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Experimental results on behaviour and welfare of rabbits. A review.

A húsnyúl viselkedésével és jólétével kapcsolatos kutatási eredmények. Irodalmi áttekintés.

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Abstract

This thesis investigates the impact of various environmental conditions on the behaviour, well-being and performance of farm rabbits based on the review of the relevant scientific literature. The primary objective is to evaluate the relationship between stocking density, group size, cage size, enrichment and overall rabbit welfare. The rabbits' performance is closely linked to their housing conditions, while their stress levels can be inferred from behavioural patterns, making behaviour a reliable indicator of overall welfare. Findings suggest that rabbits housed in medium-sized cages (4 rabbits in 680mm x 415mm x 290mm) exhibit fewer signs of aggression, with better performance. Housing 3-5 rabbits per cage, instead of larger groups, offers more freedom for locomotory motion and reduces stress, promoting natural behaviour and enhanced welfare. The stocking density should not exceed the suggested 40kg/m^2, as overcrowding leads to elevated aggression and injuries. It results in reduced performance, which is an indicator of issues in the housing conditions. Moreover, adding environmental enrichment, such as gnawing sticks significantly decreases aggression and improves welfare. The ideal cage design includes plastic-net flooring and dimensions which allow for better movement and comfort, with a height of 300-400mm to minimise injuries. It is recommended to slaughter the meat-producing rabbits before 10 weeks of age, to prevent unnecessary stress. Data emphasises the importance of optimising housing conditions and calls for further studies to fully understand the behavioural and environmental needs of rabbits kept under farm conditions.

Összefoglalás

A dolgozatban a különböző környezeti feltételeknek a házinyulak viselkedésére, jólétére és teljesítményére kifejtett hatását tanulmányoztam a szakirodalom áttekintése alapján. A kutatás célja annak értékelése volt, hogy milyen összefüggés áll fenn a telepítési sűrűség, a csoportméret, a ketrecméret, a környezetgazdagítás és az általános jólét között.

A nyulak teljesítménye szoros kapcsolatban áll a tartási körülményekkel, míg a stresszszintjükről a viselkedésminták alapján lehet következtetni, így a viselkedés megbízható indikátora az általános jólétnek.

Az eredmények azt mutatják, hogy a közepes méretű ketrecben (4 nyúl/680 mm x 415 mm x 290 mm ketrec) tartott nyulaknál kevesebb agresszió figyelhető meg, miközben jobb teljesítményt érnek el. Ha ketrecenként 3-5 nyulat tartanak, szemben a nagyobb csoportokkal, az több mozgási szabadságot biztosít, csökkenti a stresszt, elősegíti a természetes viselkedést és javítja a jólétet. A tartási sűrűség nem haladhatja meg az ajánlott 40kg/m²-t, mivel a túlzsúfoltság fokozott agresszióhoz és sérülésekhez vezethet. Ez a teljesítmény csökkenésében is megmutatkozik, amely a tartási körülmények hiányosságaira utal.

Ezen túlmenően a környezetgazdagító elemek, például a rágórudak hozzáadása jelentősen csökkenti az agressziót, valamint javítja a jólétet.

Az ideális ketreckialakítás műanyag hálós padlóval és megfelelő méretekkel rendelkezik, amelyek jobb mozgást és kényelmet biztosítanak, a magassága pedig 300-400mm, hogy minimálisra csökkentse a sérülések kockázatát.

A húsnyulakat célszerű 10 hetes kor előtt levágni, hogy elkerüljék a szükségtelen stresszt.

A szakirodalmi adatok alapján ki kell emelni a tartási körülmények optimalizálásának fontosságát, és a további ilyen jellegű vizsgálatok fontosságát. Ezen adatok fontosak a haszonállatként tartott nyulak környezeti igényeinek feltárása és jólétének biztosítása érdekében.

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1. Introduction

Rabbit meat is consumed due to its nutritional value – it is low in fat and high in protein. However, due to its high feed-conversion ratio, rabbit meat is quite expensive to rear, hence high in cost and not a common meat purchased by consumers. This is due to certain semi-automated methods. The rabbit meat is mostly popular in Italy, Spain, France and Finland [1].

Rabbit meat is also a trendy dish cooked and consumed in Malta. It is known to be a healthier meat than most others due to its low cholesterol levels and high amino acid content [2].

Rabbit rearing has decreased throughout the years, due to lifestyle changes. Nowadays, most people focus more on education, hence having less time at home. Furthermore, all families have become smaller, with fewer children and both parents working full-time jobs, leaving less time for them to farm or rear rabbits for consumption [3].

Another factor contributing to the decline in rabbit meat purchases is the lack of trust in the commercial supply chain. A survey revealed that only 19% of the population regularly bought rabbit meat from supermarkets or shops. Most prefer to purchase directly from people they know, or other contacts, who have their rabbit-rearing, e.g. backyard rabbits [2].

In 2017, it was recorded that rabbit meat consumption was 0.5kg per person per year in the EU. Around 0.34kg of these 0.5kg per year came from commercial farms. However, in Malta, rabbit meat consumption was higher – above 3kg of rabbit meat per person per year [3].

This study shall investigate the behaviour of rabbits on farms and explore the best conditions for them to improve their animal welfare. We must do our best to balance the rabbits' comfort and the farmers' meat production (and finances).

Research on rabbit welfare has been limited and historically neglected the productive and commercial aspects of rabbit farming. The few European teams that have researched rabbit welfare often overlook the productive and commercial elements of rabbit farming [4] [5].

In this review, we will investigate the animal welfare in rabbit farms; different conditions (such as group sizes, housing, flooring, and enrichment); how each condition affects the rabbits' behaviour; and efficient feed conversion factors.

2. Animal welfare

In the past, farm animal welfare focused mainly on minimising negative experiences. However, scientists now recognise this approach as incomplete and not fully aligned with citizens' concerns. Positive experiences are also crucial for animals. For a good quality of life, pleasant experiences should outweigh unpleasant ones throughout their lives [6].

Valuable insights into rabbit welfare can be gained from behavioural indicators, including ethograms and responses to humans or new environments, as well as physiological indicators like glucocorticoid levels or their metabolites. The tonic immobility test is also utilised to gauge rabbits' fear responses toward humans [7].

Research on rabbit welfare has been limited and historically neglected the productive and commercial aspects of rabbit farming. The European Project COST Action 848 marked a significant shift, focusing on ethology, welfare assessment methods, doe-litter interactions, human-animal relationships, and housing systems for reproduction and fattening [4].

Studying animal behaviour, a key indicator of welfare, and identifying potential deviations from species-specific behaviours is crucial for assessing animal welfare [8].

Thirty farms were evaluated: rabbits are among the least studied species when it comes to animal welfare. Most welfare initiatives tend to prioritise cattle, swine, or poultry, often overlooking rabbits [5].

The design and upkeep of facilities have a substantial influence on rabbit health and welfare. Housing systems must ensure rabbits have sufficient space to maintain comfort, especially crucial for thermoregulation in high temperatures. Rabbits utilise their space differently depending on ambient conditions and enclosure features [5].

Today, animal welfare is in sour of housing rabbits in larger groups, as wild rabbits live in colonies themselves. This will ensure the better well-being of the rabbits [9].

It has been seen that in larger groups, there was more motion activity and socialisation, while in smaller groups of rabbits, they spent more time resting [10].

However, we must also note not only the advantages of group housing but also the disadvantages. There may be an increased risk of infection due to the higher density of rabbits in a cage or pen, and a higher chance of aggression, leading to higher injury incidence [9].

It was noted there were fewer injuries and less aggressive behaviour in smaller groups and housing having gnawing sticks. This is crucial to note when it comes to rabbit health [9].

Engaging in natural behaviour doesn't necessarily improve the welfare of farm animals. However, allowing natural behaviour effectively meets their needs, provides positive emotional experiences, and stimulates behavioural development, yielding long-term benefits [11].

3. Housing Conditions

3.1 Cages vs pens

An inadequate environment and deficient social conditions can increase stress and, therefore, negatively impact behaviour, immune response, and growth performance [12] [13]. Low performance is a sign of issues related to housing conditions, environment, and management [14].

Stress can be measured from the glucocorticoids and their metabolites from the rabbits' faeces, blood, and fur. Testing for glucocorticoids will show the stress levels of the rabbits [15].

Rabbits are very social animals [16] [17], and group housing is advised to allow for their natural behavioural traits. Unlike breeding does, fattening rabbits generally don't present significant management concerns when housed in groups, although there may be fears about disease spread and aggression. In most commercial rabbit production nations, it is typical to fatten rabbits in medium-sized groups of 7-10 animals [4].

When farm rabbits are kept in small-sized cages, they are less likely to exhibit typical behaviours such as jumping, exploring, and alerting, and group housing is recommended to allow for their natural behavioural patterns. In most commercial rabbit production nations, it's typical to fatten rabbits in medium-sized groups of 7-10 animals [4].

It was observed in this study that pen-housed rabbits spent less time eating and allogrooming than those in bicellular cages, but they were more active, engaging in increased movement and sleeping, showing a more complete behaviour [15]. It was noted that as pen-housed rabbits aged, they ate even less and showed an increase in hostile behaviour, unlike the caged rabbits [15] [18].

Rabbits housed in pens exhibited increased boldness toward humans and had higher concentrations of hair corticosterone, so experienced more stress. Stereotypic behaviours were recorded in cage-housed rabbits but not in the pen-housed ones [15].

It was suggested that rabbits housed in open-top small pens perform comparably to those in cages, with the added benefit of increased locomotory activity which enhances welfare compared to pair caging. However, the higher incidence of ear lesions in larger groups highlights a potential negative effect of increasing group size on welfare [19].

Several reports concluded that higher corticosterone levels were indicated in rabbits kept in pens, than those reared in cages. This may be due to increased aggressive behaviour from increased interactions [15] [20] [21], which negatively impacts their welfare [19].

Similarly, it was demonstrated by another study that housing rabbits in large groups, like in the case of pens, caused chronic stress from constant fighting, resulting in lower feed intake. This was suggested due to the significantly higher faecal corticosterone levels in the pen-housed rabbits' faecal corticosterone levels were significantly higher in these rabbits than in caged ones, reflecting increased aggression [22].

Additionally, pens have shown negative effects, including increased belligerence and a high incidence of comfort behaviours such as scratching, sneezing, and head shaking [18].

It was found, by this study, that kits in pens were highly sensitive to visitors, noise, and handling after weaning. They huddled in corners and tried to escape, indicating that larger group housing causes stress, which may explain why larger group kits ate less than smaller groups [22].

It was suggested by research that compared to rabbits in cages, those reared in pens experienced significantly boosted mortality rates starting from seven weeks, resulting in overall mortality of 31% throughout the fattening period [23], while fatality rates increased with group size, particularly evident in the absence of enrichment objects [24].

Furthermore, the rabbits reared in pens exhibited paler meat with lower pH levels from increased stress than the meat of those reared in cages [21], while it was found that the rabbits housed in pens had lower growth and poorer performance, compared to the caged does [10] [25] [26].

It was concluded by this study that group housing is certainly the greatest strategy to satisfy the social interaction requirements of fattening rabbits. However, further assessment is essential to establish the optimal space allowance and group size, specifically to ensure the production of a high-quality final product [4].

Extensive research has proven that the growth and live weight of caged rabbits (groups of two to six) are greater than those of rabbits kept in pens [10] [26] [27] [28].

It was detected by this research that the reason for the reduced growth rate in the rabbits housed in pens could be derived from their increased physical activity. The elevated body weight gain of caged rabbits significantly bettered their feed conversion ratio between seven and nine weeks of age and during the entire fattening phase [29]. As for does, the requirements differ, as their motivation to seek social contact during pregnancy or after kindling is relatively low [30].

3.2 Stocking density

Stocking density refers to the number of animals per square metre in a cage, pen, or building. It significantly influences investment costs, performance, and the profitability of rabbit production [31].

If the rabbits are not provided with enough space, this will lead to aggression, which results in increased injuries and stress [32]. It may also decrease the rabbits' performance, which is related to issues in housing, environment, and management [14].

However, it has lately been discovered that the effects of stocking density are affected by the total live body mass of the rabbits per square metre of floor space, and not by the number of animals housed per square metre [33].

In Europe, the cage density on commercial farms ranges from 14 to 23 rabbits/m^2 [4]. Stocking densities exceeding 19 rabbits may lead to decreased feed intake and growth rates in rabbits while having no impact on feed efficiency or mortality [34].

High stocking densities, employed to maximise profit per unit area, frequently result in negative perceptions of animal welfare and provoke adverse reactions from the public concerning animal production systems [35]. Moreover, if the rabbit stocking density exceeds the optimal level, their stress will increase, production will decrease, and their health will deteriorate [36] [37].

Many studies on group housing showed that reducing the stocking density from 20-23 rabbits/m^2 to 15-16 rabbits/m^2 significantly enhanced growth performance. It was recommended to sustain a maximum loading of 38-40kg/m^2 at slaughter [30] [34] [38] [39].

Many studies have agreed that a maximum weight at the slaughter of 40kg/m^2 was declared as being consistent with the correct behavioural actions, and when stocking density surpassed this value, their productive performance was impeded [25] [29] [38] [40]. Low performance is a sign of issues related to housing, environment, and management [14]. Similarly, it was demonstrated in this research that daily weight gain decreased when the stocking density exceeded 46kg/m^2 or 20 rabbits/m^2 [34].

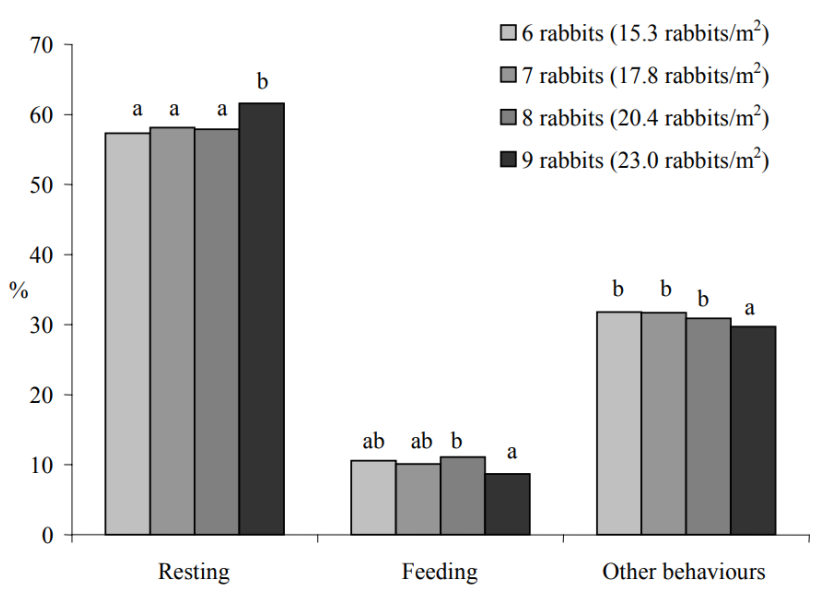


Figure 1 – Distribution of behaviours (% of observations) in fattening rabbits at 10 weeks of age, showing that the highest stocking density here shows a drop in feeding, compared to the perhaps more comfortable stocking densities [38].

It was discovered by this study that feed intake, weight gain, and body weight decrease when the stocking density exceeds 16-17 rabbits/m^2 [29]. Conversely, if the density is held below this level, as EFSA proposed, improvements in production or welfare are rarely observed [41].

Rabbits kept in collective cages (8 rabbits/cage) at stocking densities of 12 and 16 rabbits/m^2 demonstrated high growth performance, comparable to that observed in individual cages, until slaughter at 70 days [42].

It was recorded, in this experiment, that a significantly higher percentage of rabbits with lesions resulting from aggression was observed in pens with 16 rabbits/ m^2 (42.2kg/m^2) compared to those with 12 rabbits/m^2 (32.7kg/m^2), with rates of 26.2% and 8.2%, respectively. However, this was probably related to late slaughtering (>75 days of age) and the heavier live weight of each rabbit, which varied from 2.6 to 2.8kg [43].

It was reported by these researchers that the frequency of wounds significantly increased with age, independent of group size. Based on these findings, a maximum age limit of 80 days has been recommended [44], however, when rabbits were slaughtered at 72 days, another study found no lesions in rabbits housed at the same stocking density (15 rabbits/m^2) in conventional collective cages, small pens, or large pens [45].

It was investigated in this study, that the key behavioural indicators in rabbits and the results showed that 40kg rabbits/m^2 is the ideal stocking density [38]. While the previously mentioned researchers found no difference between the groups, another study recorded more ear injuries present in the group with 12 rabbits/m^2 compared to the group with 16 rabbits/m^2 [46].

It was observed that the feed intake decreased only during the final two weeks before slaughter at the highest stocking density, with consumption dropping to 185g/day for 12 rabbits/m^2 and to 179g/day for the 16 rabbits/m^2 [4] [38].

This investigation found that young rabbits when given the choice to move between four connected cages of varying sizes, preferred to stay together in the same cage at very high densities during the first few weeks after weaning, up to 60-70 rabbits/m^2 [47].

Multiple literature have agreed from their research that applying a lower than 16 rabbits/m^2 stocking density did not enhance the growing rabbits' production [34] [39] [48] [49], and the advantages have not been established [27] [29] [50].

Table 1 – behavioural pattern (% of observations) and reactivity during the open-field test in group-reared rabbits in different stocking densities, showing there isn't a significant difference between these two densities [42].

	Stocking density	
	12 rabbits/m²	16 rabbits/m²
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

In fact, in this article, it was observed that a reduction from 16 to 12 animals had only poor effects on the rabbits' behaviour [42].

It was observed in this investigation that, in general, animals intended for group housing should be of the same sex, similar in size, and preferably related, ideally grouped when young, around the time of weaning. The necessity of ongoing monitoring of the colony cannot be overstated [51].

Regardless of the strain used in research, selecting docile rabbits for breeding is recommended. Breeders should be consulted on which strains are most suitable for group housing and encouraged to breed accordingly to reduce aggression and improve welfare. Furthermore, it was concluded, by these researchers, that the younger the animals are when grouped, the lower the likelihood of encountering issues with aggressive behaviour [51].

Numerous studies proposed that the most favourable stocking density for fattening rabbits in small cages is 40kg/m², equivalent to a maximum of 16-18 rabbits each weighing about 2.5kg, per square metre [25] [29] [30] [34] [38] [39].

Exceeding this density leads to reduced production performance and altered behaviour. Conversely, lowering the stocking density does not provide any advantages in terms of production, behaviour, or animal welfare [29] [38].

3.3 Flooring types

In Europe, commercially raised rabbits are often housed in cages with wire mesh flooring, which is preferred for its cleanliness, dryness, and hygiene, especially in warmer temperatures [4] [52].

As a result of certain ongoing welfare concerns and legal constraints in some countries, rabbit farms need to develop alternative methods besides using wire mesh floors in the cages [53].

It is crucial, that instead of assuming what conditions the rabbits prefer, we perform preference tests and observe what the rabbits want. Animal activists may think that they know what they prefer, but this is only speculation until tested and proven through studies [54].

It is also believed that rearing rabbits on wire mesh floors is unsuitable, as it does not allow for the expression of certain behaviours seen in wild animals, such as digging. However, this notion remains a misconception until further experiments confirm it [4] [53] [55].

This experiment found that regardless of their age and stocking density, the rabbits preferred the wire net, over deep litter, as results showed that at least 80% of the rabbits chose this. It can be concluded that wire net cannot be considered an unfavourable environment, and it has not been proven to decrease the welfare of rabbits [56].

Raising rabbits in deep litter increases the risk of infection (e.g. coccidiosis) and intestinal inflammation, leading to higher mortality [29] [57] [58].

Research indicates that litter enhances the welfare of cage-housed rabbits. Straw provides bedding and absorbs droppings, but rabbits only use clean litter and avoid soiled areas. If litter cannot be regularly replaced, rabbits prefer the cleanliness and dryness of a wire-net floor [59].

Straw litter allows for more locomotory movements by the rabbits, however, it creates issues as the rabbits eat the straw, hence, decreasing feed consumption, and having prolonged contact with droppings [10].

Moreover, in the straw-bedded group, it was recorded that weight gain, body weight and feed intake declined [29], which can be explained since the rabbits consumed less feed because they were eating the litter instead of the feed [10] [60].

Table 2 - Growth performance, mortality and behaviour (% of observations) in fattening rabbits according to the housing system, with pen-housed rabbits in straw showing the worst performance, and mortality rate [10].

	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}

For 70% of the time, it was observed that the rabbits preferred the perforated base over the sawdust, despite expectations that they would favour the sawdust for environmental enrichment. This preference may be because they used the perforated base mainly as a latrine. Their lower preference for sawdust doesn't mean they dislike it. Interestingly, rabbits also moved enrichment items from the perforated base to the sawdust, suggesting intentional space use [61].

These results align with each other, concluding that growing rabbits preferred plastic net floors over wire net floors. In their study, rabbits showed the highest preference for plastic-net among wire-net, plastic slats, and solid floors [9] [62].

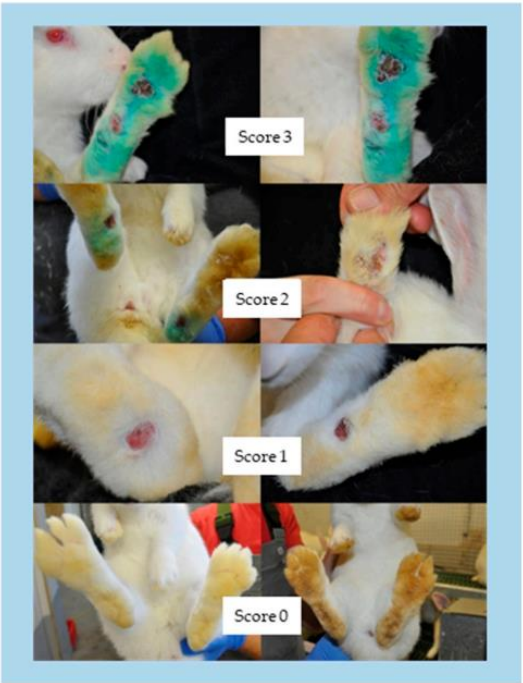
With 16 rabbits/m^2, more rabbits stayed on the wire net compared to 12 rabbits/m^2. This suggests that rabbits would rather tolerate a less preferred floor type than endure higher stocking density, though it doesn't imply they prefer wire over plastic floors. So, not all the older rabbits in the higher stocking density have a free choice [62] [63].

In this experiment, a performance test was carried out. In both stocking densities (12 and 16 rabbits/m^2), the rabbits preferred staying on the plastic-net floor longer than on the wire-net flooring. However, in the increased stocking density, more rabbits remained on the wire net flooring. This may be due to the decrease in space available [9].

Flooring design had a major impact on health as the rabbits on circular hole flooring experienced higher coccidial burdens and more soiling compared to those on plastic slats, due to excessive soiling on the circular holes. The circular holed floor had a higher mortality recorded than the slatted floors; 22.9% and 11.5%, respectively [53].

Plastic or rubber mats on wire cage floors affected drinking and aggression but didn't change other behaviours or growth. They reduced ear and eye lesions from aggression and lessened chronic stress, making them better for animal welfare [64].

Footpad injuries, also known as pododermatitis or sore hocks, can lead to pain and infections, which can significantly negatively impact rabbit welfare and increase economic costs. This may ultimately result in the culling of the doe [65].



Picture 1 – Scheme for assessing injuries to the hindlimbs of the rabbits, with score 0 = not injured, and score 3 = severely injured to evaluate the ideal flooring types [66].

The percentage of does with plantar hyperkeratosis was significantly lower on plastic mat floors than on wire floors [67] [68]. This indicates that housing rabbits on plastic slatted floors rather than

wire floors with a footrest improves their welfare [68]. Similarly, it was found by this study that the does living on floors with plastic mats had better footpad conditions [65].

The studies revealed that plastic-slatted flooring led to better rabbit growth and welfare than wooden flooring. Rabbits housed on plastic floors showed a significant increase in both daily weight gain and feed consumption, resulting in higher slaughter weights [43] [50].

It was recorded that rabbits on plastic floors had greater live and carcass weights and higher dressing percentages compared to those on wooden floors [43]. While several studies have expressed that the behaviour (such as aggression) of rabbits was not affected by the cage floor type [42] [56] [60].

These studies suggested that the cage floor type did not have a significant impact on the rabbits' average daily gain or carcass traits of the rabbits [19] [43], while another few reports found that there wasn't any significant effect on the productive performance or feed conversion efficiency of the growing rabbits [64] [42]. Furthermore, another study demonstrated that comparing wire and plastic net floors, the type of floor did not significantly affect meat quality [21].

The main results showed that growing rabbits prefer plastic net floors and cages/ pens (provided with gnawing sticks) [9]. So, plastic and rubber cage floors are advantageous from the viewpoint of animal welfare [64]. Moreover, a few studies found that the type of cage flooring did not significantly influence body weight or carcass characteristics [9] [42].

In a present study, the slatted floor with a slat distance of 10mm showed satisfactory results concerning cleanliness [53], while in another study, the highest level of cleanliness and the lowest injury rate in growing rabbits were observed on plastic slatted floors with 5mm slat width, 13mm slot width, and 75% perforation [66].

This experiment emphasises the advantages of adding plastic slatted footrests to wire-mesh rabbit doe cage floors to both prevent and treat sore hocks, hence increasing their welfare and comfort [69].

It was concluded that we are still looking for a more ideal flooring type that remains as clean as the wire mesh but needs to be more comfortable for the rabbits, as they do not prefer it [52].

3.4 Enrichment with platforms

Research has demonstrated that rabbits favour a closed, protective, burrow-like environment for hiding [70] [71].

Throughout the experimental period, regardless of the platform material, rabbits were observed on the floor more often than on the platforms [72] [73].

The animal density on the floor in front of the platforms was found to be 1.6 times greater than the density beneath the platforms, so this decreases the space they can use as they are more crammed in the preferred area [73].

It was found that platforms in the pens, regardless of the material used, did not affect productive traits [72] [73], so plastic-slatted platforms provide rabbits with more opportunities for movement and natural behaviour, without negatively impacting the production traits [74]. Similarly, it was noted that the enriched pens featuring wire-mesh or plastic-mesh elevated platforms did not affect the production, stress hormone levels, or aggression of growing rabbits [75].

It was found that the platforms enhanced movement opportunities and enriched the environment for growing rabbits, though the rabbits tended to remain on the floor more often [72] [73]. This may be attributed to the behaviour of European wild rabbits, which tend to remain on the ground during their active periods throughout the day [73].

However, the increased surface area provided by the platform, along with the larger group size, was found to significantly heighten the risk of social instability and associated aggression among pen mates, resulting in a greater incidence of injuries [74].

Rabbits demonstrated a greater preference for using platforms on wire-net floors compared to those on deep-litter platforms. This behaviour could be attributed to their instinct to avoid the warmer temperatures of the deep litter and seek safety [76].

In pens with wire-net flooring, a greater number of rabbits opted to stay on wire-net platforms without a manure tray compared to those with a manure tray, while fewer rabbits chose to occupy the area beneath the platform. This can be explained as the rabbits don’t want to get dirty from the urine, so they would rather go to a less preferred area to avoid this. Once the manure tray was installed with the wire platform, most rabbits went underneath it, proving that they preferred staying there [38].

Rabbits prefer to stay under platforms made of solid material, as this resembles a protected area for them, like a warren or dense vegetation [76].

The platforms provided growing rabbits with increased opportunities for movement, even though they preferred to stay on the floor, thereby improving their overall welfare [72] [77], without affecting the traits of the carcass and meat attributes [72] [75].

The wire-net platform with a manure tray creates an ideal environment by expanding the usable floor area without the risk of contamination from above. It also allows for effective heat dissipation and offers rabbits the option to seek cover when needed [76].

In conclusion, quite a few studies found that rabbits prefer plastic platforms over wire ones [29] [65] [67], which may be the case as they enhance locomotor activity [77]. Within the experimental conditions of this study, elevated platforms served as valuable structural enrichment for animal behaviour but hurt the injury rate [74].

3.5 Gnawing sticks as enrichment

Environmental enrichment involves enhancing the living conditions of animals by offering opportunities to engage in natural behaviours, which significantly benefits their welfare and productivity [78] [79], and it is crucial for the psychological well-being of rabbits [80] [81]. It has become increasingly important, both in society and by current standards, that animals in production live in environments that ensure their welfare [82] [83].

Rabbits possess a strong instinct to gnaw on wood, a behaviour they naturally satisfy by gnawing on roots or branches in their environment [84]. Enriching rabbit cages with gnawing materials can enhance the farming conditions for rabbits' dental health. These materials are more abrasive, helping to prevent medical issues that could compromise their well-being [85].

It was found that while enrichment did not impact growth performance, the males in enriched cages had heavier brains compared to those in non-enriched cages [86].

Throughout the entire rearing period, the rabbits consistently preferred cages with gnawing sticks, regardless of their stocking density, over cages without any enrichment [9]. It was observed that their aggressive behaviour was reduced when gnawing sticks were present [87] [88]. For this reason, the presence of gnawing sticks reduced the frequency of physical injuries, including ear

lesions [19] [89] [90]. The presence of skin lesions was utilised as a measure of aggressiveness [14].

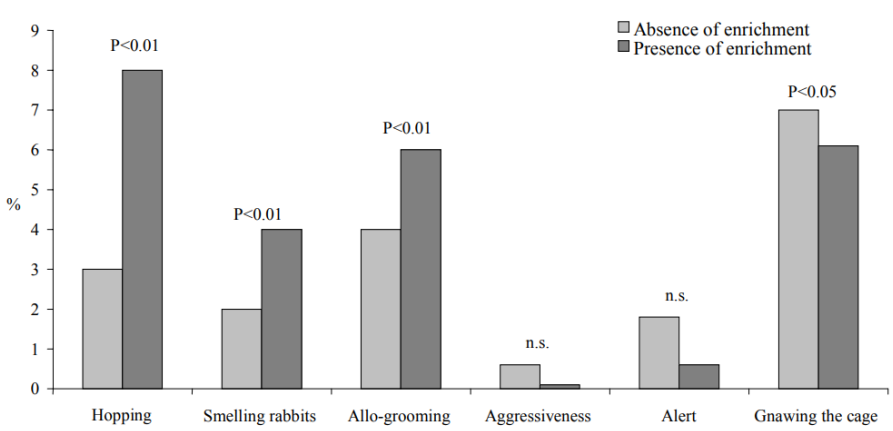


Figure 2 - Behaviour of rabbits in collective cages according to environmental enrichment, depicting that the rabbits showed less aggression and more natural behaviours in the enriched environments [48].

Due to the addition of enrichments (Eucalyptus sticks) [86], the decrease in ear lesions and aggression could positively impact weight gain during the second half of the fattening period [19].

Overall, gnawing sticks tended to reduce the rabbits' activity in the hours before the lights were turned on and increase it after the lights were turned on [91].

Environmental enrichment in growing rabbits housed individually in wire-mesh cages affected only the duration of feeding. Rabbits in enriched cages with Norway spruce gnawing sticks spent significantly more time feeding than those in unenriched cages [92].

During their active period, rabbits tend to become bored, and if gnawing sticks aren't available, they may resort to gnawing on the cage, the feeder, or even each other [9].

In this study, it was discovered that there was a lack of interest towards the sticks which could have been because the sticks were constantly available (and not because of the gnawing stick material).

Under these conditions, they lost their novelty, which is a key aspect of environmental enrichment [91] [93].

The majority of studies agree that in an enriched environment with gnawing sticks, the rabbits exhibit significantly reduced abnormal and aggressive behaviour [48] [93] [94].

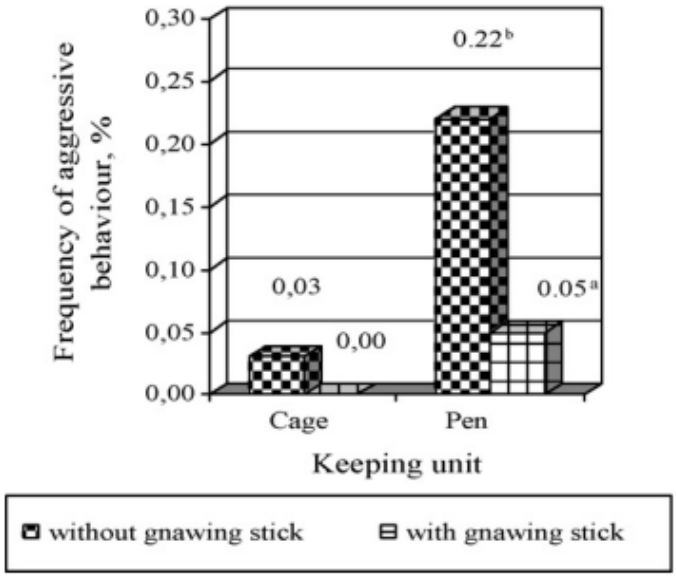


Figure 3 – Effect of group size and gnawing sticks on the frequency of aggressive behaviour in rabbits, showing the heightened aggression observed when there aren't any gnawing sticks given, especially in larger groups (pens) [63].

Multiple authors have proven that enriching the pens with gnawing sticks and the type of sticks used (whether hard or soft) did not influence the production of the growing rabbits [86] [87] [95].

Enriching wire-mesh cages with wooden gnawing sticks did not affect the average daily gain, feed intake, or feed conversion ratio of individually housed growing rabbits. Similarly, there were no differences in carcass traits between the experimental and control groups [86] [96].

On the other hand, one study found greater daily gains in rabbits with access to gnawing sticks [94]. In this study, rabbits with free access to gnawing sticks also had higher feed consumption between 5–7 and 9–11 weeks, likely because they ate more feed in those cages [9] [97].

Wooden sticks placed on the floor were more contaminated with E. coli (22.8%) compared to those on the ceiling (2.2%), which could pose health risks and lead to economic losses [98].

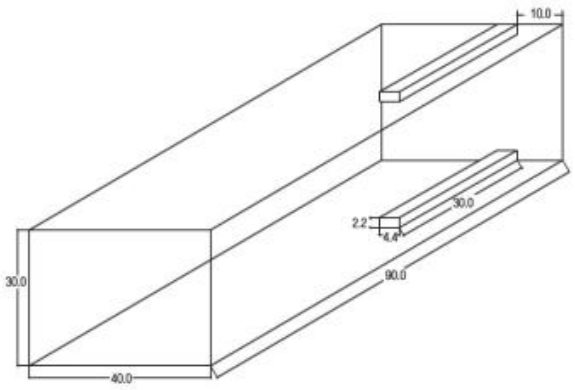


Figure 4 – Scheme of the rabbits' cage and the two locations for the gnawing sticks: fixed on the ceiling or the floor. Sticks stuck to the ceiling were much safer and less contaminated than those stuck to the floor [98].

It was confirmed that gnawing sticks made from softwoods were consumed more than those made from hardwoods, suggesting that softwood sticks are more effective for environmental enrichment. Proper use of these can minimise aggressive behaviour and hence, injuries, so increase welfare [9].

Norway spruce, classified as a softwood species [99], has recently been identified as a suitable option for gnawing sticks for rabbits. This could potentially help in mitigating aggressive behaviours among them [9], and rabbits prefer Norway spruce to oak wood [95].

Gnawing sticks are an environmental enrichment tool that has been proven to decrease the frequency of aggressive behaviours and lesions without decreasing the production of growing rabbits [87] [96].

Multiple literatures have agreed that gnawing sticks positively impact animal welfare, and the rabbits prefer to stay in enriched cages [9] [89] [94].

It was found that attaching wooden sticks to the cage floor offers the best enrichment for animals, improving their productivity and welfare. However, securing sticks to the ceiling is safer, reducing the risk of contamination and related health issues, which can prevent significant economic losses [98].

3.6 Group size

It is widely accepted that rabbits are inherently social creatures, and group housing is advised to allow them to express their natural behaviours fully [4].

The quantity of rabbits housed in a cage or pen is a critical factor affecting both their well-being and production efficiency [100].

In Europe, growing rabbits are typically kept in pairs or small group cages (4-6 rabbits). However, this arrangement may limit their ability to fully express natural behaviours, especially in terms of movement and social interactions [101]. In Italy and Hungary, rabbits are often housed in pairs, as they achieve a higher market weight ranging from 2.5 to 2.8kg [4].

Rabbit farmers are hesitant to implement large-group cages due to concerns about potential negative impacts on growth performance, as well as the quality of carcasses and meat [101].

It has been proven that when the size of the group is increased, the likelihood of fighting behaviour among the rabbits also rises [29]. The presence of skin lesions was utilised as a measure of aggressiveness [14].

On the other hand, a couple of studies found no correlation between the frequency of aggression and group size [102] [103].

While the findings in this study indicated that daily weight gain did not vary significantly across different group sizes, the highest daily weight gain values were observed in the group consisting of 8 rabbits per cage throughout the entire fattening period [104].

It was observed in this study, that the frequency of wounds increased with age, regardless of group size. Considering these findings, a maximum rearing period of 80 days or less has been suggested for group housing [44].

On the other hand, it was recorded that the incidence of ear injuries was found to increase with group size (in cages and pens), likely due to a few aggressive rabbits causing harm to others [9] [100] [105].

When rabbits were housed in pairs, no injuries were observed. In contrast, the average percentage of injured rabbits in small pens (housing 6 to 13 rabbits per cage) was 7.9%. This figure doubled in larger pens containing 20 to 26 rabbits per cage [100].

In the conditions of this study, the rabbits did not exhibit any visible signs of wounds after the trial, which involved individual cages, bicellular setups, and groups of nine rabbits per cage [101]. When rabbits were slaughtered at 72 days, we did not find any pathologies or lesions in those housed at a stocking density of 15 animals/m², whether in conventional collective cages (6 rabbits/ cage), small pens (10 rabbits/ pen), or large pens (60 rabbits/ pen) [45].

In this trial, the growth performance of rabbits housed in bicellular and collective cages with 9 animals was found to be similar but less favourable compared to those kept in individual housing [101].

It was found by multiple authors, that rabbits housed in groups of 4 exhibited the highest live weight at slaughter, while those in groups of 8 had the lowest weights [22] [106]. Correspondingly, this research concluded that the optimal solution may be to house 4 to 5 rabbits per cage or pen [29], while ensuring the density doesn't exceed 15–17 rabbits/m^2 [29].

Overall, lower productive performances were noted as group size increased [106] [10]. This can be because rabbits housed in pens exhibit higher energy expenditure and increased activity levels, resulting in lower body weight gain and fat deposits compared to those kept in cages [10] [23] [107] or individually [29] [101].

Furthermore, when comparing rabbits kept in conventional cages to those housed in alternative ground pens (containing 8-16 rabbits per pen), the productive performance of the rabbits in pens was negatively affected by poor hygiene conditions [57] [25].

It was found that there is a significant size increase in the hindquarters, which is associated with greater locomotor activity, that contributes to increased muscle size. Multiple authors have recorded that the fat deposits decreased with increasing group size [10] [100] [104] [108].

On the other hand, it was found that in collective housing systems, increasing the group size beyond 10 rabbits did not impact the daily growth rate or feed intake [25] [44] [46] and other authors found that there was no decline in productive performances with an increase in group size [42] [48].

It was recorded that housing 2 rabbits per cage limits their locomotor behaviours, leading to increased resting and feeding instead. In contrast, cages for 3-4 rabbits offer more space, as these cages naturally need to be bigger, enhancing their ability to move [109]. The recorded mortality rate was 5.71% lower in the group of 8 rabbits per cage compared to the group of 4 rabbits per cage [104].

In this experiment, no diarrhea was recorded, both for the 6 rabbits/pen and the 3 rabbits/cage. So, there was no mortality observed, even though it was expected, but the frequent changing of bedding material must have contributed to the absence of this illness among the rabbits [110].

The authors concluded that housing rabbits in larger groups (in larger pens) can cause stress. This stress may lead to reduced daily feed intake, slower growth rates, and a higher risk of infections [100] [104].

The rabbits in individual cages had higher daily growth than those in bicellular or collective setups, but their carcass quality and feed conversion remained comparable. Conversely, there was no difference in in-vivo performance or slaughter results between rabbits in collective cages with nine animals and those in bicellular cages, which are commonly used in Italy [101].

Based on the current experimental conditions and rabbits' behaviour in intensive settings, it is suggested that welfare would improve if group sizes were limited to 6 per standard cage, with a maximal density of 40kg/m² at 10 weeks of age [38].

Although consumer interest in animal welfare is elevating, awareness about rabbit well-being is deficient. It is crucial to educate customers, dealers, and shopkeepers on optimal housing for rabbits and to correct their misconceptions [29]. Further research on group size is needed to prevent abnormal behaviour [38].

3.7 Open-top cages or shallow: Cage heights

As a prey species, the European wild rabbit (*Oryctolagus cuniculus*) feels secure in narrow burrows (approximately 200mm wide) and typically emerges only at dusk to forage [70] [111] [112].

It was found that a significantly larger quantity of rabbits preferred the 400mm high cage at both 6.5 and 7.5 weeks of age, in the 16 rabbits/m² stocking density. In the 12 rabbits/m² stocking density, the rabbits one-week post-weaning endorsed the 400mm high cages. Conversely, the 8.5-week-old rabbits preferred the 300mm high cages. The growing rabbits showed the least preference for open-top cages, irrespective of the stocking density [63].

At a stocking density of 16 rabbits/m², the frequency of rabbits in the open-top cage nearly doubled at 9.5 weeks compared to 6.5 weeks. However, when housing 12 rabbits/m², the preference for the open-top cage stayed the same at both 9.5 and 6.5 weeks [63]. The rabbits preferred the less favoured open-top cage over enduring a high stocking density [62].

More rabbits preferred the 200mm high cage, over the open-top cages, which appears quite low from an animal welfare perspective. It can be assumed that for domesticated rabbits, closed and open cages are the burrow and open field, respectively [63].

This author believes that the height should be at least 380-400mm in part of the cage to allow the rabbit to sit up with its ears erect, which is important for both practical considerations and animal welfare [4], and although animal rights activists may justifiably expect rabbits to be able to stand on their hind legs, a behaviour also seen in European wild rabbits, it is important to note that this posture is used only for spotting predators [29]. Since there are no predators in the farms, standing up position is extremely rare, occurring less than 1% of the time [28].

The height of the cage had no significant impact on weekly or total feed consumption, except for the final fattening week, where the cage height affected mainly the average daily gain. During this week, the rabbit group in the 300mm high cage exhibited the poorest performance, but no mortality was recorded in either group [63].

Age had a significant impact on the occurrence of ear lesions. No injuries were noted at 9.5 weeks of age, but the proportion of injured rabbits nearly doubled between 10 and 11 weeks. At 11 weeks, ear lesions were most common in the 200mm high cage and least common in the 300mm high cage [63].

From an animal welfare standpoint, the recommendation by some animal protection organisations to use open-top cages or pens is questionable, as rabbits prefer enclosures with roofs and prefer the open-top cage the least [63].

Rabbits prefer resting in low (200mm high) cages, but these cages are insufficient for allowing locomotor behaviours and tend to increase the frequency of aggression. Taking into consideration the welfare indicators such as preference tests, ear injuries related to aggression, and the growth performance of the rabbits, it can be concluded that the widely used 300-350mm high cages are better suited and fitting for growing rabbits, while not hindering their welfare [4] [63].

Research on how housing systems affect animal welfare is still insufficient to draw definitive conclusions about the ideal accommodation for rabbits [4].

3.8 Cage size

From an animal welfare perspective, ensuring sufficient space and a suitable environment is crucial for allowing freedom of movement and enhancing comfort [100], so a small cage size and lack of environmental enrichment are likely to negatively impact welfare by limiting the ability to express a full range of natural behaviours [113].

When stocking density remains constant but group size, and therefore total cage size increases, the behaviours requiring more space are speculated to become more prevalent among the rabbits, as more free space is available for animals to share [114].

This experiment found that the medium cage design (381mm x 508mm x 406mm per rabbit) yields the highest body weight gains compared to other cage structures, although not very significant. The medium cages appeared sufficient for housing rabbits at 70 days of age [115].

Sternal lying decreased as cage size increased, while sitting also increased with larger cages, though not significantly. For other behaviours, the relationship with cage size was inconsistent [113].

The current findings suggest that it may be beneficial to house early-weaned rabbits at higher stocking densities than the conventional 16 rabbits/m^2, as younger rabbits tend to prefer smaller cages [47].

Housing rabbits two per cage restricts functional space, limiting locomotor behaviours. While small cages show few locomotor activities, they increase resting and feeding. Cages for three or four rabbits offer better movement compared to those for two rabbits [109].

However, rearing rabbits in large groups and pens raises animal welfare concerns, particularly as they age, with pen design also playing a significant role [23].

All rabbits in the samples from this experiment were observed lying down, and their growth performance was good, indicating that they were retained in a less stressful environment [115]. It was discovered by this study that housing two rabbits per cage (515mm x 280mm x 290mm) limits their locomotor behaviours, resulting in more resting and feeding activities. In contrast, cages for three rabbits (510mm x 415mm x 290mm) and four rabbits (680mm x 415mm x 290mm) provide more space, allowing for better movement, while all setups support a similar density of 714cm² per rabbit [109].

Further research is needed on cage dimensions to prevent abnormal behaviour and ensure proper hygiene [4], and on group size [38].

4. Conclusion

Rabbits are social animals and should be reared in groups for better behavioural patterns that are close to their natural behaviour. Furthermore, they should be reared in cages rather than pens, as they show better performance and exhibit less aggression in cages.

The stocking density should not exceed 40kg/m^2, which is around 16-18 rabbits/m^2, each rabbit being 2.5kg. If it does exceed, then the lesions will increase significantly, and performance will decrease. This indicates an increase in their stress levels and issues with housing and their environment.

Plastic nets are the most preferred flooring type by rabbits, showing that it is more comfortable than the widely used wire-net floors in Europe. The 5mm width slats with 13mm in between each slat (and 75% perforation) result in the least injuries and the highest cleanliness levels.

Platforms allow for more movement and better welfare without affecting their performance. However, this may increase aggression and injury rates.

Gnawing sticks as enrichment decreased the frequency of aggression and lesions in the rabbits. The rabbits were less bored and, hence, fought less. As for the ideal material for the sticks, this would be softwood, e.g. Norway spruce. So, this enrichment increases the welfare. A good solution would be to secure them to the ceiling, so they do not become contaminated with faeces. Furthermore, the sticks may be given during their active hours and taken away in between, so the rabbits don’t lose interest.

The bigger the group size, the higher the aggression and fighting among the rabbits. So, the ideal group size would be around 3-5 rabbits per cage, as this resulted in the best growth and welfare. The bicellular cages provide too little space for the rabbit, decreasing their welfare and performance.

The ideal cage size would be around 510mm x 415mm x 290mm (for 3 rabbits) and 680mm x 415mm x 290mm (for 4 rabbits). This provides more space, allowing for better movement and welfare. So, as stated earlier, cages for 3-4 rabbits provide better space than the bicellular cages.

The rabbits preferred the open-top cages the least. The better cage height for them would be around 300-400mm high, as in these cages, the rabbits exhibited fewer injuries, maintaining good welfare. Lower heights than 300mm were preferred but resulted in the highest lesion rates.

The rabbits which were slaughtered above 72 days of age exhibit the most aggression and injuries. Hence, it is encouraged to slaughter the rabbits by 72 days of age, to prevent stress and enhance their welfare. It is also important, as the cage dimensions will not be able to accommodate their size.

To ensure minimal fights and aggression, it is advised that the farmers breed only docile rabbits to decrease injuries and improve their welfare.

However, further research must be done to understand fully the behaviours and needs of the rabbits.

5. Summary

Housing conditions affect rabbit welfare, behaviour, and growth. While pens promote natural behaviours and activity, they are linked to higher stress, aggression, and lower growth performance compared to cages.

Stocking density significantly impacts rabbit welfare and productivity, with a recommended maximum of 40kg/m² (16-18 rabbits/m²) for optimal growth and minimal aggression. Higher densities increase stress and injuries while densities below this threshold show little to no improvement in welfare or production.

Rabbits in Europe are mainly reared on wire mesh floors, but studies show that rabbits prefer plastic mesh over other surfaces when provided with a comfortable stocking density. Deep litter increases

health risks and is the least favoured. The ideal flooring remains uncertain, but plastic-slatted floors offer a balance of cleanliness and comfort.

Rabbits prefer staying on the floor instead of on platforms but benefit from platforms for movement and hiding under, while not affecting their performance. Plastic-net platforms are favoured, especially with manure trays however they can increase injury risks.

Gnawing sticks improve rabbit welfare by reducing aggression and supporting dental health. They don't affect growth but encourage natural behaviours. Softwoods like Norway spruce are preferred, and fixing sticks to the ceiling reduces contamination and risk of illness.

Rabbits are social, and group housing supports natural behaviours, but larger groups can increase stress, injuries and infection risks. Optimal welfare and growth are seen in groups of 3-5 rabbits per cage. It is vital to not exceed 40kg/m² and to slaughter rabbits at around 72 days of age.

Rabbits dislike open-top cages the most. Cage height affects growth, with 300mm cages yielding the best results. Although lower cages were preferred, they increased aggression and lesions. 300-400mm high cages are considered best for welfare and growth, though more research is needed.

Medium-sized cages of 510mm x 415mm x 290mm (for 3 rabbits) and 680mm x 415mm x 290mm (for 4 rabbits) showed better weight gain. Housing 2 rabbits per cage restricts movement, while 3 or 4 rabbits per cage offers more space for locomotion. However, large groups and pens raise welfare concerns, and more research on cage dimensions and group size is needed for optimal conditions.

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