THESES OF DOCTORAL (Ph.D.) DISSERTATION

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POSSIBLE METHODS FOR IMPROVING MUSCLE MASS PRODUCTION IN THE PANNON LARGE AND THE PANNON WHITE RABBIT BREEDS

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1. BACKGROUND OF RESEARCH, OBJECTIVES

Animal breeding concentrates to improve the quality of certain products such as lean meat in case of the rabbit's carcass. Within the framework of breeding programs levels of selection pressure applied for the tissues (bone, fat, or muscle), can change the body composition (e.g. meat to bone ratio). The body size of the rabbits shows high variability from dwarf to giant. From the aspect of meat production medium body size is preferred due to their growth rate and prolificacy. Meat quality and carcass yield of the various breeds also differ substantially. The diversity of breeds also has different outcomes in meat quality and carcass yield. Studies are focusing the slaughter weight of the rabbit, measured in different breeds and age groups (Perrier and Ouhayoun, 1990; Lukefahr et al. 1982, 1983) determining the optimal slaughter age for the specific markets. Primarily the muscle tissue gives the most of the carcass weight regulated by ubiquitous and tissue-specific genes that can participate to expand fat and muscle tissue and thus, meat production. These genes can affect the cellular and biochemical composition of the muscle, thereby influencing not just the quality but the quantity of the meat.

Achieving continuously improving performance through the successive generations is made possible by selection. For this reason, the whole process should not focus on the genetic merit of the current individuals but the expected merit of the next generation. To build an organized structure for the breeding process, the breeding goal has to be defined. This requires the specification of traits that can genetically improve the population. Thus, the accuracy of breeding value estimation plays an important role in the process, because it shows the amount of transmitted genetic value to the offspring. Therefore, the parental generation has to contain individuals with the best breeding values (Oldenbroek et al. 2015). For breeding value estimation

BLUP method is widely used in practical animal breeding. Making meat production more intensive, rabbit breeders frequently use three-way crossbreeding schemes, and select lines for paternal and maternal traits to take advantage of positive heterosis (Baselga, 2004). Some breeding programs operate with profit models, which can help the breeder to rank the traits by the mathematical relationship of inputs and outputs (Amero and Blasco, 1992). Therefore the profit function can easily form the breeding goal because it is expressed in terms of economic values of the desired traits, so several equations can be calculated if the trait is improved by one unit, how much more profit can be expected.

The aims of the present work were the following:

1. Analyzing the Pannon Rabbit Breeding Program from the aspect of efficiency.

2. Calculating aggregate genotype/desired gain index (BLUP index) for the production traits of the Pannon white and Pannon large rabbit breeds.

3. Calculating economic index for the production traits of the Pannon white rabbit breed by applying the newly developed software package EcoWeight Rabbit 2.1.

2. MATERIALS AND METHODS

The doctoral thesis contains two main chapters in connection with advanced selection decisions. First, genetic parameters and breeding values were estimated for the current selection criteria traits. Desired gain indices were then developed to improve selection efficiency. In the second part of the dissertation, a software package was used, to maximize the profit in rabbit farms by determining economic weights and to define economic indices.

2.1 Desired-gain selection index in the Pannon white rabbit breed

This analysis is based on 22 002 LW21 and 8 124 TMV data from Pannon White rabbit does and growing rabbits, respectively. Records were collected between 1992 and 2016 at the Experimental Rabbit farm involved in the pedigree file was 14 124. The applied reproduction rhythm was 49 days and the generations were overlapping. To avoid inbreeding a rotational mating scheme was applied dividing the population into four subgroups. This method was described in detail by Nagy et al. (2010).

In the course of the breeding program, litter weights were measured at 21 days of age on 69 litters. Besides, TMV data were measured in the Kaposvár University Health Center Institute of Diagnostic Imaging and Radiation Oncology. A Siemens Somatom Cardiac type multidetector CT was used to make the scans with the following settings: tube voltage: 120 kV, current: 140 mAs, data collection mode: spiral. The scanned rabbits were 11 weeks old and fixed with belts in a special plastic container without anesthesia. During the CT measurement, the scans were taken of the whole body and segmented with 3D Slicer's automatic segmentation module (Fedorov et al. 2012) between the *crista iliaca* of the *os ilium* and the *patella* with 2 mm slice thickness. The muscle tissue was determined as the summed voxels between 0 and 140 on the HU (Hounsfield) scale of the CT scans.

REML and BLUP methods were used to estimate the genetic parameters and breeding values for LW21 and TMV, and these traits were analyzed jointly using a two-trait animal model. PEST software (Neustadt, Germany) (Groeneveld, 1990) was used for data coding and the variance components were estimated with VCE 6 (Groeneveld et al. 2008).

To test the modification possibility of the breeding program a two-trait BLUP index (involving LW21 and TMV) was calculated using the software SEL-ACTION *(*Rutten and Bijma, 2001). The contribution of each trait was set to 50%. The final selection index was transformed to obtain index mean and standard deviation of 100 and 20, respectively. The selection process based on the current breeding program and on the calculated index scores was compared for a chosen kindling batch where the date of insemination was 29th of January 2016. At that time, the population consisted of 160 does and 60 bucks. In the kindling batch, 928 kits were born from 121 dams. Using both selection alternatives in the first step of selection 69 litters (122 individuals) were selected for CT scan either based on either the expected breeding values or on the calculated BLUP index scores. As the two methods resulted in different rankings, altogether 139 rabbits were sent to CT scan. Regardless of the method of the first step selection after the CT scans the second step of selection was performed based on TMV breeding values.

2.2 Desired-gain selection index in the Pannon large rabbit breed

The analysis consisted of 312 randomly selected animals of Pannon Large rabbit breed from Kaposvár University, Hungary. Records were collected between 2014 and 2018, according to the changes of the scanning method (Donkó et al. 2016). In the first step of data collection, average daily gain (ADG) was measured, and animals with the best ADG were selected for the CT examination. During the evaluation, three rabbits were fixed in a special plastic container without any anesthetics at 11 weeks of age, as in the standard selection program. The used acquisition parameters were: tube voltage 140 kV, X-ray radiation dose 90 mAs, spiral data collection mode with pitch 1, field of view 500 mm, slice thickness 2 mm. Overlapping slices were recorded of the rabbits from head to toe during the measurement. For the segmentation process, masks were made for the loin muscle and the hind legs, and registered to the CT images for each animal. To estimate genetic parameters, REML and BLUP methods were used for the LM and HL in an animal model. The pedigree file consisted of 2 758 individuals. PEST software (Neustadt, Germany) (Groeneveld, 1990) was used for data coding and the variance components were estimated with VCE 6 (Groeneveld et al. 2008). After the calculation of the genetic parameters, a two-trait desired gain selection index was created by MIX software (Nath et al. 2002). The desired gain was calculated by the method of Yamada et al. (1975).

The final index was Z-transformed to get 100 as mean of the index and 20 for standard deviation.

$$Index = 6.3 \times LMV + 4.13 \times TMV$$

Number of generations required to attain the goal (t) was calculated as:

$$t = \sigma_I / i_I = (b'Pb)^{1/2} / i_I$$

Where: t is the number of generations required to attain the breeding goal, i_I is the selection intensity, σ_I is the standard deviation if the index, P is the n x n matrix of phenotypic variance-covariance and b is the n x 1 vector of weighting coefficients

2.3 Economic selection indices for the Pannon white rabbit breed

The economic model for the rabbit selection was introduced by Krupová et al., 2020. This model is deterministic and static, similar to modeling in pig-breeding systems (Wolfová et al. 2017), where performances were represented by population means. Fractions of animals are allowed, thus the model is a non-integer, besides it contains calculations of the doe population, the progeny population, and total feed and non-feed costs for all age groups. Major steps of the modeling process contained collecting information of measurable traits or features (phenotypic data) of the population, then transform these data into equations via algorithms, which can be solved by a computer program. In the last step, these model estimations were validated with actual results from a base year, where no health or financial problem occurred.

In our case 150 does are kept on the farm per breed, besides their offspring along with 80 bucks per breed to maintain genetic diversity. As a purebreeding system, replacement is produced via artificial insemination (AI) and surplus progeny goes to the slaughterhouse. Culling occurs for does due to health problems and bad mothering behavior, while all other female animals are mated post-partum. The length of pregnancy is fixed in 31 days, besides non-culled does are kept to the next reproduction cycle. The number of re-matings is assumed to be 1 in the model and weaning of kits is made at a fixed age. The breeding unit, nursery, the AI station, and the fattening unit are sometimes concentrated on different farms however, all of these units are located to one farm at Kaposvár University. Structure of the herds was calculated by the Markov chain model, previously described by Jalvingh et al. (1992), and the herd dynamics were characterized in terms of doe categories (states a doe can pass during her life) and the probabilities between them. The doe states are mainly related to the reproductive cycles (interval between kindlings). The number of reproduction cycles is 7, while the reproduction rhythm is maximized in 49 days.

Marginal economic values were added per unit of a trait, per doe and per year. When changing the trait means, a fixed number of does was assumed. The simple partial derivate was replaced with complex bio-economic modeling i.e. by a numeric derivate. The profit was calculated based on the economic values for the whole production system per breed.

The following parameters were recorded to calculate relative economic values, economic weights, and the selection indices for the Pannon white:

- Number of reproductive cycles
- Conception rate of does after mating
- Average weight of does entering in each reproduction cycle
- Total Number of kits born/born alive/weaned
- Kindling interval
- Mating type
- Average productive lifetime
- DE requirements of rabbits
- Fixed costs of the rabbit farm
- Pricing system for fattening
- Selection criteria traits
- Breeding goal traits

3. RESULTS

3.1 Desired-gain selection index in the Pannon white

The estimated heritability for LW21 was low (h^2=0.1). TMV showed higher heritability than LW21 (h^2=0.21) but considering that this trait can be defined as a carcass trait, it was lower than expected. The magnitude of permanent environmental effect exceeded that of the heritability resulting moderate repeatability of LW21. On the contrary, the common environmental effect had the same magnitude as the additive genetic effect. The first step of the selection based on the current and alternative methods thus, LW21 breeding values decreased significantly with the index selection due to the negative correlation and the weighting to the TMV. The other consequence was that preselecting the rabbits based on the two trait index scores resulted somewhat higher TMV breeding values and higher index scores. After the CT measurements the estimated breeding values of the LW21 decreased by 11.4% with the index selection after the two-stage selection process, on the other hand, own TMV values increased substantially by 27.8%.

In the first step of the selection process, the litters were ranked by the LW21 data and the best bucks in the parental generation were selected which produced the best litters. The main criterion was that the dams of the selected litters had to be the most distant relatives. In some cases, the dams were half-sibs due to the lack of diversity. According to this sorting system, after the CT examinations maximum of two females and one male offspring went for further breeding from one sire. The consequences of the different selection strategies can be originated from the negative correlation

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between LW21 and TMV.

3.2 Desired-gain selection index in the Pannon large

LMV showed relatively high heritability ($h^2 = 0.4$) and the mean values of HLV are somewhat higher than the previously measured TMV results. Inserting both valuable meat parts and adding LMV to the breeding goal may result a more accurate selection decision. For the hind legs, the heritability of the muscle volume is also high ($h^2 = 0.4$).

After the Z transformation, the means of the estimated breeding values for the examined traits were somewhat higher (4.9 for LMV and 4.9 for HLV) than the index score (4.6). A favorable genetic correlation was found between LMV and HLV (0.68) and the correlation coefficients of both the LMV and the HLV were strongly positive, therefore it is advisable to link them with a selection index.

3.3 Results of EcoWeight Rabbit

The number of reproduction cycles was 7. The average conception rate of does was 0.86. At the end of the reproduction state, the doe is either died (or culled) followed by a transition to the system (parity number 1; e.g. replacing of the doe by a young doe) or kindling interval is completed and the doe is transited into the next reproduction cycle. The mortality rate of kits was 9.08%, while the survival rate of the Pannon white rabbits in fattening was 95% in the current study.

Feeding costs were higher than non-feeding costs. Total feeding costs were 9.04 €/per reproductive cycle for does in our system, and 19.31 € for progeny in the same cycle, while non-feed costs were 6.73 € for does and 3.03 € for progeny. Fixed costs included relatively high amortization costs. Making a rabbit farm is a bigger investment per doe (38%)

while investing money in swine or broiler production is much more favorable regarding the fixed costs and amortization costs

Revenues for the rabbit farm were calculated for does and for progeny. Health costs and non-feed costs for replacements were low, which fact implies, that longevity has slight economic importance in rabbit breeding.. This simulation represents an ideal situation, with good disease management and continuous and stabile reproduction rhythm.

Economic weights were calculated as 15.15 € for the average volume of the hind part (350 cm^3) and 18.18 € for the valuable meat parts (550 cm^3), of the selection criteria traits.

The created indices from the selection criteria traits were as follows:

Index 1= -0.625 LW21 + 3.287 HP

Index 2= -0.625 LW21 + 4.532 VP

Improving the NBA (number of kits born alive) is much more difficult, than the feed conversation ratio. EWs for survival are relatively small. Our study also showed that longevity has low economic importance.

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4. Conclusions

Selection decisions are depending on many factors in animal breeding. In the case of rabbits, the number of kits and carcass traits are the most important however, the genetic basis of these traits is determined by multiple loci. Implanting the selection index method in rabbit breeding is reasonable, especially when a breed is selected for both production and reproduction traits which are not positively correlated. The indexing technique with 'desired gains' can be available for those traits which were not determined before from an economic point of view. For the slaughterhouse, the valuable meat parts represent the main source of the profit, so it is feasible to put a selection index between the valuable meat parts and one of the reproduction traits, even if the only relevance of this trait is to maintain the breed as a possible crossing partner in the future.

Economic indices are quite sensitive to the market changes and some of the extreme price changes, but they are robust to the variation of economic weights. Some traits in the breeding goal have a great role in profit incensement, but their heritability is low, so significant economic improvement is not guaranteed. Other traits are not part of the profit, but important for other reasons (such as meat quality traits), or only can be measured in one sex, or too expensive to measure in traditional farms (CT traits), so they can be part of the breeding objective, but not measured in the selection criteria.

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5. NEW SCIENTIFIC RESULTS

1. A desired–gain selection index was created for the first time for the Pannon White breed using the aggregate genotype of the litter weight and the thigh muscle volume, which can be applied in the first selection step.

2. A desired–gain selection index was created for the first time for the Pannon Large breed using the aggregate genotype of the thigh muscle volume and the loin muscle volume.

3. Economic selection indices were created for the first time for the Pannon white rabbit breed, for the current selection criteria traits and the valuable meat parts. These indices are farm-specific, thus represent a new opportunity for rabbit breeders in terms of profitable selection.

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6. SCIENTIFIC PAPERS AND LECTURES ON THE SUBJECT OF THE DISSERTATION

6.1 Peer-reviewed papers published in foreign scientific journals

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7. OTHER PUBLICATIONS

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