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# How Nutritionists can Influence Breeding Goals and Cow Size for Improved Feed Efficiency

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The efficiency of converting feed to milk in the US has doubled over the past 60 years, largely as a byproduct of selecting and managing cows for increased productivity. Increasing productivity resulted in a greater percentage of total feed intake being partitioned toward milk and less toward cow maintenance. However, as we selected for higher productivity, we selected for traits that were not necessarily consistent with greater efficiency. In particular, we frequently have selected and still do select for large cows, partly because many producers and dairy show judges simply like large, tall cows. Purebred breeders are especially influential in determining the sires used in breeding programs, but all dairy farmers determine the demand for semen, and thus the sires of future generations. Because feed suppliers, consultants, and veterinarians influence the opinion of producers, they also contribute to what sires are used in the industry. Genomic selection and advanced reproductive technologies are enabling rapid changes in the industry. We must decide thoughtfully and deliberately what traits are important for the cow of the future.

Feed efficiency can be defined many ways, but when considering breeding decisions, most definitions are highly correlated. I will discuss mostly energetic efficiency in this paper. Gross energy (**GE**) is the combustible energy of a feed and is independent of how efficiently the cow uses it. Net energy (**NE**) represents the chemical energy of secreted milk and accreted body tissues and conceptus and the chemical energy that is converted to heat in support of maintenance functions. In this paper, energetic efficiency is defined as gross feed efficiency **(GEff)**, the total milk and body tissue energy captured per unit of GE consumed. Major factors that affect GEff on farms include a) milk energy yield per cow, b) cow body weight (**BW**), which correlates with maintenance requirement, c) longevity and the percentage of lifetime a cow is lactating, d) nutritional accuracy in feeding, and e) the efficiency with which cows convert feed GE to NE.

## Selection for Milk Production to Improve Efficiency

For the typical US Holstein cow, the first 10 Mcal of NEL/day (equivalent to ~25 Mcal of GE and ~14 pounds of feed) is used for maintenance. At this level of intake, GEff is 0% as no milk or body tissue is produced. Additional feed that is consumed can be converted to milk or body tissues. If the cow eats twice as much feed—20 Mcal NEL or 2X maintenance—then only half of her feed would be used for maintenance and half would be used for production. As she eats more feed, the portion used for maintenance becomes a smaller fraction of total feed intake; this phenomenon is referred to as "***dilution of maintenance***" and it is the reason that greater productivity leads to greater efficiency. Theoretically, GEff should continue to increase as maintenance accounts for a smaller portion of total feed intake. However, the increase in GEff is less going from 3X to 4X maintenance than from 2X to 3X, and progressively less thereafter. This is true whether the increase in multiple of maintenance is caused by increased production at fixed BW or by reduced BW at fixed production. Moreover, this projection is overly optimistic, because as cows eat more feed per day, the efficiency of feed digestion is depressed. Eventually, as productivity increases, this depressed digestive efficiency should become more important than the dilution of maintenance and GEff plateaus or even declines as intake continues to increase (NRC, 2001). However, the digestibility depression is not well quantified for cows consuming >4X maintenance and where the optimal multiple of maintenance occurs is not at all clear (VandeHaar, 1998).

Because of the dynamics of the dilution of maintenance and the depression in digestibility, feed efficiency will not increase as quickly in the future as it has in the past, and it will not occur simply by increasing productivity. We must specifically focus on how to get more milk from each unit of feed and select directly for cows that have greater feed efficiency.

**Selection against Feed Intake**

One way to select for feed efficiency is select for high milk production while selecting against feed intake. Residual feed intake (**RFI)** is a measure of actual versus predicted intake for an individual cow, or, in other words, RFI is the feed that a cow consumes that cannot be justified based on her production (Figure 1).

In the most comprehensive study on feed efficiency in dairy cattle to date, Tempelman et al. (2015) examined RFI in 4900 Holstein cows in the US, Scotland, and the Netherlands. Weekly DMI was fitted as a function of milk energy output, body weight to the 0.75 power, body condition score, change in body weight, parity, and the interaction of parity with days in milk. The residuals from this analysis provide us with a measure of RFI for each cow with the RFI term representing measurement error, variation associated with pedigree-based genetics, and other variation. Based on this data, the heritability of RFI in lactating cows is ~0.17 (Tempelman et al., 2015). Previous studies, using fewer cows, reported values of 0.01 to 0.40 for the heritability of RFI in lactating cows (Berry and Crowley, 2013; Connor et al., 2013).

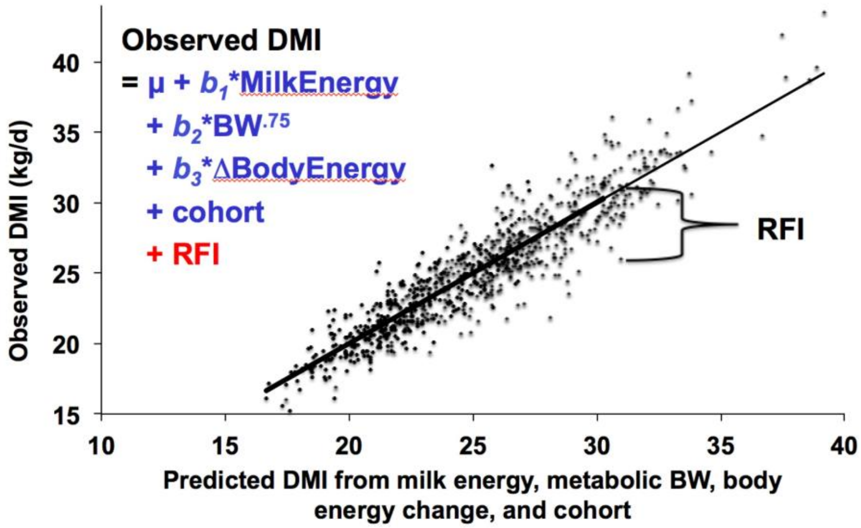


**Figure 1. Residual feed intake is a measure of feed efficiency that is useful in animal selection.** Cows with negative RFI eat less than expected based on milk output, body gain, and body weight, and are therefore more efficient at converting feed GE to NE.

For RFI to be effective in the search for a more efficient cow, it must be a repeatable trait across climate conditions, diets, lactation stage and number, and stage of life. Data to date suggest that it is. Potts et al. (2015) fed 109 cows diets with ~14 or 30% starch in a cross-over design and found the correlation for RFI of a cow when fed a high starch diet with her RFI when fed a low starch diet to be 0.7. Current data in our lab also suggest it is repeatable across diets with varying forage content (Mangual et al., unpublished). RFI also is repeatable across lactations, stages within a lactation, and stages of life (heifer vs lactating cow; (Tempelman et al., 2015; Connor et al., 2013; MacDonald et al., 2013).
In the past, direct genetic selection for feed efficiency was nearly impossible because genetic merit relied heavily on quantification of the phenotype in daughters and feed intakes of individual cows are not known on most commercial farms. However, genomic selection has made selection for feed efficiency possible in new ways. Efficiency is measured on a reference population, correlated with genotypes, and then the efficient genotypes can be selected.

Initial findings of a genomic analysis on 2900 Holsteins used in the dataset of Tempelman et al. (2015) were presented by Spurlock et al. (2014). They found 61,000 SNP accounted for 14% of the variance in RFI, with the top ten SNP accounting for 7% of the genetic variance. Six of the 8 chromosomes harboring regions of DNA influencing RFI did not influence DMI, milk energy output, or BW, indicating the possibility that genes important for digestive or central metabolic functions might be involved. This is work is ongoing, currently with 5000 cows.

Evidence that genomic selection for RFI can work in the dairy industry has been demonstrated by Davis et al. (2014), who developed genomically estimated breeding values (GEBV) for RFI in a population of growing heifers. They then ran tests with lactating cows and found that the cows who were predicted to require less feed based on heifer GEBV did in fact require less feed during lactation. The decrease in feed intake was equivalent to the decreased feed needed for maintenance in a cow weighing 80 kg less. The use of genomics in selection against RFI is already beginning in Australia (Pryce et al., 2015), where it will be included in an index for "Feed Saved", which selects against body size and against RFI while also selecting for the yield of milk components.

**Selection against Body Size**

Selection against body size is really just another way to select for cows that operate at a higher multiple of maintenance. As mentioned earlier, I believe that at some time in the future, selecting for higher multiple of maintenance will have little impact on GEff. However, at least for now, lifetime GEff will be enhanced by selecting for both more milk and for smaller cows. Unfortunately, over the past 50 years, we apparently have been selecting Holsteins for greater body size. Most top sires in the AI industry were and still are larger than breed average (Hansen, 2000), and the US genetic base for body size traits in all dairy breeds has been continually adjusted up. This larger size might be acceptable if it resulted in greater milk. One might expect a positive relationship between size and milk yield because some of the hormones that control lactation, such as somatotropin, also control growth (Etherton and Bauman, 1998). However, in a preliminary analysis of 5000 Holsteins, VandeHaar et al. (2014) demonstrated no genetic correlation between BW and milk energy output and a negative genetic correlation between BW and GEff. In a smaller subset of that data, Pech et al. (2015) showed that milk energy output had zero or negative genetic correlations with BW and stature and inconsistent correlations across country for chest width and body depth. Milk energy output was strongly and positively correlated with greater GEff and seemed more important than body size.

**Breeding for Production, Efficiency, and Profitability.**

Breeding against body size and against RFI will improve feed efficiency; however, selection against both of these traits is likely less important for profitability than is selection for greater milk production. Table 1 shows an example of possible results of breeding for more milk or for less feed consumption because of smaller body size or negative RFI in an example herd that currently has large cows (1760 lb mature BW) and milk production at 28,820 lb/yr at maturity. The magnitude of change for each breeding scenario was chosen to give the same effect on lifetime multiple of maintenance for milk and size goals and the same drop in feed consumption for the RFI goal. In this example, selection against feed intake by selecting for smaller cows increased lifetime income over feed cost (IOFC) by ~$300 per year, and selection against RFI increased lifetime IOFC by ~$400 per year. (Profit increased more from selecting against RFI than selecting against body size because of the greater salvage value of larger cows). However, selecting for greater milk yield to achieve the same GEff as the smaller cow increased lifetime IOFC by ~$1200.

**Table 1. Example of expected results from breeding for more milk or less feed.**

| | BW at maturity lb | Lifetime multiple of maintenance | Captured energy, % of GE | Milk yield at maturity kg/year | Lifetime feed costs, $ | Lifetime income $ | Lifetime income over feed cost $ |
|---|---|---|---|---|---|---|---|
| Current cows | 1760 | 2.8 | 22.6% | 28,820 | $6850 | 15,330 | $8480 |
| Select for milk | 1760 | 3.0 | 23.3% | 32,040 | $7280 | 16,970 | $9690 |
| Select for size | 1500 | 3.0 | 23.3% | 28,820 | $6470 | 15,240 | $8770 |
| Select for RFI | 1760 | 2.8 | 24.1% | 28,820 | $6470 | 15,330 | $8860 |

[1] Assumes milk is 3.5% fat.

[2] Assumes milk at $0.18/lb, cull cows at $0.82/lb, and feed at 15¢/Mcal NE (~11¢/lb) for lactating cows and 12¢/Mcal NE for heifers and dry cows.

In the preliminary analysis of VandeHaar et al. (2014), we reported that the genetic correlation of BW with GEff was negative but the genetic correlation of BW with IOFC was zero. In contrast, the genetic correlation of milk energy output was strongly positive with both GEff and IOFC. Thus, selection for milk should increase profits, whereas selection against cow size might have little impact on IOFC during peak lactation. This analysis, however, does not consider other impacts of changes in cow size. For example, cow size is negatively correlated with longevity and adaptability to a barn (Hansen, 2000), and thus selection for small cows should improve whole farm profitability more than predicted based only on feed calculations. Another problem with bigger cows is that they require more space. IOFC should always be considered on a whole farm basis, and if a farm can handle more cows, then the smaller cows will provide a greater advantage in IOFC than shown in Table 1.

Thus, in concurrence with Hansen (2000), and on the basis of enhancing feed efficiency, profitability, animal welfare, and sustainability, the US dairy industry should stop selecting for larger cows, and instead use an index that favors greater milk production and components, smaller cow size, and negative RFI.

**Summary and Implications**

What dairy geneticists and animal breeders do has a tremendous effect on the dairy industry and determines what type of animal we as nutritionists must feed and manage. How we feed cows today might have an impact over the next year, but how we breed cows will have an impact for generations. Too often, we encourage the selection of large cows just because we like large cows and think they will produce more milk, but the genetic correlation of cow size and productivity is zero. There can be absolutely no justification for favoring large cows, and it is time for all of us to quit showing them favoritism–they are making the breed less efficient! Someday we will also be able to select cows against feed intake. In the meantime, it is reasonable to continue selecting for greater milk production but should also select for modest reductions in body size.

Most geneticists value the opinions of other scientists and experts who understand the complex relationships between animal traits and farm profitability. In my opinion, the Holstein industry has put too much emphasis on type. "Functional type" is useful, but why select for cows that look like they should be more structurally sound or be less prone to mastitis when we can select for health and longevity directly? Why select for cows that look like they can produce more milk when we can select for milk directly? Nutritionists, management consultants and veterinarians can encourage better breeding goals. We must help farmers understand that larger cows have greater feed requirements for maintenance and that there is no genetic link between size and productivity.



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