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Growth Performance of Rabbits using Different Methods of Weaning Group Formation

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ABSTRACT

In rabbit meat production, weaning is a crucial phase and must be conducted properly to achieve adequate growth performance and slaughter weight in the shortest possible time. Studies on rabbit weaning, particularly concerning weaning methods (i.e. different approaches to forming weaning groups) and their effects on production, are scarce. Our study compared three weaning methods in indoor and outdoor breeding environment. In our experiment, rabbits were weaned by body size (same size together; n = 27), by litter of origin (littermates together; n = 30) or at random (n = 57). All rabbits were housed in wire cages in groups of three. Body weight, daily weight gain and feed conversion rate (FCR) were monitored over a period of 8 weeks from weaning to slaughter. The breeding environment and weaning methods affected most of the parameters, yet the interaction between the studied effects was insignificant during the entire experimental period. With the body size-based and random method, the rabbits reached significantly higher final body weight (2348 g and 2263 g, respectively) than rabbits weaned with the litter-based method (2168 g). Similarly, daily weight gain was 27.2 g, 25.7 g and 24.0 g ($p = 0.024$) for rabbits weaned using the body size-based, random and litter-based methods, respectively. Regarding the effects of the breeding environment, indoor housing provided better production results. The rabbits kept indoors grew faster than the outdoor rabbits (27.2 g/day and 24.1 g/day, respectively; $p < 0.001$) and had a 15% higher final weight (2345 g indoors, 2174 g outdoors, $p < 0.001$). Feed conversion ratio was lower ($p < 0.001$) in the indoor housing (≈2.5) than in the outdoor housing (≈3.0). However, the body size-based weaning method was found to be the most efficient for growth performance and final body weight, regardless of environment (indoor or outdoor). Randomly formed weaning groups or those formed from littermates performed better indoors; however, the latter (i.e. from littermates) anyway remained inferior to rabbits from the other two groups. The study therefore showed that the approach to weaning group formation and the environment crucially influence the efficiency of rabbit weaner fattening and should be considered by breeders when weaning kits.

Keywords: rabbit, weaning, weaning methods, growth rate, feed conversion ratio

INTRODUCTION

Cuniculture (rabbit breeding) is considered a minor livestock sector compared to meat production from predominant domestic species such as pig, chicken, and cattle. However, according to the FAO (2025), it is an important sector in some regions, particularly in Asia (China, Democratic Republic of Korea, etc.). In Europe, France and Spain, for example, have the most developed rabbit sectors, while in many other countries, including Slovenia, cuniculture is still regarded as an insignificant niche of livestock breeding. It is mainly practised as extensive side-line farming for personal needs, while intensive breeding is rare. Therefore, to the best of our knowledge, there is also a relatively small corpus of scientific literature on rabbit breeding technologies, including studies focusing on the most critical phase of rabbit breeding, namely the weaning process and the formation of weaning groups.

As with mammals in general, weaning is one of the most important phases that decisively influences the subsequent growth and development of rabbits. Therefore, special attention must be given to this process in rabbit breeding. Although breeders often wean the offspring by moving the doe to another location while the kits remain together in the same hutch, weaning is also frequently done the other way round. In either case, it is generally considered that all kits should be immediately separated from their mother, with the littermates kept together for at least two weeks to

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reduce weaning stress (Klinar, 2012). There are various methods of group formation, in which smaller groups are formed (e.g. separated by sex, in pairs or trios), or animals are placed in individual cages. Some combined methods are also used; for example, weaning and housing male kits individually due to potential aggression and inbreeding. However, housing individual kits is only necessary from around 70 days (10 weeks) of age, when sexual maturity begins (Klinar, 2012). Group housing, by contrast, offers many benefits, including reduced anxiety in rabbits housed in group cages compared to those weaned individually or in pairs, as well as less or no stereotypic behaviour (Dorning and Harris, 2017). In addition to the importance of weaning methods for rabbit welfare, the weaning process also affects the transition to the fattening period and growth performance. However, little is known about the influence of different weaning methods and various approaches to forming weaning groups on rabbit fattening. Existing studies have mainly focused on the effects of weaning age (Kovács et al., 2012), weaning body weight (Oke et al., 2011), the combined influence of birth weight and group size (Poigner et al., 2000), age and nutrition (Xiccato et al., 2016), weaning age and cage type (Alfonso-Carrillo et al., 2014), or stocking density and housing conditions on rabbit performance until and after weaning, that is, during the fattening period (Szendrő and Zotte, 2011).

Our research focused on various methods of weaning group formation, primarily with respect to litter of origin and body size. In addition, we examined the influence of the breeding environment, i.e. outdoor versus indoor breeding. We hypothesised that rabbits would grow faster and have a lower (better) feed conversion ratio (FCR) if weaned into groups of kits from the same litter (littermates), due to reduced weaning stress. We also expected that rabbits kept indoors would grow faster and have a lower (better) FCR than those kept outdoors, as they are protected from unfavourable weather conditions and large temperature fluctuations.

MATERIALS AND METHODS

Location and Experimental Period

The study was conducted on a family farm practising small-scale, extensive rabbit farming. The farm kept 10 breeding does, each housed individually in wire mesh cages with straw bedding. Each doe produces an average of four litters per year, with an average litter size of 8.7 kits. Kits are usually weaned at 42 days of age and does are mated (introduced to the buck) 10 days after weaning. The farm is located in the north-eastern part of Slovenia. The experiment was conducted in accordance with the farm's long-standing standard practice and took place from February 2024 to March 2025.

Animals and Housing

Rabbits were reared in accordance with current legislation on the protection of farm animals. National and European legislation on the protection of farm animals (Directive 2010/63/EU) was followed during the experiment. The study included nine does of different meat rabbit breeds or lines (Slovenian SIKA, Checkered Giant, New Zealand Red, Californian, Hycole), aged 1 to 3 years. Mating was arranged to achieve kindling within five days. A total of 114 kits from 19 litters were included in the study. Litters remained intact throughout the entire lactation period; cross-fostering was not conducted. The does were housed in individual cages measuring 100 × 60 × 40 cm, each with a separate section containing a nest box.

Weaned kits were housed in wire mesh cages without bedding. Six outdoor cages (55 × 50 × 45 cm) and eight indoor cages (45 × 75 × 40 cm) were available for weaning. The outdoor cages were located in a fully shaded, windless area, covered by a roof and enclosed by back and side walls. The indoor cages were located in a barn with mainly natural lighting, supplemented by some artificial light, and with ventilation. The indoor temperature remained constant without significant fluctuations. The cages were equipped with metal feeders and standard nipple drinkers for rabbits. The wire mesh cages were designed and positioned so that faeces fell through the mesh onto the floor. Faeces accumulating under the cages were removed after each experiment. The cages were thoroughly washed and prepared for the next weaning.

Feeding of rabbits

The rabbits were fed twice daily, in the morning and evening. To avoid feed waste, the feeding plan (i.e. the amount of feed; see Table 1) was determined by a preliminary trial before the experiment began. Thus, rabbits were fed *ad libitum*, but the amount of feed was adjusted to minimise residual feed. As residuals were absent or negligible, we did not collect or measure them. The feed ration consisted of home-grown hay and a concentrate mixture of home-grown barley and commercial rabbit pelleted (CRP) feed.

Table 1: Average feed intake measured by group by week

	Week after weaning							
	1	2	3	4	5	6	7	8
Hay, g	280	308	308	367	600	600	667	667
Concentrate mixture (70% barley + 30% CRP), g	371	371	433	433	433	600	600	600

CRP – commercial rabbit pelleted feed

Experimental Design

The rabbits were weaned at 42 days of age. At weaning, each kit was weighed and sexed. In each weaning batch, kits from at least two litters were grouped into sets of three using three different methods, as shown in Table 2: i) all kits from the same litter, regardless of body size or sex (litter-based group; n = 30); ii) grouping kits of similar body size (body size was determined by visual estimation, i.e. individuals that appeared to differ least in body size) from different litters, so that the largest or smallest rabbits from different litters were grouped together (body size-based group; n = 27); and iii) randomly selected kits from different litters, with groups composed of kits from one, two, or three litters, ensuring all combinations were comparably represented (random group; n = 57). Weaning batches were also balanced for breed. As the effect of breeding environmental conditions were additionally tested, 67 weaners were housed indoors and 47 outdoors.

Table 2: Basic data for individual weaning batches

Weaning batch	Number of litters	Number of weaned kits (m:f)	Litter sizes	Environment (weaning period, months, average T in °C *)	Weaning group based on
1	2	12 (5:7)	9:3	Outdoor (Feb.-Mar., 7.3-9.2)	Body size-based
2	4	27 (12:15)	12:6:5:4	Outdoor, Indoor (May-Jun., 16.2-21.1)	Random
3	2	15 (7:8)	9:6	Indoor (Jun.-Jul., 21.1-23.0)	Body size-based
4	4	18 (10:8)	6:6:3:3	Outdoor (Aug.-Sept., 22.9-16.7)	Litter-based
5	3	12 (7:5)	6:3:3	Indoor (Sept.-Oct., 16.7-12.8)	Litter-based
6	4	30 (11:19)	10:8:6:6	Outdoor, Indoor (Jan.-Feb., 3.3-1.3)	Random

* Slivnica, Maribor Edvard Rusjan Airport weather station (ARSO, 2025); m:f – male:female ratio

Observations and Measurements

After weaning, the rabbits were weighed weekly for eight weeks, and daily weight gain was calculated from body weight and age. Conversion ratio (FCR) was calculated from feed intake (i.e. feed offered) and body weight gain. Table 3 shows the body weight of the rabbits at the start of the experiment (at weaning), when the groups were formed. Differences in kit weaning weights between weaning groups and breeding environments (Table 3), as well as the small sample size, prevented complete balancing of weaner weights; thus, weaning weight was included as a covariate in the model to adjust body weight values to the same weight at weaning.

Table 3: Body weight of rabbits at the beginning of the experiment

	Weaning method			Environment		p		
	Body size-based	Random	Litter-based	Outdoor	Indoor	Weaning method	Environment	Weaning method × Environment
Body weight, g	761.9 a	824.9 ab	880.7 b	862.2	782.7	0.058	0.031	0.160

Statistical Analysis

The data were processed in SPSS. The dependent variables (body weight, daily gain, FCR) were analysed using the MIXED procedure (linear mixed model). The weaning method (litter-based, body size-based, random), breeding environment (indoor, outdoor), and their interaction were included in the model as fixed factors, with weaning weight as a covariate. Estimated means and standard errors of the means for the analysed factors and their interaction were calculated for all models. Post hoc comparisons with Bonferroni correction for multiple comparisons were also

performed. Visual inspection of the residual plots of the models revealed no major deviations from homoscedasticity or normality. The analysis was conducted separately for each week and for the entire study period.

RESULTS

The results concerning the effects of weaning method, breeding environment, and their interaction on rabbit body weight from weaning to slaughter showed that the interaction between the analysed factors (weaning method × breeding environment) was statistically insignificant throughout the experimental period (p = 0.366–0.831; Table 4). Therefore, the effects of the studied factors are presented separately. Results showed that body weight was generally similar across all three weaning methods during the first six weeks after weaning. In the third week, the body weight of rabbits in the random group was significantly higher (1391 g, p < 0.05) and also tended to be the highest in the fourth week (Table 4). In the fifth week and during the last two weeks of the fattening period, rabbits from the body size-based and random groups had statistically equal weights and were significantly heavier than those in the litter-based group (p < 0.05). The final body weights were 2348 g, 2263 g, and 2168 g for the body size-based, random, and litter-based groups, respectively (p = 0.010; Table 4). Over the entire experimental period, rabbits from the litter-based method had the lowest weight, although they were the heaviest at weaning. At the end of the experiment, rabbits in the litter-based group had a significantly lower final weight, approximately 180 g or 8% lower than those in the body size-based group and approximately 100 g or 4% lower than those in the random group.

The results also indicate a significant effect of breeding environment on rabbit body weight. One week after weaning, body weight was similar in rabbits from both breeding environments (p ≥ 0.05, Table 4). From week 3 onwards, rabbits kept indoors had a higher average body weight than those kept outdoors, with differences between breeding environments becoming statistically significant from week 6 onwards (p < 0.05). The final body weight was 2175 g for rabbits kept outdoors and 2345 g for those kept indoors (p < 0.001). Therefore, the difference between outdoor and indoor breeding at the end of the experiment was approximately 170 g, or 8%.

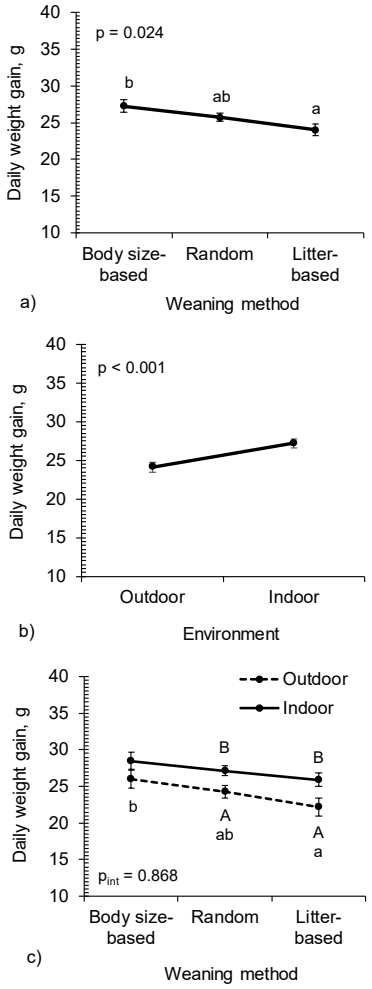
Table 4: The effect of weaning method, breeding environment and their interaction on rabbit body weight from weaning to slaughter

	Body weight, kg							
Week after weaning	1	2	3	4	5	6	7	8
	Mean ± standard error							
Weaning method								
Body size-based	968 ± 22	1129 ± 28	1285a ± 32	1490 ± 37	1682ab ± 41	1912 ± 41	2165b ± 45	2348b ± 47
Random	1007 ± 14	1184 ± 18	1391b ± 21	1581 ± 25	1772b ± 27	1947 ± 27	2108ab ± 29	2263b ± 31
Litter-based	1007 ± 20	1152 ± 25	1296a ± 30	1511 ± 34	1673a ± 37	1848 ± 38	2021a ± 41	2168a ± 43
	Mean ± standard error							
Breeding environment								
Outdoor	1000 ± 17	1156 ± 21	1307 ± 25	1504 ± 28	1676 ± 31	1844 ± 32	2039 ± 34	2174 ± 36
Indoor	987 ± 14	1154 ± 18	1341 ± 21	1550 ± 24	1742 ± 27	1960 ± 27	2156 ± 29	2345 ± 31
	p-value							
Weaning method	0.295	0.237	0.005	0.074	0.048	0.109	0.059	0.024
Breeding environment	0.591	0.928	0.312	0.228	0.110	0.007	0.011	<0.001
Weaning method × Breeding environment	0.541	0.496	0.426	0.424	0.424	0.438	0.457	0.831

a,b – different letters indicate significantly (p < 0.05) different mean values between weaning groups; p (Weaning body weight) < 0.001

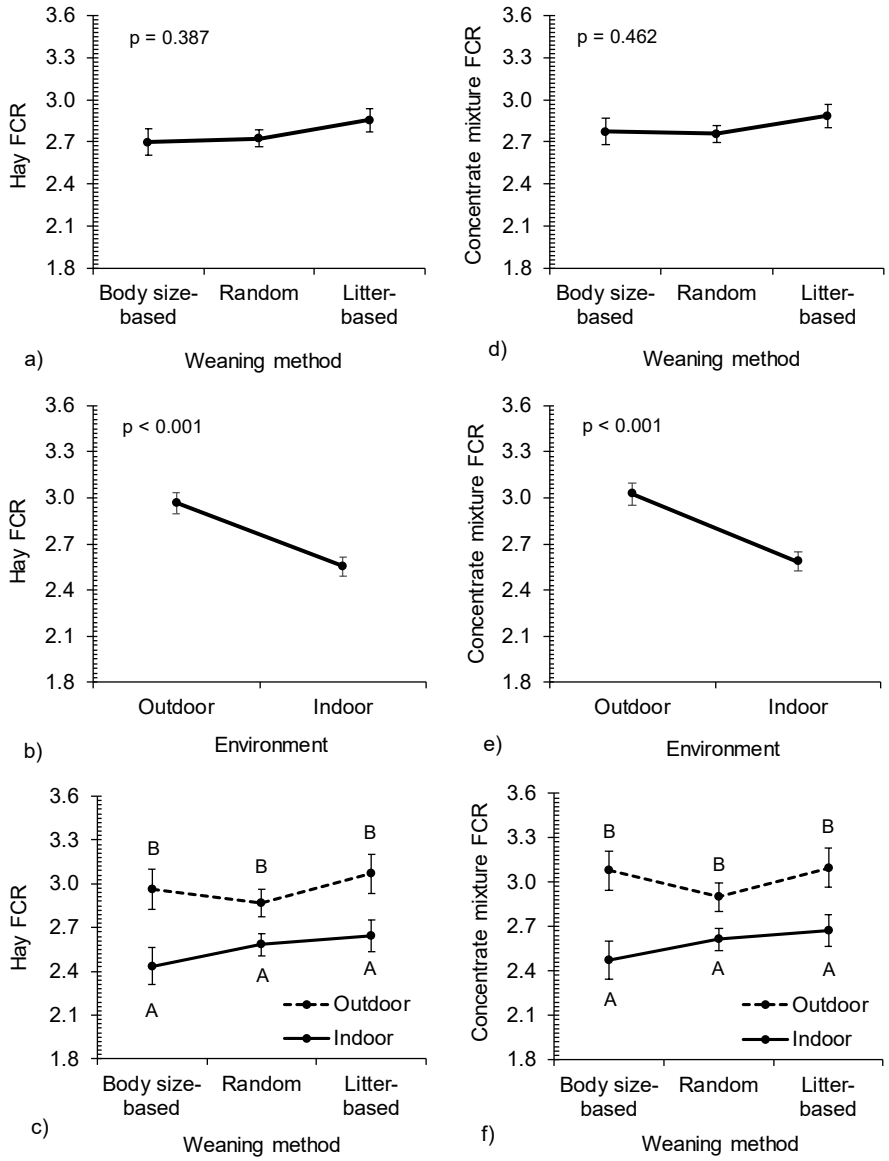
As shown in Fig. 1, the effects of weaning method, breeding environment, and their interaction on daily weight gain are consistent with the results for body weight from weaning to slaughter. The interaction between the studied factors was not significant ($p = 0.831$); however, when considered separately, both the weaning method and breeding environment significantly affected daily gain. Kits weaned according to body size gained weight faster than those weaned by the random method, and especially those weaned based on their litter of origin (27.2 g, 25.7 g, and 24.0 g, respectively; $p = 0.024$). Thus, daily gain in the body size-based group was 12% higher than in the random group and 6% higher than in the litter-based group. The results also showed 11% higher daily weight gain in rabbits kept indoors compared to those kept outdoors (27.2 g and 24.1 g, respectively; $p < 0.001$). Interestingly, rabbits grouped by body size showed no difference in weight gain with regard to breeding environment.

The effect of weaning method, breeding environment, and their interaction on FCR from weaning to slaughter is shown separately for hay and concentrate mixture in Fig. 2. Neither the weaning method nor the interaction between weaning method and breeding environment significantly affected FCR ($p \geq 0.05$). The method used to form the weaning groups had no influence on FCR for either feed. Hay FCR was 2.70, 2.73, and 2.86 for the body size-based, random, and litter-based weaning methods, respectively ($p = 0.387$), while concentrate mixture FCR was 2.77, 2.76, and 2.89 for the body size-based, random, and litter-based weaning methods, respectively ($p = 0.462$). In contrast, breeding environment had a significant effect on FCR. Indoor rabbits had lower hay FCR than outdoor rabbits (2.55 g and 2.97 g, respectively; $p < 0.001$), with the difference in hay FCR being approximately 15% (Fig. 2). Concentrate mixture FCR was also significantly lower for rabbits kept indoors compared to those kept outdoors (2.59 g and 3.03 g, respectively; $p < 0.001$). The difference in concentrate mixture FCR was also about 15%.



[ab] Different letters indicate significantly ($p < 0.05$) different means between weaning groups (in case of Fig. c within each breeding environment); [AB] Different letters indicate significantly ($p < 0.05$) different means between breeding environments within each weaning group.

Figure 1: The effect of weaning method, breeding environment and their interaction on the daily weight gain of rabbits from weaning to slaughter



[AB] Different letters indicate significantly ($p < 0.05$) different mean values between breeding environments within each weaning group (the mean values of the weaning groups do not differ within breeding environment).

Figure 2: The effect of weaning method, breeding environment and their interaction on hay and concentrate mixture FCR from weaning to slaughter

DISCUSSION

The study showed that the breeding environment affects growth performance and FCR in rabbits after weaning, while different methods of group formation at weaning appeared to affect growth performance but not FCR. Generally, rabbits weaned indoors and those weaned in groups with conspecifics of similar body size or grouped randomly achieved the highest final body weight and highest growth rate. It must be emphasised that the study was conducted with a relatively small sample size, which limits the ability to draw firm conclusions, particularly regarding FCR.

Due to variable and often suboptimal outdoor conditions compared to the relatively constant and optimal indoor environment, particularly regarding temperature, the lower growth performance and higher FCR observed outdoors in our study were expected. Outdoor animals must expend additional energy to maintain optimal body temperature if it fluctuates below or above the rabbit comfort zone of 21°C (Fayez et al., 1994). High environmental temperatures, in particular, have been shown to affect rabbits negatively, as they are very sensitive to heat stress due to their thick fur and lack of sweat glands, which prevent them from dissipating excess heat (Oladimeji et al., 2022). Therefore, when temperatures are high, for example in summer, rabbits decrease feed intake and increase FCR, resulting in lower growth (Marai et al., 2002; Sirotkin et al., 2021). Conversely, rabbits tolerate low temperatures well, exhibiting an even better growth rate as temperature decreases; however, lthis is accompanied by a marked

increase in feed intake and FCR (Cervera et al., 1997; D'Agata et al., 2009).

However, previous studies on the growth performance of rabbits in relation to the housing environment are inconclusive, showing that the impact of suboptimal temperature depends on space allowance, group size (Sommerville et al., 2017), and diet (Cervera et al., 1997), with some studies reporting better performance outdoors (D'Agata et al., 2009).

Furthermore, contrary to our expectations, rabbits weaned into groups with their littermates showed lower growth performance, with the lowest weight gain and final body weight. Offspring of polytocous mammals (i.e. those that give birth to multiple offspring at the same time) are expected to form social bonds with their littermates, and sudden disruption of these bonds is considered stressful. Apart from the rabbit, the only other true polytocous farmed mammal is the pig, for which it is well known that piglets establish a cohesive social order during lactation through contest competition (agonistic competition), manifesting as a teat order (Skok and Škorjanc, 2014). Therefore, piglets must be weaned together to prevent distress, potential aggression, and impaired growth performance (Camerlink et al., 2021). However, rabbit kits form much looser social bonds and do not establish a teat order during lactation (Bautista et al., 2005). Instead of contest competition, they exhibit scramble competition. Scramble competition (e.g. for food) means that competitors do not compete for food through agonistic interactions, such as aggression, but indirectly by trying to acquire as much food as possible when it is available, that is, by outpacing others in consumption (Mock et al., 1998). In rabbits, scramble competition occurs during lactation between littermates when suckling (Bautista et al., 2005), and it can be proposed that it continues after weaning until sexual maturity, when contest competition accompanied by aggression replaces scramble competition. Rabbits have therefore been shown to tolerate mixing with other individuals after weaning very well (Dorning and Harris, 2017). Accordingly, mixing different litters at weaning in our study showed better results than keeping littermates together after weaning. In particular, kits weaned using the body size-based method gained weight most efficiently and reached the highest final body weight. Moreover, daily weight gain in the body size-based group did not differ with respect to environmental conditions (indoor vs outdoor).

In addition, two aspects make the differences in growth performance between the weaning groups even more notable. First, the weaning weight in the body size-based group was significantly lower than in the litter-based group. Typically, young animals with a higher initial body weight are known to grow more rapidly and achieve a higher final weight, which also applies to rabbits (Oke et al. 2011). However, our results show that this pattern can be altered or even reversed by the weaning method. Rabbits weaned based on their body size reached, and even exceeded, the body weight of the other groups – which had a significantly higher initial weight – by the middle of the fattening period. Secondly, we found that the daily weight gain in the body size-based weaning group remained consistently high regardless of environmental conditions (indoor or outdoor), whereas in rabbits weaned under the other two methods, daily weight gain decreased significantly when housed outdoors. This highlights the generally better growth performance of kits weaned using the body size-based method compared with the others.

CONCLUSIONS

The study confirmed the effect of weaning method and breeding environment on the daily weight gain and FCR in rabbits. Breeding environment appears to have decisive role with indoor breeding resulting in overall better production results, while the most effective weaning method, considering growth performance and final body weight, was grouping individuals of the same body size (body size-based method), regardless of breeding environment. The growth performance of weaning groups formed from littermates or random individuals was better indoors, but still inferior to the body size-based group. Although no firm conclusion can be drawn, the study indicated that certain methods of weaning group formation may be best avoided, particularly when rabbits are bred outdoors.

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Rastnost kuncev pri različno tvorjenih odstavitvenih skupinah

IZVLEČEK

Odstavitev je ključna faza reje kuncev in jo je potrebno primerno izvesti, da omogočimo dobro rast in klavno maso. Raziskav o odstavitvi kuncev, zlasti o metodah odstavitve (tj. različnih pristopih oblikovanja odstavitvenih skupin) in njihovem vplivu na prirejo, je malo. V naši raziskavi smo primerjali različne metode odstavitve v dveh rejskih okoljih (v hlevu in na prostem). Kunci so bili odstavljeni po eni izmed treh metod odstavitve: po telesni velikosti (skupina kuncev, izenačenih po telesni velikosti; n = 27), glede na izvorno gnezdo (skupina kuncev iz istega gnezda; n = 30) ali naključno (n = 57). Odstavitvene skupine s po tremi kunci so bile nameščene v žičnih kletkah. V obdobju 8 tednov, od odstavitve do zakola, smo spremljali telesno maso, dnevni prirast in koriščenje krme. Rezultati so pokazali vpliv rejskega okolja in metode odstavitve na večino preučevanih parametrov, interakcija med rejskim okoljem in metodami odstavitve pa je bila v celotnem poskusnem obdobju neznačilna. Z metodo 'po telesni velikosti' in naključno metodo so kunci dosegli bistveno višjo končno telesno maso (2348 g proti 2263 g) kot kunci, odstavljeni z metodo 'po gnezdih' (2168 g). Skladni s tem so bili tudi rezultati dnevnih prirastov, ki so znašali 27,2 g pri metodi 'po velikosti', 25,7 g pri naključni metodi in 24,0 g pri metodi 'po gnezdih' ($p = 0,024$). Kar se tiče vpliva rejskega okolja, so bili v hlevski reji boljši proizvodni rezultati, saj so imeli kunci, vzrejeni v hlevu višji povprečni dnevni prirast kot kunci, rejeni na prostem (27,2 g/dan oziroma 24,1 g/dan; $p < 0,001$), kar je rezultiralo v 15 % višji končni telesni masi (2345 g v hlevu, 2174 g na prostem, $p < 0,001$). Koriščenje krme je bilo v hlevski reji učinkovitejše (≈2.5) kot v reji na prostem (≈3,0; $p < 0,001$). Izkazalo se je, da je metoda odstavitve 'po velikosti' ne glede na rejsko okolje (v hlevu ali na prostem) najučinkovitejša v smislu rastnosti in končne telesne mase. Kunci iz naključno oblikovanih odstavitvenih skupin in tisti iz skupin, oblikovanih 'po gnezdih' so v hlevski reji dosegli boljše rezultate, pri čemer so kunci iz slednje ('po gnezdih') dosegali slabše rastne rezultate v primerjavi s preostalima odstavitvenima metodama. Raziskava je torej pokazala, da pristop oblikovanja odstavitvnih skupin in rejsko okolje ključno vplivata na učinkovitost pitanja kuncev po odstavitvi in da bi ju morali rejci upoštevati pri odstavitvi mladičev.

Ključne besede: kunec, odstavitev, odstavitvene metode, rastnost, konverzija krme