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Hot topic: Definition and implementation of a breeding value for feed efficiency in dairy cows

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ABSTRACT

A new breeding value that combines the amount of feed saved through improved metabolic efficiency with predicted maintenance requirements is described. The breeding value includes a genomic component for residual feed intake (RFI) combined with maintenance requirements calculated from either a genomic or pedigree estimated breeding value (EBV) for body weight (BW) predicted using conformation traits. Residual feed intake is only available for genotyped Holsteins; however, BW is available for all breeds. The RFI component of the "feed saved" EBV has 2 parts: Australian calf RFI and Australian lactating cow RFI. Genomic breeding values for RFI were estimated from a reference population of 2,036 individuals in a multi-trait analysis including Australian calf RFI (n = 843), Australian lactating cow RFI (n = 234), and UK and Dutch lactating cow RFI (n = 958). In all cases, the RFI phenotypes were deviations from a mean of 0, calculated by correcting dry matter intake for BW, growth, and milk yield (in the case of lactating cows). Single nucleotide polymorphism effects were calculated from the output of genomic BLUP and used to predict breeding values of 4,106 Holstein sires that were genotyped but did not have RFI phenotypes themselves. These bulls already had BW breeding values calculated from type traits, from which maintenance requirements in kilograms of feed per year were inferred. Finally, RFI and the feed required for maintenance (through BW) were used to calculate a feed saved breeding value and expressed as the predicted amount of feed saved per year. Animals that were 1 standard deviation above the mean were predicted to eat 66 kg dry matter less per year at the same level of milk production. In a data set of genotyped Holstein sires, the mean reliability of the feed saved breeding value was 0.37. For Holsteins that are not genotyped and for breeds other than Holsteins, feed saved is calculated using BW only. From April 2015, feed saved has been included as part of the Australian national selection index, the Balanced Performance Index (BPI). Selection on the BPI is expected to lead to modest gains in feed efficiency.
Key words: feed efficiency, residual feed intake, body weight

INTRODUCTION

It is widely recognized that selecting for feed efficiency in dairy cattle is highly desirable, as feed costs comprise a large proportion of variable costs associated with dairy production (Shalloo et al., 2004; Ho et al., 2013). However, there has been little success in developing breeding values to select for this trait in dairy cattle breeding (Berry and Crowley, 2013).

The quest to include feed efficiency as part of dairy breeding objectives started in the 1990s, with research at organizations that were able to collect individual feed intake records (Van Arendonk et al., 1991; Nieuwhof et al., 1992; Veerkamp et al., 1994; Veerkamp, 1998). Most of these studies focused on feed efficiency traits calculated using individual feed intake records measured on lactating cows, with the exception of Nieuwhof et al. (1992), who showed that lactating cow feed efficiency was genetically correlated with measurements made in young AI bulls and growing dairy heifers. It was, and still is, expensive to collect data on feed intake and, without sufficient data, a breeding value could not be implemented at that time.

An alternative was to select for improvements in feed efficiency without using real data on feed intake,

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by approximating feed requirements for maintenance based on measurements of BW (Visscher et al., 1994). If appropriately weighted in a selection index that also includes production, controlling maintenance costs through selection will improve gross efficiency; that is, more product is produced per unit of maintenance. In fact, several national selection indices include BW as a breeding objective, predicted using either linear type traits (VanRaden, 2004; VanRaden et al., 2007; Pryce et al., 2014a) or visual estimates of BW, which is the case in New Zealand (Peter Amer, AbacusBio, Dunedin, New Zealand; personal communication). One of the limitations with this approach is that true variation in feed efficiency remains uncaptured. In fact, the correlation between true feed efficiency and predicted feed efficiency (derived from BW and production) was estimated to be 0.84 (Gibson, 1986), implying that there is additional variation in feed efficiency that could be exploited if measurements or predictions of feed intake could be made. One way of capturing the remaining variation in feed efficiency is by selecting for residual feed intake (**RFI**; Connor, 2015), which is defined as the difference between actual and predicted DMI (Berry and Crowley, 2013; Connor, 2015). In fact, there has been a resurgence of interest in RFI in recent years because of its suitability for genomic selection. Genomic predictions for RFI can be developed in small, well-recorded reference populations that have genotypes and phenotypes, and the prediction equation can then be applied to genotyped animals without phenotypes (Calus et al., 2013; Gonzalez-Recio et al., 2014a). Although genomic selection is an obvious route to enabling breeding values to be estimated for RFI (Pryce et al., 2014a; Tempelman et al., 2015), the size of the reference population and its relationship to the predicted population are limiting factors. For a trait with a heritability of 0.2, typical of RFI (Connor, 2015), more than 30,000 individuals are required for the reference population to achieve reliabilities of greater than 50% (Calus et al., 2013; Gonzalez-Recio et al., 2014a). However, even assuming fairly modest reliabilities (18% in Australian cows, derived from 958 cows from the Netherlands and UK and 843 growing calves; Pryce et al., 2014b), RFI contributes about 3% per year of the genetic gain for extra profit in Australia (Gonzalez-Recio et al., 2014b).

One of the challenges with traits such as RFI, where negative values are favorable, is making the description of the breeding value clear, so that incorrect interpretation of breeding value estimates is minimized. The lack of clear definition was suggested as one of the reasons for the low uptake of RFI breeding values in the beef industry (Wulfhorst et al., 2010). It is important for understanding acceptance and encouraging wide adoption to carefully consider how to define and subsequently calculate the breeding value.

One solution could be to combine RFI with mature live weight estimated using EBV for predicting maintenance costs, so that feed requirements are quantified in a single breeding value. Here we propose a breeding value, called "feed saved," that can be incorporated into the Australian national selection index, to select for overall economic merit, or alternatively the breeding value can be used independently. For example, where 2 individuals have similar breeding values for milk production traits, the one that requires less feed (for maintenance predicted for BW and RFI combined) will be more efficient and save more feed.

The aims of this paper were (1) to define the expression of a trait (feed saved) that can be used as a breeding value in a way that combines energy requirements for maintenance based on predictions of mature live weight with RFI evaluated in growing calves and lactating cows; and (2) to describe how breeding values could be calculated and implemented for this new trait.

MATERIALS AND METHODS

Definition of the Trait

Most classical measures of feed efficiency, such as the ratio of milk output to feed input have significant limitations because (a) they are strongly correlated with milk yield (Prendiville et al., 2009), which is already under intense selection; (b) selection for a ratio trait can lead to unpredictable outcomes; that is, an increase in the error to total variance; and (c) there is no distinction between the energy used for separate functions (Berry and Crowley, 2013). Therefore, it is desirable to use an alternative measure for breeding purposes. Here, a new "feed saved" breeding value for Australia is described. Specifically, it is the feed saved by selecting for cows that have actual feed intake that is less than predicted for their level of production and lower predicted maintenance requirements. This is achieved through combining RFI with feed required for maintenance predicted from BW. Additionally, the RFI trait encompasses both the lactation and the growth phases of life. Including prelactation feed is important because it is estimated that around 25% of a herd's total DMI is in the prelactating stage (Connor, 2015).

In the dairy industry, many breeding values are expressed such that larger values are more beneficial and while expression of the trait is a cosmetic issue, it is important that the users of the breeding value easily relate to the trait. The sign of the breeding value