8. Sources of variation in the population. Genetic and environmental variability

Prof. dr hab. Stanisław Socha
Siedlce University of Natural Sciences and Humanities, Faculty of Agrobioengineering and Animal Husbandry, Institute of Animal Science and Fisheries.

Phenotype, genotype and environment
The value of the phenotype (P) depends on:
- the genotypic value of the individual
- influence of environmental conditions
P = G + E
P – animal phenotype
G – animal genotype
E - environmental factors

Characteristics important in animal husbandry include traits:
- related to the performance of animals (e.g. milk yield),
- animal reproduction,
- health.

Generally, the features can be classified into two groups:
- quality features,
- quantitative characteristics.

Quantitative features and qualitative features
The main factor differentiating these two groups of features is the number of pairs of alleles (genes) affecting their shape and the number of classes of differentiated phenotypes. In the case of qualitative traits, the number of pairs of genes (or a series of alleles) influencing their formation is limited and varies within quite narrow limits from 1 to a maximum of 2-4. This, in turn, affects a limited number of genotypes (hereditary assumptions of individuals) and, as a result, individuals with specific phenotypes (all the characteristics of the organism)

EXAMPLES OF QUALITY CHARACTERISTICS
- animal color,
- feather color in poultry,
- horned or polled cattle, sheep and goats,
- blood group systems.

QUANTITATIVE FEATURES
In the case of features defined as quantitative, the situation is much more complex. Firstly, the number of genes (polygens) affecting their shape is very numerous, sometimes difficult to determine. Then, in addition to genetic assumptions, environmental factors have a significant impact on their formation. This type of inheritance not only significantly increases the diversity of individuals in the herd but also makes it extremely difficult to identify genotypes based on phenotype.

HERITABILITY OF TRAITS
With the multiplicity of factors affecting traits, it is impossible to determine the contribution of a single gene to the formation of a quantitative trait. Only statistical methods allow to determine the influence of genotype and environment on the variability of the trait in the herd (population) and to estimate the heritability of the traits of interest on this basis.

VARIABILITY

It is the variation in the value or quality of traits observed among individuals in a herd, in a population. Genetic variation is the basis for the genetic improvement of animals. Its sources are:

- recombination (leads to the formation of different, new genotypes)
- mutations (lead to the formation of new genes, other systems within a chromosome or between chromosomes).

THE MEANING OF VARIABILITY

The three main reasins for variability are:

- Aesthetic - diversity of forms in nature,
- Material nature - a variety of products is necessary to meet your needs,
- Improvement - thanks to the variability, the breeder can select the best animals for a given trait for further breeding (Jeżewska-Witkowska).

USEFULNESS OF KNOWLEDGE OF GENETICS IN ANIMAL HUSBANDRY

In animal husbandry knowledge of genetics can prove quite useful as it can help with:

- Improvement of animals,
- production planning for market needs, e.g. coat color, marking, color of subcutaneous fat, color of shell,
- in animal reproduction,
- predicting their vitality, temperament and physique, the possibility of avoiding defects and diseases of genetic origin,
- creating lines of laboratory animals for the needs of human medicine (Jeżewska-Witkowska, 2010).

Estimating heritability - analysis of variance

We estimate the average and variance for:

- for the whole population,
- for all groups of half-siblings,
- for all sibling groups.

We rely on the analysis of:
- half-sibling groups: cattle, sheep,
- full sibling groups: poultry, pigs.

Variation analysis of full-sibling groups, half-sibling groups, and overall variability of unrelated animals.

HERITABILITY OF TRAITS

Heritability varies depending on the type of trait. The size of the indicator varies from 0 to 1 (or from 0 to 100%).

We distinguish features:
- with a low index, their value ranges from 0.00 to 0.20 - these are the predominant traits related to reproduction (fertility and fertility of animals, laying),
- with an average value of the index from about 0.25 to 0.40 - milk yield, daily gain, body weight at birth, egg weight,
- with an increased heritability index - above 0.4, these are, among others, such features as: protein and fat content in milk, backfat thickness, carcass length in pigs, the surface of the "sirloin eye", egg shell color in poultry, wool thickness in sheep.

BREEDING PROGRESS, VARIABILITY AND HERITABILITY OF TRAITS

Breeding progress can be defined as the difference between the average value of a trait in the progeny population compared to the average value in the parent population.
The increase in the value of traits achieved by improving environmental conditions is called non-genetic progress.
Breeding progress is considered to be the difference that has been achieved through breeding work.

SELECTION EFFICIENCY

The breeding progress achieved is a measure of the effectiveness of selection.
The amount of breeding progress (Δ G), and thus the effectiveness of selection, depends on:

- accuracy of breeding value assessment,
- selection intensity,
- genetic variation.

BREEDING PROGRESS - MATHEMATICAL APPROACH

A simplified formula for breeding progress is as follows:

$$\Delta G = R_S * h^2$$

where:
R_S – selection difference expressed (in units in which the feature is measured);
h^2 – heritability of the trait.

HERITABILITY AND BREEDING PROGRESS

Genetic variability existing in the herd (population) has a significant impact on the size of breeding progress, in particular the value of heritability (h2) of a given trait in this herd. With the value of h2 equal to 1, the entire selection difference is "transferred" to the offspring in the form of an increase in the value of the trait. Breeding progress will be equal to the size of the selection difference. Of course, the example is hypothetical and for very few traits there is such a high heritability. With a heritability of 0.5, the offspring will outnumber the parent by 50% of the selection difference.

HERITABILITY AND BREEDING PROGRESS

On the other hand, if the heritability of traits is zero, breeding progress will be impossible.
If any of the terms of the product is equal to zero, there will be no breeding progress. The breeder may slightly influence the amount of genetic variation. Using the appropriate mating system or introducing animals from outside to your herd. However, it can significantly affect the accuracy of selection (R - correlation between the breeding value and the phenotypic value. This issue was presented earlier, when assessing the breeding value.

THE LIMITS OF SELECTION

Reasons for the lack of breeding progress - selection limit:

- the limit of the physiological possibilities of animals;
    - lack of genetic variation: attempts to maintain genetic variation:
    - through skilful crossbreeding,
    - importing "breeding material" from outside.

SUMMARY

When conducting breeding work - also starting breeding work, we first need to know the size of genetic parameters in the herd in the population: heritability of traits and correlations between traits.

Thank you for your attention!