1. Genetics principles in breeding

Hello. Domestication, evolution, and breeding. What do they have in common? Everything. Everything is essentially evolution. The lecture is part of Module 3, Animal Breeding. The creation of this presentation was supported by the ERASMUS+ KA2 grant within the ISAGREED project, Innovating the content and structure of study programs in the field of animal genetic and food resources management using digitization.

Domestication is an evolutionary process in which the influence of humans weakens the effects of many natural selection factors (although they still exist). Humans began using selective breeding to change desired traits and their values. The effects of selection also affected related traits. At the same time, humans controlled movement, feeding, and other factors that, along with breeding, influenced the development of domesticated animal forms.

Breeding is an evolutionary process in which humans are the driving force behind changes in traits. Humans define goals for breeding and select only the best individuals with desired trait values. Typical goals for breeding are combinations of different trait values that are important for production. We want to change the average value of traits in a population in the desired direction. The main problem is that most utility traits have a complex, quantitative nature ($P = G + E$), so breeding must be based on knowledge of the genetic structure of the population and environmental conditions.

We start from the basic breakdown of phenotypic variability, which is composed of genetic variability and environmental variability.

Genetic variability in a population is characterized by the heritability coefficient, which is the proportion of genetic variability to the total phenotypic variability. In other words, heritability tells us to what extent phenotypic differences among individuals in a population are caused by genetic differences.

Animal breeding is based on these hypotheses: The subject of evolution/breeding is not the individual, but the population. Most utility traits are determined by polygenes – typical for quantitative traits. Genotypes, not genotypes, are transmitted from generation to generation through genes (alleles) via gametes, which combine to create new genotypes in the offspring generation. The phenotype of quantitative traits in individuals is modified by environmental influences: $P = G + E$.

The amount of genetic improvement (ΔG) and its reflection in economic efficiency (financial gain) depends on: The genetic basis of traits and their variability in the population (the value of heritability of a given trait in the population must be known); Estimation of breeding values of individuals and populations (genetic value of an individual), and the accuracy of defining breeding goals. Ultimately, everything depends on the optimal utilization of animals with high breeding values or the optimal dissemination of the genes of this individual into next generations.

What information is needed in breeding? Phenotypic data - Utility; Genetic (genotypic/genomic) data (Kinship relations, Genotypes of genetic markers) and the use of statistical methods to link data and analyze to determine the genetically superior individual (best alleles -> offspring, for a given environment). The decisive problems in breeding that are addressed are defining a realistic breeding goal, choosing a suitable strategy, utilizing data that explain phenotypic variability, identifying genetically superior individuals through genetic analysis, and selecting and passing on genes to the next generation using reproductive methods.

The genetic evaluation system helps optimize breeding programs. Roughly 100 years ago, selection was based on phenotype and genetic progress was not as clear-cut. The reason was that utility traits are of a quantitative nature and have complex inheritance. Phenotypically valuable individuals may not have been genetically superior but may have developed in better conditions. After understanding how inheritance works and the development of population genetics and quantitative traits in the first half of the 20th century, we can speak of genotype-based selection, in other words, based on estimated breeding values, practically since the 1950s.

This reason can be seen in the diagram of the principles of genetic improvement through selection. We start with the original population from which we want to select the genetically superior individuals. We use a certain degree of selection intensity, which is influenced by selection differential d and phenotypic variance (standard deviation sigma P). We also need to know the estimated heritability value (essentially genetic variance) as accurately as possible. If a trait has high heritability, meaning there are large genetic differences between individuals, then with high selection intensity, I select parents with the best alleles in the given environment, and by transferring them to the next generation, I can expect the difference between the average of the new generation of offspring and the original generation from which the parents were selected (genetic gain delta G) to change in the desired direction and with significant value. For traits with low heritability (e.g. reproductive traits), more intense selection does not increase genetic gain much because there are small genetic differences among individuals in the population. A breeding equation has been developed, where genetic gain equals selection intensity times the accuracy of breeding value estimation times additive genetic standard deviation. If we divide it by the generation interval, we obtain genetic gain per year.

The genetic value of an individual cannot be directly determined, so estimates of genetic differences between evaluated individuals, i.e. breeding values, are used. This is the genetic deviation in utility traits from the average of peers (individuals living in the same conditions as the evaluated individual).

We must realize that with sexual reproduction, inheritance occurs through the gametes of parents, and gametes do not contain both alleles of the genotype, only one allele. Therefore, breeding value is the value of allele effects transmitted from parents to offspring.

Methods for estimating breeding value are mathematical-statistical processes for purifying genetic influences affecting utility traits from non-genetic influences (environment). The simplest expression of estimated breeding value based on individual utility is the phenotypic difference multiplied by heritability. The estimated breeding value is then not phenotypic but genetic deviation.

An example for explanation. We have a bull with a weight of 350 kg at one year, the population average was 300 kg. Its phenotypic deviation is +50 kg. The question is, is this phenotypic deviation caused only by genetic differences, i.e. is it really genetically superior to other individuals in the population? The bull could be good based on its genes, but also because it developed in better conditions. Therefore, it is necessary to estimate breeding value as genetic deviation in order to decide which individual to use as parents to pass on alleles to the next generation.

In another example, we compare two individuals, Karel and Rudolf. And even though we see that Karel has a greater weight and our ancestors would probably choose him as a stud (based on phenotype), today, when selection is based on genotype (based on breeding value), we would choose Rudolf as the genetically superior individual, who is compared to another group of peers but with the same heritability.

In conclusion: The main method of breeding and evolution in general is selection. The goal of genetic evaluation of individuals is to determine genetically superior individuals with the highest breeding values; It is based on population variability and heritability for a specific trait; Select individuals with the most suitable alleles for the given conditions as parents; By intentional reproduction, transfer their alleles to the next generation; Expect a shift in the average value of the bred trait in offspring (genetic gain); Breeding must generate economic profit.

And thank you for your attention.