Feed Efficiency: Its Economic Impact In Lactating Dairy Cows

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Take Home Message

- Feed Efficiency (FE) is closely related with profitability in meat producing livestock. Transferring FE directly to dairy where there are multiple requirements (milk production, BW changes, reproduction, growth) complicates the measure, but does not diminish usefulness.
- Because of the many factors affecting FE, no one FE value can be set as a standard or goal across all cows, all stages of lactation or all herds.
- Within a herd, changes in FE can be used by dairy managers to help determine the economical impact of feeding and management changes.
- Improvements in FE will always be profitable whether increasing milk from the same amount of DM fed or getting the same milk production from a lower DM intake.

Introduction

Feed is the largest single expense associated with the production of milk at 40 to 50% of production costs. Therefore, improving the conversion of feed nutrients into milk either through more milk per nutrients fed or similar milk production from fewer nutrients will improve profitability of dairy farms. Other livestock industries (beef, swine and poultry) have measured and benchmarked feed efficiency (FE) for several years. Only recently has the dairy industry begun measuring and evaluating FE. Measuring and using FE is more complicated in dairy production than for other animal industries. In beef, swine and poultry, FE is measured as a single product output (tissue growth) in animals of similar body weight, age and growth rate fed similar diets during a single growth phase. In dairy, feed nutrients are required for multiple functions and not just for milk production. Besides milk production, feed nutrients are partitioned into maintenance, reproduction, body weight gain, growth, and activity. This multifunctional use of feed by dairy cows complicates the use and interpretation of FE as a profitability benchmark.

Measuring Feed Efficiency

A simple measurement of FE is quantity of milk produced per quantity of dry matter (DM) consumed. The calculation on a per cow basis is: kilograms of daily milk produced divided by the kilograms of feed DM consumed ((feed fed – feed refused) x DM % of the feed). For example: 34 kg of milk per day produced ÷ ((48 kg feed fed – 2.7 kg feed refused) x 50% DM) of the ration = 1.50 FE.

The problem with this simple FE measure is it doesn't consider the fat content of milk. Production of milk fat is a large energy or feed expenditure by the cow. Therefore, the fat or energy content of milk needs to be standardized in the calculating of FE to get the most accurate measurement and comparison across cows and groups. A 3.5% fat corrected milk (3.5% FCM) should be used in calculating FE and denoted as FE-3.5%. The formula for calculating 3.5% FCM is [3.5% FCM, kg = (0.432 x kg milk) + (16.23 x kg fat)]. A rule of thumb is to add or subtract 0.5 kg of milk for every one-tenth percentage point change above or below a 3.5% fat. For example, for a herd averaging 34 kg of 4.0% fat milk, the estimated 3.5% FCM would be 36.5 kg of milk.

In this paper, FE-U indicates milk was not corrected for fat content whereas FE-3.5% indicates milk was corrected to a 3.5% fat content in the calculating of FE.

The reason 3.5% FCM should be used in calculating FE when ever possible is illustrated in the following example of a cow milking 36.3 kg and consuming 22.7 kg of DM per day:

Fat %	FE-U	FE-3.5%
3.0	1.60	1.47
3.5	1.60	1.60
4.0	1.60	1.73

Without correcting for milk fat percentage, the FE is 1.6 and with correction the FE-3.5% changes 0.26 with every 1% unit change in milk fat percent. Data from a scientific literature data base agrees with this indicating a 1% change in milk fat percent equated to a 0.25 change in FE-3.5%.

Factors Affecting Feed Efficiency

Feed efficiency can vary from 1.0 to nearly 2.0 during the lactation of a cow or across farms. Several factors influence FE measurement besides milk fat content and need to be considered when interpreting and comparing FE or FE-3.5%.

Body Weight

Body weight (BW) is of particular importance in evaluating FE between cows in different stages of lactation and between breeds. Veerkamp (1998) pointed out in a paper on selection for economic efficiency that if two cows of equal BW are compared, the cow with 25% more milk production will have a 10 to 15% higher FE. Conversely, two cows at equal milk production, the cow with 25% less BW will have a 10 to 12% higher FE. An example of how BW affects FE at equal milk production is shown in Table 1. Cows with lower BW have a higher FE.

Table 1. Impact of body weight on feed efficiency[1]

Body Weight, kg	DM[2], kg/day	Feed Efficiency
544	22.3	1.52
635	23.7	1.43
726	25.0	1.36
816	26.2	1.30

[1]Milk production at 34.0 kg and 3.6% fat.

[2]DM intake from 2001 Dairy NRC.

High Milk Production

High producing cows are more energetically efficient because more of the consumed energy goes to milk production than maintenance or stated differently, maintenance becomes a smaller proportion of the total energy intake and therefore, more product output per unit of energy intake is achieved increasing FE. High producing cows are always more efficient than low producing cows even though they consume more feed. But are they more efficient in using energy or feed DM consumed above maintenance for milk production than lower producing cows? If the amount of feed DM needed for maintenance is subtracted from total DM intake, the effect of BW on FE is removed and the remaining feed DM is primarily used for milk production. An example of how FE-3.5% can change when only DM intake above maintenance is used to calculate FE-3.5% is shown in Table 2.

Table 2. Effect of BW on FE-3.5% of cows producing 36.3 kg/day of milk.

Body weight, kg	590	680
DM intake, kg/day	24.4	25.6
Feed Efficiency-3.5%	1.49	1.42
Maintenance DM intake, kg/day	11.6	12.8
DM intake above maintenance for milk, kg/day	12.9	12.9
Feed Efficiency (FE-3.5%) above maintenance	2.81	2.81

Body Weight Change

Before 60 days in milk (DIM), a high FE value may reflect the loss of BW to support milk production. Because BW or more correctly the energy in BW loss is unaccounted for in FE calculations, cows losing BW energy to support milk production will always have a higher FE than cows gaining BW. Between 100 and 200 DIM, cows should not be gaining or losing substantial amounts of BW and be in the period of lactation where BW change has the least effect on FE. After 200 DIM, cows will begin to gain body weight and FE will decrease as feed is partitioned into weight gain and not milk production.

Body Condition Score (BCS)

Because BCS is easier to obtain on farms than BW data, consideration was given to the possible use of change in BCS as an indicator for adjusting feed intake for gain or loss in body tissue (weight). A 30 day change in BCS could be obtained and the energy corresponding to the loss or gain in BCS could be credited either negatively or positively to milk production. By converting BCS gain or loss into milk equivalents, FE of early and late lactation cows can be compared. An example of how converting BCS change into milk production equivalents changes the comparison of FE between early and late lactation cows is in Table 3. Correcting for BCS change indicates cows in late lactation and early lactation have similar efficiencies in converting feed to milk (Table 3). Because replenishing energy reserves (BW) is an essential function of cows in late lactation, feed utilized for this should not be considered as inefficiency. On the contrary, BW loss is a normal and important function of early lactation cows; however, excessive losses should not be given credit as efficient feed utilization. A BCS-corrected FE-3.5% of 1.5 should be a good target for conversion of feed to milk across all days in milk.

Table 3. Impact of correcting for body condition score (BCS) change on feed efficiency (FE-3.5%) measurements of early and late lactation cows*.

Item	Early	Late
Days in milk	45	265
DM intake, kg/day	22.7	20.0
Milk – 3.5% FCM, kg/day	40.8	20.4
Unadjusted FE - 3.5%FCM/DM intake, kg	1.80	1.02
Body condition score change/30 days	-0.5	+0.5
Milk equivalent to BCS change/day, kg/day	9.0	11.4
Milk adjusted for BCS change, kg/day	31.8	31.8
Adjusted FE – 3.5%FCM/DM intake, kg	1.40	1.59

*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 0.73 Mcal/kg, therefore, a loss of 6.6 Mcals/day supports 9.0 kg of milk/day (6.6 Mcals – BCS loss/0.73 Mcal/kg milk). 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/30days) of energy goes to BCS gain. Milk equivalency is 11.4 kg/day (8.3 Mcal per day to BCS/.73 Mcal for milk).

Days in Milk (DIM)

Figure 2 shows farm FE-U data from 686 pens of lactating Holstein cows by DIM. Pen milk composition data were not available. The average FE-U across DIM was 1.56 with the lowest FE-U occurring in late lactation and the highest FE-U occurring in very early lactation. The differences in FE-U between early and late DIM are reflections of BW being lost or gained.

In early lactation, a high (>1.7) FE reflects BW loss to support milk production, signals potential ketosis problems and inflates FE-3.5% through high milk fat percentages. For cows less than 60 DIM, a FE above 1.8 is possible with high energy diets containing highly digestible forages and the loss of some BW to support milk production. However, a high FE could indicate significant amounts of BW are being mobilized to support milk production in which case cows often become ketotic and body reserves depleted to a point where both milk production and reproduction are negatively affected. A very low FE in early lactation, below 1.2, can signal health problems such as acidosis or if healthy, a very poor producing animal.

A 1.5 to 1.6 milk FE is a reasonable target for cows or herds 150 to 200 DIM. For cows greater than 250 DIM, a FE below 1.4 should be expected. The lower FE is a result of lower energy diets being fed and the need for cows to regain BW, replenish body condition and support pregnancy. All of these functions require nutrients and the diverting of DM intake away from milk production. The decrease in FE during late lactation is from a decrease in milk production without a proportional decrease in feed intake.

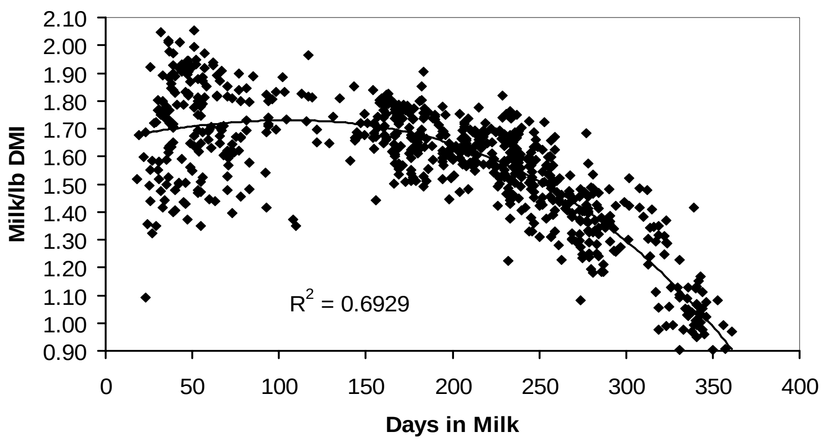

Figure 2. Relationship between feed efficiency (milk/DM intake) and days in milk.

Changes in Maintenance Requirement

Any factor that changes the maintenance requirement will affect FE. Common factors include:

- Cold or heat stress – Tennessee research in 13 herds showed that cool weather (<21º C) favored higher FE than hot weather (>21º C). Extremely cold weather will decrease FE.
- Walking or exercise decreases FE. Long walks to parlors or pastures decrease FE.
- Extended standing will decrease FE.

Genetics

Genetics ultimately determines how nutrients are partitioned between maintenance, milk production and other metabolic functions. Gibson (1986) compared FE between high and low milk production genetic lines of British Friesians and Jerseys. Friesians had a higher FE-U but when milk was corrected for fat content there was no difference in FE. High milk genetic lines were more efficient than low genetic lines in both breeds.

Feed Digestibility

Increasing the digestibility of feeds in the diet means more nutrients will be available for milk production. Ways of increasing DM digestibility include:

proper processing of corn silage and grain, feeding high quality forages with high NDF digestibility and balancing rations to meet nutrient requirements.

Digestibility of a diet decreases as total DM intake of the diet increases. The 2001 Dairy NRC takes this into consideration when calculating the energy content of a diet and has a formula to apply a variable discount to TDN content of the diet as DM intake increases. Gabel et al. (2003) demonstrated this effect by feeding the same diet to lactating dairy cows at 1.4, 2.7 and 4.6 times maintenance energy requirements. The DM digestibility of the diet decreased linearly from 74.8% to 72.3% to 67.2% as diet DM intake increased. Digestibility of energy decreased 4.1% per multiple increase of maintenance energy intake; a very similar value as reported in the 2001 Dairy NRC. Cows require amounts of digestible nutrients to produce milk and not percentages or concentrations of nutrients in the diet DM. Although digestibility as a percent of the diet decreases with increasing DM intake, the quantity of digested nutrients available to an animal increases with increasing intake.

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%.

Maximizing both the digestibility of nutrients and DM intake will result in the highest milk production. When both diet digestibility and DM intake are maximized, FE may not be the highest, but economic returns from milk production should be optimal.

Growth and Reproduction

Young cows will generally have a lower milk production because nutrients are being partitioned to growth. Pregnant cows will have decreased FE because of fetus energy requirements; however, this is minimal until into the third trimester of gestation.

Nutrient Imbalance

Overfeeding or underfeeding of nutrients may adversely affect FE. University of Illinois research (Ipharraguerre, 2005) has shown both the amount and source of crude protein (CP) in the diet affects FE-3.5% (Table 4). As dietary CP increased (14.8, 16.8 and 18.7%), FE-3.5% only increased slightly. Substituting a higher rumen undegradable protein source of animal-marine protein for soybean meal increased FE-3.5% with increasing dietary protein level. Efficiency of converting CP into milk protein was highest when low protein diets were fed.

■ Economics of Feed Efficiency

Feed efficiency can be used as one measure of efficiency, but can be misleading if used as a single parameter to evaluate economic efficiency of cows or herds. Data from a farm study conducted by the University of Minnesota demonstrates that groups of cows can have the same FE (1.47), but not the same economic efficiency (Table 5). The group with the highest milk production, Group 2, returned the most milk income and had the highest income over feed cost. Higher milk production will always be the most profitable at equal FE. When milk price is two times the feed DM price per kg, a 0.4 unit decrease in FE is equivalent in income over feed cost (IOFC) to a 5 kg increase in milk production. For example, IOFC at 30 kg of milk and a FE of 1.7 is equal to 35 kg of milk at a 1.2 FE.

Table 4. 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.

	14.8% CP		16.8% CP		18.7% CP	
	SBM	AMP	SBM	AMP	SBM	AMP
Feed efficiency – 3.5%	3.5% FCM/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 5. Economic efficiency at the same feed efficiency but different milk productions.

Item	Group 1	Group 2
Days in milk	260	195
Feed efficiency, 3.5% Milk/DMI	1.47	1.47
Milk, kg/cow/day	36.7	44.3
Milk income, milk price = $0.33/kg	12.11	14.62
DM intake, kg/cow/day	25.0	30.2
Feed cost/day at $0.18/kgDM	4.50	5.44
Income over feed cost, $/cow/day	7.61	9.18

Increasing FE by producing similar amounts of milk with lower DM intake will improve profitability. However BEWARE, as purposefully trying to reduce DM intake within a herd to improve FE will usually result in decreased milk production and lower profitability. The best approach is to increase the digestibility of feed ingredients, particularly forages, in the diet to get more milk without increasing DM intake. If FE of Group 1 could be increased to 1.57 by increasing milk to 39.3 kg through better forages in the diet or feed utilization, IOFC would be increased another $0.85 per cow per day.

■ Feed Efficiency (FE-3.5%) Guidelines

- Check DM intake and milk production numbers for accuracy before making decisions on FE values. Feed efficiency values outside guidelines often result from feed intakes, either too high or too low. Be sure feed refusals are accounted for in calculations.

- Whole herd or mid-lactation cows – 180-220 Days in milk
    - 1.4 to 1.6 kg milk/kg of DM intake is normal

- Early lactation - <30 Days in milk
    - 1.5 to 1.8 kg milk/kg of DM intake is good.
    - FE above 1.8 can indicate excessive weight loss and ketosis problems
    - FE below 1.4 indicates milk production problems or erroneous feed intakes

- Late lactation - >300 Days in milk
    - FE follows the lactation curve downward after peak production
    - 1.1 to 1.4 FE is normal for this stage of lactation as cows are regaining body weight for next lactation.
    - It may be difficult to achieve a FE of 1.0 if cows are gaining weight and well beyond 300 days in milk.

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