EIP-AGRI Focus Group
Robust & Resilient Dairy Production Systems

Mini-paper – A genetically robust and resilient dairy cow for the future

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1. Introduction

Genetic variation between animals have been exploited for generations in dairy cattle. This is possible due to the huge amount of data recording done by farmers and artificial insemination (AI) organisations worldwide and follow up ranking using statistical modelling. Since the development of AI and freezing of sperm, a huge amount of exchange of semen across countries has been introduced in many breeds. This has lead to increased genetic improvement but also increased inbreeding.

Since 2000 the price of genotyping has dropped dramatically. This has made it possible to introduce genomic selection in many countries. Thereby ranking is done based on the DNA information rather than on the pedigree information of each animal. The main focus in selection has historically been on production traits rather than on cost-reducing traits such as fertility and health. With the introduction of genomic selection. also the possibility of making progress for cost-reducing traits has improved.

Although factors influencing the development of phenotype have been a focus of research for over a century, there is recently a substantial increase in interest in resilience and robustness of animals to environmental effects.

2. What is needed?

A focus on breeding solely or primarily for milk yield has been associated with a rise in health and welfare problems, (Rauw et al., 1998) such as decline in fertility and increase in foot and leg health problems (Pryce et al., 1997). Many countries have moved away from this approach by creating broader breeding goals with health and ‘fitness’ traits included in them or by reducing the emphasis or weighting on the production traits. Despite this, in situations where farmers chose the bulls to be used to breed the next generation of productive cows, many are tempted to use only the bulls with good scores for yield and place less value on fitness traits, or may be persuaded by offers from semen salesmen.

In the benefit for animal welfare and productivity that a livestock has a capacity to cope with environmental challenges having the capacity to reestablish homeostasis when insults to its integrity occur.

Resilience can be described as the capacity of the animal to be minimally affected by a disturbance or to rapidly return to the initial state (including physiological, health and production) that pertained before exposure to a disturbance. Towards improving resilience in farm animals, breeding approaches can provide significant benefits that may help achieve better adaptation to environmental challenges. In animal breeding, robustness is commonly pursued, defined as the ability of the animal to achieve its genetic potential for production traits in environments that have greater resource constraints or adverse environmental conditions than the environment in which the genetic merit of parents was assessed.

2.1. PHENOTYPES/REGISTRATIONS

The impact of genetic selection is restricted by the quality of the system that is set up to ensure progress. That means that if the amount and quality of the data used for ranking is low then the quality of the ranking will also be low. It is essential to have good registrations including animal identification. Also, the registrations must be performed the same way for all animals so no preferential treatment can be in the data.

The trait one selects for must be equivalent to the trait one wants to improve or at least to a very high degree resemble the trait. For traits like efficiency and resilience this can be difficult because it will depend on how the traits are defined.

Is resilience the ability to produce in different environments without dying and/or being sick or is resilience the ability to recover from diseases and produce at a high level? Is efficiency only related to feed intake and productivity or is it also related to eg insemination efficiency so that an efficient cow gets pregnant at any given time when the farmer has made the decision that the cow should get pregnant? More and more technology is being developed currently that will make decision making easier for the farmer in relation to everyday production.

2.2. HEAT STRESS RESILIENCE

Effects of increased thermal load to farm animals is one of the greatest challenges of livestock adaptation to climate change. Heat stress is a physiological condition when the core body temperature of an animal exceeds its range specified for normal activity, which results from a total heat load (internal production and environment) exceeding the capacity for heat dissipation inducing physiological and behavioral responses to reduce the strain.

The effects of heat stress are an alteration of post-absorptive energy, lipid and protein metabolism, impairs liver function, causes oxidative stress, jeopardizes the immune response and decreases reproductive performance. There is evidence of genetic differences within ruminants with respect to heat tolerance which may provide an opportunity to include thermotolerance into breeding programs. In consequence, numerous authors advocate the inclusion of this operational genetic trait in animal selection in order to improve their resilience to thermal load improving animal welfare and productivity.

2.3. SOCIABILITY

Sociability can be described as the degree to which an animal is comfortable to be in close proximity to their group-mates (Sibbald et al., 2006; Gibbons et al., 2010). Research has shown that there is variation between animals in their motivation to do this (see Gibbons et al., 2010 for refs…).

Clearly, cows housed indoors will have closer individual distances that grazing cattle. This may have implications for stress. Animals with high social motivation will integrate better into groups and cope better with group housing than animals with low social motivation. Methods have been established to assess sociality and studies have shown that animals show consistency in their social motivation (Gibbons et al., 2010; Mackay et al??). However, there have been no estimates of heritability and more research is needed for this subject.

2.4. NEEDS OF THE ANIMAL - EMOTIONS

The individual's response to environmental stimuli is influenced by numerous factors including, among others, the emotional state (Veissier and Miele 2014). Two important proximate outputs of stimulus modulation by the operational state of the central nervous systems are the affects termed emotions and moods of the animal (Mendl et al. 2010). Acceptance that animals do experience emotions has been slow to develop (Veissier and Miele 2014) and opinions differ on the nature of emotions and the ultimate functions they serve.

Although some developments have been done to evaluate emotions (Desire et al., 2002; Wemelsfelder et al., 2007) it is still difficult to infer quantitative values of emotions that can be added to breeding models.

2.5. AGGRESSION

Aggression between animals typically occurs in response to competition for resources such as feed, water or favoured lying spaces. Aggression is a welfare issue as it may cause injury and stress to both the aggressor and the recipient. Aggression can be assessed and shows consistency. Studies of heritability show low levels, but samples sizes have been small. More research in this area is still needed.

2.6. FEED EFFICIENCY

Selection for more productive animals has been the main goal in livestock breeding programs during the last century. Recently, the focus has swiped to select animals for an efficient use of resources, as for example feed efficiency. Selecting for improved feed efficiency is today limited by the fact that feed intake is only recorded individually on cows at research facilities.

The technology available to make individual recording is too expensive for commercial farmers to make the investment and make money on the information one will get from such a system. Therefore development of new types of equipment for recording is necessary in order to implement such a system on commercial farms and thereby develop a successful genetic index.

2.7. BREEDING GOAL

In order to achieve genetic progress towards resilience and efficiency it will be important to have a balanced breeding goal. A balanced breeding goal will ensure progress for productivity as well and cost-reducing traits.

Most countries in Western Europe either has implemented such an index or has it under development. Recently also indeces feed intake has been developed and included into total merit indeces and in the near future more countries will do so. Resilience is not included as a specific trait currently in any country, but traits like health, longevity, reproduction, are included in one or the other way in many countries.

2.8. METHODOLOGY

Traditionally breeding values have been predicted based on pedigree information. This means that animals without registrations get a breeding value based on the performance by relatives. These type of models has worked well for decades.

A set back for these type of models is that eg in a group of full sibs it is impossible to select the best due to the mendelian difference there will be. All full sibs will have the same breeding value and one cannot separate these before they have an own performance. DNA based methods where the animal genome is split in several thousand small pieces and the genetic value of each of these piece generates an aggregate genotype is currently under development. With such methods one can locate the best genetic animal in a group of full sibs before they have their own performance at a low age and thereby increase genetic progress.

Genomic prediction is implemented in many developed countries and the models are improving every day. This development will also help selecting for efficiency and resilience, especially if methods will be able to handle data from different breeds and species in the same evaluation. This can help both in small breeds, but also in the evaluation for crossbreed animals.

An alternative to index selection is to find alternative and more robust breeds and through introgression increase the genes related to robustness in the commercial breed. This is to some extend practiced in pig breeding.

Recently gene editing has been proposed as a method to incorporate and fixate genes into animal species. That could be done with traits like polledness controlled by one gene. Health stress might also be a trait of interest since Inducus cattle seem to be more heat tolerant. It might be that genes could be located and introduced in Taurus cattle using gene editing.

Resilience and efficiency is in general quantitative traits controlled by multiple genes and therefore it is hard to believe that his method will have huge impact on the progress for such traits.

2.9. GENOTYPE BY ENVIRONMENT INTERACTION

Currently genetic evaluations are done assuming, that all environments are equal. That means a genetic merit for an animal will be the same in northern Europe as well as in southern areas f.ex. Italy, even though it is obvious there is huge differences between the two places. Models needs to be developed to handle these differences.

The environmental differences can come both from weather, humidity and temperature differences. Other environmental differences that could be taken into account is production, reproduction and health level in the herd. One could also make categorical groups such as grassing vs indoor or organic vs commercial farming. Also differences can be in terms of variation over time both within and across years. These differences influence both resilience and efficiency and have to be taken into account.

2.10. CROSSBREEDING

It has been found that crossbreed dairy cows will be more resilient than purebred cows. However, dairy cattle production has primarly used pure breed animals in production, but over the last years more and more farmers have selected also crossbreeding. This is done with two aims:

1) exploiting heterosis in terms of improved health and fertility in the following generation by crossing two dairy breeds.
2) Improving the end-product in terms of slaughter quality by crossing the genetic worst dairy cows with beef breed semen.

2.11. GENETIC DIVERSITY

Genomic prediction works best for large populations. This puts a pressure on small breeds which often are local or regional. It is important that these breeds are maintained because they are both a financial and cultural resource. It is also expected that many of these often dual-purpose breeds will be superior in terms of robustness compared to many of the large one-purpose breeds.

2.12. FARM STRUCTURE AND MANAGEMENT

Data ownership will be a very important issue in the future in relation to farm management. There will be an ongoing discussion whenever a farmer is purchasing a new piece of technology.

Commercial robustness will be important. Many local and regional AI companies may change the owner and be bought or merged by larger AI companies. There has to be a good communication between farmers and AI companies that ensures that the product the AI company is offering is in line with what the farmer is willing to use – also in relation to robustness.