Genetic Selection Opportunities to Improve Feed Efficiency

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Historic selection for feed efficiency

Interest in genetic selection for more feed efficient dairy cows has grown substantially in the past five years due to a spike in feed prices. Unfortunately, opportunities to directly select for improved feed utilization have been limited because feed intake measurements from individual cows are required to generate predicted transmitting abilities (PTA) for traits related to feed utilization.

We should recognize that tremendous gains in feed efficiency have been made through genetic selection even though we did not have feed intake measurements available. Selection for higher yields of milk, fat and protein has enhanced the efficiency of feed utilization in the dairy industry in an indirect manner. We require far fewer cows and replacement heifers to generate our milk supply because each cow produces more milk, and individual cows are more efficient because they partition a larger proportion of their intake toward milk production when compared to cows from previous eras. It was recently estimated that the current dairy production requires 23% of the feedstuffs to produce an equivalent amount of milk when compared to the 1944 dairy industry (Capper et al., 2009).

Feed efficiency is an indirect component of the $ Lifetime Net Merit ($LNM) index developed by USDA. The PTAs for milk, fat and protein yields are weighted positively in the formula in proportion to their expected economic value. Feed expenses are expected to increase for higher levels of yield and for larger cows. Crediting sires for the expected economic gain in yield of their daughters and subtracting associated feed expenses effectively creates an Income over Feed Cost (IOFC) component to $LNM.

Research Trials

Despite successful efforts to improve feed efficiency in the past, it is generally believed that direct selection for feed utilization will increase feed efficiency more rapidly than indirect selection for yield and other traits. Research trials are now underway to collect feed intake data with the intent to facilitate the development of genomic selection tools that will allow direct selection of feed utilization. Our research team at Penn State collected feed intake from 970 cows in commercial tie-stall herds in the fall of 2008 through the spring of 2009 to evaluate genetic associations of feed intake with other performance characteristics (Vallimont et al., 2010; 2011; 2013). Genetic correlations of selected feed utilization traits with cow performance are reported in Table 1.

A challenge when discussing selection programs for feed efficiency is that there is no one single definition of feed utilization that all researchers find satisfactory. We have considered the following primary feed utilization traits in our research program:

- Dry Matter Intake = total 305 day intake.

- Dry Matter Efficiency (DME) = energy corrected milk yield / dry matter intake.
  The average cow in our dataset produced 1.61 lbs of fat corrected milk for every 1 pound of DMI. DME is easy to calculate and is the most recognized measure of feed efficiency because it is used by dairy cattle nutritionists and other farm consultants. It is very similar to IOFC because higher yield and lower intake result in more favorable evaluations. Selection for higher DME is not a favored strategy by some geneticists because it may not increase the physiological efficiency of cows (i.e. reduce heat loss, increase digestive efficiency) even though there will be a reduction in the feed required to produce milk. A more severe limitation for DME, from my perspective, is that body condition mobilization can inflate DME for early lactation cows. The evaluation of early lactation DME without factoring body condition changes can lead to ambiguous or misleading conclusions.

- Crude Protein Efficiency (CPE) = protein yield / crude protein intake.
  CPE is a measure of gross feed efficiency and has similar limitations to DME. The average cow in our dataset produced 0.32 pounds of protein for every 1 pound of protein consumed.

- Residual Feed Intake (RFI) = DMI – feed required to support yield, growth and body maintenance. A low RFI is more efficient than a high RFI. RFI is independent of yield and body size, which means that cows with low RFI may have greater digestive or metabolic efficiency. Cows with low RFI may not, however, always be the most profitable. Heritability estimates for RFI were low in our dataset and genetic correlations with other traits are not reported because they were imprecise.

Table 1. Genetic correlation estimates of feed utilization traits with other performance traits.

	DMI	DME	CPE
Milk Yield	0.51	0.75	0.82
Fat Yield	0.53	0.86	0.54
Protein Yield	0.53	0.76	0.95
Body Weight	0.52	-0.66	-0.66
Body Condition Score	0.37	-0.70	-0.64
Days Open	-0.14	0.53*	0.42*

* = Unfavorable

The genetic correlation estimates in Table 1 suggest that selection for higher yield and lower body size will enhance feed efficiency. There may be consequences for other economically important traits such as fertility when selecting for feed efficiency. We have observed an increase in days open and reduction in daughter pregnancy rate as a cow’s feed efficiency increases. The consequences of such a result are important, and could negate any positive impact of selecting for feed efficiency if more replacement animals need to be grown in order to

compensate for lower cow fertility levels. This highlights the importance of considering multiple trait selection indices that include all traits that impact herd performance.
The importance of large cows producing more milk than smaller herdmates is demonstrated by the example in Table 2. Three cows with varying body weight and milk yield are considered, and the expected DMI from standard feed intake prediction equations has been calculated. The example demonstrates that, at equivalent levels of milk yield, larger cows are less efficient than smaller cows.

Table 2. Expected Dry Matter Efficiency (DME) for cows of varying body weight and milk yield.

Body Weight	305-d Milk Yield	305-d DMI	DME
1250	22,000	13,646	1.61
1450	22,000	14,340	1.53
1450	24,500	15,235	1.61

Selecting for higher yield and a moderation in body size is the most efficient approach to improve feed efficiency currently. The goal of current feed intake research trials is to improve the precision of selecting for feed efficiency by facilitating the development of genomic predictions for feed utilization. Such predictions will have lower reliability than traits such as milk yield or type traits, but will help to provide more refined methods of selecting for feed efficiency than are currently available.

Breed Differences

The inverse relationship between gross feed efficiency and body size contributes to the perception that Jersey cows are more efficient than Holsteins and other breeds. The amount of research available to directly compare the efficiency of Jersey to Holsteins is modest. It is clear that Jersey cows have higher feed intake relative to their body weight than Holsteins due to a larger relative digestive tract than Holsteins (Grainger and Goddard, 2004). Jersey cows thus produce more milk per unit of body weight than Holsteins (Rastani et al., 2001). Maintenance of a relatively larger digestive tract may offset some, but not all, of the assumed gain in efficiency.

A review by Grainger and Goddard (2004) reported feed efficiency differences between Jersey and Holstein for ten studies that occurred from 1986 to 2001. Feed efficiency differences ranged from a 7.1% advantage for Holsteins to an 18.7% advantage for Jerseys among the studies summarized. Holsteins tended to meet or exceed the DME of Jersey cows in TMR based feeding systems whereas Jersey DME exceeded Holsteins by significant amount for pasture or forage based feeding systems. A recent evaluation in Ireland supported the conclusion that Jersey cows produce more milk solids per unit of feed consumed in pasture based feeding systems (Prendiville et al., 2009).

Recent studies have compared feed efficiency in Holstein versus Jersey x Holstein crossbreds (Heins et al., 2008; Xue et al., 2011). Evidence of substantial differences for efficiency differences was minimal. Relative heat production was reported to be higher for pure Holsteins, but there were no differences in the efficiency of energy use for lactation.

To some degree, efficiency differences between Holstein and Jersey may depend on the type of milk market. Jersey cows were recently reported to be more efficient and produce less "greenhouse gases" per pound of cheese due, primarily, to higher solids concentrations in milk and longer productive lives (Capper and Cady, 2012). The results received a lot of publicity, but need to be viewed cautiously because the modeling system did not make actual measurements of methane and other gas emissions, feed intake, or cheese yields and such models can become biased if assumptions are inaccurate.

Genotype – Feeding Management Interactions

An important, and overlooked, consideration for feed efficiency is the interaction of feeding management with cow genotype. We've contrasted response to genetic selection in herds that provided a large quantity of feed (measured as the amount of feed not consumed after 24 hours) to herds that tried to minimize feed wastage and that had low levels of feed refusals (Dekleva et al., 2012). Milk, fat and protein yield was regressed on sire predicted transmitting abilities for yield. The expectation is a 1 lb increase in yield for every 1 lb increase in PTA. The regression coefficients in the herds with high refusals ranged from 0.87 (fat yield) to 1.23 (protein yield), which indicated feeding practices were allowing cows in those herds to fully express their genetic potential. However, herds feeding to a clean bunk or with low levels of refusals had a significantly lower response with regression coefficients ranging from 0.34 (fat and protein yield) to 0.44 (milk yield).

Relationships among body weight, BCS and yield in the same two groups of herds were also considered. The genetic correlation estimate between yield and body weight was near 0 in the herds feeding to a high rate of refusals, whereas the genetic correlation was strong and negative (-0.80) in the herds that fed to a low rate of refusals. The ability of a large cow to fully express her genetic potential for yield was more severely impacted by limiting feed availability than for a small cow. Likewise, the relationship between yield and body condition score was more unfavorable in the low feed refusal herds (-0.21) than in the high feed refusal herds (-0.63)

Conclusion

Large gains in feed efficiency have been realized because of genetic selection for higher yield over the past five decades. Producers should also work toward a moderation in cow size in order to reduce feed requirements further. Despite some ambiguity in research trials and a lack of studies making direct breed comparisons, it is likely that Jerseys have some feed efficiency advantages in cheese production markets because of their smaller body size coupled with higher milk solids concentration.

Income over Feed Cost is currently considered in the $ Lifetime Net Merit index and will help drive further increases in the feed efficiency of our national dairy herd. We should expect to have additional genomic selection tools in the future to accelerate genetic gain by facilitating direct selection for feed utilization. Such evaluations will lead to a refinement in our genetic selection programs rather than provide a radically different approach toward genetic selection.

Perhaps the single most important strategy toward improving feed efficiency is to allow cows to fully express their genetic potential for yield. High feed prices motivate producers to minimize feed refusals. Such a strategy will result in lower yield and effectively lower feed efficiency if not managed in a manner that allows cows to consume enough feed to fulfill their genetic potential. This is particularly true for large cows that need more nutrients to meet their basic maintenance energy requirements.

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