Improving Feed Efficiency with Feed Additives

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INTRODUCTION

Feed efficiency (**FE**) or dairy efficiency (**DE**) has been a popular topic of observation and discussion on dairy farms the past few years. Many articles, both scientific and popular press, along with several conference proceedings (Atwell, 2006a, 2006b; Britt et al., 2003; Britt and Hall, 2004; Casper et al., 2003, 2004; Hinders, 2005; Hutjens, 2005, 2006, 2007; Linn et al., 2004) have been written on what FE is, how to measure FE, and factors affecting FE on the farm. In this presentation to keep things simplistic, FE will be defined as unit of milk produced per unit of dry matter (**DM**) consumed.

Other livestock industries, such as the poultry, swine and beef industries, have used FE as a benchmark for profitability. Agri-King has been monitoring FE for approximately 15 yr because of our focus on improving profitability of dairy operations. Our first experience (Casper et al., 2003) with increasing FE occurred when dairy herds were having high milk production on lower than expected dry matter intakes (**DMI**). The apparent reason for these dairy herds achieving higher milk production on lower than expected DMI appeared to be related to extremely high quality forages being fed.

Many examples have been published demonstrating the economics of FE (Casper et al., 2003). The interest in FE is due to its relationship to reduce feed cost while increasing the profitability of producing milk. Figure 1 demonstrates the reductions in feed costs on a per cow per day basis as FE increases. What is interesting about this graph is that the slope of this relationship in not linear, but curvilinear. Thus, a greater savings in feed costs can be realized by improving FE from 1.2 to 1.4 rather than improving FE from 1.6 to 1.8 ($.67 vs. $.39) respectively. During periods of low milk prices, finding ways to improve FE or maintaining a high FE can be the difference between producing milk at a profit or a loss.

Figure 1. Change in feed costs as feed efficiency ratio improves and dry matter intake (DMI) declines for producing 70 pounds of milk at a cost of 8 cents per pound of dry matter.

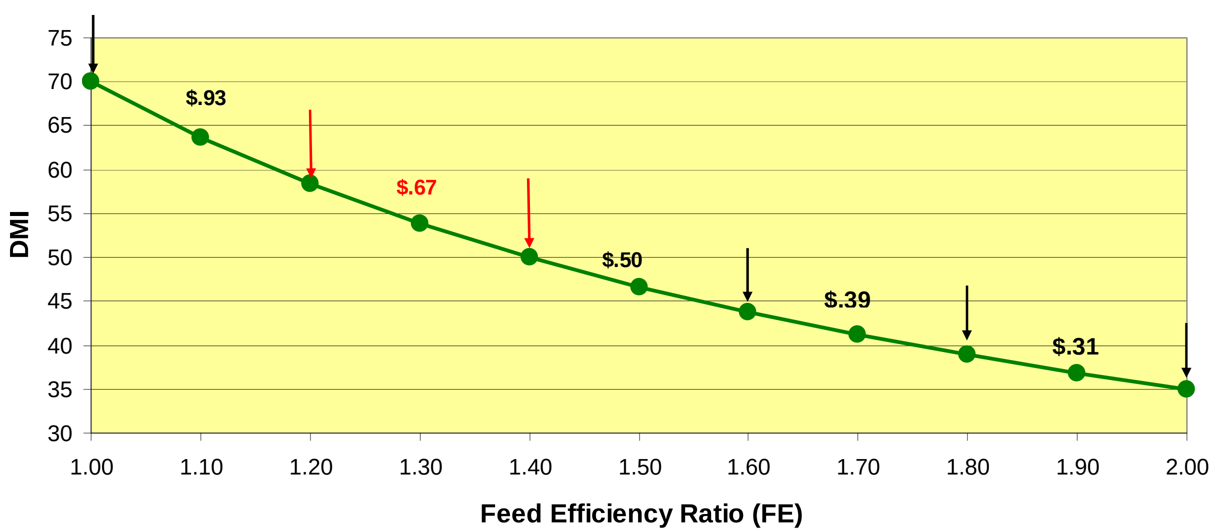


Table 1. Nutrient concentrations, neutral detergent fiber digestibility, cell wall digestibility (CWD), and digestibility of dry matter (DMD) of corn silage samples when ranked by DMD.

Item	CP	ADF	NDF	CWD	Lignin	Oil	NFC	Starch	DMD
Poor	8.0	30.8	51.1	46.8	3.29	1.94	21.1	22.2	55.5
Fair	8.5	29.3	50.1	50.1	3.06	2.29	36.4	22.9	67.8
Medium	8.4	24.5	42.9	52.0	2.44	2.70	43.8	30.4	72.7
Good	8.6	20.9	37.4	54.1	2.01	2.96	39.2	36.2	76.5
Excellent	9.0	16.5	30.7	55.2	1.58	3.25	55.8	43.9	80.9
Average	8.5	24.4	42.7	52.0	2.44	2.69	43.9	30.6	73.0

Many authors have published excellent reviews on factors influencing FE, such as days in milk, age, etc. (Atwell, 2006a, 2006b; Linn et al., 2004; Hutjens, 2005, 2006, 2007). However, our work (Casper et al., 2003, 2004; Casper and Mertens, 2007) has focused on identifying those basic fundamental factors that can be measured, manipulated, and managed to increase FE. This presentation will address what fundamental factor(s) influence FE and how feed additives might be used to influence FE.

DIGESTIBILITY

The National Research Council (2001) demonstrates the greatest factor affecting energy availability to the lactating dairy cow is digestibility. In a small field study, Casper et al. (2004) reported that nutrient digestibility had a direct effect on FE. Six dairy farms feeding a total mixed ration (**TMR**) were used to collect samples of TMR and manure samples along with data on milk production, composition, and DMI. Nutrient composition of TMR and manure samples was measured and nutrient digestibilities were calculated using acid insoluble acid (**AIA**) as an internal digestibility marker. The FE of the dairy herds were directly related to the ration DM digestibility (FE = 0.032 + 0.02 $*$ DMD, $R^2 = .59$, $P < .01$).

Within this study, the range in digestibility of the forages explained most of the variation observed in the digestibility of the ration by the lactating dairy cows. Thus, in most feeding situations, forages usually comprise the largest portion of the ration compared to other feed ingredients. Forages have much more variability in digestibility than grains or commodities; therefore, forage quality and digestibility is going to have a major impact on FE. Tables 1, 2, and 3 demonstrate the ranges in forage quality and digestibility observed from samples submitted to our laboratory. As these tables demonstrate, the range in nutrient concentrations and the digestibility on a DM or NDF basis can be very large between samples within these forage categories.

ENERGY METABOLISM DATABASE

If FE is directly related to nutrient digestibility, then it follows that FE would be directly related to dietary energy density. One of the biggest databases in the world measuring the energy density of the diet is the Energy Metabolism Database from the Energy Metabolism Unit (**EMU**) of the United States Department of Agriculture – Agriculture Research Service (**USDA-ARS**). The EMU database, which was compiled by Casper and Mertens (2007), represents more than 40 yr of studies measuring the energy and protein digestibility of dairy cattle fed diets that varied in forage types, grain sources, protein sources, and fat supplements. Of the 3,018 individual energy and N digestion trials, only 1351 individual trials used lactating dairy cows of different breeds and stages of lactation.

Table 2. Nutrient concentrations, neutral detergent fiber digestibility, cell wall digestibility (CWD), and digestibility of dry matter (DMD) of ensiled haylage samples when ranked by DMD.

Item	CP	ADF	NDF	CWD	Lignin	NFC	DMD
Bad	12.3	47.5	66.0	46.0	12.2	17.5	43.2
Poor	13.9	42.7	61.6	52.3	8.5	19.6	56.6
Fair	18.3	36.1	50.9	57.6	6.9	23.8	66.4
Medium	21.1	31.4	43.7	60.0	5.9	27.2	72.4
Good	22.7	27.7	38.6	61.9	5.2	29.8	76.8
Excellent	24.3	23.8	33.3	65.2	4.4	32.8	81.5
Average	19.8	33.2	46.6	59.0	6.33	25.9	69.8

Table 3. Nutrient concentrations, neutral detergent fiber digestibility, cell wall digestibility (CWD), and digestibility of dry matter (DMD) of hay samples when ranked by DMD.

Item	CP	ADF	NDF	CWD	Lignin	NFC	DMD
Bad	8.71	45.9	71.7	41.6	7.2	15.9	45.9
Poor	12.2	40.6	63.8	48.8	6.3	19.9	55.7
Fair	18.1	34.9	51.7	54.4	6.5	24.8	65.7
Medium	21.3	29.8	42.3	57.1	6.0	29.5	72.4
Good	23.2	25.8	35.4	58.5	5.3	33.1	76.9
Excellent	24.9	21.8	29.2	62.1	4.6	36.2	81.4
Average	18.7	33.2	48.8	54.6	6.14	26.5	67.4

The initial analysis of the EMU database indicated that ruminal acidosis may have occurred in many of the individual balance trials, which negatively affected nutrient digestibility. Thus, digestion trials conducted on lactating dairy cows having inverted fat and protein ratios (acidosis criteria) were removed from the data analysis, which resulted in the final data set having 495 observations relating FE and nutrient digestion. These energy balance trials demonstrated that FE was directly related to the amount of absorbed DM consumed by the lactating dairy cow (Figure 2). (FE = .383 + .074 $*$ DM absorbed g/d; R^2 = .44, P<01). Therefore, lactating dairy cows which have higher FE are those cows that are consuming rations containing more digestible DM.

Because dietary energy density is directly related to the digestibility of the ration, it becomes apparent that FE is directly related to the net energy (**NE**) density of the diet (Figure 3; FE = -.01 + 1.25 $*$ NE, Mcal/kg DM; $R^2 = .60$, $P < .01$). Since, absorbed DM is a function of both digestibility of the ration and DMI by lactating dairy cows, it becomes apparent that improving DM digestibility has the potential to reduce the amount of DMI needed to meet her nutrient requirements. Pushing dairy cows for maximum DMI may not always result in maximal or optimal milk production. Why push cows for high DMI to get 80 lb of milk when higher digestibility can result in the same production on less feed?

Figure 2. The relationship of feed efficiency (FE) to the amount of dry matter (DM) absorbed by lactating dairy cows.

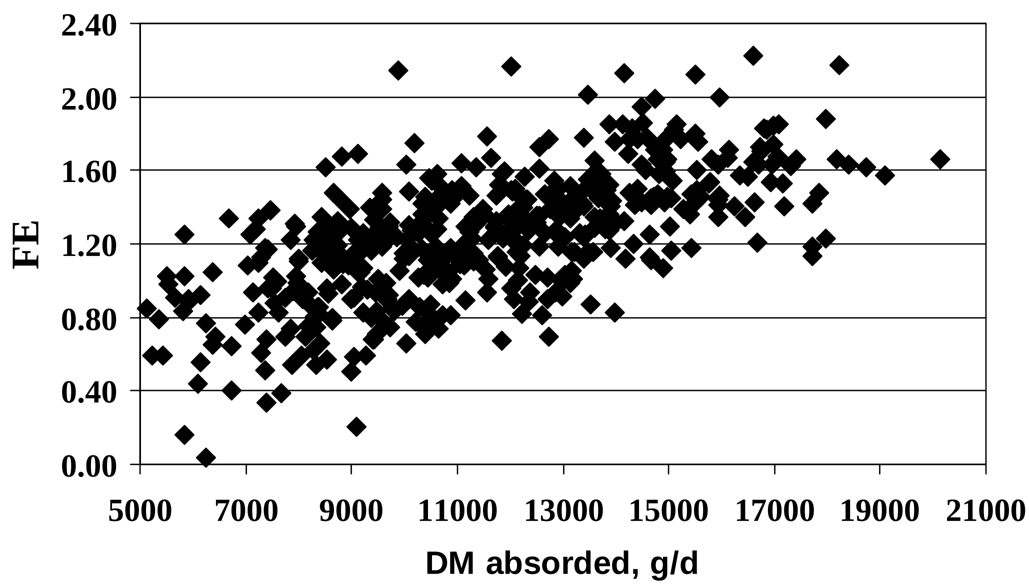
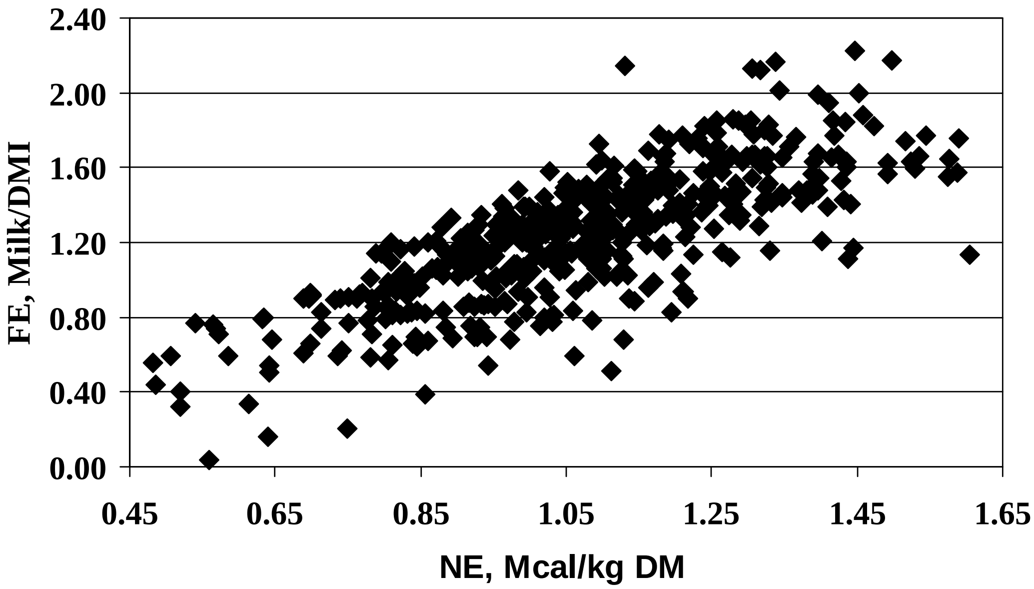


Figure 3. The relationship of feed efficiency (FE) to the net energy (NE) content of the diet fed to lactating dairy cows.



ACIDOSIS

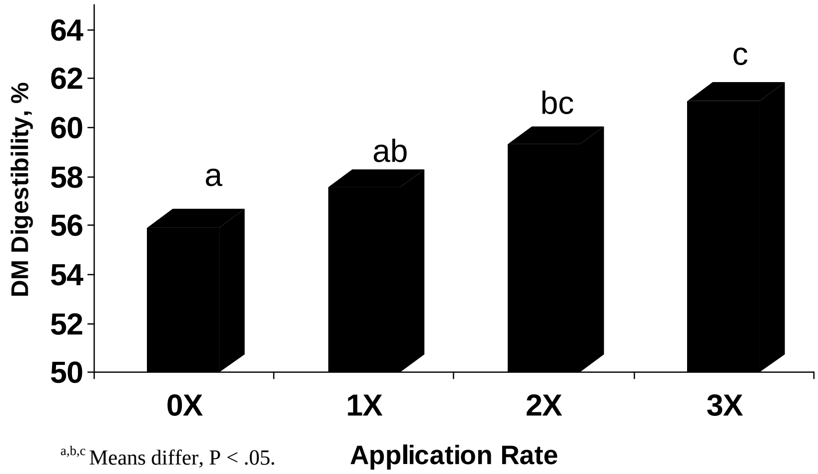
In the EMU database, feeding diets that resulted in lactating dairy cows having inverted fat and protein ratios (acidosis criteria) certainly had a negative effect on FE. Acidosis dramatically reduced the relationship of FE to absorbed DM (FE = 0.40 + 0.10 ∗ DM absorbed, kg/d; $R^2 = .28$, $P < .01$). Acidosis, as expected, caused reductions in the digestibility of ADF and cellulose, which are the fiber fractions of the diet. Casper and Mertens also reported (2007) that acidosis increased the amount of heat produced per unit of digestible energy (51.4 vs. 54.6 %), which resulted in a poorer conversion of digestible energy into NE available for productive purposes. Acidosis negatively influences the energy metabolism of the lactating dairy cow, which we know also affects the health of the cow in a negative manner.

These data demonstrate that the biggest factor affecting energy availability to the lactating dairy cow is ration digestibility. This database analysis also demonstrates that by improving ration digestibility; the FE of the lactating dairy cow will increase as well. The corollary from an environmental standpoint is that improving ration digestibility will reduce manure output. In this data set, fecal energy output ranged from a low of 20 % to more than 60 % of gross energy intake. The data demonstrate that improving the nutrient digestibility of the diet to improve FE should result in more energetically efficient cows. Also, it stands to reason that using the best management practices of forage production to produce the highest quality forages or using feed additives that improve nutrient digestion, while preventing acidosis, have the greatest potential for improving FE.

SILAGE ADDITIVES

Forages represent a major portion of the diet and the digestibility/quality of these forages will have a major impact on ration digestibility (Casper et al., 2004; Casper and Mertens, 2007). In this author's opinion, forage quality cannot be too good. Thus, producing or purchasing forages having the highest digestibility is going to result in the highest FE and the most economical milk production. The use of silage inoculants or silage fermentation aids during the ensiling process has increased in recent years to enhance the production of lactic acid along with other benefits for the long-term storage of forages.

Figure 4. Effect of Silo-King® application rate on dry matter (DM) digestibility of alfalfa haylage by growing wethers.



[a,b,c] Means differ, P < .05.

The use of specific silage inoculants or silage fermentation aids (products) during the forage harvesting process that have been formulated with specific features and benefits have the potential to improve the digestibility of nutrients in ensiled forages. For example, we conducted a study (Ayangbile et al., 2001) evaluating the addition of a silage additive (Silo-King®, Agri-King, Inc., Fulton, IL) during the ensiling process at increasing rates to determine if the digestibility of alfalfa haylage could be enhanced. The additive was applied to alfalfa haylage at increasing applications rates (0.33, 0.67, and 1 lb/ton of alfalfa forage) at the time of ensiling. The ensiled alfalfa haylage was allowed to proceed through the ensiling process and was stored (> 60 d) before being fed to growing wethers. The experimental design was a replicated 4 x 4 Latin square design using metabolism crates to measure the digestion and absorption of nutrients. Figures 4 and 5 demonstrated that application of the additive at increasing application rates resulted in increasing ($P < .05$) the digestion and absorption of DM and NDF. Thus, improvements in DM and fiber (NDF) digestibility can be achieved by treating forages during the ensiling process. These improvements have the potential to improve the FE of lactating dairy cows through improvements in the digestibility of forages by the animal.

DFM and ENZYMES

This is an exciting area of research and product development being undertaken by several companies that holds great promise for improving FE by lactating dairy cows. Schingoethe et al. (2004) demonstrated that feeding enzymes resulted in an improvement in milk production. The stage of lactation and the cows' energy requirement will dictate the type of responses observed in FE.

For example, we have developed a product based on the combination of direct fed microbials (**DFM**) and enzyme technologies, (Ru-Max, Agri-King, Inc., Fulton, IL) that was evaluated using 1000 dairy cows split into 2 groups using a switchback trial design. Milk production (Figure 6) was similar (P >.10) for both groups of cows, but the improvements in ration digestibility resulted in a 5.3 lb. decrease in DMI. Therefore, feeding the DFM resulted in an improvement in FE of .16 units (1.57 versus 1.73 for control and treatment, respectively). This resulted in a return on investment of 4.2 for every $1 spent. These types of products hold promise in improving the FE of lactating dairy cows and the economics of producing milk.

Figure 5. Effect of Silo-King® application rate on neutral detergent fiber (NDF) digestibility of alfalfa haylage by growing wethers.

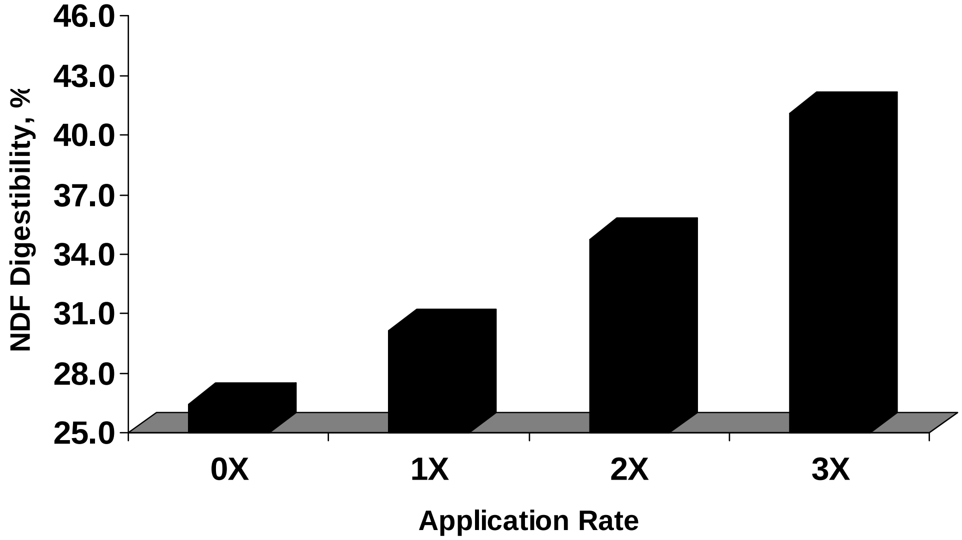
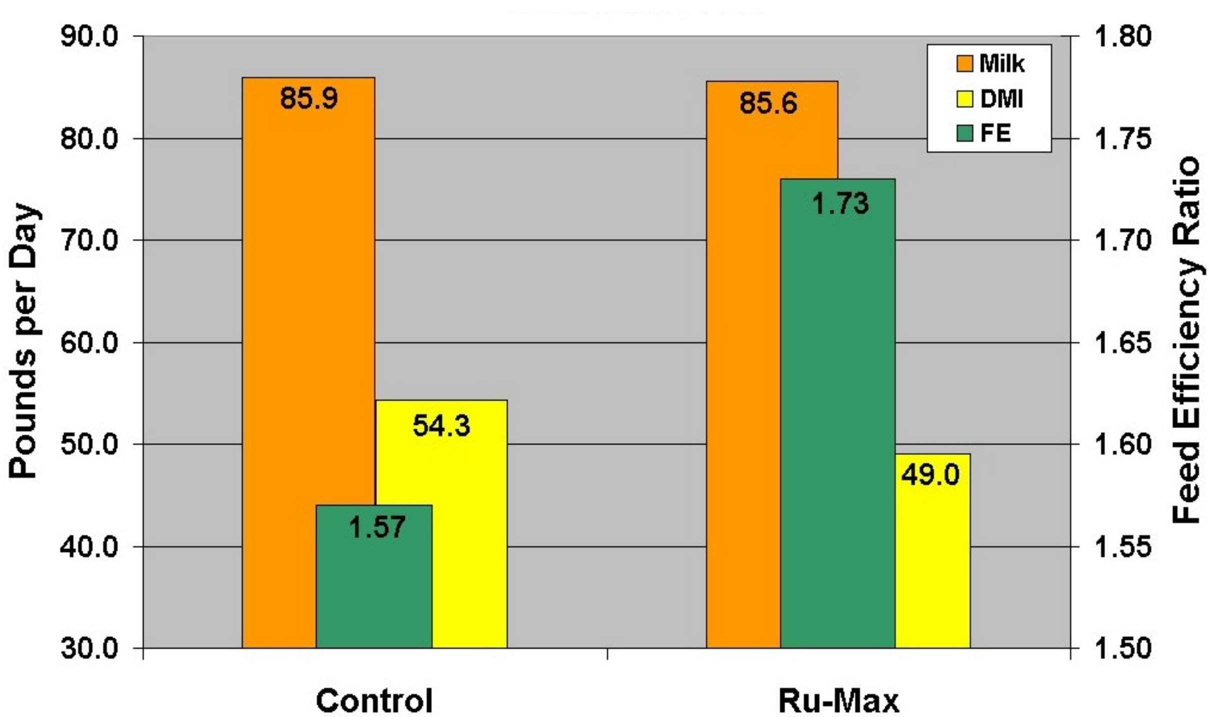


Figure 6. Milk production, dry matter intake (DMI), and feed efficiency (FE) ratio when lactating dairy cows are fed the same ration without (Control) or with Ru-Max.



YEAST

Table 4. Nine trial summary with Rumensin® feeding affects on milk production, milk components, and feed efficiency (FE).

		Rumensin® Level		
Parameter	Control	11 g/ton	15 g/ton	22 g/ton
DMI, lb/d	43.9	43.4	42.8 [a]	42.3 [b]
Milk, lb/d	65.0	66.7	66.8	67.5 [a]
Fat, %	3.65	3.53 [a]	3.49 [b]	3.38 [b]
Protein, %	3.15	3.13	3.13	3.10 [a]
FE, % increase		2.0	2.5	4.0

[a] Control vs Rumensin Level ($P < .05$).
[b]Control vs Rumensin Level ($P < .01$).
Adapted from Elanco, 2004.

Yeast and yeast cultures have been fed to dairy cattle for more than 60 yr. Yeast culture has improved DMI and milk production in controlled studies (Miller-Webster et al., 2002; Schingoethe et al., 2004; White et al., 2008). Schingoethe et al. (2004) reported an increase in FE of 0.1 unit (P < .04) when cows where fed yeast. This was the result of numerically greater (P > .10) milk production and lower DMI. It is interesting to note that milk fat was numerically increased due to feeding yeast, which would be hypothesized to occur from greater DM and fiber digestion. Miller-Webster et al. (2002) reported increases in DM digestibility of 2.4 and 5.0 percentage units when yeast products were evaluated using a continuous culture system. White et al. (2008) demonstrated a 3.2 percentage unit improvement in NDF digestibility by feeding cows yeast culture compared to cows receiving the same diet without yeast culture. Using yeast as a feed additive has the potential to improve FE by approximately 0.1 units by improving rumen function and nutrient digestion.

It is the authors' experience that reductions in DMI do not occur until cows are in a positive energy balance or gaining body weight. It is interesting to note that in the study by Schingoethe et al. (2004) that a numerical increase in body condition score was observed with the reduction in DMI for fed yeast.

MONENSIN

Monensin (Rumensin®, Elanco, Greenfield, IN) was approved by the FDA for feeding to lactating dairy cows to improve milk production efficiency. Monensin achieves this effect by shifting ruminal fermentation towards more propionate production. Monensin also has a protein sparing effect in the rumen; thereby reducing the breakdown of protein. Table 4 contains a summary of 9 trials demonstrating the effects of monensin to improve the FE of lactating dairy cows. The improvements in FE are dose related because increasing the concentration of monensin in the diet results in additional improvements in FE.

Depending on the stage of lactation or days in milk, monensin may improve FE through 1 of 2 mechanisms. The first mechanism,observed in early lactation and high producing cows, results in an increase in milk production on similar amounts of DM. This occurs because gut fill regulates DMI and the greater energy supply drives milk production. However, the 2nd mechanism, which comes into play in mid- to late-lactation dairy cows, results from a reduction in DMI while maintaining similar milk production. Both mechanisms improve or enhance FE; however, it depends on the stage of lactation.

CONCLUSIONS

The greatest factor affecting nutrient availability to lactating dairy cows is the digestibility of the ration. The FE potential of the dairy herd is directly related to the DM digestibility and energy density of the forages and feeds used in ration formulation. Producing or obtaining forages with the highest digestibility possible represents the greatest potential for improving FE and reducing the cost to produce 100 lb milk. Proper ration balancing to maximize fiber digestion and eliminating acidosis will improve FE and energetic efficiency of the dairy cow. The use of forage inoculants and feed additives (yeast cultures, live yeast, DFM, and enzymes) that improve ration digestibility can be used to further improve FE; however these improvements are not as dramatic as improving forage quality. Improving FE can increase the income over feed costs and reduce the cost to produce 100 lb milk. Tracking and improving FE on your dairy operation using those nutritional technologies that enhance digestibility and FE will improve profitability in good times and can be the difference between profit and loss in times of low milk prices.

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