Role of Feed (Dairy) Efficiency in Dairy Management

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Feed has always been a major cost of producing milk and with the current low milk price and high feed costs, maximizing the efficiency of converting feed into milk production is of paramount importance. Feed efficiency (FE) or dairy efficiency (DE) is a way of expressing and monitoring how efficiently cows convert feed into milk and is defined as the pounds (or kilograms) of milk produced per pound (or kilogram) of dry matter (DM) consumed by the cow. The dairy industry is now interested in benchmarking FE or DE on farms as a means of reducing feed costs and improving profitability. However, there are many indirect nutrition and non-feed factors on dairy farms that directly affect FE values and not considering or correcting for them can lead to misinterpretations of FE measures. This paper will cover some of the author's experiences of using FE measures on farms and some of the important factors that affect FE measures.

ECONOMICS AND FEED EFFICIENCY

The goal of a feeding program should be to maximize income over feed cost (IOFC). Although FE can be used as a measure of evaluating feed costs related to milk production, it can also be misleading if used as the single parameter to evaluate economic efficiency of herds or groups of cows. For example, at any single milk production level, herds with the highest FE will return more IOFC than those with a lower FE. However, a high FE at a low milk production will not return as much IOFC as high milk production at a lower FE. Examples of this are shown in Table 1. In scenario 1, where milk production is equal for both herd A and B at 75 pounds per cow per day, increasing FE by 0.10 units, from 1.50 to 1.60, increases IOFC $0.31/cow/day. In example 2, where herd B has a lower FE by 0.10 units but milk production is 10 lb/cow/day higher than herd A, IOFC is $0.22/cow/day higher for herd B compared to herd A.

Unless feed costs surpass milk price, the objective of a feeding program should never be to minimize feed costs and/or maximize FE at the expense of a loss in milk production. Nutritionists and lenders should never base the economics of herds or groups of cows solely on FE, but should use it along with other measures (IOFC, feed cost/cow/day, feed cost/100 lb of milk, feed cost/lb of DM) to evaluate feeding program economics (St-Pierre, 2008; Hutjens 2007).

FACTORS AFFECTING FEED EFFICIENCY

<u>Fat or energy corrected milk.</u> The most accurate assessment of FE is when milk production is expressed on a 3.5% fat-corrected basis (3.5% FCM). The following example illustrates differences in FE of a cow producing 80 lb/day and consuming 50 lb of DM when expressed on milk with no fat correction or 3.5% FCM.

Feed Efficiency at 80 lb of milk production and 50 lb DM intake		
Milk fat %	FE with no correction for milk fat %	FE corrected to 3.5% FCM
3.0	1.60	1.47
3.5	1.60	1.60
4.0	1.60	1.73

Without correcting for fat content in the milk, the FE is 1.6 at all three milk fat percentages. When corrected to 3.5% fat basis (3.5% FCM), FE changed 0.26 units between 3.0 and 4.0 percent milk fat. The FE change in this example is consistent with data compiled from the scientific literature where a change in milk fat of 1% unit equated to a 0.25 change in FE.

Hutjens (2007) suggests for Holsteins adding one pound of milk per 0.1% point above or subtracting one pound of milk per 0.1% point below 3.5% milk fat is similar to calculating 3.5% FCM from one of the following equations:

<u>3.5% FCM – using fat only</u>
3.5% FCM, lb = (.4324 x lb of milk) + (16.216 x lb of milk fat)

<u>3.5% FPCM – using fat plus protein corrected</u>
3.5% FPCM, lb = (.323 x lb of milk) + (12.82 x lb of milk fat) + (7.13 x lb protein)

When comparing FE across herds or groups very divergent in milk fat content such as between Holstein and Jersey herds or very high and low production pens, correcting milk to a standard fat or energy basis is necessary. However, within an individual herd, milk fat content of the herd or groups in the herd usually stay relatively constant negating the need to correct milk production to 3.5% FCM. Sanchez et al. (2008) showed through statistical process control analysis the average change in fat content of Pacific Northwest dairy herds was 0.0012% per day. Over a 30 day period, this is a change of only 0.036%. Thus, when evaluating FE of a single herd or groups within the herd on a weekly or monthly basis, correcting milk production for milk fat content is not necessary. A FE calculated using actual milk production uncorrected for fat content will be an acceptable benchmark for managing feed intake, milk production and IOFC information.

<u>Herd management.</u> In 2008, Bach et al. published a paper, *Associations Between Nondietary Factors and Dairy Herd Performance*, documenting the feeding of the exact same diet to 47 different herds with a similar genetic base resulted in herd average milk productions ranging from 45 to 75 lb of milk/cow/day. The amount of diet DM delivered per farm ranged from 36 to 55 lb/cow/day. Unfortunately data for individual herds was not shown, but assuming DM intakes and milk productions were correlated, FE on these herds ranged from 1.25 to 1.36. After evaluating over 40 different herd management variables, the 4 most important factors accounting for 56% of the difference in milk

production across these herds were: age of heifers at first calving, presence of feed refusal, frequency of pushing up feed and number of free stalls available per lactating cow. Cows in herds where feeding for some feed refusal occurred produced more milk than those feeding for no refusal and herds pushing up feed an average of two times per day produced 8.6 lb more milk/cow/day than herds with no feed push up.

Every nutritionist has experienced this difference in milk production across herds despite similar diet formulation and quality of feedstuffs. The Bach et al. (2008) study illustrates many factors affect milk production and FE on a farm. Nutrition or diet is only one factor and often erroneously accused of low milk production and low FE. A good FE is always the goal (1.45 to 1.65), but evaluating and monitoring FE within a dairy farm is more beneficial than comparing absolute FE numbers across farms. The relative change in FE of the herd or group is an excellent monitoring measure to changing nutrition and management factors within the herd.

<u>Days in Milk (DIM).</u> Figure 1 shows FE (milk/DM intake) by DIM from a large Holstein dairy farm with multiple production pens over a two year period. Average FE across all DIM (average 187) is about 1.47 with the lowest FE occurring in late lactation and the highest FE occurring in early lactation. St. Pierre (2008) used milk production and DM intake models to determine FE across the lactation curve of a cow producing 22,000 lb of milk in 330 days of lactation. Based on this model, St. Pierre concluded the average FE of farms should be 1.4 at 150 DIM and FE should be reduced 0.11 units for each month DIM exceeds 150 days.

Differences in FE values between the on farm data shown in this paper and that of St. Pierre (2008) can be attributed to two major points. First, the on farm data is from a higher producing herd, 28,000 lb of milk/lactation, than the individual cow (22,000 lb of milk) modeled by St. Pierre. The second and probably most salient point is in DM intake. St. Pierre used the 2001 Dairy NRC DM model to predict actual intake whereas the on farm data is based on the actual amount of DM fed with limited information on feed weigh back. On farms, getting true DM intake is challenging. Farms using feed management software can get a good recording of feed or DM fed to the herd or pen of cows, but weigh back is usually not recorded or estimated at best. When farms feed for weigh back, but do not correct DM intakes for it, a lower than true FE will be calculated.

A FE between 1.4 and 1.6 milk is a reasonable target for cows or herds between 150 to 200 DIM. For cows greater than 250 DIM, a FE below 1.3 should be expected and in extended lactations over 325 DIM a FE near 1 is not unrealistic. A low FE results from low energy (digestibility) diets being fed, cows regaining body weight (BW) or replenishing body condition and in very late lactation supporting pregnancy. For cows less than 60 DIM, a FE of 1.8 is possible with high energy diets containing highly digestible forages and some loss of BW to support milk production. However, a FE above 1.8 could signify excessive amounts of BW are being loss to support milk production which leads to ketosis and if continued for any period of time, milk production and reproduction will be negatively affected.

Body weight (BW). Veerkamp (1998) pointed out in a paper on selection of economic efficiency in dairy cattle that decreasing BW reduces maintenance requirements which should improve feed efficiency. If two cows of equal BW are compared, the cow with 25% greater milk production will have a 10 to 15% higher FE. Likewise, a 25% decrease in BW at the same milk production improves FE by 10 to 12%.

A long term genetic study on body size (large vs. small body weight lines) and its relation to production parameters has been conducted at the University of Minnesota (Yerex et al. 1988; Hansen et al, 1999). Over the years, average BW of large line cows across all parities has increased 200 pounds while BW of small line cows has remained relatively constant. Milk production of the two lines has increased over the years, but difference in 305 day milk production between the two lines has remained similar at less than 600 lb/cow/year. A recent study using these two genetic lines resulted in nearly identical 305 day production of 3.5% FCM (average 22,476 pounds), but the small line or lower BW cows had a much better FE (1.74) than the large line or heavier BW cows (1.56). In an earlier study by Yerex et al. (1988) when large and small line cows only differed by about 110 lb, similar results were reported with the small line cows being 2.8% more efficient at converting feed into milk than the large line cows.

Body condition score (BCS). Change in BW has a significant effect on FE calculations and interpretations, but obtaining BW of cows on commercial farms almost never occurs. Some quantitative measure of BW change over a period of time is important if FE comparisons between cows in different stages of lactation are to be made. Body condition score is a much easier measurement to get on farms than BW and changes in BCS across time is reflective of gain or loss in body tissue (weight). By converting BCS change (gain or loss) into milk equivalents, FE of early and late lactation cows can be more equitably compared. An example of how converting BCS change into milk production equivalents can be used to compare FE of early and late lactation cows is in Table 2. Cows in the later stages of lactation are often considered inefficient where as in reality they are as efficient in converting feed into milk as cows in earlier stages of lactation when replenishing energy reserves, a essential function, is accounted for.

Feed digestibility. Increasing the digestibility of feeds in the diet is the single most effective way of improving FE. Casper (2004) has shown FE is highly correlated to diet digestibility (Figure 2) and therefore FE can be used indirectly to monitor diet digestibility on farms. Some reasons for a low FE related to feed digestibility are low quality forages being fed, incomplete processing of grains or corn silage and/or an imbalance of nutrients.

Overfeeding or underfeeding of nutrients may adversely affect FE. University of Illinois research (Ipharraguerre and Clark, 2005) has shown both the amount and source of crude protein (CP) in the diet affects FE (Table 3). As dietary CP increased (14.8, 16.8 and 18.7%), FE only increased slightly. Substituting a higher rumen undegradable protein source of animal-marine protein for soybean meal increased FE with increasing dietary protein level. Efficiency of converting CP into milk protein was highest when low protein diets were fed.

Neutral detergent fiber (NDF) is less digestible than nonfiber carbohydrates (starch and sugar). If digestibility is related to FE, then as the percentage of NDF in the diet increases, particularly from forages, FE should decrease. A summary of studies published in the Journal of Dairy Science from 2002 to 2004 showed a decrease in FE from 1.7 to 1.4 as total NDF in the diet DM increased from 25 to 35%.

Other factors affecting FE. Readers are referred to a companion paper at this conference by DeFrain et al. (2009) that discusses several other factors affecting FE and how changes in maintenance requirements affect the calculation of FE. To summarize, anything that changes the nutrient requirement for maintenance of a lactating cow will affect FE. Activity, environmental conditions, health and stress are some commonly observed changes on dairy farms that affect FE and usually in a negative way. Cows on pasture or cows required to walk long distances to and from a parlor will have a lower FE than tie-stall housed cows. Tennessee researchers (Britt et al., 2003) reported FE was higher when temperatures were below 70º F than when temperatures were above 70º F and cows were subjected to heat stress.

ON FARM FEED EFFICIENCY

As previously discussed, a variety of factors can affect FE on farm. When FE is calculated taking these factors into consideration, it is considered an adjusted feed efficiency (AFE) value. To compare FE with AFE, a field study was conducted using nine dairy farms in Western Wisconsin, and Northwest and Southeast Minnesota. Three farms utilized tie-stall facilities and 6 farms free-stalls. Milking herd size ranged from 63 to 740 cows. Data was collected twice on each farm; once during the summer of 2005 and then again in the winter/spring of 2006. An AFE value was calculated using the Feed Efficiency Determinator (FED) program developed by Zinpro Corporation, Eden Prairie, MN. Information required by the FED program included: average DM intake and milk yield, DIM, BW, fat %, protein %, temperature, relative humidity, wind speed, sunlight, and walking distance. Feed efficiency and AFE are calculated on energy corrected milk (ECM) in this program rather than 3.5% FCM.

Results are shown in Table 4. Across all farms, FE was within a range (1.3 to 1.8) expected for herds between 158 and 231 DIM. An exception was Farm 3 during the winter/spring measurement period where FE was very high at 2.2. After the data collection period on this farm, it was discovered the weigh scales on the mixer wagon were incorrectly weighing feed amounts. The AFE was higher than FE for 16 of the 18 data recordings indicating that on all farms, feed is being utilized for functions other than milk production. The large variation in FE across farms shows why there should not be a single target for FE and why a comparison of FE for benchmarking across farms is difficult. The best utilization of FE for management purposes is within a farm, and for monitoring changes in feeds and the feeding program on the farm.

The authors have also used FE as a monitor for management and production changes on a farm. Simply calculating FE every week from the weekly average of DM fed and milk production from a herd or group of cows along with evaluating changes in DIM, provides an excellent monitor of the nutrition or feeding program on the farm for nutritionists and others. By following FE and DIM on a weekly basis, any changes or deviations are quick signals something has changed on the farm. In the experience of the authors, some on farm changes in the nutrition or feeding program that have been observed through changes in FE are:

- Uncorrected forage DM. Cows eat DM and changes in the DM of ensiled forage or other wet feed are reflected in the amount of feed cows consume. Sudden decreases in FE have been found to reflect a decrease in forage DM through an increase in the total amount of feed fed to a group when forage amounts had not been adjusted to compensate for the decrease in DM.
- Forage quality changes. Milk production is highly correlated with forage quality. Increases or decreases in forage quality are quickly reflected in milk production and FE. When corn silage is the major forage fed, changes in starch content or fiber digestibility can be detected through FE monitoring.
- Change in feeding program or feeder. On most farms, weigh backs from groups are not recorded and therefore included in the DM "fed" denominator used to calculate FE. Good feeders are consistent in the amount fed on a per cow basis to groups with changes occurring slowly. Through weekly histories of FE, changes in feeding patterns or feeders can be observed. If FE remains constant over time, check to see if the amount of DM fed to the group or herd changes. In some herds, the same amount of DM fed was being reported over several weeks. In another instance, a new feeder did not change amounts fed over time to reflect a downward trend in milk production and the FE drop was readily apparent.
- Feed digestibility. A change from fine ground corn to partially cracked in a herd was reflected in decreased milk production and FE. Feed intake was unaffected.
- Mixing and mixer scale problems. As noted in our on farm studies, a major deviation from what would be considered a normal FE can be a sign of incorrect mixing of feeds and/or scale malfunction on mixers.
- Regrouped cows. On one farm, management regrouped cows and did not notify the nutritionist. Through following DIM of pens along with FE, this change was detected and the nutrition program adjusted accordingly.

CONCLUSION

Feed efficiency can be an important economic measure on dairy farms. Although affected by several non-nutrition as well as nutrition factors, FE is a good benchmark for the efficiency lactating cows convert nutrients into milk production. Because many factors affect the absolute FE value on a farm, comparison of FE values across farms should only be done when FE values are corrected for all the variables. Within a farm, the same variables affecting FE across farms can be effectively monitored through routinely measuring of FE on the farm. The best use of FE measures is to monitor changes in production and economics within a herd where animal factors, environment and multiple requirements for feed nutrients remain relatively constant. Improvements in FE will always be profitable whether from more milk per pound of DM fed or getting the same milk production at a lower DM intake.

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Table 1. Economics of herds at the same milk production with different feed efficiency or the same feed efficiency with different milk productions.		
	Herd A	Herd B
Scenario 1 - Same milk production – Different Feed Efficiency		
Milk, lb/cow/day	75.0	75.0
Milk income, milk price = $0.12/lb	9.00	9.00
DM intake, lb/cow/day	50.0	46.9
Feed cost/day at $0.10/lb DM	5.00	4.69
Feed efficiency, Milk/DMI	1.50	1.60
Income over feed cost, $/cow/day	4.00	4.31
Scenario 2 - Lower FE – Higher Milk Production		
Feed efficiency, Milk/DMI, lb	1.60	1.50
Milk, lb/cow/day	75.0	85.0
Milk income, milk price = $0.12/lb	9.00	10.20
DM intake, lb/cow/day	46.9	56.7
Feed cost/day at $0.10/lb DM	4.69	5.67
Income over feed cost, $/cow/day	4.31	4.53

Table 2. Impact of correcting for body condition score (BCS) change on feed efficiency (FE) measurements of early and late lactation cows[a].		
Item	Early	Late
Days in milk	45	265
DM intake, lb/day	50.0	44.1
Milk – 3.5% FCM, lb/day	89.9	45.0
Unadjusted FE - 3.5%FCM/DM intake, lb	1.80	1.02
Body condition score change/30 days	-0.5	+0.5
Milk equivalent to BCS change/day, lb/day	19.8	25.1
Milk adjusted for BCS change, lb/day	70.1	70.1
Adjusted FE – 3.5%FCM/DM intake, lb	1.40	1.59

[a] Assumptions used to calculate milk equivalency to BCS change were as follows:

Early lactation cows started at BCS of 3 and lost 0.5 BCS during a 30-day period.

A decrease of 0.5 BCS equals 200 Mcals of NE_L or 6.6 Mcals of NE_L/day over 30 days.

Milk NE_L requirement is 0.33 Mcal/lb; therefore, a loss of 6.6 Mcals/day supports 19.8 lb of milk/day. In late lactation cows, a gain of 0.5 BCS from 3.0 to 3.5 in 30 days requires 250 Mcals of NE_L or 8.3 Mcal/day (250 Mcals/30 days) of energy goes to BCS gain. Milk equivalency is 25.1 lb/day (8.3 Mcal per day to BCS/0.33 Mcal for milk).

Table 3. Feed efficiency of cows fed two sources, animal-marine protein blend (AMP) or soybean meal (SBM) at three dietary concentrations (14.8, 16.8 or 18.7%) of crude protein (Ipharraguerre and Clark, 2005).						
	14.8% CP		16.8% CP		18.7% CP	
	SBM	AMP	SBM	AMP	SBM	AMP
Feed efficiency (3.5% FCM, kg/DM intake, kg)						
15 to 112 days in milk	1.59	1.64	1.58	1.65	1.61	1.68
15 to 210 days in milk	1.46	1.49	1.43	1.52	1.50	1.57
Feed efficiency by milk production						
Average 45.6 kg/day	1.62	1.73	1.63	1.64	1.65	1.72
Average 37.9 kg/day	1.53	1.58	1.55	1.61	1.54	1.64
Milk nitrogen/intake nitrogen						
Nitrogen efficiency, %	30.1	33.0	28.5	27.5	25.6	25.1

Table 4. Feed efficiency (FE) and adjusted feed efficiency (AFE) of 10 Wisconsin or Minnesota dairy farms taken during the summer of 2005 or winter of 2006.

	Summer 2005				Winter/Spring 2006			
Farm	DIM	FE[a]	AFE[b]	AFE-FE	DIM	FE[a]	AFE[b]	AFE-FE
1	187	1.85	1.95	+0.10	213	1.66	1.70	+0.17
2	194	1.40	1.47	+0.07	190	1.57	1.64	+0.07
3	178	1.76	1.82	+0.06	197	2.20	2.35	+0.15
4	186	1.49	1.69	+0.20	189	1.59	1.63	+0.04
5		1.29	1.43	+0.14	175	1.45	1.55	+0.10
6	231	1.47	1.58	+0.11	149	1.41	1.42	+0.01
7	195	1.74	1.82	+0.08	203	1.30	1.89	+0.59
8	191	1.76	1.86	+0.10	215	1.46	1.44	-0.02
9	201	1.66	1.76	+0.10	158	1.77	1.75	-0.02

[a] FE = Feed efficiency (ECM, kg/DMI, kg).

[b] AFE = Adjusted feed efficiency (ECM, kg/DMI, kg); calculated using the FED program by Zinpro Corporation, Eden Prairie, MN.

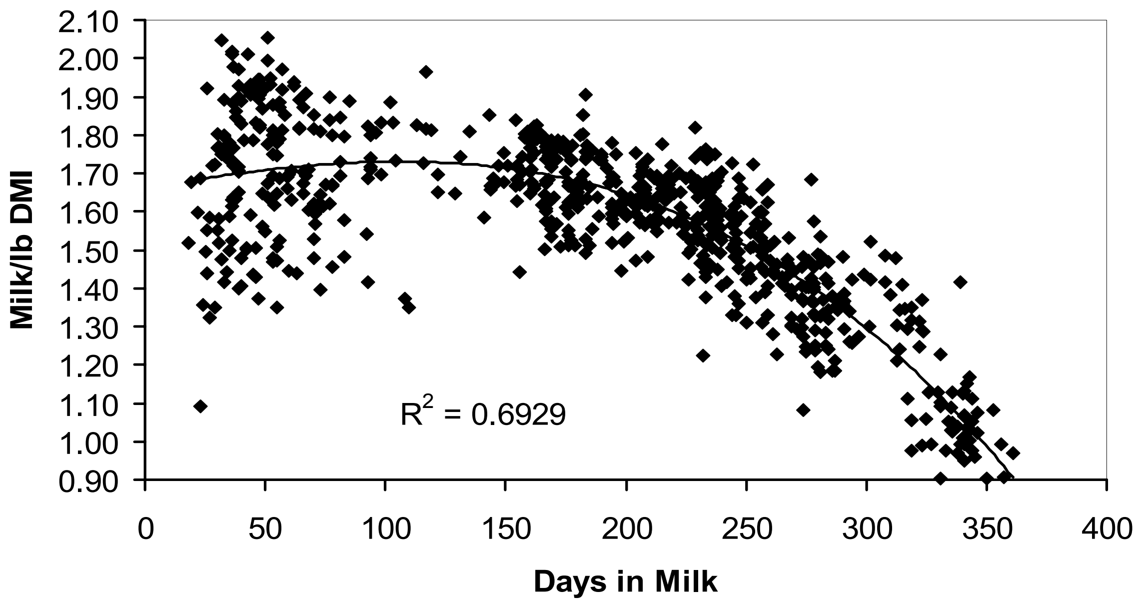

Figure 1. Relationship between feed efficiency (milk/lb DM intake) and days in milk for 686 pens of Holstein cows.

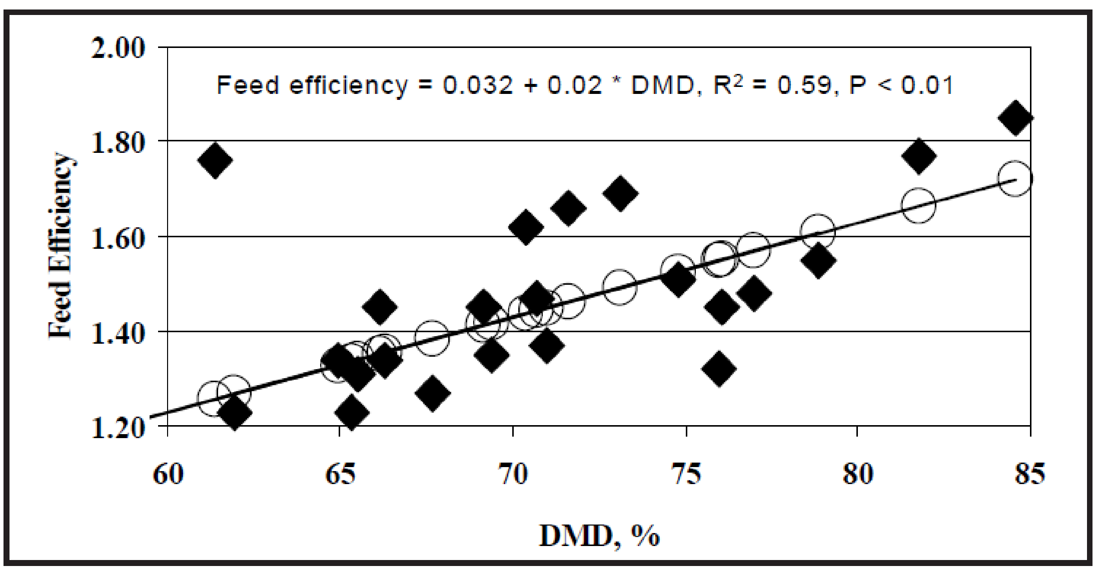

Figure 2. The relationship between feed efficiency and ration dry matter digestibility (DMD) by lactating dairy cows (Casper et al., 2004).