Practical Application of Dairy Efficiency—A Consultant's Perspective.

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Introduction

In recent years, it has become increasingly popular to use feed efficiency (FE) as a benchmark for a dairy's success in converting feed to a salable product. Feed costs have traditionally comprised about 50% of a dairy's production costs and commonly exceeding 70% during the past year of high commodity and forage prices. It is assumed that the better a herd converts these costs to milk, the more profitable the herd. This should be done with caution, as there is not a financial component in the calculation of feed efficiency. The authors suggest that FE is used in conjunction with a financial measure, such as income over feed cost (IOFC). Income over feed cost is a function of milk prices, feed costs, and the animal's response to nutrient intake (Smith, 1976). The IOFC values reported in table 1 are calculated keeping milk price at $11/cwt and feed costs at $0.11 per pound of dry matter (DM). With these two variables held constant, the value of increased production across similar dry matter intakes (DMI) is evident and the the highest FE aligns with the largest IOFC. If the ration fed during August utilized a feed additive to help alleviate heat stress and the cost per pound of DM increased to $0.115, then IOFC would be reduced to $2.69. In this case, August and June would still have equal FE's, but June would have gained $0.27 of income per head over August. Further discussion of FE calculation and on-farm observations will be presented later in the paper.

Methods of Improving FE

Milk Production

Increasing production typically has the most impact on a dairy's efficiency or profitability, as long as the dairy did not invest more in achieving the higher yield than they will be paid in return. Despite its importance to efficiencies and IOFC, milk yield is often ignored as a method for improving FE. Improvements in productivity will occur as a result of genetic selection, nutritional advances, and improved management practices and technologies. Improved digestive efficiency, improved metabolic efficiency, and changes in nutrient partitioning toward milk production will also be essential to improved milk yields and FE (Tyrrell, 1980; Coppock, 1985).

Digestive Efficiency

A major cause of digestive inefficiency in lactating cows is the depression in digestibility that occurs with increasing DMI in high producing cows (Tyrrell, 1980, Van Soest, 1982, Coppock, 1985). Because rumen fill cannot adapt to the higher DMI levels, rumen turnover increases (Van Soest, 1982). This increase in passage rate causes larger fecal losses of potentially available fiber, protein, and carbohydrates. The pursuit of the optimal balance between digestion and passage rate is a complex issue and does not have a solution that works across all stages of lactation and ingredient combinations in diets. A few topics within this digestion-passage rate relationship enable progress in finding this balance. The first area for improving digestive efficiency is improved forage quality, especially through improved NDFD. As stated by Van Soest (1982), within a roughage class poor-quality forages are less efficient than higher quality forages. Oba and Allen (1999) demonstrated a one unit increase in NDFD results in a 0.35 lb/cow increase in DMI and a 0.55 lb/cow increase in milk yield. Although many extrinsic factors (i.e., weather) can negatively impact forage quality, there are many factors that can be controlled such as maturity at harvest, proper storage and ensiling, adequate sampling before purchasing or feeding, proper processing of corn silage, and proper processing of alfalfa hay in the TMR. Over the past 3 years, Oord Dairy has made forage quality the core of our nutrition program.

The second area for improving digestive efficiency is to determine an optimal forage to concentrate ratio that meets production requirements and gives the cow the benefit of improved digestive efficiency of the concentrates while simultaneously maintaining good rumen pH and function. This requires adequate levels of forage NDF and effective NDF. Additionally, concentrates tend to lower rumen fill and alleviate some of the limitations of fill on milk production in high producing cows (Allen et al., *In Press*).

A third area of focus is to know the nutrient content of the feeds. Through extensive sampling of all forages and concentrates used at Oord Dairy, we have observed much lower variability in the nutrient content of most concentrates compared with forages. For example, when comparing ground corn analyses to alfalfa hay (same cutting and grower), corn has 33%, 23%, and 49% of the variation for crude protein, ADF, and NDF. In our feeding program, concentrates help to reduce nutrient variability delivered to the cows. Within the concentrate category, there is also efficiency in selecting ingredients that correspond with the cow's physiologic state. Allen et al. (In Press) has demonstrated that highly fermentable diets are advantageous to high producing cows (in established lactation) in which fill is limiting intake. However, the opposite is true in later lactation cows in which rumen fill is not as limiting to intake and production can be sustained with higher forage diets. Increasing insulin sensitivity and increased blood glucose in late lactation cows supports the deposition of body reserves at the expense of milk production. Thus, replacing some highly fermentable carbohydrate in low-producing cow diets with forage may help minimize over conditioning of late lactation cows. Moe and Tyrrell (1975) observed similar effects when the feeding of cracked corn resulted in a higher retention of energy in milk plus body reserves than the feeding of beet pulp. However, the cracked corn diets resulted in only 17% of the retained energy going to milk and 83% was retained in body reserves. In the cows fed beet pulp, 70% of the retained energy was in milk and only 30% in body reserves.

A fourth focus addresses processing of both concentrates and forages to aid in DMI, digestibility, and consequently milk yield. Proper processing of corn silage is beneficial to digestion by improving starch digestibility as a result of fracturing the kernals and improved fiber digestibility by the crushing and shearing of the cob and plant stover (Johnson et al., 1999). As mentioned previously, alfalfa hay (and other hay types) need a chop length appropriate to maximizing DMI, rumen function and digestibility, while minimizing ration sorting. Hay processing will be different for different hay qualities. For example, supreme quality alfalfa hay will require less processing than fair quality alfalfa hay with lower digestibility. Within concentrates, corn processing has been our biggest challenge. With steam flaked corn, a proper flaking density is the key to realizing the benefits in starch digestion from this process. Based on data of Zinn et al. (1990) and Sindt et al. (2006), maximum starch degradability occurs with flaking densities less than 28 lb/bu. In our region, it would be difficult to find steam-flaked corn less than 30 lb/bu. With ground corn, the guidelines for fineness of grind best suited for dairy rations are somewhat ambiguous. We monitor corn particle size and within our operation we suggest that a fine grind (80 to 85% passing a number 16 grain sieve) results in an apparent improvement in digestibility as less corn is observed after screening manure. Our guideline is also ambiguous and certainly not proper science; it is simply a parameter that we have established for our operation. Most other commodities do not have the processing challenges associated with corn, but should be monitored to for mold, excessive moisture, or foreign debris (i.e., sticks in almond hulls) that will reduce intake and/or digestibility.

In summary, our management emphasis is on forage quality, frequent ingredient sampling, rumen health, feed processing, and managing ingredient combinations for energy output in milk to improve digestive efficiency.

Metabolic Efficiency

Coppock (1985) estimated that a 1325 lb cow producing 88 lb of 4.0% FCM loses more than 30% of its consumed energy to heat production associated with maintenance and heat increment associated with feed intake. Heat increment (HI) from intake is comprised of heat of product formation, heat of digestion, heat of waste formation and excretion, and heat of fermentation (Coppock, 1985). Determining a method or feeding strategy that would reduce any of these aspects of HI without detriment to the cow or productivity would improve efficiency. There are two states in which cows already alter HI (Coppock, 1985), but both have some negative impacts on the animal and/or milk production. The first is heat stress; during which reduced intakes reduce HI of digestion and excretion by improved metabolic efficiency and reduced heat to dissipate. The second state is the period of negative energy balance in early lactation. The heat production resulting from metabolism of body reserves is half that of heat production associated with converting metabolizable energy from the diet to milk. While neither of these states are sustainable, they demonstrate that the cow has mechanisms to reduce metabolic heat production and beg the question about other mechanisms she may have that remain undiscovered. One area that has been explored and improved in recent years is amino acid nutrition. With high energy costs of protein turnover (10 to 15% of maintenance costs; Baldwin et al., 1980) and excretion of excess nitrogen, the ability to fine-tune amino acid nutrition and protein requirements could result in a marked decrease in energy lost via heat production. Manipulation of dietary fat amount and sources has also been suggested to reduce heat increment (Chalupa, 1982). Another process that is energetically expensive is the maintenance of sodium/potassium pumps (20 to 30% of maintenance requirements; Baldwin et al., 1980). Currently, no direct management interventions are used to increase metabolic efficiency.

Nutrient Partitioning

Methods of improving peak milk yield and lactation persistency improve efficiency by maximizing the amount of dietary energy converted to milk even when the priority of lactation is decreasing with advancing lactation and pregnancy. It is certainly easy to negatively impact peak milk and persistency with bad management practices or nutritional insults, but the inverse is not as easily accomplished. One of the simplest practices that results in a greater partitioning of nutrients to lactation is to increase milking frequency from twice daily to three or four times daily. Increased milking frequency results in an increase in milk yield of up to 20% with approximately a 5 to 7% increase in DMI (Wall and McFadden, 2008). Limitations to increased milking frequency on some operations are inadequate time in the parlor, excessive time in the holding pen, too much time away from feed, poor access to feed, and excessive walking distance to the parlor. The technology of rbST also improved lactation persistency and increased the amount of dietary energy used for milk production. An rbST-free mandate from our coop resulted in the removal of rbST supplementation from our management practices. This change has resulted in an 8 to 10 lb/cow reduction in milk yield when compared historical production and a 2 to 3 lb reduction in DMI. An additional 10 lbs over 3 lbs of DMI is an efficiency of 3.33 on this additional milk yield.

Other Factors

Some other factors affecting feed efficiency that have been mentioned in the literature are days in milk, breed, and changes in maintenance requirements (Britt et al., 2003; Hutjens, 2005; Linn et al., 2004). Days in milk is impacted more by the physiological state of the animal than DIM itself. Early lactation cows tend to have higher feed efficiency values because they are converting body reserves to milk, a more efficient process than converting feed to milk. Late lactation cows tend to divert nutrients to deposition of body reserves and pregnancy and lose efficiency. Clearly cows in early lactation utilize the nutrients deposited in late lactation so the efficiency of early lactation must include the late lactation inefficiency. Studies evaluating breed differences in feed efficiency have concluded that when FCM milk was used in the efficiency equation, there were no apparent differences (Blake et al., 1986; Gibson, 1986). Heat and cold stress both increase maintenance costs to maintain normal body temperature and reduce feed efficiency (Britt et al., 2003). Reduced intakes during heat stress have some efficiency improvements discussed earlier, however, the fact that production decreases are in excess of that explained by the reduction in DMI result in overall lower feed efficiency (Rhoads et al., 2009). Cold stress also reduces efficiency due to increased DMI and reduced DM digestibility (NRC, 2001).

Practical Application of Feed Efficiency

Given the importance of accurate information on DMI, milk yield, and milk components to the resulting FE value, we raise some questions about how to properly use feed efficiency data. In our experience, measurement of DMI is difficult due to inaccurate determination of feed refusals. Weigh-back inaccuracies are derived from changes in ration DM between delivery and bunk cleaning, frequency of bunk cleaning, equipment breakdowns, and weather. Changes in DM occur naturally throughout the day even in a mild climate. Additionally, added moisture from feed lane cooling (soakers), rain, or snow, or rapid drying from wind change DM of orts continually. It is not feasible to get a precise DM on feed refusals across 23 milking pens and 8 dry or close-up cow pens, so we have chosen to use DM values obtained from the lab that does a nutrient analysis of the feed refusals twice weekly. This also enables us to use weigh-backs as in ingredient in our diet formulations. In addition to the DM issue, weigh-backs are a relatively low priority when the truck used is needed as a feed truck because a main truck is broken or when the weigh-back truck itself needs repairs. During these times, feed bunks are still cleaned but weights are not obtained. Punctual and accurate feeding always has priority. Since weigh-backs are an important part of the DMI equation, we can assume that DMI has inherent error. These problems may be exclusive to Oord Dairy, but are likely universal. The other side of the feed efficiency equation may also be difficult to accurately assess.

Daily milk yield should be straight forward information to collect. However, irregular milk pick up times may require some type of correction to a particular farm's data. It is also not uncommon for a dairy farm to not know their actual cow count. Both the DMI and milk yield values are better data when actual rather than estimated cow numbers are used in the equation. Milk composition data is probably the most simple to collect, as it is typically published by milk coops on each load of milk.

Upon collecting reasonably accurate data, then the debate over which FE calculation to use begins. Gross FE is milk over DMI, but FE is perhaps more meaningful if there is some type of standardization added to the equation allowing the data to be compared over time and varying milk compositions. The most common standardization of FE is to utilize 3.5% fat-corrected milk yield (3.5% FCM) rather than gross milk yield (Linn et al., 2004). This conversion is represented in the following equation: 3.5% FCM (lb) = (0.432 x lb milk) + (16.23 x lb fat) (Linn et al., 2004). This conversion puts dairy cows on an energy output equivalent basis, but does not account for protein. In order to account for both fat and protein content of milk the following equation can be used: 3.5% FPCM (lb) = (12.82 x lb fat) + (7.13 x lb protein) + (0.323 x lb milk) (Hutjens, 2005). It is most appropriate to account for both fat and protein along with yield when determining feed efficiency. An additional calculation is to correct FE, 3.5%FCM-FE, or 3.5% FPCM-FE for maintenance costs. This concept was investigated by Agri-King, Inc. and has been published in Linn et al., 2004. The NRC (2001) reported the following equation for determining the amount of feed DM required for maintenance: $DMI = BW^{0.75} \times 0.968$. Using this equation, DMI can be adjusted for the portion that was used for maintenance and FE can be calculated using the DMI that was actually available for milk production. Importantly, this adjustment in DMI does not account for increased maintenance costs in cows with longer walking distances, longer standing times, or cold/heat stress. Additional factors that alter FE are body weight gain or loss, DIM, growth, and pregnancy. As the industry continues to fine-tune FE some standardization for these factors will likely be added to FE equations in the future. From a practical perspective, it would be interesting to evaluate the differences between 3.5% FPCM-FE and a maintenance-adjusted 3.5% FPCM-FE to monitor the impact of changes in maintenance costs the herd undergoes during summer and winter seasons. It could provide a means for estimating returns on investments that alleviate stress (i.e., heat abatement).

Even without the variability introduced by weigh-back, intakes are quite variable from day to day. Figure 1 depicts DMI of a pen of AI cows in established lactation during two months with mild weather. The daily changes in DMI are often a magnitude of 8 to 12 lb per cow. This pen typically averages approximately 105 lb/cow/d, 3.55%

fat, and 3.0% protein. If you picked May 16th to calculate 3.5% FPCM-FE, the result would have been 1.90, but if you calculated it on May 17th the efficiency would have been 1.63. If a person is monitoring FE (using any equation) sporadically, a 24 h difference in timing could completely change your response to the information. In the example above, the nutritionist would likely panic on May 16th because the cows (>60 DIM) are probably still mobilizing body reserves, but on May 17th he/she would have thought this group of cows was converting feed to milk nicely without much concern. Feed efficiency values should be monitored over time rather than at snapshots in time to be able to make correct decisions about how the cows are actually performing.

Evaluating feed efficiency by stage of lactation is more valuable than an overall herd efficiency value. The FE, 3.5% FCM-FE, and 3.5% FPCM-FE for July and August 2009 are shown in Figure 2 for fresh, AI, and pregnant cow pens. As expected, fresh cows were the most efficient and pregnant cows the least efficient. Importantly, in July, the fresh cows appeared to be mobilizing more body reserves than we prefer, but in August they appear to be losing less weight. July was a very hot month for this region and heat stress was most likely the causative factor of FE values of near 2.0 in fresh cows. The herd FE values are presented in Table 1. In the month of July the herd FE's were higher than in the neighboring months, but these data do not allow you to determine that AI and pregnant cows have similar FE's in July and August and the increase is driven by higher FE's in the fresh cows.

Do so many calculations and benchmarks focus efforts on calculations and records at the cost of cow observations? In our opinion, nothing replaces the act of observing cows. Changes in digestion can be picked up by walking pens or screening manure. Under or over conditioning have to be determined cow-side, but changes in FE may give you an indication a change is coming before it is apparent in the cows. Preferably, dairies and nutritionists have a plan for monitoring productivity and efficiency with a balance between animal and data monitoring.

Other Aspects of Operating Efficiently

Minimizing feed shrink, the difference between the amount of a feed ingredient purchased and the amount of that ingredient actually fed to the cows, is critical in managing feed costs. Shrink is not an easy number to determine, especially if the dairy does not have their own scale and a computerized feeding system. Oord Dairy has the luxury of having both, so we are able to closely manage the shrink on our commodities and silages. Industry goals for commodities are 5% or less and less than 10% with silages (Brouk, 2009). Shrink costs are expensive, even when a dairy is controlling shrink reasonably well. On most of our commodities, we average about 4% shrink and on our last silage pile we averaged 8% shrink. Shrink on ground corn averaged 3.2% through the first 6 months of 2009. While we are proud of the feeding team for achieving this value, the fact that this translates to 174 tons of missing corn that is worth more than $30,000 leads us to believe we need to improve this number. On corn silage, several management changes including a different pile type, increased packing weight, double covering, and improved face management have helped reduce our shrink considerably from years past. However, 8% shrink on 60,000 tons is 4,800 tons of silage that was never available to convert to milk, albeit some of this missing silage left as effluent early in the ensiling process. Using last year's silage price, this equates to $228,000 of lost feed. When you look at the actual amounts of feed disappearing, it seems achievable to create new standards on minimizing shrink.

Labor, repairs and maintenance are the remaining areas of a feeding program subject to inefficiencies.   Labor is self explanatory; operate with as few employees as possible to get the work done correctly and maintain morale. Repairs and maintenance can be a huge expense to the feed area given the amount of rolling equipment.   In order to minimize repairs and maximize equipment longevity, we have a set time of day to service equipment and written policies and instructions about the maintenance program. In our program, break-downs result in the expense of the repairs, but perhaps hidden expenses resulting from increased sorting and reduced intakes when the diets are mixed in a back-up feed truck. Other efficiencies to be gained with equipment include: monitoring mixer knives to minimize feed processing time and minimizing the time the trucks run at higher engine revolutions per minute to reduce fuel usage.

Conclusion

Monitoring FE over time, preferably by pen or animal type (i.e., fresh, AI, pregnant) in conjunction with IOFC can prove beneficial in recognizing periods of inefficiency. Management can then intervene and improve financial returns. Feed efficiency needs to be determined accurately and should be monitored consistently to help avoid an erroneous interpretation of the resulting FE values.

Practical means for improving FE through improved digestive efficiency, metabolic efficiency, and nutrient partitioning to milk production include (but are not limited to) improved forage quality, optimizing the forage:concentrate ratio for rumen function, DMI, and digestive efficiency, pairing ingredients with the proper stage of lactation for optimal conversion of energy to milk, proper feed processing, and through the use of galactopoietic and management practices that increase milk yield.   Do not lose sight of the fact the milk yield is a powerful driver of FE. Finally, manage the entire feeding program to be efficient by minimizing feed lost as shrink, repair costs, and fuel usage.

References

Allen, M.S., B.J. Bradford, and M. Oba. *In Press*. Board-Invited Review: The hepatic oxidation theory of the control of feed intake and its application to ruminants. J. Anim. Sci.

Baldwin, R.L., N.E. Smith, J. Taylor, and M. Sharp. 1980. Manipulating metabolic parameters to improve growth rate and milk secretion. J. Anim. Sci. 51:1416-1428.

Britt, J.S., R.C. Thomas, N.C. Speer, and M.B. Hall. 2003. Efficiency of converting nutrient dry matter to milk in Holstein herds. J. Dairy Sci. 3796-3801.

Brouk, M. 2009. Don't Let Shrink Kill You with High Feed Prices. *In* Proc.: 9th Western Dairy Management Conf. p.p. 227-232.

Chalupa, W. 1982. Dietary fat for lactating dairy cows. Feed. Manage. 33:39.

Coppock, C.E. 1985. Energy nutrition and metabolism of the lactating dairy cow. J. Dairy Sci. 68:3403-3410.

Firkins, J.L. 2008. Considerations associated with corn processing in dairy rations. *In* Proc. 23rd Annual Southwest Nutr. Conf. p.p.1727-143.

Hutjens, M.F. 2005. Dairy efficiency and dry matter intake. *In* Proc.: 7th Western Dairy Management Conf. p.p. 71-76.

Johnson, L., J.H. Harrison, C. Hunt, K. Shinners, C.G. Doggett, and D. Sapienza. 1999. Nutritive value of corn silage as affected by maturity and mechanical processing: a contemporary review. J. Dairy Sci. 82:2813-2825.

Linn, J., M.T. Trulla, D. Casper, and M. Raeth-Knight. 2004. Feed efficiency of lactating dairy cows. *In* Proc.: Minnesota Nutr. Conf.

Moe, P.W. and H.F. Tyrrell. 1975. Symposium: Production efficiency in the high producing cow. Efficiency of conversion of digested energy to milk. J. Dairy Sci. 58:602-610.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle, 7th ed. National Academy Press, Washington, DC. p.p. 18-21.

Oba, M. and M.S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: Effects on dry matter intake and milk yield. J. Dairy Sci. 82:589-596.

Rhoads, M.L., R.P. Rhoads, M.J. VanBaale, R.J. Collier, S.R. Sanders, W.J. Weber, B.A. Crooker, and L.H. Baumgard. 2009. Effects of heat stress and plane of nutrition on lactating Holstein cows: I. Production, metabolism, and aspects of circulating somatotropin. J. Dairy Sci. 92:1986-1997.

Sindt, J.J., J.S. Drouillard, S.P. Montgomery, and E.R. Loe. 2006. Factors influencing characteristics of steam-flaked corn and utilization by finishing cattle. J. Anim. Sci. 84:154-161.

Smith, N.E. 1976. Maximizing income over feed costs: evalutation of production response relationships. J. Dairy Sci. 59:1193-1199.

Tyrrell, H.F. 1980. Limits to milk production efficiency by the dairy cow. J. Anim. Sci. 51:1441-1447.

Van Soest, P.J. 1994. Energy Balance. *In*: Nutritional Ecology of the Ruminantt 2nd Ed. Cornell Univ. Press, Ithyca, NY. p.p. 385-401.

Wall, E.H., and T.B. McFadden. 2008. Use it or lose it: enhancing milk production by frequent milking of dairy cows. J. Anim. Sci. 86:27-36.

Zinn, R.A. 1990. Influence of flake density on the comparative feeding value of steam-flaked corn for feedlot cattle. J. Anim. Sci. 68:767-775.

Table 1. Summary of whole herd production and feed efficiencies during the Spring and Summer months of 2009.

	Month				
Variable	April	May	June	July	August
Milk Yield, lb/cow/d	76.6	77.7	81.2	82.2	80.5
Milk Fat, %	3.65	3.59	3.51	3.47	3.51
Milk Protein, %	3.05	3.05	3.00	2.96	2.96
Dry Matter Intake, lb/cow/d	54.1	54.7	54.3	53.6	53.6
FE	1.43	1.43	1.50	1.66	1.50
3.5% FCM-FE	1.46	1.45	1.51	1.65	1.50
3.5% FPCM-FE	1.44	1.43	1.48	1.62	1.47
IOFC, $	2.48	2.53	2.96	3.14	2.95

Abbreviation Key: FE= gross feed efficiency, 3.5% FCM-FE = 3.5% fat-corrected feed efficiency, 3.5% FPCM-FE = 3.5% fat and protein-corrected feed efficiency, IOFC = income over feed costs

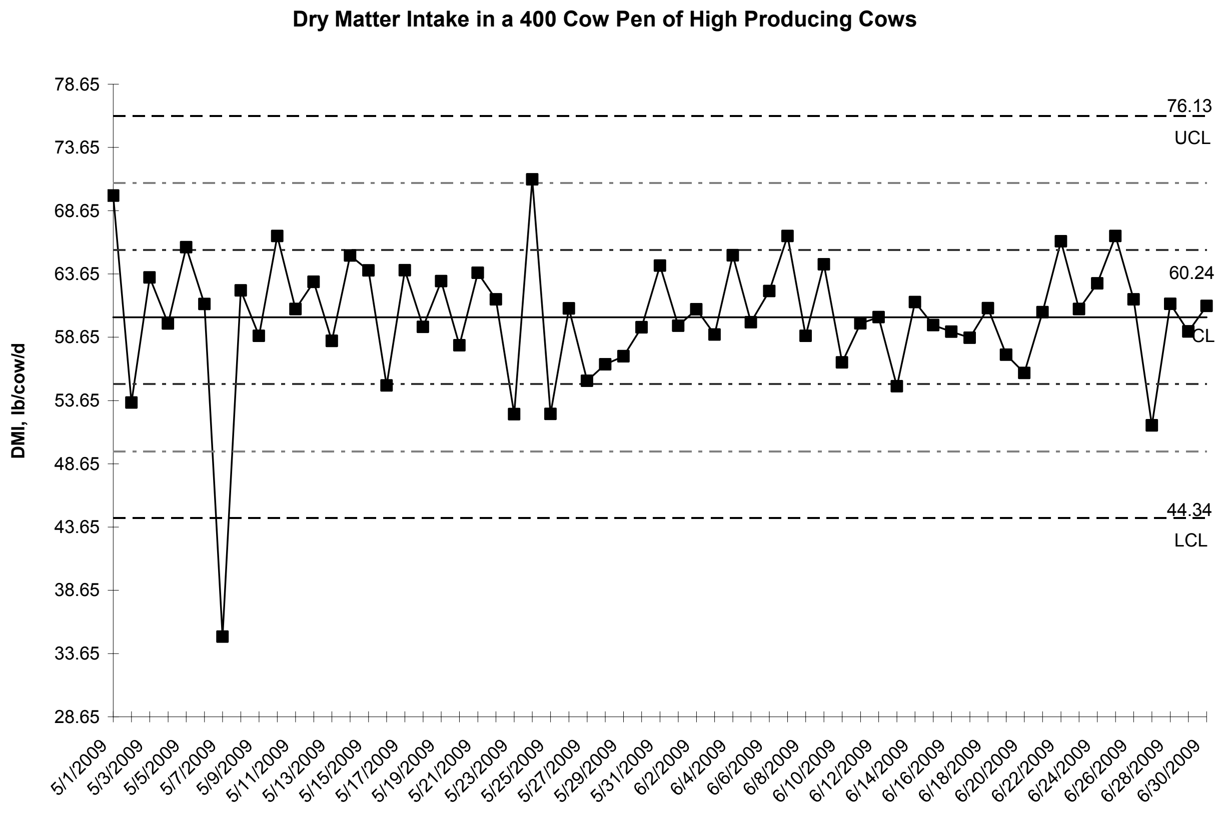

Figure 1. A graph depicting the amount of variation in dry matter intake on a large dairy operation.

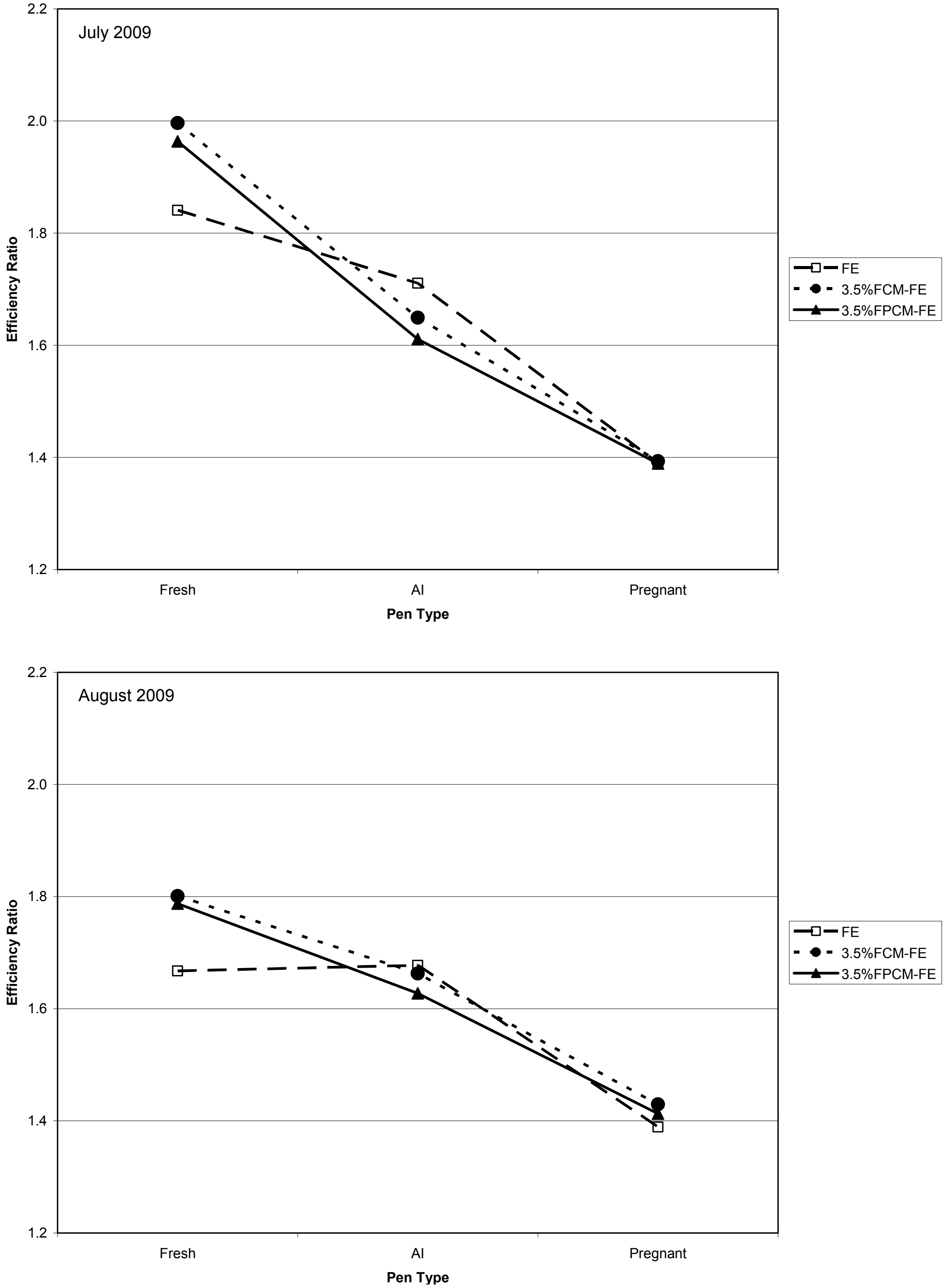

Figure 2. Summary of gross feed efficiency (FE), 3.5% fat-corrected feed efficiency (3.5% FCM-FE), and 3.5% fat and protein-corrected feed efficiency (3.5% FPCM-FE) during July and August 2009.