What You Feed vs. What You Get:
Feed Efficiency as an Evaluation Tool

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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 indices of how closely a ration meets an animal's specific 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 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 to salable product can be another useful tool for deciding whether you can 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 pounds of growth, reserves and pregnancy on lactating cows. It's 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 <u>consumed</u> (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.

<u>Milk/Dry Matter Intake</u>

The simplest version of feed efficiency is pounds of milk per pound of dry matter intake, or preferably, fat- and protein-corrected milk per pound 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 one-shot feeds (built in roughage rations). High producing groups may attain values of 1.7 to 1.8. Herds with heat stress, poorly balanced rations, ruminal acidosis, long days in milk, etc. may have values lower than 1.2.

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

It is preferable to use 3.5% fat- and protein-corrected lb of milk, rather than lb of milk:
3.5% fat- protein-corrected milk, lb =
(12.82 x lbs fat) + (7.13 x lbs protein) + (0.323 x lbs milk)

If protein is not measured, use 3.5% fat corrected milk in the calculations:
3.5% fat-corrected milk = (0.515 x lbs fat lb) + (13.86 x lbs milk)
(Derived from table 4, Tyrrell and Reid, 1965)

Dry matter intake = (lb feed offered – lb feed refused) x (ration dry matter%/100)
Milk fat lbs = lb milk x (milkfat%/100)
Milk protein lb = lb milk x (milk protein %/100)

Milk Nitrogen/ Intake Nitrogen

This gives an index of feed protein utilization, and should likely go in the opposite direction that milk urea nitrogen values do, unless much of the protein in the ration is indigestible, in which case MUN and efficiency may both be low. We talk about milk nitrogen (N) and feed N to put milk 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 contains a different proportion of nitrogen (15.7%) than does feed crude protein on average (16.0%). Cows can achieve a feed efficiency of 0.30 or better. Overfeeding of protein that the cow is not using, or underfeeding fermentable carbohydrates to the microbes, or underfeeding overall energy (digestible carbohydrates and fats) to the cow can all result in reduced protein efficiency value.

Milk N / Feed N = lb milk nitrogen/ lb feed nitrogen

Milk Nitrogen, lb = (lb milk x (milk protein% / 100)) / 6.38

Feed Nitrogen, lb = (lb dry matter intake x (ration crude protein %/100) / 6.25

Factors Affecting Feed Efficiency

Changes in Maintenance Requirements Any factor that increases an animal's maintenance requirements decreases the proportion of feed nutrients devoted to production. Common factors that increase maintenance requirements are:

- Heat or cold stress
- 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

0.000328 Mcal NEL x cow bodyweight lb x miles walked to maintenance requirements)(NRC, 2001)

- Extended standing (no comfortable place to lie down)
- Grazing (Add 0.00054 Mcal NEL x cow bodyweight lb 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 (^oF)	Maintenance Requirements (% of requirements at 68^oF)	Dry Matter Intake for 59.5 lb of milk + extra maintenance	Expected Dry Matter Intake lb	Expected Milk lb	Milk / Intake
68	100	40.1	40.1	59.5	1.48
77	104	40.6	39.0	55.1	1.41
86	111	41.7	37.3	50.7	1.36
95	120	42.8	36.8	39.7	1.08
104	132	44.5	22.5	26.5	1.18

Adapted from NRC, 1981. 68^oF is roughly thermoneutral for cattle.

<u>Feed Digestibility.</u> If a feed is indigestible, it never had the opportunity to make a contribution to 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 #4 (4.75 mm/0.187 inch opening; equivalent 4 mesh) or #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. The finer the grind on the grains, the more rapidly they may ferment, and the more important it becomes to have adequate 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.

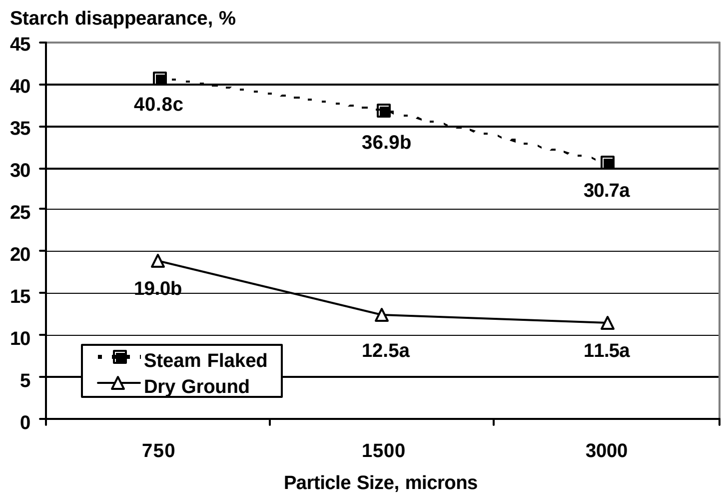

Figure 1. In situ ruminal starch disappearance, and presumably digestion, increased with decreasing particle size of steam flaked or dry ground corn grain. (Galyean et al., 1981) (105 micron pore size in situ bags; avg. of 2, 4, 6, and 8 h of incubation; a,b,c means differ within a feed $P < 0.05$).

Proper processing of corn silage can have positive or negative effects on digestibility. In studies that evaluated the effect of mechanical processing on corn silage characteristics, decreasing the number of intact kernels increased total tract starch digestibility and increasing mean particle size of processed or unprocessed silage decreased total tract neutral detergent fiber (NDF) digestibility (Johnson et al., 2002). The diets in the study contained 40% forage (26.8% corn silage and 13.2% alfalfa hay) and 31 to 40% NDF (DM basis). Conceivably, in rations that do not have sufficient effective fiber, reduction in particle size could have a negative impact on NDF digestibility through decreased rumination and more acidic ruminal pH.

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, that high producing cows with high dry matter intakes 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 0.5 inches long, “lots” (subjective/relative) of undigested ground grain, 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 can have feed efficiencies of 1.1 to less than 1 pound of milk per pound 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 is devoting 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 a nutrient is already provided at adequate levels, or is not the main limitation to production, pouring more 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 the study of Grings et al. (1991). The objective of the study was to evaluate the effects of increasing dietary levels of cottonseed meal for early lactation cows on an alfalfa-based diet. Barley and corn were removed from the diet to make room for the inclusion of cottonseed meal. Dry matter intake increased linearly with increasing crude protein (CP) intake; milk increased between 13.8 and 17.5% dietary CP ($P<0.01$), with no differences in milk yield at higher CP levels (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 more inefficiently as more was supplemented. Likely, the 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.

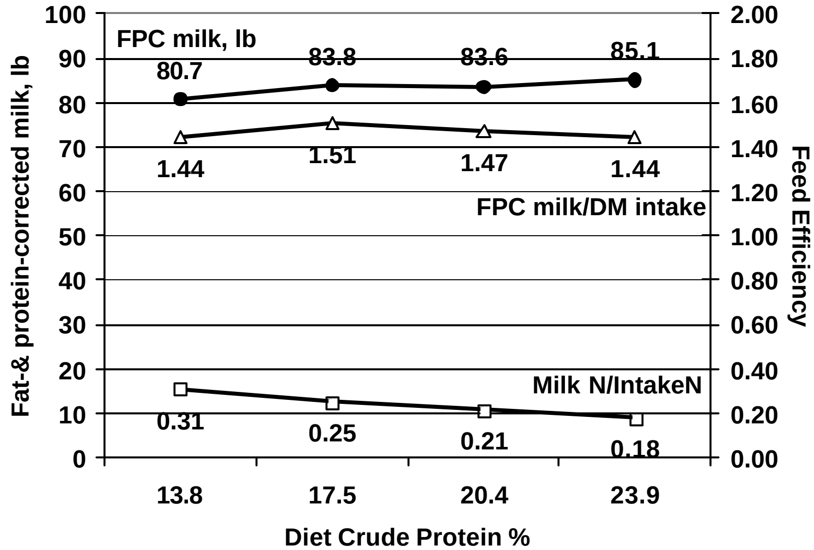

Figure 2. Increases in cottonseed meal as corn and barley were removed gave an initial increase in 3.5% fat- & protein-corrected milk, but an apparent decrease in feed nitrogen efficiency (Grings et al., 1991).

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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