*Scientific Annals of the Polish Society of Animal Production - Vol. 16 (2020), No 1, 37-49*

DOI: 10.5604/01.3001.0014.0503

# The influence of maternal and paternal components and breeding season on the reproductive results of New Zealand White and Californian female rabbits

**Justyna Pycha[1], Magdalena Zatoń-Dobrowolska[1], Sylwia Pałka[2#], Michał Kmiecik[2]**

[1]Wroclaw University of Environmental and Life Sciences, Department of Genetics, ul. Kożuchowska 7, 51-631 Wrocław, Poland

[2]University of Agriculture in Krakow, Department of Genetics, Animal Breeding and Ethology, Al. Mickiewicza 24/28, 30-059 Kraków, Poland; [#]e-mail: sylwia.palka@urk.edu.pl

**The research compares reproduction of female New Zealand White (NZW, n=55) and Californian (CAL, n=12) rabbits after mating with purebred Flemish Giant, Californian, and Burgundy Fawn males, as well as New Zealand White and Californian crossbred males. The influence of the dam's breed, the birth season, and the paternal component on reproduction parameters was analysed. Three groups of does were studied: those which had two litters (21 females), those which had three litters (15), and all does (irrespective of the number of litters, i.e. 67 females). In the first group, the mother's breed was found to affect litter size at weaning (5.20 for Californian and 7.33 for New Zealand White), which was largest for the NZW×CAL crossbreed (10.50). Among the females with three litters, the breed of the dam influenced rearing efficiency, with greater efficiency noted for the New Zealand White breed (90.2%) than for the Californian breed (69.8%). Where all litters were considered, the two breeds differed in terms of the number of live-born kittens per litter (6.59 for NZW vs 7.71 for CAL) and litter size at weaning (6.34 vs 7.50). In this group, litter size at weaning was larger in winter (4.65) than in autumn (2.00). New Zealand White females that mated with Flemish Giant males produced fewer live-born kittens per litter (5.85) than Californian females that mated with Burgundy Fawn males (10.00). Purebred litters were smaller (2.04) at weaning than crossbred ones (from 5.39 to 10.00). For females with three litters, repeatability was 0.36 for total litter size and 0.35 for the number of live-born kittens per litter. For**

**litter size at weaning, however, it was only 0.15, indicating a strong effect of environmental factors on rearing outcomes.**

**KEY WORDS: rabbit reproduction, litters, rabbit rearing, crossbreds, cross-breeding, repeatability**

Meat rabbit production is based on intensive reproduction. Rabbits of medium-sized breeds reach sexual maturity at around 3-4 months of age, and females are ready to reproduce at around 5-7 months of age, after reaching a body weight two-thirds that of an adult female. Body weight is closely linked to body condition. According to de la Fuente and Rosell (2012), the healthiest female rabbits are those with a body condition score (BCS) of 4.6 (on a scale of 1.0 to 9.0). In their study, these rabbits had the lowest incidence of mastitis, tarsal joint disorders, catarrh, and other diseases.

As polyoestrous animals, rabbits can breed throughout the year. This does not mean, however, that conditions are the same in all seasons. Lazzaroni et al. (2012) showed that rabbit litters are larger in spring and autumn than in summer, but largest in winter. Winter was the best reproduction season in terms of both the number of weaned kittens and their mean birth weight, although the number of weaned kittens did not differ between winter and spring (in both seasons it was greater than in autumn and summer).

Due to their high fertility and fecundity, rabbits are a very attractive species for breeders. Pałka et al. (2017) compared reproduction of females of five breeds: Black Californian, New Zealand White, Popielno White, Blanc de Termonde, and Flemish Giant. The largest litters were born to Flemish Giant rabbits, a breed seldom used as a maternal component due to late sexual (six months) and somatic (10–12 months) maturity. The other breeds did not differ in litter size.

Like the breed of the mother, the choice of paternal component is important as well. Bieniek et al. (2012) found that purebred litters of Burgundy Fawn and New Zealand White rabbit breeds weighed more than crossbred litters from these breeds. However, the crossbred animals grew faster, so that by the end of the fattening period they had a higher mean body weight than the purebred rabbits.

The aim of this study was to analyse whether the breed of the mother, season of birth, and maternal and paternal breeding components affect total litter size, the number of kittens born alive, litter size at weaning, mean body weight, and rearing efficiency.

## Material and methods

### *Animals*

The data used in the research pertained to the breeding performance of female rabbits of two breeds: Californian (CAL) (n = 12) and New Zealand White (NZW) (n = 55).

The following data were collected: ID number and breed of the dam and sire, the size and weight of the litter from which the individual was obtained, and the sex of the offspring. The data were used to determine breeding parameters for the dams and the characteristics of their litters. As numerous studies indicate that a rabbit's sex does not affect production, this factor was omitted in the analyses. The data were collected from one farm and one period, so that variation in environmental conditions did not affect the analyses.

The litters analysed were obtained from crosses of Californian (CAL) and New Zealand White (NZW) females with males of the Burgundy Fawn (BUR), Flemish Giant (FG), and New Zealand White (NZW) breeds as well as the FG×NZW crossbreed.

The following litters were obtained in the F1 generation: purebred New Zealand White and NZW×CAL, FG×CAL, BUR×CAL, (FG×NZW)×CAL, FG×NZW and BUR×NZW crossbreds. The breeding programme did not include purebred mating within the Californian breed.

***Breeding conditions***

Does were kept with their offspring in wooden cages located inside a closed building equipped with a forced ventilation system and adequate lighting. The light programme consisted of 14 hours of light and 10 hours of darkness. The does were fed commercial complete pellets, with 15% crude protein, 4.2% crude fat, and 17.6% crude fibre. They had unlimited access to feed and water (through nipple drinkers).

According to the breeding programme, does mated for the first time at the age of 4.5 months, irrespective of their body weight. For does with more than one litter, the next mating took place seven days after the offspring were weaned. Kittens were weaned at 35 days of age, irrespective of their weight and body condition. Litters were weighed for the first time 24 hours after birth. The mean body weight of a single kitten was determined by averaging the weight of all kittens in the litter.

Birth seasons were classified as follows: winter (for births between 1 January and 31 March), spring (between 1 April and 30 June), summer (between 1 July and 30 September), and autumn (between 1 October and 31 December).

***Statistical analysis***

The data were divided into three subsets, according to the number of litters obtained from the does. The first group comprised results obtained from 21 females that had two litters during the analysed cycle, for a total of 42 litters. The second group consisted of results from 15 females that had three litters (45 litters for analysis). The third group, which included the two mentioned above, consisted of the results from all 67 does that had had at least one litter (118 litters).

The statistical analysis was conducted in R (R Core Team 2019). The normality of the distributions was checked by the Shapiro-Wilk test and the homogeneity of variance by Bartlett's test. When both these assumptions were met, one-way ANOVA was applied to test whether individual factors affected the variation between groups for the traits tested. If ANOVA showed a factor to be significant, Tukey's HSD test for pairwise mean comparisons was applied. Where normality or homogeneity or variance was not confirmed, the non-parametric Kruskal-Wallis test was used instead. If the test rejected the null hypothesis, its post-hoc version was used for pairwise comparisons. The variables tested were the breed of the dam, season of birth, and breed of the litter, and the traits studied were litter size (both live and dead kittens), number of kittens born alive per litter, litter mean birth weight, litter size at weaning, and rearing efficiency.

In addition, for females with three litters, a repeatability analysis was conducted for normally distributed traits, using the rptR package (Stoffel et al., 2017) of R.

A significance level of 0.05 was assumed for all analyses.

## Results

In all three groups, total litter size, the number of kittens born alive per litter and the number of weaned kittens were normally distributed, while the distributions of litter mean birth weight and rearing efficiency deviated from the normal distribution.

In the group of does with two litters, the breed of the dam significantly influenced the number of weaned kittens, with 5.20 weaned kittens for New Zealand White does and 7.33 for Californian does (Table 1). In the other two groups, the breed of the dam did not affect this trait.

Females of the two breeds differed significantly in rearing efficiency, with 90.2% efficiency for New Zealand White does and 69.8% for Californian (Table 1). Among the females with two litters, rearing efficiency did not differ significantly between the breeds (80.9% for New Zealand White and 83.8% for Californian; Table 1). Lower rearing efficiency was obtained for the group comprising all litters: 75.1% for New Zealand White females and 75.5% for Californian (Table 1). These values were not statistically significant.

The analysis of all litters showed differences between breeds in litter size (live and stillborn kittens) and the number of live-born kittens per litter. New Zealand White does had smaller litters (6.59) with fewer live kittens (6.34) than Californian does (7.71 and 7.50, respectively; Table 1). No such differences were detected in the groups of females with two and three litters.

The breed of the mother was not shown to significantly affect the mean birth weight of rabbits. However, in each of the groups birth weight was higher in the litters of New Zealand White females than Californian females (Table 1).

**Table 1**
Influence of the dam's breed on reproductive parameters in female rabbits

| Trait | All does | | Does with two litters | | Does with three litters | |
|---|---|---|---|---|---|---|
| | NZW (n=90) | CAL (n=28) | NZW (n=30) | CAL (n=12) | NZW (n=30) | CAL (n=15) |
| Total litter size | $6.59^a$ ±2.29 | $7.71^b$ ±2.31 | 6.90 ±2.54 | 8.50 ±2.75 | 6.57 ±1.99 | 7.13 ±1.85 |
| Number of live-born kittens per litter | $6.34^a$ ±2.40 | $7.50^b$ ±2.47 | 6.73 ±2.70 | 8.50 ±2.75 | 6.37 ±2.01 | 6.87 ±2.03 |
| Mean litter birth weight (g) | 66.54 ±14.58 | 61.66 ±11.76 | 66.76 ±17.31 | 58.31 ±11.08 | 67.30 ±13.48 | 64.94 ±11.97 |
| Litter size at weaning | 4.58 ±2.54 | 5.64 ±2.92 | $5.20^a$ ±2.57 | $7.33^b$ ±3.39 | 5.67 ±2.19 | 4.47 ±1.73 |
| Rearing efficiency (%) | 75.08 ±32.23 | 75.47 ±25.21 | 80.90 ±29.18 | 83.79 ±22.33 | $90.20^a$ ±20.40 | $69.84^b$ ±26.90 |

NZW – New Zealand White, CAL – Californian
a, b – statistically significant differences at $p < 0.05$

The birth season influenced litter size at weaning, but the effect was significant only for the analysis of all litters, with 4.65 weaned kittens per litter in winter and 2.00 in autumn. Litter size at weaning was 7.18 in summer and 5.52 in spring, but these differences were non-significant (Table 2). Similar results were obtained for the group of females with two litters. Females with three litters had the largest litters in winter, followed by spring and summer, with the smallest litters born in autumn. These values, however, did not differ significantly (Table 2). For all females and the group with three litters, rearing efficiency was the highest in winter.

Since there was just one NZW×CAL female with three litters, the influence of the paternal component on reproduction was not analysed for this group. The analyses conducted for females with two litters and for all females showed that the paternal component significantly influenced breeding results (Table 3). There were noticeable differences in litter size, with a significant difference between the NZW×FG and BUR×CAL crosses for all females and those with two litters. New Zealand White females mated with Flemish Giant males had 6.05 (females with two litters) and 6.26 (all females) kittens per litter. Californian females mated with Burgundy Fawn males had larger litters, with 10.00 kittens per litter for all females as well as those with two litters (Table 3). The other differences were statistically non-significant, but the results suggest that mating of New Zealand White females with Californian males increases litter size. This hypothesis is supported by the influence of the breed of the dam on litter size; Californian does produced larger litters than New Zealand White does.

The analysis of all the litters in terms of the influence of the paternal component showed that litter size at weaning was smallest for purebred New Zealand White litters, which were significantly smaller than the NZW×CAL, BUR×CAL, FG×NZW, and BUR×NZW litters, with 8.00, 10.00, 5.39 and 6.55 weaned young, respectively (Table 3). CAL×FG and (NZW×FG)×CAL litters, on the other hand, did not differ significantly from the other litters.

Similar results were obtained for rearing efficiency, an indicator of the survival rate of the litters. Purebred New Zealand White litters had the lowest rearing efficiency, at 30.3%. Crossbreeding greatly improved kitten survival, as the minimal rearing efficiency for crossbred litters (67.3%) was over twice the level for New Zealand White purebred litters. Crossbred litters also varied in terms of the number of kittens born alive per litter. The highest number, 10.00 live-born kittens per litter, was observed for BUR×CAL crossbred litters, a significantly different value from the lowest number, observed for FG×NZW(5.85).

**Table 2**
Effect of birth season on reproductive parameters in female rabbits

| Trait | All does | | | | Does with two litters | | | | Does with three litters | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | winter (n=29) | spring (n=48) | summer (n=17) | autumn (n=24) | winter (n=12) | spring (n=22) | summer (n=5) | autumn (n=3) | winter (n=12) | spring (n=16) | summer (n=10) | autumn (n=7) |
| Total litter size | 6.83 ±2.00 | 6.39 ±2.28 | 7.70 ±2.17 | 7.21 ±2.78 | 7.58 ±1.68 | 7.23 ±2.72 | 7.60 ±3.91 | 7.00 ±4.58 | 6.58 ±1.93 | 7.50 ±1.97 | 6.40 ±1.65 | 5.86 ±2.11 |
| Number of live-born kittens per litter | 6.48 ±2.20 | 6.02 ±2.40 | 7.70 ±2.17 | 7.21 ±2.78 | 7.33 ±2.10 | 7.18 ±2.75 | 7.60 ±3.91 | 6.67 ±5.03 | 6.33 ±2.06 | 7.25 ±1.95 | 6.30 ±1.70 | 5.57 ±2.30 |
| Mean litter birth weight (g) | 65.16 ±11.72 | 69.27 ±16.04 | 59.18 ±9.43 | 62.25 ±13.50 | 66.89 ±5.72 | 60.73 ±13.57 | 78.93 ±33.35 | 56.40 ±13.38 | 67.17 ±14.44 | 62.48 ±12.08 | 71.90 ±12.99 | 66.90 ±11.32 |
| Litter size at weaning | $4.65^{a}$ ±1.84 | $5.52^{ab}$ ±2.50 | $7.18^{ab}$ ±2.45 | $2.00^{b}$ ±1.21 | 5.75 ±1.66 | 5.77 ±3.22 | 7.40 ±4.28 | 3.67 ±2.08 | 5.75 ±2.14 | 5.31 ±2.52 | 5.00 ±1.56 | 4.71 ±1.89 |
| Rearing efficiency (%) | 85.43 ±20.04 | 76.75 ±31.60 | 82.73 ±22.19 | 58.49 ±37.84 | 82.32 ±22.77 | 80.44 ±29.50 | 90.00 ±22.36 | 75.00 ±43.30 | 91.16 ±15.70 | 75.96 ±31.46 | 82.31 ±22.46 | 88.79 ±20.14 |

a, b – statistically significant differences at $p < 0.05$

**Table 3**
Effect of litter breed on reproductive parameters in female rabbits

| Trait | Breed of litter (pure and crossbred) | | | | | | |
|---|---|---|---|---|---|---|---|
| | NZW | NZW×CAL | FG×CAL | BUR×CAL | (FG×NZW)×CAL | FG×NZW | BUR×NZW |
| | All does | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| n | 25 | 4 | 13 | 4 | 9 | 54 | 9 |
| Total litter size | 7.16[ab] | 8.00[ab] | 7.23[ab] | 10,00[a] | 6.78[ab] | 6.26[b] | 7.22[ab] |
| Number of live-born kittens per litter | 7.16[ab] | 8.00[ab] | 6.77[ab] | 10,00[a] | 6.78[ab] | 5.85[b] | 7.22[ab] |
| Mean litter birth weight (g) | 62.60 | 55.42 | 59.97 | 55,05 | 68.83 | 69.81 | 59.89 |
| Litter size at weaning | 2.04[a] | 8.00[b] | 4.23[ab] | 10,00[b] | 4.67[ab] | 5.39[b] | 6.55[b] |
| Rearing efficiency (%) | 30.33[a] | 100.00[b] | 67.27[ab] | 100,00[b] | 70.95[ab] | 92.18[b] | 91.25[b] |
| | Does with two litters | | | | | | |
| n | 6 | 2 | 2 | 4 | 4 | 20 | 4 |
| Total litter size | 8.83[ab] | 10.50[ab] | 6.50[ab] | 10.00[a] | 7.00[ab] | 6.05[b] | 8.25[ab] |
| Number of live-born kittens per litter | 8.83 | 10.50 | 6.50 | 10.00 | 7.00 | 5.80 | 8.25 |
| Mean litter birth weight (g) | 57.16[ab] | 53.53[ab] | 53.45[ab] | 55.05[a] | 66.37[ab] | 71.45[b] | 57.75[ab] |
| Litter size at weaning | 2.50[a] | 10.50[bd] | 4.00[abe] | 10.00[d] | 4.75[ae] | 5.60[e] | 7.25[bde] |
| Rearing efficiency (%) | 28.35[a] | 100.00[ab] | 61.25[ab] | 100.00[b] | 70.74[ab] | 95.12[b] | 88.65[ab] |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| | Does with three litters | | | | | | |
| n | 2 | 1 | 10 | 0 | 5 | 23 | 4 |
| Total litter size | 6.00 | 7.00 | 7.40 | | 6.60 | 6.61 | 6.50 |
| Number of live-born kittens per litter | 6.00 | 7.00 | 7.00 | | 6.60 | 6.35 | 6.50 |
| Mean litter birth weight (g) | 56.01 | 60.86 | 62.01 | | 70.80 | 69.35 | 62.76 |
| Litter size at weaning | 4.00 | 7.00 | 4.40 | | 4.60 | 5.69 | 6.00 |
| Rearing efficiency (%) | 66.67 | 100.00 | 69.20 | | 71.12 | 91.57 | 91.67 |

NZW – New Zealand White; CAL – Californian, FG – Flemish Giant; BUR – Burgundy
a, b, c, d, e – statistically significant differences at $p < 0.05$

Among females with two litters, the New Zealand White × Californian crossbreed had the largest litter size at weaning (10.50), about two times larger than for the FG×NZW (5.60) and (NZW×FG)×CAL (4.75) crossbreeds (significantly differences). Purebred New Zealand White litters had fewer kittens at weaning (2.50), which did not significantly differ from the values for FG×CAL and (NZW×FG)×CAL (Table 3). Mean birth weight also varied in this group of does, with a significant difference between FG×NZW (71.45 g) and BUR×CAL (55.05 g). Among the crossbreeds, the influence of the FG breed is evident. The use of males of this breed for mating with New Zealand White females increased mean birth weight relative to litters of other crossbreeds. What is more, when crossed with the same breeds, Californian does had kittens with lower birth weight than in the case of New Zealand White does. The negative effect of the former breed on the birth weight of kittens can also be seen in New Zealand White females mated with Californian males, whose kittens had a lower mean birth weight than purebred New Zealand White kittens (Table 3). The differences, however, were statistically non-significant, as in the analysis of the influence of the breed of the dam on mean litter birth weight (Table 1).

Repeatability is a measure of the similarity of the performance of individuals in successive litters throughout the production cycle. It depends on both genotypic and environmental factors. Similar repeatability was shown for total litter size and the number of kittens born alive per litter (0.36 and 0.35, respectively). The repeatability of litter size at weaning, however, was lower (0.15), indicating a strong influence of environmental factors on this trait during rearing.

## Discussion

Litter sizes reported by Pałka et al. (2017) for Californian and New Zealand White rabbits were similar to the results of our study: 7.50 and 6.47, respectively. The litter sizes obtained in our research are greater than those published by the Polish National Animal Breeding Centre regarding herds subject to use value assessment, according to which the mean litter size for the New Zealand White breed was 5.6 in 2012–2014 and 5.2 in 2015-2016, and for the Californian breed 6.6 in 2012, 6.5 in 2013-2014, 6.7 in 2015, and 6.2 in 2016. Bielański et al. (2011) reported a litter size of 5.15 for the New Zealand White breed, which was 1.44 smaller than in the present study for the group of all females of this breed.

Lazzaroni et al. (2012) also found that the season influenced litter size at weaning, which was the smallest in summer (5.68) and larger in spring (6.46), winter (6.53), and autumn (6.86). Litter size at weaning in winter significantly differed from the values obtained in summer and autumn, but not spring. Thus, the results of our study differ from those of Lazzaroni et al. The authors cited also showed that the season affected litter size, which was 7.51 in spring, 7.97 in autumn, 6.94 in summer, and 7.68 in winter. In our study, however, in all three groups of females, the season affected neither litter size nor the number of kittens born alive per litter (Table 2). This can be explained by the fact that the animals were kept indoors, so that the microclimate conditions, i.e. temperature, humidity, and air flow, were fixed and invariable. Due to artificial lighting, female fertility does not depend on daylight length.

Janczak et al. (2008) showed that the semen of New Zealand White and Californian rabbits did not significantly differ, although they did find more sperm defects in the former. The liquid fraction of the semen of Californian rabbits had a greater volume (2.07 ml) than that of New Zealand White rabbits (1.83 ml). Although the differences were not significant, this result might suggest differences in the fertility and fecundity of the breeds.

The effect of the Flemish Giant breed stands out in the crossbreeds. The differences between litters from different crosses may be due to differences between the breeds in mean adult body weight. According to Barabasz and Bieniek (2003), adult New Zealand White rabbits weigh from 4.5 to 5.5 kg, while Californian rabbits weigh from 4.1 to 4.3 kg. In contrast, adult Flemish Giant rabbits weigh up to 7.0 kg (Kostro and Gliński, 2005). Bieniek et al. (2012) reported a negative influence of the Burgundy Fawn breed on litter mean birth weight, which was lower when Burgundy Fawn males were crossed with New Zealand White females. The mean birth weight of purebred New Zealand White kittens was 69 g, while that of crossbreds was 58 g, a similar result to that reported here (though the differences were not statistically different). In their analysis of an 84-day rearing period, Bieniek et al. (2012) showed that crossbred rabbits had on average 200 g greater carcass weight than purebreds.

The repeatability of litter size at weaning was fairly low (0.15). Litter survival is influenced by a number of environmental factors during rearing, such as the protectiveness of the mother, the amount of colostrum ingested during the first days of life, genetic disorders, and pathogens. Rosell and la Fuente (2016) list respiratory diseases and diarrhoea due to bacterial infections as the most common causes of death among farmed rabbits. Rastogi et al. (2000) report similar repeatability values: 0.30 for litter size, 0.32 for the number of kittens born alive per litter, and 0.19 for litter size at weaning. Piles et al. (2014) reported much lower repeatability values than those obtained in our study: 0.10–0.14 for litter size, 0.07–0.12 for the number of kittens born alive per litter, and 0.04–0.12 for litter size at weaning.

## Conclusions

In the analysis of all litters, Californian females gave birth to more kittens per litter (all kittens and live kittens) than New Zealand White does. When we take into account only females with two litters, however, the breeds differed only in litter size at weaning. For females with three litters, New Zealand White females had better rearing efficiency than Californian females. For the group of all females, the birth season was shown to affect litter size at weaning. It was greater in winter than in autumn, but the greatest litter size was obtained in summer. The paternal component was also found to influence litter size (both at birth and at weaning), especially in comparison to purebred mating.

The repeatability of litter size at weaning was very low, meaning that this trait is not strongly determined by the genetic predisposition of the female.

*The research was financed by the Ministry of Science and Higher Education of the Republic of Poland - SUB.215-D201*

## REFERENCES

Barabasz B., Bieniek J. (2003). Towarowa produkcja mięsna. Podstawy pracy hodowlanej i charakterystyka materiału zwierzęcego. PWRiL, Warszawa (ISBN: 83-09-01821-5), ss. 33–60.

Bielański P., Kowalska D., Wrzecionowska M. (2011). Wykorzystanie rodzimej rasy królików popielniańskich białych i ich mieszańców do produkcji mięsa. Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego, 7 (3): 67–73.

Bieniek J., Maj D., Derewicka O., Bonczar Z. (2012). Slaughter traits of meat obtained from Burgundy Fawn rabbits and their crosses with New Zealand Whites. Żywność. Nauka. Technologia. Jakość, 1 (80): 154–163.

de la Fuente L.F., Rosell J.M. (2012). Body weight and body condition of breeding rabbits in commercial units. Journal of Animal Science, 90: 3252–3258.

Janczak M., Kowalczyk A., Grondowska A. (2008). The comparison of semen of Californian and New Zealand breed rabbits. Zeszyty Naukowe Uniwersytetu Przyrodniczego we Wrocławiu, Biologia i Hodowla Zwierząt, LVI, 566: 81–88.

Kostro K., Gliński Z. (2005). Choroby królików. PWRiL, Warszawa (ISBN 83-09-0175-2), ss. 44-48.

Krajowe Centrum Hodowli Zwierząt (2013-2017). Hodowla zwierząt futerkowych za 2012, 2013, 2014, 2015, 2016 rok. KCHZ, Warszawa.

Lazzaroni C., Biagini D., Redaelli V., Luzi F. (2012). Technical Note: year, season, and parity effect on weaning performance of the carmagnola grey rabbit breed. World Rabbit Science, 20: 57–60.

Pałka S., Kmiecik M., Kozioł K., Otwinowska-Mindur A., Migdał Ł., Bieniek J. (2017). The effect of breed on litter size and milk yield in rabbits. Roczniki Naukowe Polskiego Towarzystwa Zootechnicznego, 13 (3): 25–29.

Piles M., Garcia M.L., Rafel O., Ramon J., Baselga M. (2014). Genetics of litter size in three maternal lines of rabbits: Repeatability versus multiple-trait models. Journal of Animal Science, 84: 2309–2315.

Rastogi R.K., Lukefahr S.D., Lauckner F.B. (2000). Maternal heritability and repeatability for litter traits in rabbits in a humid tropical environment. Livestock Science, 67: 123–128.

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria (https://www.R-project.org/, 2019-04-03).

Rosell J.M., de la Fuente L.F. (2016). Causes of mortality on breeding rabbits. Preventive Veterinary Medicine, 127: 56–63.

Stoffel M., Nakagawa S., Schielzeth H. (2017). rptR: Repeatability estimation and variance decomposition by generalized linear mixed-effects models. Methods in Ecology and Evolution, 8: 1639–1644 (DOI:10.1111/2041-210X.12797).