GenTORE

Genomic management Tools to Optimise Resilience and Efficiency

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D5.5
Long-term consequences of adopting breeding management indexes

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Dissemination level:

- X **PU:** Public (must be available on the website)
- ☐ **CO:** Confidential, only for members of the consortium (including the Commission Services)
- ☐ **CI:** Classified, as referred to in Commission Decision 2001/844/EC

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1. Summary

To date, no breeding goal has been developed or implemented that includes resilience as a breeding goal trait. We simulated the consequences of breeding for more resilience in dairy cows in two different studies. In the first study, we simulated breeding goals with varying emphasis on resilience indicators in two key production environments. Resilience indicators were defined as body condition score, the log-transformed, daily deviation from the lactation curve (LnVAR), and 'true' resilience. True resilience was defined and developed based on expert opinions within the GenTORE innovation program. The results of the first study showed that adding weight to resilience or resilience indicators in the BG adversely affected genetic gain in the aggregate genotype and milk production. On the other hand, we see a significantly higher genetic gain in true resilience and resilience indicators. In the second study, we elaborated a new methodology to predict selection response based on a mechanistic model developed in WP6. This method has two main advantages: it gives insight in the biological mechanisms involved in the genetic improvement and it enables prediction of selection response for nutritional environments that can be tailored according to anticipated future environmental conditions. First results confirmed that including resilience indicators in dairy cattle breeding goals will lead to a decrease in genetic gain on milk production but an increase on fertility in non-limiting nutritional environments. It also highlighted that genetic improvement was achieved by changing energy acquisition profiles of cows and energy allocation to different functions.

2. Introduction

Dairy cattle breeding goals have mainly focused on increased milk production for several decades. Functional traits have a negative genetic correlation with milk yield, and therefore, a decline in health and fitness has been observed. In the last two decades, many more functional traits have been included in breeding goals worldwide. However, to date, no breeding goal has been developed or implemented that includes resilience as a trait. It has been shown that animals differ in their ability to cope with environmental disturbances. A resilient dairy cow can avoid being affected by or quickly recover from environmental disturbances and return to its normal status. These disturbances can be caused by changes in quantity or composition of feed intake, pathogens or heat waves. Selecting for improved resilience is expected to reduce gains achieved on production traits, e.g. feed efficiency, whilst improving functional traits. To assist breeders in comparing different selection strategies including resilience, we simulated the consequences of increasing weight on resilience indicators (and our definition of true resilience) in breeding goals typical of different production environments / within different environments.

3. Approach

We simulated the consequences of breeding for more resilience in dairy cows using two complementary approaches.

In the first study, we simulated breeding goals with varying emphasis on resilience indicators in two key production environments. Resilience indicators were defined as body condition score, the log-transformed daily deviation from the lactation curve (LnVAR), and 'true' resilience. True resilience was defined and developed based on expert opinions within the GenTORE innovation program. Although there is currently no consensus on a satisfactory measurement of true resilience, it was defined in the simulation as a measurable trait, and its meaning was described by the genetic correlation of this trait to each of the other traits. In addition, five economically important breeding goal traits where included: milk production, beef production, dry matter intake, fertility, and udder health. Breeding goal weights for these traits were initially based on economic values calculated for usage in the Nordic Total Merit index (NTM) for Holstein cows, and adjusted to match correlations of each sub index with the NTM. In total ten different scenarios were stochastically simulated in a so-called pseudo-genomic simulation approach. Annual genetic gain was calculated in genetic standard deviation units for every trait in every environment and scenario by using genetic levels in the last ten years of the simulation. Genetic gain in the aggregate genotype was calculated for the economically important traits to evaluate the economic impact of the different breeding goals.

To gain a deeper insight in the biological mechanisms underlying selection response on resilience, we developed a new methodology to predict genetic gain by accounting explicitly for key drivers of cow responses to a nutritional challenge. In this second study, we capitalized on a mechanistic bioenergetic model developed in WP6 and implemented in a simulation tool (D6.1). This tool simulates milk production, feed efficiency, body weight, body reserves and reproduction performances of cows depending on the nutritional environment and individual cows' characteristics (their energy acquisition and allocation strategies). It was coupled with a genetic model to enable prediction of selection response.
The strength of this model is that it can accommodate the simulation cow populations in any nutritional environment. In contrast, environments were fixed in the first study to two mainstream production systems for which we had genetic parameters. The consistency of selection response predictions for usually selected traits was validated in a case study. Selection response was predicted for a breeding scheme with the same structure as in the first study. Genetic parameters were estimated from simulated datasets for cows reared in a non-limiting environment. The breeding goal was defined to match the relative weights between production and functional traits used in the first study. We considered two alternative breeding goals including as resilience indicators either the proportion of body reserves in early lactation (equivalent to the body condition score) or the overall change in body reserves between the beginning and end of lactation.

4. Results

The results of the first study showed that adding weight to resilience or resilience indicators in the BG adversely affected genetic gain in the aggregate genotype and milk production (Table 1). On the other hand, we see a significantly higher genetic gain in true resilience and resilience indicators (Figure 1), and due to favorable genetic correlations, higher genetic gain in beef production, fertility, and udder health. From an economical point of view, the increased gain in functional traits was however not high enough to counteract the reduction in genetic gain in MP.

Table 1. Genetic gain[1] in σ_A units and change in genetic gain (%) in the aggregate genotype[2] (H) compared with the basic scenario ($\Delta G, H_{change}$) in the West Atlantic environment.

	Scenario[3]									
Traits[4]	Basic	BCS 1	BCS 2	BCS 3	LnVAR 1	LnVAR 2	LnVAR 3	TRUE 1	TRUE 2	TRUE 3
MP	0.25	0.17	0.07	-0.01	0.13	-0.03	-0.14	0.14	0.02	-0.06
BP	-0.05	0.02	0.08	0.12	0.02	0.09	0.13	-0.02	0.01	0.02
DMI	-0.21	-0.24	-0.23	-0.21	-0.18	-0.10	-0.03	-0.15	-0.08	-0.03
FERT	-0.03	0.03	0.09	0.12	0.05	0.13	0.17	0.05	0.12	0.15

UH	0.03	0.05	0.06	0.07	0.11	0.16	0.19	0.12	0.19	0.22
$\Delta G, H_{change}$[5]	0%	-14%	-35%	-56%	-13%	-47%	-76%	-14%	-37%	-57%

[1]Standard deviations were in the range 0.01-0.02.

[2]Genetic gain in aggregate genotype was calculated for the current breeding goal traits (milk production, beef production, dry matter intake, fertility, udder health)

[3]Basic = scenario with breeding goal weights for milk production, beef production, dry matter intake, fertility, udder health (Table 2); In the other scenarios, Basic scenario breeding goal weights and breeding goal weights (50/100/150) for BCS = BCS(1-3) or log-transformed variance of daily deviation from the lactation curve (LnVAR) = LnVAR (1-3) or our defined true resilience (TRUE) = TRUE (1-3).

[4]MP = milk production, BP = beef production, DMI = dry matter intake, FERT = fertility, UH = udder health.

[5]$\Delta G, H_{change} = \left(\frac{\Delta G, H_{alt,i}}{\Delta G, H_{basic}} - 1\right) * 100\%$ where $\Delta G, H_{change}$ = change in genetic gain in H in percentages compared with the basic scenario, $\Delta G, H_{alt,i}$ = genetic gain in H in alternative scenario (BCS(1-3), LnVAR(1-3), TRUE(1-3)), and $\Delta G, H_{basic}$ = genetic gain in H in the Basic scenario

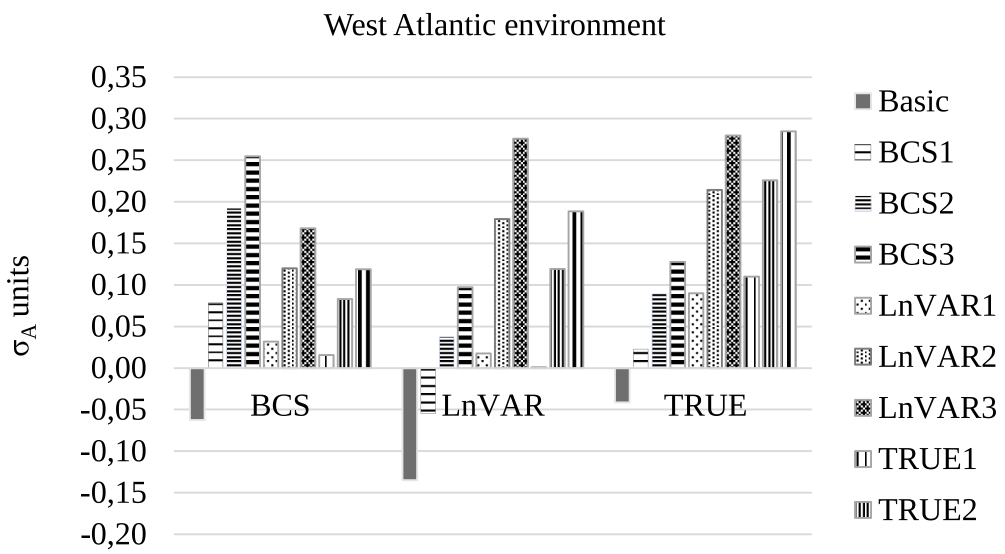

Figure 1. Genetic gain per year in σ_A units for BCS, Log-transform variance of daily deviation from the lactation curve (LnVAR), and true resilience in each scenario in the West Atlantic environment. Basic = scenario with breeding goal weights for milk production, beef production, dry matter intake, fertility, udder health; in the other scenarios, Basic scenario breeding goal weights and breeding goal weights (50/100/150) for BCS = BCS(1-3) or LnVAR = LnVAR (1-3) or TRUE = TRUE (1-3). Standard deviations were in the range 0.01-0.02.

Predictions obtained with the mechanistic-based approach confirmed a decrease in annual genetic gain on milk production (-0.06 to -0.07 genetic standard deviation units) when resilience indicators were added to the breeding goal but also an equivalent increase on fertility (0.08 to 0.09 genetic standard deviation units). Interestingly, the predictions of selection response expected with both alternative scenarios led to similar genetic gain on milk production (0.25 to 0.26 genetic standard deviation units). However, different levers were activated in terms of acquisition and allocation of energy by cows to achieve this gain on milk production. This new modelling approach opens new opportunities to evaluate the expression of genetic gain in prospective environments accounting for physiological trade-offs at stake. It

was used for the sustainability assessment of new breeding strategies under environments affected by climate change in WP6.
Results of these studies are in the process of being published in peer-reviewed journals and disseminated in international conferences (Details in section 6).

5. Conclusions

There are many ways of improving resilience in dairy cattle breeding by putting more weight on different resilience indicators. The indicators we used, body condition score and LnVAR, can be measured on a large scale today with relatively cheap methods, which is crucial if we intend to improve these traits through breeding. Adding weight to resilience indicators could turn the negative trend for resilience (indicators and our definition of true resilience) due to selection on milk production and efficiency, but with an economic cost in genetic gain in the aggregate genotype. Economic values for resilience have to be estimated to find the most optimal breeding goal for a more resilient dairy cow in the future. The new methodological developments coupling mechanistic and genetic modelling will also help breeders finding this right balance between efficiency and functional traits in breeding goals.

6. Scientific papers

Emphasis on resilience in dairy cattle breeding – possibilities and consequences. C. Bengtsson, J.R. Thomasen, M. Kargo, A. Bouquet, M. Slagboom. Submitted to Journal of Dairy Science. In revision.

Mechanistic-based prediction of selection response on resilience and feed efficiency traits in dairy cattle. A. Bouquet, M. Slagboom, J.R. Thomasen, N. C. Friggens, M. Kargo, L. Puillet. Peer-reviewed paper accepted for the World Congress of Genetics Applied to Livestock Production (WCGALP). July 2022, Rotterdam, the Netherlands.

Coupling genetic and mechanistic models to benchmark selection strategies for feed efficiency in dairy cows: Sensitivity analysis validating this novel approach. A. Bouquet, M. Slagboom, J.R. Thomasen, N. C. Friggens, M. Kargo, L. Puillet. In preparation.