Using Feed Efficiency as a Ration Evaluation and Nutrient Management Tool

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Take Home Messages

- Feed efficiency for dry matter intake or protein can give an idea of how well cows are using a ration. Unless the cow is losing body weight, higher efficiency means more feed is being converted to milk.
- Feed efficiency can be improved by reducing other demands for energy or nutrients such as excessive walking or standing, heat stress, cold stress, etc.
- A ration that is not properly balanced or managed, including a ration that cause ruminal acidosis, decreases feed efficiency.
- Improving feed efficiency can reduce the amount of nitrogen and phosphorus excreted in the manure.

Introduction

Feed efficiency is a measure of how well cows convert the nutrients they eat into products: milk, muscle, fat, and calves. On the most basic level, it gives an idea of how closely a ration meets an animal's nutrient requirements, and of the relative demands of maintenance and production. In the larger picture, feed efficiency speaks to ration, management and environmental factors that affect feed digestibility and animal maintenance requirements. By and large, for lactating cows, if feed doesn't make milk, it makes manure. Evaluation of how well a herd converts feed dry matter and protein into salable product can be another useful tool for deciding whether it may be possible to get a better return on your feed investment, and if you can decrease the amount of manure nutrients you will have to manage.

■ Calculating Feed Efficiencies

Typically, we consider the feed efficiencies related to milk production on dairies because of the relative ease of getting the numbers, as compared to trying to measure kilograms of growth, fat reserves and pregnancy on lactating cows. It is important to use reasonably accurate dry matter intakes for groups (in freestalls) or individual cows (tiestalls), or the efficiency values will be rather worthless. Calculate what the cows actually consumed (feed offered minus feed refused) times the dry matter percentage of the ration. Dry matter intake information is part of the basis for sound ration formulation, and the information will be useful beyond calculating efficiencies. For protein efficiency calculations, information on the content of protein in milk (from milk analysis) and in the ration (preferably from feed analyses) are needed.

Milk/Dry Matter Intake

The simplest version of feed efficiency is kilograms of milk per kilograms of dry matter intake, or preferably, fat- and protein-corrected milk per kilogram of dry matter intake. The adjustments for milk fat and protein more accurately assess the amount of feed nutrients going into the milk. This puts all animals (including Jerseys) on a more even footing. Dr. Mike Hutjens of the University of Illinois suggests that herds should average more than 1.4 pounds of milk per pound of intake. This may be decreased for herds on built-in roughage (typically cottonseed hull) rations. High producing groups may attain values of 1.7 to 1.8. Extended days in milk and cold stress decrease feed efficiency. Herds with heat stress, poorly balanced rations, ruminal acidosis, etc. may have values lower than 1.2.

Calculations:

Milk / Dry Matter Intake = Average milk, kg / Average Dry Matter Intake, kg

To calculate 3.5% fat- and protein-corrected milk use in place of milk:

3.5% fat- protein-corrected milk, kg =

(12.82 x kg fat) + (7.13 x kg protein) + (0.323 x kg milk)

(Derived from Tyrrell and Reid, 1965, table 4)

Milk fat kg = kg milk x (milkfat%/100)

Milk protein kg = kg milk x (milk protein %/100)

Dry matter intake = (kg feed offered – kg feed refused) x (ration dry matter%/100)

Milk Nitrogen/ Intake Nitrogen

This measure of efficiency gives an index of feed protein utilization, and usually decreases when milk urea nitrogen values increase. If much of the protein in the ration is indigestible the MUN and efficiency may both be low. We talk about milk nitrogen (N) and feed N to put milk protein and feed crude protein on the same basis: the crude protein in milk has a different multiplier (nitrogen x 6.38) than does the crude protein in feed (nitrogen x 6.25). Different multipliers are used because milk protein on average contains a different proportion of nitrogen (15.7%) than feed protein (16.0%). Cows can achieve a feed efficiency of 0.30 or better (30% of the N in feed converts to N in milk). Feeding protein that the cow does not use, underfeeding fermentable carbohydrates to the microbes, or underfeeding overall energy (digestible carbohydrates and fats) can all reduce protein efficiency.

Calculation:

N Efficiency = Milk N / Feed N = kg milk nitrogen/ kg feed nitrogen

(Milk Nitrogen, kg = (kg milk x (milk protein% / 100)) / 6.38 and
Feed Nitrogen, kg = (kg dry matter intake x (ration crude protein %/100) / 6.25)

▪ Factors Affecting Feed Efficiency

As we formulate rations and use feed efficiency in the evaluation, we need to consider the factors within and outside of the ration that can increase or decrease feed efficiency.

Changes in Maintenance Requirements

Any factor that increases an animal’s maintenance requirements decreases the proportion of feed nutrients available to production. Common factors that increase maintenance requirements are:

- Cold or heat stress (Table 1)
- Walking (how far and through how much mud do cows walk to and from the parlor or pasture? For cows walking on fairly level ground, add 0.00045 Mcal NEL x cow bodyweight kg x kilometers walked to maintenance requirements)(NRC, 2001)
- Extended standing (no comfortable place to lie down)
- Grazing (Add 0.0012 Mcal NEL x cow bodyweight kg to maintenance requirements) (NRC, 2001)

Even if the animal can increase its intake to consume more nutrients to fill the increased maintenance requirements, feed efficiency declines because a greater proportion of that intake goes to maintenance. In the case of heat stress, intake, milk production and feed efficiency all decrease (Table 1). Keeping animals comfortable and minimizing demands for extra physical activity allows them to devote more nutrients to production.

Table 1. Predicted effect of heat stress on feed efficiency.

Temperature (^{o}C)	Maintenance Requirements (% of requirements at 20^{o}C)	Dry Matter Intake for 27 kg of milk + extra maintenance	Expected Dry Matter Intake kg	Expected Milk kg	Milk / Intake
20	100	18.2	18.2	27.0	1.48
25	104	18.4	17.7	25.0	1.41
30	111	18.9	16.9	23.0	1.36
35	120	19.4	16.7	18.0	1.08
40	132	20.2	10.2	12.0	1.18

Adapted from NRC, 1981. 20^{o}C is roughly thermoneutral for cattle.

Weight Gain or Loss

When you evaluate feed efficiency, you need to take change in body condition or body weight into your accounting. First and second lactation animals need to grow, and cows need to regain body condition, so weight gain is a necessary demand. However, using nutrients for weight gain decreases feed efficiency as a smaller portion of the nutrients consumed are used for milk production. Conversely, when a cow in early lactation is losing body condition, her feed efficiency may appear to be very high because she is using ration nutrients as well as nutrients from her own body to support production.

Feed Digestibility

If a feed cannot be digested, it never will have the opportunity to be used for milk production, and will reduce feed efficiency. Reducing particle size of corn and sorghum grains (Galyean et al., 1981) makes those feeds more digestible (Figure 1). A rough guideline for grinding corn finely enough to reduce unnecessary passage of undigested corn particles into the manure is for little to none of the grain to be retained on #8 (2.36 mm/0.0937 inch opening; equivalent 8 mesh) USA Standard Testing Sieves (A.S.T.M.E. – 11 Specification; Fisher Scientific Company, Atlanta, GA). These sieves retain ~1/4 kernel to whole kernels, and very coarsely ground grain, respectively. Grain in silage also needs to be cracked or broken into fine pieces to be well digested. The finer the grind on the grains, the more rapidly they may ferment, and the more important it becomes to have adequate neutral detergent fiber (NDF) and physically effective fiber in the ration to maintain rumen function. Remember, digestibility of even fine particles is affected by other components in the diet that affect ruminal retention time or passage rate, ruminal pH, etc.

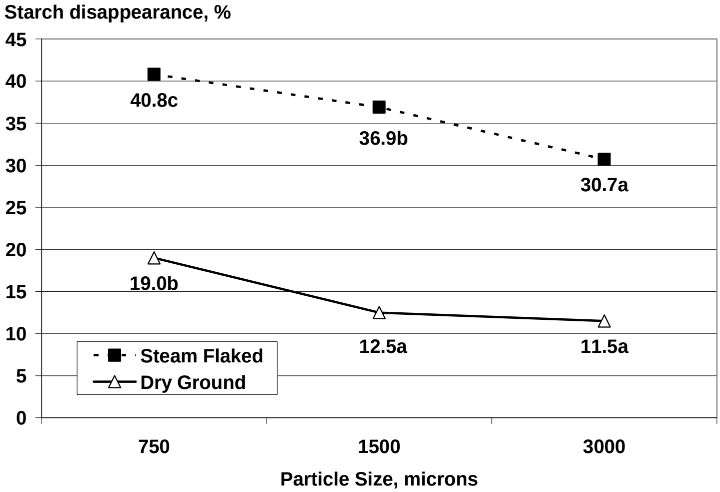

Figure 1. In situ ruminal starch disappearance, and presumably digestion, increased with decreasing particle size of steam flaked or dry ground corn grain. (Galyean et al., 1981) (105 micron pore size in situ bags; avg. of 2, 4, 6, and 8 h of incubation; a,b,c means differ within a feed $P < 0.05$).

Protein in heat-damaged feeds can be indigestible and of no use to the cow. This can be a particular problem with feeds, such as distillers grains, that are heated during processing. High proportions of feed protein present as acid detergent-insoluble nitrogen signal heat damage.

Poor retention/rapid passage of feeds in the rumen can decrease digestibility. Granted, high producing cows with high dry matter intakes will have an increased rate of digesta passage, and potential for more feed to leave the rumen before it is completely digested. HOWEVER, this should not be used to excuse rations that do not promote good rumen function. Presence in the manure of much coarse fiber more than 1 cm long, “lots” (subjective/relative) of undigested ground grain, and feeds you can still recognize (citrus pulp that is still orange, cottonseed that retained its lint, etc.) are indications that feed is passing through the rumen too quickly to be properly broken down through rumination and microbial digestion. The digestibility of such feed is decreased.

Dry Matter Intake

More is not always better. Intakes can be quite high on rations low in forage/fiber and high in concentrate. Cottonseed hulls can increase dry matter intake. If dry matter intakes are high, but production does not follow and the cows are presumed to be capable of responding, reevaluate the situation.

Sick Cows

Cows with ruminal acidosis or other illnesses can have feed efficiencies of 1.1 to less than 1 kilogram of milk per kilogram of dry matter intake. If cows are devoting their energies to being ill, odds are they will not make as much milk.

Days in Milk

Generally, as days in milk increase, feed efficiency declines. This is largely due to a decrease in production as the cow devotes more nutrients to replenishing body reserves and growing a fetus. Feed efficiency will be greatest in early lactation and at peak production. High efficiencies in early lactation may be related in part to use of body reserves for production.

Most Limiting Nutrient

If a particular nutrient requirement is not met, feed efficiency may be increased by adding the needed nutrient. This can be the case with the whole array of nutrients in the diet from carbohydrates through amino acids. However, if enough of a nutrient is already provided, or it is not the main limitation to production, pouring more of that nutrient into the ration may actually worsen feed efficiency. If a nutrient added into a diet displaces a nutrient that is limiting, production may not increase or may decline.

A case in point is a study that evaluated the effects of increasing dietary levels of cottonseed meal for early lactation cows on an alfalfa-based diet (Grings et al., 1991). Barley and corn were removed from the diet to make room for the inclusion of cottonseed meal, a protein source. Dry matter intake increased linearly with increasing crude protein (CP) intake; milk increased between with the first addition of cottonseed meal ($P<0.01$), with no further increase in milk yield as more cottonseed meal was added (Figure 2). Milk/intake appeared to increase with the first protein addition, and then to decline (calculated from data in tables). Plasma urea nitrogen and milk nonprotein nitrogen increased linearly with increasing dietary CP ($P<0.001$). In accord with this data, efficiency of nitrogen utilization appears to decrease with increasing dietary protein (calculated from data in tables), suggesting that dietary CP was used less efficiently as more cottonseed meal was supplemented. Likely, the first addition of cottonseed meal helped to fill unmet protein requirements, and then the increased removal of energy/carbohydrate sources from the diet to allow inclusion of more cottonseed meal left the ruminal microbes and animals relatively energy deficient, reducing their ability to capture the feed protein for productive uses.

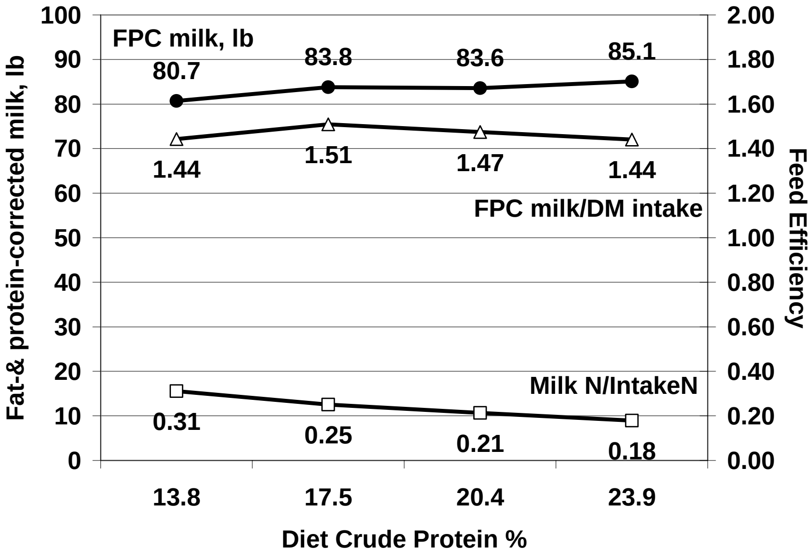

Figure 2. Increased feeding of cottonseed meal as corn and barley were removed gave an initial increase in 3.5% fat- & protein-corrected milk, but an apparent decrease in feed nitrogen efficiency (Grings et al., 1991).

■ Feed Efficiency and Nutrient Management

If feed makes manure when it doesn't make milk in lactating cows, it follows that the more nutrients are converted to milk, the less we have to manage in manure. In the case of feed efficiency for protein or nitrogen, things are pretty straightforward: 1 – feed efficiency for nitrogen = proportion of diet N in manure.

Improvements in feed efficiency can even be used to decrease phosphorus (P) excretion. How? The P content of milk is rather stable at 0.09%. If you improve feed efficiency by decreasing intake or increasing milk production at any given concentration of dietary P, a greater proportion of P will be exported from the farm as milk and less excreted (Table 2). A key with reducing P excretion is to feed to meet, but not exceed, animal requirements.

Table 2. Changes in daily phosphorus excretion with feed efficiency (per cow per day).

--When dry matter intake changes--				--When milk production changes--			
FE	**Milk, kg**	**DMI, kg**	**P exc g**	**FE**	**Milk, kg**	**DMI, kg**	**P exc g**
1.2	32	26.7	78	1.2	26.4	22.0	64
1.4	32	22.9	63	1.4	30.8	22.0	60
1.6	32	20.0	51	1.6	35.2	22.0	56
1.8	32	17.8	42	1.8	39.6	22.0	52

Ration: 0.40% of dry matter as phosphorus
Milk: 0.09% phosphorus
FE = feed efficiency = Milk kg / dry matter intake kg
DMI = dry matter intake
P exc g = grams of excreted phosphorus

▪ Implications

Enhancing feed efficiency while maintaining high milk production can offer a better economic return on money invested in feed and decrease the flow of nutrients that have to be managed in manure. Feed efficiency values can help indicate if a herd is performing reasonably with a particular ration, management, or environment, or if these can be improved.

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