs., Villagrá A. 2017. Main results of the international Anihwa rabbit project RABHO (In German). *In Proc.: 20 International Symposium on Housing and Diseases of Rabbits, Fur Providing Animals and Pet Animals, May 17-18, 2017. Celle, Germany, 14-26.*

Hudson R., Distel H. 1982. The pattern of behaviour of rabbit pups in the nest. *Behaviour, 79: 255-271. https://doi.org/10.1163/156853982X00292*

Hudson R., Schaal B., Martínez-Gómez M., Distel H. 2000. Mother-young relations in the European rabbit: physiological and behavioural locks and keys. *World Rabbit Sci., 8: 85-90. https://doi.org/10.4995/wrs.2000.424*

Hull D., Hull J., Vinter J. 1986. The preferred environmental temperature of newborn rabbits. *Biol. Neonate, 50: 323-330. https://doi.org/10.1159/000242616*

Hungary, 2009. Ministry of Agriculture. Minimum requirements for the housing of rabbits on large-scale farms. *Decree of the Ministry of Agriculture (32/1999. /III. 31./ and 178/2009. / XII. 29./) (in Hung.).*

Italian Ministry of Health (Ministero della Salute) 2014. Linee di indirizzo: allevamento del coniglio. *Available at: http://www.salute.gov.it/imgs/C_17_pubblicazioni_2358_allegato.pdf. Accessed January 2019.*

Johannson S.G., Raginski C., Schwean-Lardner K., Classen H.L. 2015. Providing laying hens in group-housed enriched cages with access to barley silage reduces aggressive and feather-pecking behaviour. *Can. J. Anim. Sci., 96: 161-171. https://doi.org/10.1139/cjas-2015-0133*

König B. 1997. Cooperative care of young in mammals. *Naturwissenschaften, 84: 95-104. https://doi.org/10.1007/s001140050356*

Lidford L. 1997. Behavioural effects of environmental enrichment for individually caged rabbits. *Appl. Anim. Behav. Sci., 52: 157-169. https://doi.org/10.1016/S0168-1591(96)01141-0*

López M., Carrilho M.C., Gómez C. 2004. Evaluation of the use of straw as an entertainment in Gigante de España rabbit cages: the effect of the placing of the straw in cage on the behaviour. *In Proc.: 8th World Rabbit Congress, September 7-10, 2004. Puebla, Mexico, 1241-1246.*

Machado L.C., Martínez-Paredes E., Paragliola F., Cervera C. 2016. Performance of rabbit kits originating from collective and individual cages. *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 699-702.*

Maertens L. 2017. Recent developments in rabbit housing in Northen Europe. *In Proc.: Convegno ASIC, April 7, 2017. Forlì, Italy. 1-17. Available at: http://www.asic-wrsa.it/documenti/convegno2017/presentazioni/ASIC2017_Maertens.pdf. Accessed January 2018.*

Maertens L., Buijs S., 2013. Performances de femelles logées temporairement en groupe dans des parcs polyvalents et en système tout plein tout vide. *In Proc.: 15èmes Journées de la Recherche Cunicole en France, November 20-21, 2013. Le Mans, France, 35-38.*

Maertens L., Buijs S. 2015. Production performances of semi-group housed rabbit does. *In Proc.: 19th International Symposium on Housing and Diseases of Rabbits, Fur Providing Animals and Pet Animals, May 27-28, 2015. Celle, Germany, 22-31.*

Maertens L., Buijs S. 2016a. Comparison of fattening performances housed in parks or enriched cages. *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 703-706.*

Maertens L., Buijs S. 2016b. Production performances of rabbit does in a part-time group housing system. *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 711-714.*

Maertens L., Buijs S. 2016c. Impact of housing system (cage *vs.* part-time housing) and floor type on rabbit doe welfare. *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 707-710.*

Maertens L., Debie Y. 2017. Logement de lapines "part-time" en groupe: résultats dans un élevage équipé avec des parcs polyvalents *In Proc.: 17èmes Journ. Rech. Cunicole, November 21-22, 2017. Le Mans, France, 55-58.*

Maertens L., Rommers J., Jacquet M. 2011. Le logement des lapins en parcs, une alternative pour les cages classiques dans un système "duo"? *In Proc.: 14èmes Journ. Rech. Cunicole, November 22-23, 2011. Le Mans, France, 85-88.*

Maertens L., Buijs S., Davoust C. 2013. Gnawing blocks as cage enrichment and dietary supplement for does and fatteners: intake, performance and behaviour. *World Rabbit Sci., 21: 185-192. https://doi.org/10.4995:wrs.2013.1195*

Mahmoud E.E.A., Tulip A.A.G. 2004. Effect of the nest box type on the performance of young New Zealand White rabbits until weaning. *Dept. Hygiene, Animal Behaviour & Management Fac. Vet. Med., Zagazig Univ., Benha Branch, 31-39.*

María G.A., Salduendo D., López M., Buil T., Alierta S. 2005. Enriquecimiento ambiental en conejas reproductoras alojadas en jaulas individuales. *In Proc.: XXX Symposium de Cunicultura, May 19-20, 2005. Valladolid, Spain, 71-76.*

Meijesser F.M., Kersten A.M.P., Wiepkema P.R., Metz J.H.M. 1989. An analysis of the open-fields performance of sub-adult rabbits. *Appl. Anim. Behav. Sci., 24: 147-155. https://doi.org/10.1016/0168-1591(89)90042-7*

Mikó A., Matics Zs., Gerencsér Zs., Odermatt M., Radnai I., Nagy I., Szendrő K., Szendrő Zs. 2014. Performance and welfare of rabbit does in various caging systems. *Animal, 8: 1146-1152. https://doi.org/10.1017/S1751731114001244*

Mirabito L. 2002. Le bien-être des lapins: impact de nouveaux systèmes de logement. *In Proc.: Journée nationale ITAVI Elevage du lapin de chair, November 21, 2002. Nantes, France. ITAVI Ed. Paris. Available at: http://www.itavi.asso.fr. Accessed January 2018.*

Mirabito L. 2003. Logement et bien-être du lapin: les nouveaux enjeux. *In Proc.: 10èmes Journées Recherche Cunicole, November 19-20, 2003. Paris, France, 163-172.*

Mirabito L., Buthon L., Cialdi G., Galliot P., Souchet C. 1999. Effet du logement des lapines en cages rehaussées avec plat-forme: Premiers résultats. *In Proc.: 8émes Journées Recherche Cunicole, June 9-10, 1999. Paris, France, 67-70.*

Mirabito L., Galliot P., Souchet C. 2004. Effet de la surface disponible et de l'aménagement des cages sur les performances zootechniques et le comportement des lapines et des jeunes. *In Proc.: Journée nationale de l'élevage du lapin de chair, Paris, France, 40-52.*

Mirabito L., Galliot P., Souchet C., Dumont F., Thomeret F. 2005. Logement collectif des lapines reproductrices: Conséquences zootechniques. *In Proc.: 11émes Journées Recherche Cunicole, November 22-23, 2011. Paris, France, 53-56.*

Mount N.C., Seabrook M.F. 1993. A study of aggression when group housed sows are mixed. *Appl. Anim. Behav. Sci., 36: 377-383. https://doi.org/10.1016/0168-1591(93)90134-B*

Mugnai C., Dal Bosco A., Castellini C. 2009. Effect of different rearing systems and pre-kindling handling on behaviour and performance of rabbit does. *Appl. Anim. Behav. Sci., 118: 91-100. https://doi.org/10.1016/j.applanim.2009.02.007*

Mykytowycz R. 1958. Social behaviour of an experimental colony of wild rabbits. *Oryctolagus cuniculus* (L.) I. Establishment of the colony. *CSIRO Wildlife Research, 3: 7-25. https://doi.org/10.1071/CWR9580007*

Negretti P., Bianconi G., Finzi A. 2010. Rabbit posture and behaviour to determine cage height in relationship with animal welfare. *In Proc.: XXXV Symposium de Cunicultura ASESCU, May 27-28, 2010. Segovia, Spain, 54-58.*

Olivas I., Rodríguez-Latorre A., Estellés F., Calvet S., Villagrá A. 2013. Short communication: assessment of activity patterns of growing rabbits in a flux-controlled chamber. *World Rabbit Sci., 21: 107-110. https://doi.org/10.4995/wrs.2013.1187*

Oliveira M.C., Lima S.C.O., Silva T.R., Silva J.A., Mesquita S.A., Oliveira H.C., Oliveira J.C., Oliveira E.S. 2014. Effect of different materials for bed of nest to pregnant does on the nest building pattern. *In Proc.: 5th American Rabbit Congress, September 8-11, 2014. Toluca, Mexico, 470-471.*

Petersen J., Schlender-Böbbis I., Mennicken L. 2000. Evaluation of optimal slat distance in slatted floor for rabbits using behavioural studies. *In Proc.: 7th World Rabbit Congress, July 4-7, 2000. Valencia, Spain. Vol. B, pp. 559-565.*

Pizzi F., Crimella C. 1985. Allattamento controllato in coniglicoltura. Influenze sugli accrescimenti ed indici di conversione alimentare dallo svezzamento all'età di macellazione. *In Proc.: XXXIX Congress SISVET, Bari, Italy, 467-470.*

Prola L., Cornale P., Renna M., Macchi E., Perona G., Mimosi A. 2013. Effect of breed, cage type and reproductive phase on fecal corticosterone levels in doe rabbits. *J. Appl. Anim. Welfare Sci., 16: 140-149. https://doi.org/10.1080/10888705.2013.768903*

Rödel H.G., Bora A., Kaiser J., Kaetzke P., Khaschei M., von Holst D. 2004. Density-dependent reproduction in the European rabbit: a consequence of individual response and age-dependent reproductive performance. *Oikos, 104: 529-539. https://doi.org/10.1111/j.0030-1299.2004.12691.x*

Rödel H.G., Starkloff A., Bautista A., Friedrich A.C., von Holst D. 2008. Infanticide and maternal offspring defence in European wild rabbits under natural breeding condition. *Ethology, 114: 22-31. https://doi.org/10.1111/j.1439-0310.2007.01447.x*

Rommers J.M., De Greef K.H. 2018. Are combi parks just as useful as regular parks for fatteners for part-time group housing of rabbit does? *World Rabbit Sci., 26: 299-305. https://doi.org/10.4995/wrs.2018.9587*

Rommers J.M., De Jong I. 2011. Technical note: Plastic mats prevent footpad injuries in rabbit doe. *World Rabbit Sci., 19: 233-237. https://doi.org/10.4995/wrs.2011.868*

Rommers J.M., Meijerhof R. 1998. La dimension de la cage influence-t-elle la productivité et le bien-être des lapins? *Cuniculture, 25: 67-72.*

Rommers J.M., Boiti C., de Jong I., Brecchia G. 2006. Performance and behaviour of rabbit does in a group-housing system with natural mating or artificial insemination. *Reprod. Nutr. Dev., 46: 677-687. https://doi.org/10.1051/rnd:2006038*

Rommers J.M., Gunnink H., Klop A., de Jong I.C. 2011. Dynamics in aggressive behaviour of rabbit does in a group-housing system: a descriptive study. *In Proc.: 17th International Symposium on Housing and Diseases of Rabbits, Fur Providing Animals and Pet Animals, May 11-12, 2011. Celle, Germany, 75-85.*

Rommers J.M., Gunnink H., de Jong I.C. 2013. Effect of different types of places on aggression among does in a group-housing system: A pilot study. *In Proc.: 18th International Symposium on Housing and Diseases of Rabbits, Fur Providing Animals and Pet Animals, May 22-23, 2013. Celle, Germany, 59-68.*

Rommers J.M., Reuvekamp B.J.F., Gunnink H., de Jong I.C. 2014a. Effect of hiding places, straw and territory on aggression in group-housed rabbit does. *Appl. Anim. Behav. Sci., 157: 117-126. https://doi.org/10.1016/j.applanim.2014.05.011*

Rommers J.M., Bracke M.B.M., Reuvekamp B., Gunnink H., de Jong I.C. 2014b. Cage enrichment: rabbit does prefer straw or a compressed wooden block. *World Rabbit Sci., 22: 301-309. https://doi.org/10.4995/wrs.2014.1353*

Rosell J.M., Dronda M.A., de la Fuente L.F. 2000. Dermatology. *In: Disease of the Rabbit, Rosell J M. (Ed.), Ediciones Mundi-Prensa, Madrid, Spain, vol. 2, pp. 355-398.*

Rosell J.M., de la Fuente L.F. 2009a. Culling and mortality in breeding rabbits. *Preventive Veterinary Medicine 88: 120-127. https://doi.org/10.1016/j.prevetmed.2008.08.003*

Rosell J.M., de la Fuente L.F. 2009b. Effect of footrests on the incidence of ulcerative pododermatitis in domestic rabbit does. *Anim. Welfare, 18: 199-204.*

Rosell J.M., de la Fuente L.F. 2013. Assessing ulcerative pododermatitis of breeding rabbits. *Animals, 3: 318-326. https://doi.org/10.3390/ani3020318*

Ruchti S., Meier A.R., Würbel H., Kratzer G., Gebhardt-Henrich S.G., Hartnack S. 2018. Pododermatitis in group housed rabbit does in Switzerland-Prevalence, severity and risk factors. *Preventive Veterinary Medicine, 158: 114-121. https://doi.org/10.1016/j.prevetmed.2018.06.011*

Ruis M. 2006. Group-housing of breeding does. *In: Maertens L. and Coudert P. (ed.). Recent advances in Rabbit Sciences, Plot-it bvba, Merelbeke, Belgium, 99-105.*

Seaman S.C., Waran N.K., Mason G., D'Eatch R. 2008. Animal economics: assessing the motivation of female laboratory rabbits to reach a platform, social contact or food. *Anim. Behav., 75: 31-42. https://doi.org/10.1016/j.anbehav.2006.09.031*

Stauffacher M. 1992. Group housing and enrichment cages for breeding, fattening and laboratory rabbits. *Anim. Welfare, 1: 105-125.*

Szendrő Zs., Dalle Zotte A. 2011. Effect of housing conditions on production and behaviour of growing meat rabbits: A review. *Livest. Sci., 137: 296-303. https://doi.org/10.1016/j.livsci.2010.11.012*

Szendrő Zs., McNitt I.J. 2012. Housing of rabbit does: Group and individual systems: A review. *Livest. Sci., 150: 1-10. https://doi.org/10.1016/j.livsci.2012.09.017*

Szendrő Zs., Gyarmati T., Lévai A., Radnai I., Biró Németh E., Milisits G. 1999. Comparison of once-daily, free and combined forms of suckling in rabbits. *Acta Agr. Kapós., 3: 155-163.*

Szendrő Zs., Mikó A., Odermatt M., Gerencsér Zs., Radnai I., Dezséry B., Garai É., Nagy I., Szendrő K., Matics Zs. 2013. Comparison of performance and welfare of single-caged and group-housed rabbit does. *Animal, 7: 463-468. https://doi.org/10.1017/S1751731112001760*

Szendrő Zs., McNitt I.J., Matics Zs., Mikó A., Gerencsér Zs. 2016a. Alternative and enriched housing systems for breeding does: A review. *World Rabbit Sci., 24: 1-14. https://doi.org/10.4995/wrs.2016.3801*

Szendrő Zs., Matics Zs., Szabó R.T., Mikó A., Odermatt M., Gerencsér Zs. 2016b. Aggressivity and its effect on lifespan of group housed rabbit does. *In Proc.: 11th World Rabbit Congress, June 15-18, 2016. Qingdao, China, 719-722.*

The Netherlands 2006. Verordening welzijnsnormen konijnen (PPE). (Regulations for welfare standards of rabbits). Law of The Netherlands Government: nl/BWBR0019560.

Trocino A., Xiccato G. 2006. Animal welfare in reared rabbits: A review with emphasis on housing systems. *World Rabbit Sci., 14: 77-93. https://doi.org/10.4995/wrs.2006.553*

Turner V.P., Buijs S., Rommers J., Tessier M. 2017. Code of practice for the care and handling of rabbits: Review of scientific research on priority issues. *National Farm Animal Care Committee, Québec, Canada.*

van de Weerd H.A., Day J.E.L. 2009. A review of environmental enrichment for pigs housed in intensive housing systems. *Appl. Anim. Behav. Sci., 116: 1-20. https://doi.org/10.1016/j.applanim.2008.08.001*

Verga M., Luzi F., Carenzi C. 2007. Effects of husbandry and management systems on physiology and behaviour of farmed and laboratory rabbits. *Horm. Behav., 52: 122-129. https://doi.org/10.1016/j.yhbeh.2007.03.024*

Villafuerte R., Moreno S. 1997. Predation risk, cover type, and group size in European rabbits in Donana (SW Spain). *Acta Theriol., 42: 225-230. https://doi.org/10.4098/AT.arch.97-23*

von Holst D., Hutzelmeyer H., Kaetze P., Khashei M., Schönheiter R. 1999. Social rank, stress and life expectancy in wild rabbits. *Naturwissenschaften, 86: 388-393. https://doi.org/10.1007/ s001140050638*

von Holst D., Hutzelmeyer H., Kaetze, P., Khashei M., Rödel H.G., Schrutka H. 2002. Social rank, fecundity and life time reproductive success in wild European rabbits (*Oryctolagus cuniculus*). *Behav. Ecol. Sociobiol., 51: 245-254. https://doi.org/10.1007/s00265-001-0427-1*

Wheeler S.H., King D.R., Robinson M.H. 1981. Habitat and warren utilization by the European rabbit, *Oryctolagus cuniculus* (L.), as determined by radio-tracking. *Aust. Wildl. Res., 8: 581-588. https://doi.org/10.1071/WR9810581*

Zomeño C., Birolo M., Zuffellato A., Xiccato G., Trocino A. 2017. Aggressiveness in group-housed rabbit does: Influence of group size and pen characteristics. *Appl. Anim. Behav. Sci., 194: 79-85. https://doi.org/10.1016/j.applanim.2017.05.016*

Zomeño C., Birolo M., Gratta F., Zuffellato A., Xiccato G., Trocino A. 2018. Effects of group housing system, pen floor type and lactation management on performance and behaviour in rabbit does. *Appl. Anim. Behav. Sci., 203: 55-63. https://doi.org/10.1016/j.applanim.2018.03.002*