disarm

Disseminating Innovative Solutions for Antiobiotic Resistance Management

Best Practice Guides

Potential of Breeding and Genetics for Robust and Resilient Animals

PROLOGUE


CATTLE


PIGS


POULTRY


SHEEP

This guide is written as part of the DISARM project 'Disseminating Innovative Solutions for Antibiotic Resistance Management', funded by the European Union's Horizon 2020 research and innovation programme under grant agreement 817591.

The DISARM project aims to reduce antibiotic resistance through a focus on disease prevention and animal health, thereby reducing the need for antibiotic use. DISARM has a wide range of resources available via our website and YouTube channel. We also have a vibrant and knowledgeable community within our Facebook discussion group (we welcome you to join, simply click this link and answer some short questions to gain access), and wider social media channels: Twitter, Facebook, LinkedIn.

DISARM also promotes the multi-actor approach – different people (farmers, veterinarians, nutritionists and other advisors) working together towards improved animal health and farm performance. If you want to find out more about this, check out our toolbox to get started!

This guide was based on the information that was gathered during the DISARM project; it should not be considered as a complete reference book. It gives a useful overview with links to practical videos, abstracts, articles, testimonies etc., to facilitate good practices. Not all recommendations will be applicable or suitable for your farm and any interventions should be discussed with your farm advisor(s).

This guide is one of the 10 Best Practice guides made during the DISARM project. The 10 guides all have the goal to inform you about a specific topic in order to reduce the antimicrobial use in the livestock industry.

The other DISARM Best Practice guides can be found here.

Find us on **Facebook**

Follow us on **Twitter**

Watch us on **YouTube**

Follow us on **LinkedIn**

Visit our **Website**

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no. 817591. The contents of this publication are the sole responsibility of the DISARM project and do not necessarily reflect the opinion of the European Union.

Coordinated by | Partners

ILVO Flanders research institute for agriculture, fisheries and food

Innovation for Agriculture; ifip; nutrition sciences; ZLTO; Agricultural University of Athens; IDF International Dairy Federation; SEGES; USAMV Bucuresti; ANPROGAPOR; ITAVI; copa cogeca; Ghent University; angst; acta; Institut de l'Elevage idele; Wageningen University & Research; Latvia University of Life Sciences and Technologies

DISCLAIMER

While all reasonable efforts have been taken by the author to ensure the validity of this Best Practice Guide, the DISARM project team and funding agency accept no liability for any loss or damage stemming from reliance upon this document. Use this document at your own risk, and please consult your veterinarian and/or advisor(s) to ensure the actions you wish to pursue suit your farm.

INTRODUCTION

This guide aims to provide information to farmers about best practices and new approaches regarding breeding and genetics.

By selecting for robust and resilient animals, overall herd/flock health can be improved thus the need for antibiotic treatments can be reduced.

Genetics can play an important role in determining animals' susceptibility to disease and their responses to other physical, environmental and social stressors. Breeding for improved resilience fosters good health and wellbeing for animals in future generations, benefiting overall farm performance.

Resilience is an animal's capacity to be minimally affected by, or to quickly recover from, challenges to their physical and mental states.

Challenges may include disease, temperature stress, novel environments, human interactions and changes to social groups. Animals' ability to cope under different conditions is in part determined by genetics. Selective breeding for favourable traits can make them more common in future generations.

Indicators for general resilience are being researched, but health-related traits like longevity and growth can act as indicators for disease resilience to help protect the health status of your animals.

There are various gene identification and selection methods which can be safely used to produce farm animals that are resistant to various diseases, thereby decreasing overall antibiotic consumption.

New genomic techniques, (e.g. gene editing) are not currently allowed under EU legislation as resulting animals would be classed as Genetically Modified Organisms (GMOs) – although this legal position might be reviewed in the future, this area is not a focus of this guide.

Further on you will find practical information about the use of selective breeding; genomic testing; crossbreeding for hybrid vigour, use of indexes for selection and examples of using genetics for different farming sectors.

SELECTIVE BREEDING

Over the centuries, in many regions, different local animal breeds have been developed. It is estimated that there are approximately 5000 local breeds, globally. All these animal breeds are well adapted to withstand local conditions and serve specific needs. In breed development, extremes in climate and infectious diseases circulating in the region act as a selective pressures, influencing the resistance gene distribution within the population.

Based on these visible traits (animal phenotype), as well as the particular farming system and nutritional capabilities and limits, farmers could select breeding stock to increase the frequency of those favourable heritable traits in future generations of their domesticated animals.

In selective breeding, usually the set of characteristics that are selected for include:

- productivity in the current environmental conditions or conditions expected in the future
- fertility
- disease resilience or longevity that relate to costs of production

Historically, producers focused on breeding for increased production – this often resulted in negative health and welfare consequences for the animals as the animals bred for production efficiency seem to be more at risk for behavioural, physiological and immunological problems (you can read more about it here). Nowadays more sophisticated selection processes, like genomic testing offer accurate genetic assessment to select beneficial traits whilst reducing unwanted ones.

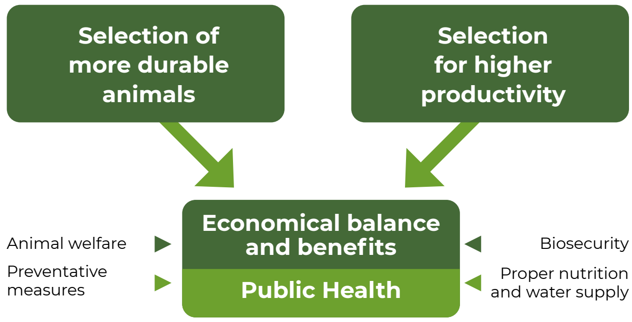
Breeding for Resilience

In livestock farming there are different factors that influence the economic performance of the farm. Genetics and breeding of animals is one aspect, but factors such as animal welfare, biosecurity and preventive measures of diseases, proper nutrition and water supply are equally important.

Breeding can be successfully used to create breeds with specific traits e.g. animals of a particular colour, or to increase the overall productiveness through improved weight gain, musculature, egg size, milk yield etc. Generally speaking one should always aim to use the best available genetic material, but how can you identify the best?

- **Animal resistance to specific infection disease**
- **Animal ability to have higher immunoreaction to vaccination**
- **Resistance to specific metabolic diseases**

- **Animals with higher muscle amount**
- **Animals with higher weight gain**
- **Animals with higher FCR**
- **Animals higher with meet quality characteristics**



Intensive crosses ? Extensive crosses

There are several approaches to selective breeding, overall you should use the best available genetic material considering the factors you are breeding for – productivity, health, resilience, tolerance to particular climate and nutrition, even infrastructure sometimes – e.g. keeping in mind the size of the animals in respect to the animal housing available where breeding has outpaced the development of farm buildings.

In many cases there are benefits in choosing to crossbreed for **hybrid vigour** that can contribute to better production traits, e.g. in **dairy farming** those can be milk production traits and content, decrease of the somatic cell count, cow fertility and productive life span. Check out these videos about **genomic testing** and **crossbreeding**.

The selection of best adapted and productive animals for reproduction plays an important role in disease resistant animal breeding while not sacrificing productivity. For example, the deep-freezing and storing of semen created possibilities for artificial insemination. On average, 2,000 semen doses per collection per bull can be collected, deep-frozen and stored for years. The deep-freezing of semen enables transportation of it around the world and as a result, the best bulls with beneficial traits can be exploited heavily (**view the full study here**). This practice is beneficial, but carries risk as it may spread not just wanted traits, but some unintentional disease susceptible genes as well that are not a problem in some regions, but can be devastating in others. Thus the sire selection and use of indexes plays an important role to enhancing desirable traits and limiting undesirable ones. The same semen freezing approach can be applied to other fields of animal production.

Considering the advantages of producing animals of a particular gender (e.g. female cattle in dairy farming) there is a practice of using sexed semen in which the fractions of X-bearing (female) and Y-bearing (male) sperm have been modified from the natural mix through sorting and selection. The benefit is a much higher selection intensity on the females – allowing more emphasis on health traits. It is proven to be very effective when combined with female genomic testing and/or embryo transfer. If that sounds interesting, you can find more info about the technology and economic pros and cons **in this article**.

Selecting for low heritability traits, such as disease resilience and fertility is challenging, but becomes easier if the selection is based on progeny group averages in programmes where the size of the progeny groups is relatively large. A prerequisite for consideration of disease resilience in a breeding programme is that the diseases, or other traits closely related to these, are recorded accurately. The systematic recording of clinical cases of mastitis is the most important way to evaluate the sires accurately for resistance to mastitis among their daughters. The important means of detecting mastitis resistance is the use of somatic cell count (SCC). It is possible to improve resistance to clinical mastitis by selecting for lower somatic cell count. This is primarily achieved by excluding from breeding those bulls for which the highest SCC values are demonstrated in their daughters. Due to the higher heritability of SCC, selection based on this trait was more efficient than selection based directly on cases of clinical mastitis in the improvement of mastitis resistance when only small progeny groups are available. However, a combination of both measures is about 20% more efficient than the former alone (see the studies: **Knap et al**, **Lindhe & Philipsson**)

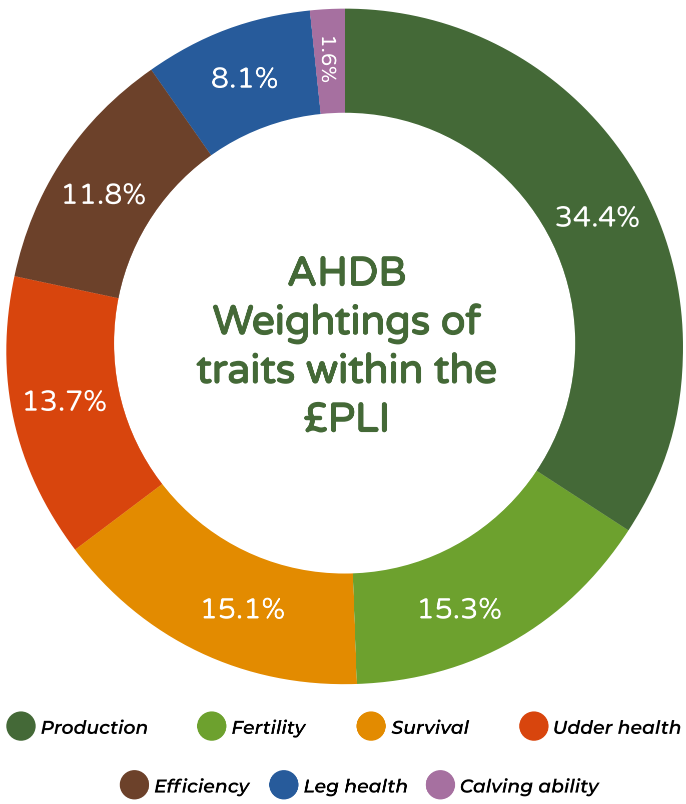
Female fertility is considered using information about the number of inseminations required per serviced heifer, first- and second-calvers combined with number of days open in the first and the second lactations, in a fertility index. Bulls are evaluated both as sires of calves and as sires of first-calvers, as the fertility trait is clearly dependent on the effects of both the calf and the dam.

Multi-trait selection for total merit is an approach by which selection for many traits occurs simultaneously. Consideration of the relative economic importance of different traits, their heritability and the genetic correlations between all traits of interest is possible by means of a selection index. Each trait is given an economic weight which reflects its importance for the net return of production. This 'economic' weight may also include ethical values and animal welfare aspects. The selection index procedure allows the following (the study can be found **here**):

- Selection of individuals for a given trait using records on the individual and/or on their relatives, and
- Selection of individuals for several traits considered simultaneously, using records on the individual and/or on their relatives so that the total economic gain from the expected genetic progress is maximised.

One can use indexes like **The Profitable Lifetime Index (£PLI)** which indicates the additional profit that a daughter of a high £PLI bull is expected to earn over her lifetime, compared with a daughter sired by an average bull with a £PLI of zero. This index is composed of 1/3 production traits, 1/2 health traits/longevity, 1/6 efficiency (the breakdown of the individual weightings of traits is shown in the pie chart by UK Agriculture and Horticulture Development Board (AHDB)). Or select solely on health traits.

A similar approach can be applied to other animal production sectors when beneficial traits and productivity is carefully recorded, analysed and selection of breeding stock is based on this data. Their effective and wide implementation in livestock breeding programmes is currently hampered by the lack of adequate tools to measure, or accurately estimate, these resilience component traits, in particular pathogen load. If you would like to know more, **please read the full study here**.



EXAMPLES OF HOW GENETICS IS USED IN DIFFERENT FARMING SECTORS

Disease Resistance for Chickens

Resistance genes against Salmonellosis, Marek's disease and Newcastle disease (ND) have been identified. Currently investigations are ongoing for the application of these research findings that could lead to improved vaccines for Marek`s and ND. Also, breeders might be able to select chickens for increased resistance against those diseases. **Here you can find an article** about the heritability for all ND response traits in studies involving African ecotypes and US commercial laying birds.

Another approach is choosing more robust, **slower growing crosses** - the classic conventional broiler crosses are fast growing and kept in high densities so they are more susceptible to heath disorders including bacterial and protozoal diseases which are usually treated with antibiotics.

By choosing a more resilient breed of poultry, farmers can reduce antimicrobial usage, obtaining both healthy and easier-to-manage flocks. These breeds tend to have lower feed conversion rates so achieve less intensive growth.

Improvement of resilience can be accomplished by different strategies. One strategy is to increase resilience by genetic selection in breeding programs. The advantage of genetic selection, in contrast to management improvements, is that it can be a longer-lasting solution.

Furthermore, it can be done through adequate resilience-improving breeding programs. For example, **dual-purpose breeds** or local (traditional) breeds have been shown to be more resilient than more conventional breeds.

Also some breeds of layers may be more prone to **injurious pecking** – choose calm, robust breeds and good rangers for free-range systems. If you are interested you can read more about feather loss and good practice to improve the feather cover **here**.

An organic poultry farm in Latvia shared their insights about the broiler crossbreed they are using in their farm, if you would like to find out more, **here is a video** about their approach to small scale antibiotic free poultry farming.

"One of the keys that has allowed us to avoid the use of antibiotics is the choice of the slower growing broiler crosses that are intended for keeping in organic farms" – Latvian poultry farmer

Sheep and goats

Transmissible spongiform encephalopathies (TSEs) are fatal degenerative diseases caused by prion protein (PrP) which affect the central nervous system of many mammals. Host genetic variation in TSE resistance is well characterized, particularly in sheep and goats affected with classical scrapie. In many countries breeding schemes based on PrP genotype have been successfully implemented to reduce the incidence of scrapie in sheep (complete description of this approach **can be found here**).

Selective breeding is most commonly used to promote resistance against gastrointestinal Nematodes in sheep. Good results in UK, New Zealand and Australia have been achieved in recent decades. Breeding sheep for enhanced resistance has been suggested as a viable method of parasite control. The majority of breeding programs for parasite control are based on indicator traits, in particular worm egg count (WEC) in faeces, and blood analysis parameters can be used in specific algorithms to predict resistance heritability. **Here you can read further** about the studies done in sheep flocks in Australia.

The experience of a UK Superfine Merino wool grower in comprehensive approach to sheep management to ensure the wellbeing of livestock and ensuring high genetic merit via embryo transfer (ET) **can be found here**.

Pigs

Genomic approaches have been used to define swine resistance to viral pathogens, particularly for the most economically important viruses, porcine reproductive and respiratory syndrome virus (PRRSV) and porcine circovirus (PCV). This information has been used to breed disease resistant pig strains.

Several porcine genes that are differentially up or downregulated during Salmonella infection have been identified and used for Salmonella resistant pig strain development.

Also a genetic resistance for E. coli infection is developed for some pig breeds (**the study can be found here**).

Cattle

Cattle viral diseases where host genetic variation has been quantified, or significant genetic marker associations demonstrated, include bovine leukaemia, various bovine respiratory diseases, bovine herpesvirus 1 (BHV-1) and foot and mouth disease. Breed or species-level variation in resistance to rinderpest, malignant catarrhal fever (MCF) and lumpy skin disease has also been reported. Overwhelming evidence suggests that genetics could provide new approaches to disease control in the rapidly changing environment faced by cattle breeders, both in developed and developing countries (**the study can be found here**).

Eventually this should lead to animals with a higher general disease resistance with lower antibiotic use, lower costs for farmers, and higher animal welfare. The prevention of lameness in dairy herds is one of the health aspects that can be affected by breeding, check out this video about it.

But how can you breed to reduce antibiotic use? For example, Zoetis' Genomic evaluation with CLARIFIED Plus includes specific health trait evaluations including mastitis, metritis, lameness, calf respiratory and cow respiratory. Clarified have developed a Dairy Wellness Profit (DWP) index which combines production, type, fertility, longevity and health traits. Analysis based on the balanced DWP index still shows the top 25% of cows using 44% less antibiotics for mastitis. Read the DISARM summary here or visit the website of CLARIFIED Plus to find out more about the approach they use.

In the table below, you can see a summary of the genetic values for Holstein cow health traits, these genetic predictions are based on data collected from health records within U.S. commercial herds.

Average reliability and average, minimum and maximum genetic values for holstein cow wellness traits, fertility traits and calf wellness traits*

	Average % reliability	*Minimum Score (STA)*	*Maximum Score (STA)*
Cow Wellness Traits			
Mastitis	*52*	*76*	*115*
Lameness	*52*	*73*	*115*
Metritis	*51*	*73*	*115*
Retained Placenta	*51*	*71*	*116*
Displaced Abomasum	*50*	*69*	*111*
Ketosis	*51*	*72*	*113*
Milk Fever	*36*	*68*	*114*
Respiratory Disease	*40*	*70*	*114*
Fertility Traits			
Cystic Ovaries	*29*	*69*	*118*
Abortion	*35*	*70*	*118*
Twinning	*42*	*66*	*112*
Calf Wellness Traits			
Calf Livability	*42*	*85*	*117*
Calf Respiratory	*36*	*83*	*116*
Calf Scours	*39*	*66*	*116*

**Numbers reflect data from reference population of animals under 2 years of age*
Average disease risk is represented by an STA value of 100. Values greater than 100 reflect animals with lower expected average risk for the associated disease relative to their herdmates. Selection for a high STA will apply selection pressure for reduced risk of disease.

THE FUTURE PERSPECTIVES OF THE USE OF GENETIC MODIFICATIONS

While gene editing is not allowed in EU, recently new genomic techniques (NGTs) beyond natural selection have been developed both for plant and animal genetic modification mostly in other parts of the world, excluding the EU from these research initiatives due to legislative constraints.

For example CRISPR–Cas9 has revolutionized the generation of transgenic animals. This system has demonstrated an unprecedented efficiency, multiplexability, and ease of use, thereby reducing the time and cost required for genome editing and enabling the production of animals with more extensive genetic modifications. It has also been shown to be applicable to a wide variety of animals. Therefore, a more targeted approach can be used to develop new resistant animal breeds with desired characteristics. There been many examples of CRISP-Cas9 gene editing technique applications to produce farm animals resistant to common pathogens that cause major economic losses in the feedstock industry. CRISPR–Cas9 has been used to generate pigs resistant to African swine fever and the Porcine Reproductive and Respiratory Syndrome Virus (PRRSV). Resistance to PRRSV was accomplished by inactivation of the gene CD163, which encodes the porcine receptor for PRRSV. CRISPR–Cas9 was used to introduce a gene in cattle that provides resistance to bovine tuberculosis, enzootic pneumonia and mastitis. Similar results regarding mastitis have been reported in goats (you can find more information about this technique in the studies of Shrock & Güell and Islam et al).

The developments of NGTs have the potential to contribute to the more resilient and sustainable agri-food system. Experts argue that in certain cases, targeted mutagenesis and cisgenesis carry the same level of risk as conventional breeding techniques as insertions, deletions or rearrangements of genetic material arise in all of the above-mentioned techniques and random changes to the genome occur independently of the breeding methodology. Still there are many concerns linked with application of NGTs in livestock farming that would require a risk assessment and a case-by-case assessment. You can read further about the EU stance on this NGTs here.

More from the DISARM Best Practice Guide Series

- Internal Biosecurity
- External Biosecurity
- Optimal Housing for Livestock
- Precision Livestock Farming for Early Disease Detection
- Drinking Water Quality
- Youngstock Management and Early Rearing
- Vaccination Protocols
- Improving Animal Health by Using Adapted Feeding, Watering, and Feed Additives
- Good Practices for Prudent Use of Antibiotics

disarm

Disseminating Innovative Solutions for Antibiotic Resistance Management

Visit our Website
Find us on Facebook
Follow us on Twitter
Watch us on YouTube
Follow us on LinkedIn

Design: Henry Burridge / henryburridge.com