MEASURING AND IMPROVING FEED EFFICIENCY IN LACTATING DAIRY COWS

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INTRODUCTION

Increased global competition, rising cost of production and falling milk prices have forced dairy producers to increase efficiency in order to sustain profitability. One factor having a profound effect on profitability of the dairy is conversion of feed to milk. For example, improving feed efficiency (FE) from 1.4 to 1.5, while maintaining milk production increases profitability of a 1000 cow dairy by $91,980/year (Table 1). However, obtaining an accurate estimate of FE is difficult due to confounding factors such as energy required for temperature maintenance, variability in milk composition and body weight (BW) loss and gain as lactation progresses. This paper will review factors to consider when estimating FE and measures producers can implement to improve FE.

OBTAINING A MORE ACCURATE ESTIMATE OF FE

Observed FE is the amount of milk produced per lb dry matter intake (DMI). More recently, this measure of FE has been titled Dairy Efficiency (Hutjens, 2005). Workers at Land O’Lakes Purina™ evaluated 19 New York dairy herds for FE (Figure 1, J.G. Seymour et al., personal communication) and found that as milk production increased there was a trend toward higher FE. Of particular interest is the number of observations with similar levels of milk production but markedly different FE. For example, in this summary there are two herds (Herd A and B) producing approximately 76 lb/d milk (not corrected for milk composition), but Herd A is producing 1.72 lb of milk per lb dry matter (DM) and Herd B is producing 1.39 lb milk per lb DM (red highlights in Figure 1). For these two herds, if one assumes an equal

Table 1. Effect of FE on dairy profitability.

<table>
<thead>
<tr>
<th>Herd Size, Cows</th>
<th>Milk Yield, lb/d</th>
<th>Dry Matter Intake, lb/d</th>
<th>Feed Cost, $/lb DM</th>
<th>Feed Efficiency</th>
<th>Feed Cost, $/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>75</td>
<td>53.6</td>
<td>$0.07</td>
<td>1.40</td>
<td>1.40</td>
</tr>
<tr>
<td>1000</td>
<td>75</td>
<td>50.0</td>
<td>$0.07</td>
<td>1.50</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Table 1.
cost/lb of DM ($0.07/lb) and milk price ($12/cwt.), the herd with the higher FE yields $0.71/cow/d greater income over feed costs. For a 1000 cow dairy, this increase in profitability translates to $259,515 per year. Upon further investigation, the feed cost/lb DM was $0.061 for Herd A and $0.079 for Herd B, thus translating into $583,744 difference in profitability or $1.60/cow/d with the higher FE. However, while these differences in FE are great, there are several questions one must ask before concluding that Herd A is more efficient at converting feed to milk than Herd B. These questions include:

- Is there a difference in milk composition between these two herds?
- Is Herd B under temperature stress conditions while Herd A is under thermo neutral conditions?
- Is Herd B walking excess distances to and from the milking center?
- Are cows in Herd A primarily in early lactation while cows in Herd B are primarily in mid to late lactation?

Adjusting for these factors allows nutritionists to obtain a better estimate of the true conversion of feed to productive purposes such as tissue accretion, activity and milk production.

Figure 1. Relationship between observed feed efficiency and milk production\(^a\)

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\(^a\)19 New York herds, evaluated 4 times by Land O’Lakes
MILK COMPOSITION

Fat and protein content of milk are the primary determinants of milk energy content. For this reason, milk energy output should be corrected to a standard fat and protein concentration. The equation used to calculate milk energy content is as follows (NRC, 2001):

\[
\text{Milk energy content (Mcal/kg)} = 0.192 + (0.0929 \times \text{fat %}) + (0.0563 \times \text{true protein %})
\]

Thus, milk containing 3.5% fat and 3.0% true protein would contain 0.6861 Mcal/kg, while milk containing 3.9% fat and 3.2% true protein would contain 0.7345 Mcal/kg. A cow producing 35 kg/d (77.1 lb/d) of milk containing 3.5% fat and 3.0% true protein would produce as much milk energy as a cow producing 32.7 kg/d (72.0 lb/d) of milk containing 3.9% fat and 3.2% protein.

ENERGY EXPENDITURE FOR TEMPERATURE STRESS

Reduced milk production due to heat stress is attributed to both an increase in energy required for maintenance and reduced dry matter intake. Arizona researchers observed that when cows under thermal neutral conditions (temperature humidity index (THI), 64°F for 24 h) were offered a similar amount of DM as cows under heat stress conditions (THI, 80°F for 16 h) were consuming. Cows under thermal neutral conditions produced approximately 14 lb/d more milk. This illustrates the increased diversion of nutrients from milk production to maintenance when cows are heat stressed (Baumgard, 2006). Heat stress has been reported to increase maintenance requirements by 7 to 25% (NRC, 2001). For a 1400 lb cow this equates to between 0.71 and 2.96 Mcal of additional NEL/d. Increased maintenance requirements result from cows panting to dissipate heat. The impact of heat stress on maintenance requirements can be calculated using the following equation by Fox and Tylutki (1998):

\[
\text{Increased energy requirements due to heat stress (Mcal)} = 1.09857 - (0.01343 \times \text{CETI}) + (0.000457 \times \text{CETI}^2)
\]

Where \(\text{CETI} = 27.88 - (0.456 \times \text{mean daily temperature, °C}) + (0.010754 \times \text{mean daily temperature, °C}^2) - (0.4905 \times \text{relative humidity}) + (0.00088 \times \text{relative humidity}^2) + (1.1507 \times \text{wind speed, m/s}) - (0.126447 \times \text{wind speed, m/s}^2) + 0.019876 \times \text{mean daily temperature, °C} \times \text{relative humidity}) - (0.046313 \times \text{mean daily temperature} \times \text{wind speed, m/s}) + (0.4167 \times \text{hours per day in direct sunlight})\]

Cold stress also appears to affect feed efficiency by both reducing DM digestibility and diverting nutrients to heat generation. Young (1976) reported that cold stress reduces DM digestibility by 1.8% for each 50°F reduction in temperature below 68°F. Much of the cold stress reduction in digestibility is attributed to increased passage rate of feed through
the digestive tract (Kennedy et al., 1976). In addition, maintenance requirements have been estimated to be 51% higher at -4°F as compared to 64°F for a 1323 lb cow producing 60 lb of milk containing 3.7% fat (NRC, 1981). However, cold stress adjustments for dairy cattle in the NRC (1981) appear to be based upon limited data. There is little doubt that cold stress increases maintenance requirements of lactating dairy cattle. To what extent cold stress increases maintenance is unclear.

**ENERGY EXPENDITURES FOR EXCESS WALKING**

On some dairies, cows walk considerable distance from their pen or paddock to the milking center. The energy diverted from milk production to walking must be taken into account in order to obtain a true measure of feed efficiency. Energy expenditure for walking can be calculated as follows:

Energy for walking (Mcal) = 0.00045 X body weight, kg X distance walked, m (NRC, 2001).

For a 635 kg cow (1400 lb), milked three times a day and housed in a pen that is 304 m (1000 ft) from the middle of the pen to the milking center, maintenance requirement increases by 5.2%. Therefore, the energy equivalent of 1.67 lb/d of energy-corrected milk (ECM, 3.5% fat and 3.0% protein) are utilized for walking to and from the milking center.

**ENERGY EXPENDITURE FOR GROWTH AND ADJUSTMENT FOR STAGE OF LACTATION**

Additional factors that should be considered in order to ascertain the true FE of dairy cattle are energy expenditure for continued growth of first lactation heifers and BW loss and gain with lactation progression. From a data set of 17,087 cow wk (5962 first lactation cow wk, 11,125 multiparous cow wk), it was estimated that first lactation heifers lost the BW equivalent of 1.17 Mcal/d in the first 40 d in milk (DIM) and gained the BW equivalent of 1.44 Mcal/d from 41 DIM through the end of their first lactation (J. G. Linn, University of Minnesota, personal communication; W. P. Weiss, The Ohio State University, personal communication). Mature cows lost the BW equivalent of 3.323 Mcal/d in the first 40 DIM and gained the BW equivalent of 1.442 Mcal/d from 106 DIM until the end of lactation. There was minimal change in BW of mature cows between 41 and 105 DIM.

Therefore, prior to 40 DIM first lactation heifers and mature cows are deriving an energy equivalent of 3.8 and 10.7 lb ECM/d from body stores. In late lactation (after 105 DIM), the first calf heifer and mature cow are diverting the energy equivalent of 4.6 lb ECM/d towards tissue accretion. It is noteworthy that the first calf heifer derives less energy from tissue reserves in early lactation than mature cows. Once cows begin regaining BW, first calf heifers divert the same amount of energy towards tissue accretion on a daily basis as mature cows, but have more days of tissue accretion reflecting continued growth of first calf heifers.
In Table 2 are two hypothetical herds. At first glance, Herd One is more efficient at converting dietary nutrients towards productive purposes. However, Herd One is producing milk with a lower milk fat and protein content, is producing milk under thermal neutral conditions, is walking less distance to and from the milking center and 50% of the herd consists of mature cows less than 40 DIM. In addition, 60% of Herd Two are first calf heifers greater than 40 DIM and they are producing milk under heat stress conditions. After correcting for milk composition, energy expenditure for walking distance, temperature stress, growth and BW loss and gain with progression of lactation, Herd Two is more efficient at converting dietary nutrients for activity, tissue accretion and milk production than Herd One (Table 2).

Table 2. Effect of correcting observed FE for milk composition, excess walking, body weight loss and gain, and increased maintenance costs due to heat stress.

<table>
<thead>
<tr>
<th>Item</th>
<th>Herd One</th>
<th>Herd Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk production, lb/d</td>
<td>77.1</td>
<td>72.0</td>
</tr>
<tr>
<td>Milk fat, %</td>
<td>3.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Milk protein, %</td>
<td>3.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Dry matter intake, lb/d</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Observed feed efficiency</td>
<td>1.54</td>
<td>1.44</td>
</tr>
<tr>
<td>Energy corrected milk (ECM): 3.5% fat, 3.0% true protein</td>
<td>77.1</td>
<td>77.1</td>
</tr>
<tr>
<td>Cow body weight, lb</td>
<td>1400</td>
<td>1400</td>
</tr>
<tr>
<td>Walking distance, ft</td>
<td>150</td>
<td>1000</td>
</tr>
<tr>
<td>Milking/d</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Average daily high temperature, degrees F</td>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>Relative humidity, %</td>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>Wind speed, mph</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Hours in direct sunlight</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>% first calf heifers &lt; 40 days in milk</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>% first calf heifers &gt; 40 days in milk</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>% cows &lt; 40 days in milk</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>% cows 41 to 105 days in milk</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>% cows &gt; 105 days in milk</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>ECM lost due to growth, lb/d</td>
<td>-0.5</td>
<td>1.7</td>
</tr>
<tr>
<td>ECM lost due to temperature stress, lb/d</td>
<td>0.00</td>
<td>9.5</td>
</tr>
<tr>
<td>ECM lost due to excess walking, lb/d</td>
<td>0.3</td>
<td>1.7</td>
</tr>
<tr>
<td>ECM adjustment for stage of lactation and parity</td>
<td>-4.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Adjusted ECM, lb/d</td>
<td>72.5</td>
<td>90.0</td>
</tr>
<tr>
<td>Adjusted feed conversion</td>
<td>1.45</td>
<td>1.80</td>
</tr>
</tbody>
</table>
In the New York survey, after correcting for milk composition, increased maintenance cost due to temperature stress, stage of lactation and walking distances, FE of Herds A and B are 1.79 and 1.53, respectively. Clearly Herd A has a better FE than Herd B.

**IMPROVING FE**

Generally, as milk production declines, FE declines due to maintenance requirements comprising a greater portion of nutrient requirements. An example comparing the FE of a cow producing 70 lb of milk versus a cow producing 95 lb of milk is shown in Table 3. Assuming that BW of both cows are static, 30.8% of dietary energy is devoted to maintenance requirements in the cow producing 70 lb of milk while 24.7% of dietary energy is diverted to maintenance in a cow producing 95 lb of milk. Using NRC (2001) predicted dry matter intake (DMI), FE for the cow producing 70 lb of milk is 1.41, while the FE of the cow producing 95 lb of milk is 1.63. Thus dairy producers restricting DMI in an attempt to improve FE may not obtain desired results if milk production is compromised.

Additional measures that can be taken to improve FE include:

1. Minimize feed wastage at the feed bunk.
2. Minimize bird, rodent and parasite infestations.
3. Minimize illness and disease.

Elevated immune system activity decreases the amount of nutrients available for milk production, activity, and tissue accretion. “Most immune responses to pathogens are accompanied by a systemic acute phase protein response, which is characterized by decreased appetite and a shift in nutrient use away from skeletal muscle accretion towards hepatic secretion of acute phase proteins” (Klasing, 2001). Research has shown that under normal conditions, 1.17% of Lys consumed by young chicks is utilized for immune processes (Klasing, 2001). However, when activity of the immune system was stimulated through lipopolysaccharide administration, 6.71% of Lys consumed by the chicks was used for immune processes. Thus, improving animal health improves FE.

**Table 3.** Portion of dietary nutrients utilized for maintenance in cows producing 70 lb of milk versus 95 lb of milk (NRC, 2001).

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>70</td>
<td>10.1</td>
<td>22.7</td>
<td>30.8%</td>
<td>49.8</td>
<td>1.41</td>
</tr>
<tr>
<td>1400</td>
<td>95</td>
<td>10.1</td>
<td>30.8</td>
<td>24.7%</td>
<td>58.4</td>
<td>1.63</td>
</tr>
</tbody>
</table>

*aContains 3.7% fat and 3.1% protein*
4. Minimize the inclusion of low digestibility and spoiled feeds in the diet.

Dry matter digestibility has been reported as a major factor affecting FE of lactating dairy cows (Casper et al., 2004). Casper et al. (2004) evaluated the relationship between milk production, milk composition, ration energy concentration, fecal energy concentration and DMI of cows from six dairy farms. Their findings indicated that diet digestibility was the most significant (P < 0.01) predictor of FE (FE = 0.032 + 0.02 * DMD; R² = 0.59). This study also indicated that as FE increased, DMI decreased. Similarly, Linn et al. (2005) showed a linear improvement in FE (1.31 – 1.78) as in vivo DM digestibility increased from 50 to 78%. The 2001 Dairy NRC takes these changes in FE into consideration when calculating dietary energy content as discounts are applied to TDN content as DMI increases.

Similarly, offering spoiled feed can compromise FE due to reduced DM digestibility. Kansas State researchers found that increasing the inclusion of spoiled corn silage from 0 to 16.0% of DM, in diets of beef steers, reduced organic matter (OM) digestibility from 75.6% to 67.8%, reduced crude protein digestibility from 74.6% to 62.8%, reduced NDF digestibility from 63.2% to 52.3%, and reduced ADF digestibility from 56.1% to 40.5% (Whitlock et al., 2000). The decrease in nutrient digestibility was largest when the amount of spoiled silage in the diet was increased from 0 to 5.4% of DM and the drop in nutrient digestibility was larger than anticipated. Inclusion of spoiled corn silage may have affected digestibility of other ingredients in the diet as well as affecting rate of passage as researchers observed that the forage mat was destroyed in the rumen of steers fed spoiled corn silage (Whitlock et al., 2000).

Clearly following good silage making practices such as harvesting forages at the correct moisture content, proper particle length, adequate packing and prompt covering can reduce silage spoilage and improve FE. Use of silage inoculants can also improve silage quality and FE. In a summary of four comparisons, addition of silage inoculants to harvested forages increased lb milk produced per lb DM from 1.63 to 1.66 (Kung et al., 1993; Stokes, 1992).

5. Proper feed processing to optimize rumen pH and the site and extent of starch digestion.

Risk factors for acidosis and the negative effects of acidosis on nutrient digestion and animal health have been extensively reviewed in the literature. Briefly, rapid fermentation of diets in the rumen results in rapid production of volatile fatty acids (VFA; Beauchemin et al., 2006). When VFA production exceeds the ability of the rumen environment to neutralize or absorb them, subacute ruminal acidosis occurs (Beauchemin et al., 2006). Decreased FE, as a result of subclinical acidosis, is attributed to reduced absorption of nutrients from the rumen due to excessive keratinization of ruminal epithelium and decreased fiber digestion as a consequence of inhibited growth of cellulolytic ruminal bacteria (Beauchemin et al., 2006).

Recently, Canadian researchers found that reducing particle size of corn silage from
1.13 in. to 0.19 in., decreased lb of ECM produced per lb DM from 1.42 to 1.32 (Yang and Beau-chemin, 2006). Corn silage, harvested at 60% moisture with a kernel processor set at 2 mm, was the sole forage source and comprised 45.8% of diet DM. While ECM production tended to decline with decreasing particle size, milk fat content and mean rumen pH (5.99 to 6.08) did not vary between treatments. However, rumen pH of cows fed corn silage chopped to 0.19 in. was below 5.5, 1.2 h/d more than rumen pH of cows fed corn silage chopped to 1.13 in. Results of this study illustrate that even minor rumen acidosis can reduce FE.

Grain processing also impacts FE as it affects site and extent of starch digestion. In a summary of studies evaluating effect of corn processing on site and extent of nutrient digestion and lactation performance, Firkins et al. (2001) found that increased ruminal starch digestion with increased grain processing generally accompanied a decrease in ruminal NDF digestibility. In addition, the effect of decreased ruminal starch digestibility was mitigated by increased starch digestion in the lower tract. Hence, total tract OM digestion only differed a few percentage points between different processing methods and production benefits obtained from different processing methods were less than predicted (Firkins, 2006). It should be noted that corn content of treatment diets were held constant and that benefits of increased corn processing may have been more evident had the amount of corn in treatment diets decreased with increased processing (Firkins, 2006). On commercial dairies, advantages of increased grain processing can be more fully exploited if diets are balanced to insure adequate amounts of physically effective NDF, and dietary starch levels are adjusted for grain processing, thus minimizing the negative effects of increased ruminal starch digestion on digestion of other dietary nutrients (Firkins, 2006).

6. Grouping heifers separate from cows.

Spanish researchers found that heifers grouped separate from mature cows consumed 1.2 lb/d less DM, produced 1.6 lb/d more ECM and had a 5.8% improvement in FE as compared to heifers housed with mature cows (Bach et al., 2006). The primary contributor to reduced ECM yield was a 0.31-percentage unit decrease in milk fat content for heifers housed with mature cows as compared to heifers grouped separately. Reduced milk fat content may be a consequence of reduced rumen pH. Although rumen pH was not monitored in this study, heifers housed separate from mature cows had more visits to the feed trough (4.91 vs. 4.02 visits/d), and thus would have had smaller meal sizes and a smaller drop in rumen pH following a meal. It should be noted that in this study, there were approximately 1.78 cows per feeding stall. Thus, when housed together, heifers were competing with mature cows for limited feeding stalls. Magnitude of improvement in FE for grouping heifers separate from mature cows may have been smaller if additional feeding stalls were provided.

7. Extended day lighting.

A summary of 6 studies conducted at laboratories located 39 to 53°N latitude showed that ECM production increased 5 lb/d when the photoperiod was extended from less than
13 h to 18 h using artificial lighting (Dahl et al., 2000). Dry matter intake did not increase to the same extent as ECM production, resulting in increased FE. While the exact mechanism has not been fully elucidated, the current theory is extended photoperiods increase ECM yield and hence FE by increasing circulating prolactin, growth hormone, and/or IGF-I concentrations (Dahl et al., 2000).


Sloan (2006) summarized seven studies in which early lactation cows were either fed a control diet or a treatment diet balanced for Lys (6.83 to 7.09% of metabolizable protein (MP)) and Met (2.13 to 2.30% of MP). The Lys to Met ratio of 3.1 to 1 was respected with ratios ranging from 2.97 to 3.32. Cows fed the diet balanced for Lys and Met produced 5.7 lb/d more ECM while consuming only 1.1 lb more DM, resulting in a 4.3% improvement in FE.

Improved FE resulting from balancing diets for Lys and Met can be attributed to both an increase in milk production and improved utilization of dietary N, reducing energy required for excretion of surplus amino acids through urea. It is estimated that the process of urea synthesis requires 4.4 kcal of NEL per g of N converted (Tyrrell et al., 1970).

Improvements in N utilization and increased milk production may explain the 18.0% advantage in FE for herds feeding two or more diets to lactating cows in comparison to herds feeding only one diet to lactating dairy cows (Castillo, 2006). In a survey of 51 California dairies, production of 3.5% fat-corrected milk (FCM) increased approximately 4 lb for each additional diet fed to lactating cows. Dairies feeding one diet to lactating cows averaged 60 lb/d FCM while herds feeding five diets to lactating cows averaged 75 lb/d FCM (Castillo, 2006). Increasing the number of diets fed to lactating dairy cows also allows nutritionists to formulate diets to more closely meet the MP requirements of cows. Not surprising, the efficiency of dietary N utilization was 12.5% higher for herds feeding two or more diets to lactating dairy cows in contrast to herds feeding one diet to lactating dairy cows.


In a summary of nine trials, researchers found that increasing the amount of rumensin from 0 to 22 g/ton DM increased the efficiency of ECM production by 3.8% (Thomas et al., 2004). Improvements in FE is a consequence of monensin shifting the microbial population in the rumen, by promoting growth of more efficient bacteria involved in carbohydrate metabolism (Aguilar, 2005).

10. Improving trace mineral status.

Trace minerals are essential for maintaining optimal health and performance of animals. Zinc, Mn, Cu, Co, I and Se impact the activity and efficiency of key enzyme systems responsible for energy and protein metabolism, cellular repair and integrity, immune
system functionality, fertility, and claw health and maintenance. The impact of trace minerals and trace mineral status on FE is clearly illustrated in a trial conducted by Engle et al. (1997). In this trial, calves that received a diet with no supplemental Zn (diet contained 17 ppm Zn) for 28 d had a 50% decrease in FE as compared to calves that received a diet containing 40 ppm Zn (23 ppm supplemental Zn from ZnSO4). The decrease in FE for the calves receiving no supplemental Zn was attributed to both a 46% decrease in ADG and a 6.7% increase in DMI. During the 14 d repletion phase, calves receiving zinc methionine (ZINPRO®) returned to control FE levels 3X faster than calves receiving ZnSO4.

Increasing Co supplementation of lactating dairy cattle above current NRC (2001) requirements has been shown to improve FE. In a series of studies conducted at Washington State University, adding approximately 10 to 25 mg of supplemental Co from Co glucoheptonate to diets of multiparous cows increased FCM yield (Kincaid et al., 2003; Kincaid and Socha, 2006). In addition, FE improved 2.56 and 7.37% when cows received approximately 10 and 20 mg of supplemental Co. The control diet in both studies exceeded NRC (2001) requirements for Co. The hypothesis that NRC (2001) requirements for Co may be inadequate for maximizing performance of lactating dairy cattle is supported by results of a study recently reported by Girard and Matte (2005). In the study, first calf heifers in early lactation receiving diets supplemented with 0.66 ppm Co produced more ECM when given weekly injections of 10 mg vitamin B12.

Increased FE due to increased Co supplementation may be attributed to several factors including increased fiber digestion and vitamin B12 synthesis. In an in vitro study conducted at the University of Minnesota, fiber digestion and bacterial production of vitamin B12 increased when dietary Co concentrations increased from 0 to 10 ppm (Allen, 1986). It should be noted that vitamin B12 synthesis was lower in a 40% forage diet as compared to a 70% forage diet (Allen, 1986). In a follow-up study, Allen (1986) observed that replacing CoSO4 with Co glucoheptonate increased bacterial production of vitamin B12 and numerically increased fiber digestion. Due to improved fiber digestion and production of vitamin B12, improving Co availability to rumen microbes should improve animal performance under conditions such as reduced intakes, feeding high concentrate diets and feeding high forage diets.

Other factors that may potentially affect efficiency of ECM production include use of rbST, feeding yeast culture and improving cow comfort. Peel et al. (1989) noted that FE improved by 2.7 to 9.3% when cows were administered rbST. Improved FE is due partially to dilution of maintenance requirements, resulting in a greater percentage of dietary nutrients being used for milk production.

CONCLUSION

Feed efficiency is becoming an increasingly important performance measure as dairy management becomes more refined. However, to effectively evaluate FE, it must be standardized for milk composition, changes in BW, environmental factors and exercise. Feed
efficiency can be enhanced by improving feed digestibility, increasing milk production and optimizing trace mineral status. Trace minerals have critical roles in maximizing FE as trace minerals are involved in nutrient capture and utilization and maintaining animal health.

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