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**INVESTIGATION OF NEW EQUALIZATION METHODS INCREASING LITTER
HOMOGENITY**

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1. BACKGROUND AND OBJECTIVES OF THE RESEARCH

In Europe, domestic rabbit farming ranks fourth in terms of volume behind the leading trio of Spain, France, and Italy; however, due to the low domestic consumption of rabbit meat (400 tons), the sector's reliance on exports is enormous. For this reason, domestically produced rabbit products must compete in foreign markets not only with locally produced rabbit products but also with other types of meat; consequently, maintaining the competitiveness of domestic production and slaughter is a key issue for the future of the domestic rabbit farming sector.

The rabbit sector is at a competitive disadvantage compared to the pork and, in particular, the poultry sectors, which are able to produce their products using far fewer workers during live animal production and, especially, through the use of automated slaughter and deboning lines.

Rabbit slaughtering technology has, however, advanced significantly in recent years; new lines, with the automation of complete processing sequences, offer the sector the opportunity to produce goods more efficiently with fewer workers, however, due to their preset cutting and portioning parameters, automated lines also require homogeneous raw material to ensure that the final product meets quality standards both aesthetically (the system must separate individual meat cuts at the correct anatomical points) and microbiologically (the animal's intestinal tract must not be damaged during evisceration).

A production parameter of great significance in the sector is production cost, which fundamentally determines the income-generating capacity of individual sector players. One way to achieve low production costs is to increase the number of offspring per breeding animal; however, this results in scattered litters in addition to larger litter sizes. From scattered litters especially when a large litter size is combined with a limited supply of milk, heterogeneous slaughter stock may be raised, furthermore, in larger litters, prolonged farrowing also increases the rate of stillbirths.

In my research, I sought to determine whether the rate of stillbirths can be reduced through selection, whether it is possible to raise slaughter rabbits of homogeneous body

weight from litters of varying weights using appropriate litter equalization methods, and whether specific equalization methods influence the rate of mortality during pre-rearing. The objectives of the thesis:

To investigate a new litter equalisation method aimed at improving the homogeneity of slaughter animals.

How does the mortality of suckling rabbits develop, and how can the mortality of low-birth-weight rabbits be reduced using the new litter equalisation method?

Reducing the rate of stillbirths using a selection method in the Pannon Ka herd.

2. MATERIALS AND METHODS

2.1 Housing conditions of experimental animals

The experiments were conducted at the Olivia Kft Oligen farm between 2019 and 2020. The animals were housed in air-conditioned buildings with 10 cm sandwich panels. The barn is a complex comprising three rooms with a floor area of 60 m × 30 m, constructed with 10 cm sandwich panels and reinforced concrete beams. It is equipped with a heating and cooling system, thus ensuring constant temperature conditions for the conduct of the experiments.

The mothers were kindled in the LK parent modules, and the kits used the rearing nest until they were 28 days old. With the exception of the mobile nest, we created the fattening module by closing two mobile mesh floors, in which we kept the experimental animals until they reached weaning age. At weaning, the animals were placed in conventional fattening cage (435 mm × 234 mm, Meneghin Rendita series 8 1.5P). The animals had ad libitum access to feed and drinking water. Feeding was provided with pellets formulated according to the animals' age.

2.2 Experimental design: new rearing method

The experiment was conducted in two replicates. In each replicate, five Pannon White does that had farrowed multiple times, possessed good rearing ability and had the same number of teats were selected. At kindling, the kits were taken from their mothers and the newborn rabbits placed in foster care were classified into three weight categories: small: 35–55 g; medium: 60–70 g; large: 75–100 g. The young rabbits were marked with individual ear tags and their weights were recorded.

We established the control and experimental groups based on the birth weight of the young and the number of young rabbits placed under the mothers (litter size).

In the control group, we placed 10 small (S10, n=100), 10 medium (M10C, n=100) or 10 large (10L, n=100) newborns under the does.

The experimental group was formed as follows: we placed 9 kits with low birth weight (S9, n=90), 10 of medium weight (M10E, n=100), or 11 of high weight (L11, n=110) in each nest.

Following the formation of the experimental groups, the nests were not replenished, i.e. kits that died were not replaced. The controlled suckling period lasted until 18 days of age, after which the does reared the litters freely until weaning. Following weaning, the fattening animals were housed in pairs in standard fattening cages. At the end of the fattening period, the animals were slaughtered on a standard rabbit slaughter line.

2.3 Collected data and data evaluation methods used: a new litter equalisation method

For the statistical analysis, I used the online version of the SAS software package. I analysed the weekly body weights using a generalised linear mixed (GLMM) model, taking repeated measurements into account. I defined the rabbits and the doe as random effects, where the rabbit levels were nested within the doe levels (nested model). Differences between groups were determined on a weekly basis using the SLICE command. Slaughter weight and slaughter traits were assessed using one-way analysis of variance, whilst mortality data and the homogeneity of the frequency distribution of 12-week weights between the experimental and control groups were examined using the chi-squared test.

During the experiment, the parameters examined and calculated were as follows:

- initial weight measured individually,
- individual weights of the animals were measured weekly,
- weekly weight gain was calculated as follows: the previous week's weight was subtracted from the current week's weight, and the resulting value was divided by seven to obtain the average daily weight gain
- the number of animals culled was recorded daily,

- we determined the amount of feed consumed on a weekly basis
- we weighed the individual animals before slaughter,
- following slaughter and evisceration, we weighed the individual carcass weights
- we calculated the dressing out percentage (carcass weight/live weight $\times$ 100)

2.4 Possibility of selection aimed at reducing the rate of stillbirths

I conducted my study using the data set for the Pannon Breeding Programme's Pannon Ka breed. In preparing the analysis, we processed data from 17,720 litters covering the period from March 1996 to April 2021. We took the following traits into account from the database:

- number of live-born kits,
- number of kits born dead,
- total number of kits born,
- 21-day litter weight,

We used the SAS 9.4 software package for data analysis and the Pest (Groeneveld, 1990) and VCE6 (Groeneveld et al., 2008) programmes for estimating genetic parameters. During the estimation of genetic parameters, we estimated the heritability of the traits under investigation, the genetic correlations between traits, and the standard errors indicating their reliability.

The structure of the individual model used was as follows:

$$y = Xb + Za + Wpe + e$$

where y = vector of observations, b = vector of environmental factors, a = vector of additive genetic effects, pe = vector of persistent environmental effects, e = vector of residual effects, X , Z and W are, in order, the occurrence matrix of environmental factors, additive genetic effects and persistent environmental effects.

The environmental effects taken into account during the evaluation were the year and month of litters and the litter number. The unevenness in litter size across parities necessitated the pooling of parity numbers (1: 1; 2: 2; 3: 3–10; 4: >10).

Repeated litters represented the common environmental effect (variance component), whilst the additive genetic effect (variance component) relating to individuals was included in the model as an additional random effect.

3. RESULTS

3.1 Development of weekly weights in the experimental and control groups

At the start of the experiment, we found no significant difference in either the mean birth weight or the standard deviation between the experimental (67.3 g, 16.6 g) and control (66.1 g, 16.3 g) groups.

We also found no significant difference in body weight measured in the first week; however, at 14 days of age, we observed a significant difference in favour of the control group (282 g) compared to the experimental group (268 g), and this difference persisted until weaning, in favour of the control (1355 g, 1317 g) group.

During the fattening period, the earlier trend continued, and the control group maintained its advantage over the experimental group throughout the entire fattening cycle. Although the control group (2973 g) was significantly heavier than the experimental group (2923 g) at 12 weeks of age, in terms of standard deviation, the experimental group (219) proved to be better than the control group (238), meaning that the experimental group proved to be more consistent than the control group.

3.2 Body weight within the subgroups of the experimental and control groups

When the groups were formed, three distinct subgroups were created in accordance with the basic arrangement; however, some changes were already apparent at one week of age. The smallest category still included the S10 (135 g) and S9 (133 g) rabbits, whilst the medium category comprised the M10C (167 g) and M10E (166 g) rabbits, which differed significantly from them; however, the weight of the L11 (169 g) subgroup no longer differed significantly in weight from either the M10C and M10E subgroups or the L10 (178 g) subgroup, which represented the heaviest weight category.

At 21 days of age, the weight of the L11 (385 g) rabbits was no longer different only from the M10E subgroup, but was also the same as that of the S9 rabbits, which were the smallest at birth, and even that of the S10 rabbits.

The weaning weights measured at 35 days of age were as follows. The lowest weights were recorded in the S10 (1044 g), S9 (1043 g) and L11 (1045 g) subgroups; these subgroups did not differ significantly from one another. Only the weights of the M10C (1112 g) and L10 (1137 g) subgroups differed from these, and this trend remained unchanged throughout the entire fattening period.

As expected, there was no difference between the three subgroups of the experimental group; body weight, at least in terms of averages, levelled out. In contrast, the order established at birth remained unchanged among the three subgroups of the control group: 2828 g < 2974 g < 3049 g, which indicates that body weight equalisation is less evident in traditional suckling (control group).

3.3 Mortality rates

When examining mortality, we analysed mortality rates in four periods respectively. The period from birth to 7 days of age is one of the most critical in terms of mortality. We examined separately the mortality trends between 7 and 35 days of age, as well as mortality during the period from birth to weaning (0 to 35 days), and finally assessed mortality during the fattening period (36–84 days) separately.

When examining mortality in the first week, there were hardly any losses from the medium-weight M10E (1%) and M10C (1%) subgroups, or the heavy-weight L10 (1%) and L11 (0%) subgroups, whereas significantly more suckling rabbits died from the S9 and S10 subgroups (8.9% and 20%, $P > 0.001$).

Between 7 and 35 days of age, low mortality was recorded in four subgroups: L11 (0.9%), L10 (1%), S9 (2.4%) and S10 (2.5%); there was no significant difference between the two high- and two low-birth-weight subgroups. However, interestingly, mortality was highest in the two medium-weight subgroups: M10C (8.1%) and M10E (9.1%).

During the period between birth and weaning, the fewest rabbits died in the high-birth-weight subgroups (L11, 0.9% and L10, 2%). Significantly more rabbits died in the

medium-weight subgroups (M10C, 9%, and M10E, 10%) and in the S9 subgroup (11.1%), with the highest mortality rate recorded in the S10 subgroup (22%).

During the fattening period, minor differences emerged between the subgroups, with mortality rates ranging from 1.8% to 6.1%, but these differences were not statistically significant.

3.3 DEVELOPMENT OF SLAUGHTERING YIELD

The same differences in body weight measured at slaughter can be observed as in the body weight at 84 days. In the control group, which corresponds to the litter equalisation currently in use, body weight increased continuously from the small newborns to the large newborns subgroup (S10, M10C and L10), even though the difference was not significant between all subgroups. In contrast, body weights were similar across all three subgroups in the experimental group (S9, M10E and L11).

The same order was observed in carcass weights as in slaughter weights: the S10 subgroup had the lowest, the L10 subgroup the highest, and within the experimental group, the three subgroups were identical.

In terms of dressing yields, no group differed significantly from any other; dressing yields varied within a very narrow range, between 58.7% and 59.5%.

3.4 Selection to reduce stillbirths, genetic correlation between the individual traits studied

We determined the heritability estimates for each trait using the repeatability individual model. For all traits examined, we obtained low heritability estimates. For the number of live-born kits (0.08 ± 0.01), the number of stillborn kits (0.03 ± 0.01) and the total number of kits born (0.09 ± 0.01) were low, in line with data in the literature, whilst for litter weight at 21 days (0.15 ± 0.01) we obtained a slightly higher heritability index.

With regard to the individual parameters examined, in terms of the magnitude and extent of the relationship between them, we found a positive correlation between the number of stillborn kits and the number of live-born kits (0.19 ± 0.16); however, the

estimated standard error was very large, meaning that the correlation obtained did not differ significantly from zero. We also found a positive correlation, but one even stronger than the previous one, between the total number of kits born and the number of stillborn kits (0.37 ± 0.14). The only negative correlation that can be considered favourable was found between the litter weight at 21 days and the number of stillborn kits (-0.27 ± 0.13).

4. CONCLUSIONS

When examining the average weights of the experimental (L11, M10E, S9) and control (L10, M10C, S10) groups, we see that the average weight of the experimental group lagged behind that of the control group from as early as 14 days of age, and this trend remained unchanged until the end of the fattening period. However, thanks to the foster-rearing method, the rabbits in the experimental group became more uniform compared to those in the control group. Our hypothesis, established when designing the experiment, was confirmed: the foster-rearing method can clearly influence the homogeneity of slaughter animals.

The carcass weights practically mirrored the trend in live weights at slaughter, and in the case of slaughter yields, neither the weight at the start of the trial nor the foster-rearing method had any statistically significant effect.

It can be clearly established that, during the initial phase of pre-rearing (0-7 days), birth weight had the greatest influence on mortality, and this effect could be modified by the fostering method only in the case of kits born with a low birth weight. In the later stages of rearing, it can be established that birth weight remained a key factor determining mortality; however, even the foster-rearing method (L11), which provided an inadequate supply of nutrients, was unable to reduce the survival chances of rabbits born with a high birth weight. However, survival rates in litters of low and medium weight can be significantly influenced by the rearing method, i.e. compared to a rearing method resulting in a plentiful supply of nutrients, the rearing method used here led to a significant reduction in mortality rates.

We found a favourable negative correlation (-0.27 ± 0.13) between 21-day weight and the number of stillborn kits, meaning that selection for 21-day weight also substantially reduces the number of animals born dead at birth. The favourable direction of the correlation examined, the small standard error relative to the obtained value, and the highest heritability value (0.15 ± 0.01) found among the traits examined, it can be stated

that selection for this trait simultaneously constitutes positive selection for reducing the incidence and proportion of stillbirths.

5. NEW SCIENTIFIC RESULTS

1. In contrast to the litter balancing method used in practice (where an equal number of small, medium or large newborns are placed in each litter), the new litter balancing method, whereby one fewer than average small newborn and one more large newborn are placed in a litter, can slightly reduce the heterogeneity observed in slaughter weight and carcass weight.
2. If an unequal number of small, medium or large newborn rabbits are placed in a litter—fewer of the small ones and more of the larger ones—this is particularly beneficial from an animal welfare perspective, as fewer than half of the newborns born with low birth weight (9% compared to 20%; $P > 0.001$) die.
3. In the Pannon Ka flock studied, traits related to litter size (number of live, dead and total offspring born) showed low heritability (< 0.1), whilst the heritability of litter weight at 21 days was moderate (0.15).
4. We were able to clearly establish for the Pannon Ka flock that selection for 21-day litter weight reduces the proportion of stillbirths. Due to the positive and moderate correlation between the two traits and the sufficiently high heritability of the trait under investigation, 21-day litter weight proved to be a suitable trait for selection aimed at reducing stillbirths, which otherwise have a low heritability.
5. As a result of our study, it can be concluded that neither birth weight nor the rearing method had an effect on the development of slaughter yield.

6. SCIENTIFIC PUBLICATIONS RELATED TO THE THESIS

6.1 Journal articles in foreign languages

Atkári, T., Gerencsér, Zs., Nagy, I., Szendrő, Zs., 2025. A New Method of Litter Equalization in Rabbit. *Animals*, 15(11), 1644. <https://doi.org/10.3390/ani15111644>

Szendrő, Zs., Cullere, M., Atkári, T., Dalle-Zotte, A., 2019. The birth weight of rabbits: Influencing factors and effect on behavioural, productive and reproductive traits: A review. *Livest. Sci.*, 230, 103841. <https://doi.org/10.1016/j.livsci.2019.103841>

6.2 Conference paper in a foreign language

Nagy, I., Bokor, Á., Gerencsér, Zs., Gyovai, P., Atkári, T., Garreau, H., 2025. Evaluation des possibilités de sélection pour l'homogénéité du poids au sevrage intra portée chez les lapins de la lignée Pannon. *Proc. 20^{èmes} Journées de la Recherche Cunicole*, Rennes, France, 97-99.

Atkári, T., Matics, Zs., Nagy, I., Gazbar, F., Gerencsér, Zs. 2021. Analysing the possibilities of selection increasing the rabbit litters' uniformity, *Proc. 29th Animal Science Days*, Gödöllő, Hungary, 64-64.

Gerencsér, Zs., Benedek, I., Matics, Zs., Nagy, I., Atkári, T., 2021. Analysing the possibilities of selection decreasing the rabbit kits' mortality. *Proc. 29th Animal Science Days*, Gödöllő, Hungary, 63-63.

6.3 Journal article in Hungarian

Szendrő Zs., Atkári T., 2020. A nyulak termelése a születési súlyuktól függően, *Baromfi Ágazat: Baromfi- és nyúltenyésztők lapja*, 20, 90-96.

Szendrő Zs., Atkári T., 2019. Mitől függ a házinyúl születési súlya?, *Baromfi Ágazat: Baromfi- és nyúltenyésztők lapja*, 19, 85-88.

6.4 Conference paper in Hungarian

Nagy I., Bokor Á., Gerencsér Zs., Gyovai P., Atkári T., 2024. Az alomkiegyenlítettségre végzett szelekció lehetőségének vizsgálata Pannon nyulakban. 35. Nyúltenyésztési Tudományos Nap, Kaposvár, Magyarország: Magyar Agrár- és Élettudományi Egyetem Kaposvári Campus, 53-57.

Atkári T., Gerencsér Zs., Matics Zs., Nagy I., 2022. Az elhullás csökkentése érdekében végzett szelekció lehetőségeinek vizsgálata. 33. Nyúltenyésztési Tudományos Nap, Kaposvár, Magyarország: Magyar Agrár- és Élettudományi Egyetem Kaposvári Campus, 37-40.

Atkári T., Gerencsér Zs., Nagy I., Matics Zs., 2021. Az alomkiegyenlítés hatása a nyulak növekedésére. 32. Nyúltenyésztési Tudományos Nap, Kaposvár, Magyarország: Magyar Agrár- és Élettudományi Egyetem Kaposvári Campus, 41-47.

7. SCIENTIFIC PUBLICATIONS OUTSIDE THE SCOPE OF THE DISSERTATION

7.1 Journal articles in foreign languages

Gerencsér, Zs., Matics, Zs., Szabó Rubina, T., Kustos, K., Mikó, A. Nagy, I., Odermatt, M., Atkári, T., Szendrő, Zs., 2019. Aggressiveness, Mating Behaviour and Lifespan of Group Housed Rabbit Does. *Animals*, 9(10), 708. <https://doi.org/10.3390/ani9100708>

7.2 Conference paper in a foreign language

Atkári, T., Jós, D., Nagy, I., Gerencsér, Zs., 2024. Use of physically separated sunflower meal with 20% crude protein content as an alternative source of protein in the diet of growing rabbit. *Proc. 13th World Rabbit Congress*, Tarragona, Spain. 484-487.

Atkári, T., Jós, D., Gerencsér, Zs., Nagy, I., 2021. Using a mixture of Red clover and Bird's-foot trefoil in diets for growing rabbits. *Proc. 12th World Rabbit Congress*, Nantes, France, N-04.

Nagy, I., Farkas, J., Atkári, T., Kövér, Gy., 2021. Estimating lethal equivalent of the Pannon White rabbit population applying generalized linear mixed models, *Proc. 12th World Rabbit Congress*, Nantes, France, BG-17.

7.3 Journal article in Hungarian

Atkári T., Puskás G., 2021. Az anyanyulak felnevelése csökkentett energiatartalmú takarmánnyal. *Éghajlatváltozás az agráriumban: Kihívások és megoldások*. MTA Pécsi Területi Bizottság, Pécs, Magyarország, 87-92.

7.4 Conference paper in Hungarian

Atkári T., Jós D., Nagy I., Gerencsér Zs., 2023. A szeparált 20 %-os nyersfehérje tartalmú extrahált napraforgódara, mint alternatív fehérjeforrás használata a nyulak

keveréktakarmányaiban,. 34. Nyúltenyésztési Tudományos Nap Kaposvár, Magyarország: Magyar Agrár- és Élettudományi Egyetem Kaposvári Campus, 41-46.

Atkári T., Jós D., Gerencsér Zs., Nagy I., 2021. Vörösherét és szarvaskerepet tartalmazó keveréktakarmány etetési kísérlete növendéknyulakkal, 32. Nyúltenyésztési Tudományos Nap, Kaposvár, Magyarország : Magyar Agrár- és Élettudományi Egyetem Kaposvári Campus, 67-71.