THE GRAZING DAIRY COW OF 2030 – WHAT WILL SHE NEED TO DO AND WHAT DO WE NEED TO DO TO HELP HER ACHIEVE IT?

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Introduction

Globally, agriculture is undergoing seismic disruptions arising from the competing challenges of food security, the environment, and societal needs. The dairy sector is not exempt from this disruption as it faces a confluence of challenges including the rapidly expanding global demand for dairy products, the growing concern over the impact of cattle production on climate change, and the long-term volatility of global dairy markets. Fortunately, the solutions to these challenges are emerging from a parallel revolution in trait measurement techniques, genetics and DNA technologies.

Genetics is responsible for approximately half the observed improvements in animal performance in well-structured breeding programs Almost all, if not all, individual characteristics, have a genetic basis. Once genetic variation exists, then breeding for improvement is possible. Moreover, despite antagonistic genetic correlations existing among some traits (e.g., milk production and reproductive performance), once the antagonistic genetic correlations are less than unity, then genetic improvement in all traits is achievable.

Key characteristics of the grazing dairy cow of the future include (1) production of a large quantity of high-value milk and meat output – milk components that have high value domestically and internally and high direct meat value or saleable animals for beef production systems), (2) good reproduction - gets in calf early and every year, (3) good health status - naturally resilient to disease, (4) good longevity - produces to high levels for many lactations, (5) efficient grazer - an ability to consume and process high levels of pasture, (6) easy to manage - easy calving, docile (7) good conformation - an udder and body that lasts, (8) low environmental footprint - lower urinary nitrogen and methane outputs, and (9) resilience to external perturbations (e.g., weather fluctuations or feed scarcity). When initially defining the ideal cow, it is crucial not to 1) overlook traits despite the sometimes-perceived lack of genetic variation in the trait, and 2) ignore a trait if it cannot be (easily) measured given the current state-of-the-art.

Production of a large quantity of high value milk and meat output.

Almost all international dairy cow breeding goals include milk volume, fat and protein yield. Milk fat, however, is composed of both saturated and unsaturated fats, as well as the respective individual fatty

acid components. Similarly, milk protein is composed of a casein and whey fraction as well as the individual protein fractions. Milk processing characteristics (e.g., milk coagulation properties) are also important determinants of milk quality. Although these individual components currently do not have an explicit economic value in most production systems, they can influence the type and volume of different milk products processed and consumer perception of milk products and thus market demand. For example, the average milk fat of a dairy cow contains 70% saturated fatty acids, 25% monounsaturated fatty acids and 5% polyunsaturated fatty acids. Currently dairy products provide 15% to 25% of the fat consumption in the average human diet but represents 25 to 35% of the saturated fat intake. We expect that milk payment will become more granular scale to represent the underlying value of specific milk fat and protein characteristics and fractions. Although the main source of revenue from dairy herds is milk, beef, through the sale of cull cows and surplus calves as bull beef or service sires, represents 5-20% of the gross income in most production systems. Thus, beef merit, however defined, is an important characteristic of (the caloric output from) dairying and the future dairy cow.

Good reproduction

The ideal cow gets in calf early and every year. The importance of excellent reproductive performance in dairy production systems has been extensively discussed. The importance of superior reproductive performance is greatest in seasonal calving herds where the calving season is synchronised with the availability of low-cost feed (e.g., grazed grass). In seasonal calving herds, compromised reproduction is synonymous with the necessity for involuntary culling. In Ireland, it takes 1.63 lactations for a cow to repay her replacement costs.

Good health status.

Not only does sub-optimal animal health erode herd profit through increased veterinary and farmer intervention, and antibiotic usage and reduced performance (i.e., milk yield and reproductive performance) but compromised animal health status also influences consumer perception of modern-day dairy production systems. Producers are predominantly concerned with clinical signs of disease but non-observed, often sub-clinical disease, also impairs performance. Past experience from the observed decline in reproductive performance in the global Holstein population should not be repeated for animal health. As we strive to improve longevity in cows, animal health is likely to become an increasingly important concern. Increasingly, we will want animals naturally immune to disease or able to withstand health challenges.

Good longevity.

We want cows that produce to high levels for many lactations. A second lactation cow yields approximately 14% more than a first lactation cow while a third lactation cow (e.g., mature cow)

yields approximately 22% more than a first lactation cow. Therefore, achieving good longevity will not only reduce herd replacement cost but will increase herd revenue through having more cows at their optimal age for milk production and less cows not reaching maturity. Moreover, younger parity cows are more prone to calving difficulty, stillbirths, and some disease thereby impacting both labour requirements and overall herd profit; of course very old cows are also more prone to some diseases. The impact of reduced replacement rate on herd genetic gain must also be acknowledged; assuming a rate of genetic gain in calves born of 1% per annum, a halving of replacement rate from 20% to 10% (assuming culling is independent of genetic merit) equates to a loss in genetic gain at the herd level of just 0.1% (i.e., 10% of the 1% annual gain) per annum. So, good longevity needs to be balanced with sufficient replacement rates for genetic gain. In addition to the considerable impact on farm profit, poor cow longevity is also a growing consumer concern.

Efficient grazer

We want cows that can consume and process high levels of pasture. Feed costs represent 50% to 80% of the overall costs of production in dairy production systems. Reducing (the cost of) feed intake, therefore, without any repercussion on the other animal characteristics is of utmost importance. There is increasing commentary on the use of residual feed intake (RFI) as a measure of efficiency in dairy production systems to reduce feed intake without necessarily impacting other performance traits. Consideration must be given to the capacity of a grazing animal to meet (as much of) its dietary requirements from grazed pasture

Easy to manage.

Expanding herd size, and in some regions, access to only labour with less expertise in animal husbandry requires an easy-care cow. Characteristics of an easy-case cow not already accounted for directly in EBI or BW include good animal temperament and no requirement for assistance at calving. Polledness is also a management trait, as is the ability of the animal as a new-born calf to be vigorous and ingest and absorb sufficient colostrum. Milking speed could also be considered as an ease of management trait as it affects milking parlour throughput.

Good conformation.

Certain animal morphological characteristics such as body condition score, udder and leg configuration are known to associate with improved reproductive performance, health (e.g., mastitis, lameness) and longevity. Many, if not all, of these factors are usually already accounted for through the inclusion of the performance traits themselves within an overall holistic breeding objective such as expressed in the Economic Breeding Index in Ireland and Breeding Worth in New Zealand. If all traits are not considered (e.g., mastitis, lameness) then there may be merit in considering such traits particularly within the multi-trait genetic evaluations to augment the accuracy of selection for the goal

traits. Good udder conformation is nonetheless required, for example, for efficient automatic milking and the appropriate animal size is necessary for the design of the milking parlour as well as the housing facilities. Cows that do not conform to the standards required will be culled and thus this will be captured by the resulting inferior genetic merit for survival of these animals and their relatives. This however assumes that such production systems (e.g., automatic milking systems or very high levels of feed input) contribute substantial quantities of data to the current genetic evaluation system.

Low environmental footprint

Animal agriculture generates greenhouse gas emissions (GHG) as methane (CH_4) from enteric fermentation and manure, nitrous oxide (N_2O) from the widespread use of nitrogenous fertilizers and animal urine and faeces, nitrates from animal urine, and carbon dioxide (CO_2) from the fossil fuels for energy usage plus land use change. Reducing nitrate leaching from urinary output is a focal area in New Zealand and many regional councils have initiatives looking to improve and preserve water quality in lakes, rivers and streams. Methane, however, is not only an environmental hazard but is also associated with a loss of carbon from the rumen and therefore an unproductive use of energy. Animal agriculture is responsible for 8.0 to 10.8% of global greenhouse gas emissions based on calculations from the Intergovernmental Panel on Climate Change (IPCC). If however complete lifecycle analysis (i.e., accounting for the production of inputs to animal agriculture as well as change in land use such as deforestation) is undertaken this figure can be up to 18%. Cattle are the largest contributors to global greenhouse gas emissions.

Resilience to climate fluctuations and change

There is considerable commentary on the impact of ruminant production systems on climate change. Less discussed, however, is the impact of climate change on ruminant production systems. Climate change is expected to result in rising global temperature, changes in patterns of precipitation, and more extreme weather events. As well as imposing heat stress on individual animals, such climatic changes may alter the geographical risk areas for certain diseases which may have implications for animal populations naïve to such diseases and frequency and duration of drought that will impact pasture supply The animal of the future, therefore, as well as achieving all the aforementioned characteristics, will have to be robust to various external perturbations such as tolerating heat stress conditions or not overly eroding body condition score when pasture is scarce.

Existence of genetic variation

Most discussions on breeding programs and genetic gain focus on heritability estimates for different traits. Heritability however is only one of the factors that influences genetic gain. Annual genetic gain for a given trait may be described as:

$$Genetic\ gain = \frac{selection\ intensity \cdot accuracy\ of\ selection \cdot genetic\ variability}{generation\ interval}$$

The accuracy of selection is affected by both the heritability of the trait and the information available on the animal itself and its relatives. Heritability summarises the proportion of phenotypic variation, or differences among a cohort of animals, attributable to genetic variation between individuals. Heritability estimates for a range of performance traits in dairy cattle are given in Figure 1. In general, traits associated with viability and fitness (i.e., health and reproductive performance) are lowly heritable while traits associated with animal morphological characteristics are more highly heritable.

Accuracy of selection of near unity is nonetheless achievable, even for low heritability traits, if sufficient information is available. Therefore, with the appropriate breeding programme (e.g., large paternal half-sib groups, exploitation of genomic information) and infrastructure for the collection and storage of data, genetic gain in low heritability traits is certainly achievable if ample genetic variation is present.
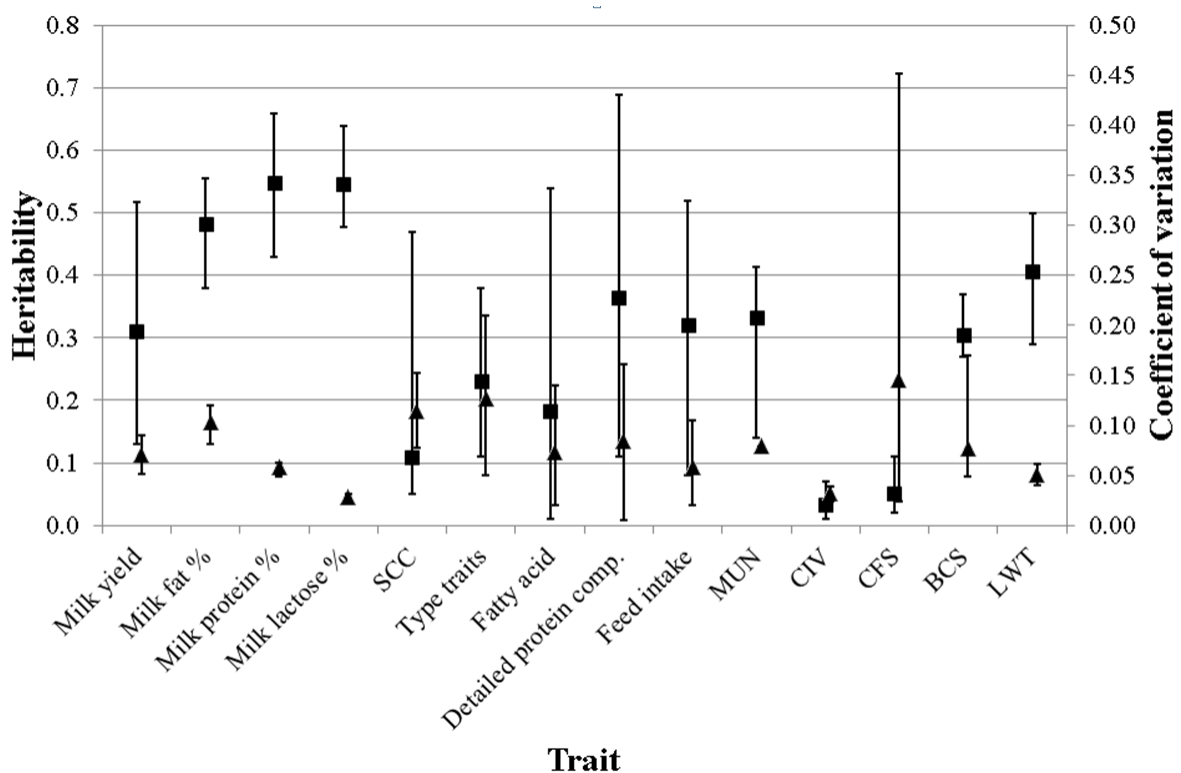

Figure 1. Mean heritability (squares) and coefficient of genetic variation (triangle) and variation (represented by error bars) for a range of performance traits including somatic cell count (SCC), milk urea nitrogen (MUN), calving interval (CIV), calving to first service interval (CFS), body conditions core (BCS) and live-weight (LWT)

Figure 1 summarises the coefficient of genetic variation for a range of performance traits in dairy cattle; the coefficient of (genetic) variation is unit-less and therefore facilitates the direct comparison of the variation present in traits differing in mean values but moreso the units of measurement. Although heritability estimates varies considerably across traits, the coefficient of genetic variation is relatively consistent across traits (~5%). The existence of considerable genetic variation in all traits clearly signifies that once high accuracy of selection is achievable, rapid genetic gain in each of these traits is indeed possible.

Conclusions

The first step in breeding for the cow of the future is to agree on the characteristics that describe that ideal cow and the relative importance of each of those characteristics. Because of genetic antagonisms, it may not be possible to achieve ideal performance for each characteristic. Acquisition of phenotypic data remains one of the key components for achieving high accuracy of selection and thus genetic gain, even in the genomics era. Key suites of traits warranting consideration for inclusion in dairy cow breeding goals include product quality, environmental footprint and animal health and, for Ireland, a measure of feed intake.