

Milk Production Efficiency in Dairy Cows Fed Monensin

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Introduction

There are several polyether ionophores approved in the US with indications for a variety of uses in cattle, sheep and goats as well as poultry (lasalocid, monensin, narasin and salinomycin). Important differences in activity between compounds exist and relate especially to differences in chemical, physical and biological properties, most notably drug specific ion selectivity, and pharmacokinetic properties (Shumard and Callender 1968).

Rumensin (monensin) is the first ionophore to be approved by the Food and Drug Administration (FDA) for increased milk production efficiency (production of marketable 4.0% solids-corrected milk per unit of feed intake) when fed to dairy cows.

The dairy industry has adopted new technologies and improved the efficiency of milk production over the years. Milking machines, artificial insemination, total mixed rations and bovine somatotropin are examples of technologies that have led to a more than four fold increase in milk production per cow since 1940. However, the feed required for production of that milk only increased two fold (NRC, 2001). These changes led to a doubling in the efficiency of milk production. However, milk production efficiency (MPE) as a metric, is not commonly measured like feed conversion is in other livestock enterprises. For example, Rumensin increases feed efficiency in feedlot cattle. More than 95% of the cattle fed in feedlots in the U.S. use Rumensin in their cattle rations (Raun, 1990).

Milk Production and Composition

A number of investigations have demonstrated that monensin increases milk yield when fed to cows offered mixed grain and forage diets (Mohsen et al 1981; Kube et al 1988; Granzin and Dryden 1999) or pasture based diets (Pankhurst and McGowan 1978; Lynch et al 1990; Hayes et al 1996).

While milk fat yields are frequently unchanged (Pankhurst and McGowan 1978; Moate et al 1990; Hays et al 1996), milk fat concentration is often reduced (Walker et al 1996).

Milk protein content has been unchanged (Granzin and Dryden 1999; Moate et al 1990; Ramanzin et al 1997) leading to increased protein yields (Moate et al 1990; Lowe et al 1991; Granzin and Dryden 1999).

In addition to the significant improvements in milk production described above, studies by Symanowski et al (1999) and McGuffey and Giner (1998) found that the efficiency of milk production was also improved, by 3.6% and 7.0% respectively, further increasing the economic returns of milk production.

McGuffey et al (2001) pooled the results of 11 studies of Rumensin premix (administered at approximately 300mg/head/day) in dairy cattle. The results of the statistical analysis of this large series of studies are presented in table 1.

Metabolic Implications

The mode of action of ionophores is specific to ruminal fermentation, in which rumen bacteria ferment carbohydrates and produce volatile fatty acids (VFA), methane, carbon dioxide, and water. Rumen microbiologists divide these rumen bacteria into two general categories, those that ferment fiber and those that ferment starches and sugars (Overton, 2004).

Monensin shifts the microbial population in the rumen by promoting the growth of more efficient bacteria involved in carbohydrate metabolism. This results in an increase in propionate production in the rumen (Russell, 1989). Thus, more energy is obtained from every pound of feed.

Haimoud et al (1995) investigated the effect of monensin (33ppm) on nitrogen, starch and fibre digestion in the lactating dairy cow and found that compared with control cows, monensin reduced rumen degradation of protein allowing greater flow of amino acids to the small intestine. Haimoud et al (1996) in a study of non-lactating dairy cows also observed increased flow of nitrogen in the form of essential and nonessential amino acids to the duodenum where increased rates of absorption were also observed.

The sudden onset of lactation places significant metabolic demands on the cow. The energy requirement commonly doubles in the first 24 hours after parturition. Glucose precursors, primarily propionate and amino acids, become essential for a successful lactation. Most of this glucose is produced by liver, and propionate is the single largest contributor to liver glucose production. Glucose synthesis must increase to meet the needs of lactose synthesis. Lactose concentration is fairly constant in milk. Glucose is also used to generate reducing equivalents for the synthesis of milk fat.(Bennick et al, 1972). Total energy requirement can increase three-fold or more in a matter of three to four weeks at a time when dry matter (energy) intake fails to meet demand. High-producing dairy cows meet the increased energy requirement by mobilizing body fat.

Milk Production Efficiency

Feed cost is still the largest operating expense in milk production. Therefore, any improvement in the conversion of feed to milk has a direct impact on the profit margin of the dairy farm (Britt et al, 2004). Dairy records from Wisconsin and New York reveal that profitability of dairy farms is closely linked to the amount of milk produced per pound of feed consumed. Hutjens (2003). defines dairy efficiency as milk produced per pound of feed consumed. In this definition, milk is often corrected to 3.5 % fat-corrected milk (FCM). Because milk varies in milk fat % day to day, scientists developed equations to standardize the energy value of milk in order to more accurately compare milks with differing yields and fat percents. Gaines (1928) developed the term, 4% fat-corrected milk (FCM). More recently, 3.5% FCM is used because milk fat percent is lower than in 1928 when the original equation was developed. The formulas for calculating 4% FCM, 3.5 % FCM and SCM are:

$$4\% \text{ FCM, lb} = 0.4 \times \text{milk yield, lb} + 15 \times (\text{milk yield, lb} \times \text{fat \%})$$

1 pound of 4.0 % FCM contains 0.34 Mcal (Tyrrell, 1965)

$$3.5 \% \text{ FCM, lb} = \text{Milk yield, lb} \times [(0.4324) + (16.218 \times \text{fat \%} \times 0.01)]$$

1 pound of 3.5 % FCM contains 0.313 Mcal

$$\text{SCM} = \text{Milk, lb} \times ((12.24 \times \text{Fat}\%) + (7.10 \times \text{Protein}\%) + (6.35 \times \text{Lactose}\%) - 0.0345)$$

1 pound of SCM contains 0.34 Mcal (Tyrrell, 1965)

Elanco received approval to feed Rumensin to dairy cattle by the U.S. Food and Drug Administration. The claim “*For increased milk-production efficiency*” in dairy cows defined as “*marketable solids corrected milk (SCM) per unit of feed intake*” was granted by FDA following the review of a large data package on efficacy and safety of Rumensin.

Rumensin and Milk Production Efficiency

The claim was based on a study conducted in 9 locations, six in the United States and three in Canada. A total of 966 Holstein dairy cows including 357 primiparous and 609 multiparous cows were initially assigned to treatment. The four treatments were Rumensin at 0 g/ton (control), 7 g/ton, 15 g/ton and 22 g/ton (100% dry matter basis). Rumensin was fed continuously throughout a complete lactation and dry period.

Milk production efficiency (MPE) was expressed as marketable SCM per Mcal NE_L intake corrected for changes in body weight. Energetics of body weight change were considered according to the following formula:

$$\text{MPE} = \frac{\text{Solids Corrected Milk, lb}}{NE_L - (k \times \text{Change in Body Weight})}$$

Where, $k = 5.12$ if body weight increased and $k = -4.92$ if body weight was lost (NRC, 1989).

Feeding of Rumensin consistently increased MPE at all doses at all sites (Figure 1). Results of pooled statistical analysis showed that MPE was increased linearly with dose of Rumensin. The minimum effective dose of Rumensin was established statistically using the concept of overlapping confidence intervals (Figure 2). The results established the effectiveness of Rumensin for use in dairy cows within the dose range of 11-22 g/ton on a 100% dry matter basis (Table 2).

Commercial Implications

Dairy operations ship milk on regular basis either daily or every other day. Milk components (fat, protein, lactose and other solids) are determined on each shipment. An example printout for a milk shipment (300 lactating cows) is shown below:

Date	Milk, lb	Fat %	Protein %	Lactose %	Total Solids %
08/10/04	44290	3.63	2.99	4.80	12.12

In the example the SCM equation would be

$$\begin{aligned} \text{SCM} &= (44290) \times ((12.24 \times 0.0363) + (7.10 \times 0.0299) + (6.35 \times 0.0480) - 0.0345) \\ &= 44290 \times ((0.4443) + (0.2123) + (0.3048) - 0.0345) \\ &= 19679 + 9402 + 13500 - 1528 \\ &= 41,053 \text{ pounds of SCM} \end{aligned}$$

Since milk was picked up every two days, daily SCM production would be: 41,053/2 or 20,526.5

Dry matter intake in commercial dairies is obtained by measuring quantity of feed offered, quantity of feed refused (usually after 24 hrs), percent dry matter in the ration, and number of cows fed. Few operators measure feed refusals. If these are not known, dry matter intake offered to cows taken from the ration sheet provided by the herd nutritionist can be used (Bagg, 2003). The ration for the example herd of 300 cows was feeding 54 pounds of dry matter having an energy density of 0.76 Mcal NE_L per cow per day.

The claim for Rumensin, Milk Production Efficiency (MPE) is calculated as

$$\begin{aligned} \text{MPE} &= \frac{20526}{(54) \cdot (0.76) \cdot 300} \\ &= \frac{20526}{12312} \\ &= 1.67^* \end{aligned}$$

An increase in MPE of 2 % with Rumensin changes MPE to 1.70 (1.67 * 1.02)

$$\begin{aligned} \text{Improvement with Rumensin} &= 1.70 \times 12312 \text{ (Mcal from feed)} \\ &= 20930 \end{aligned}$$

An extra 404 pounds of SCM shipped.

Dairy Efficiency (DE) has been defined as energy corrected milk such as 3.5 % FCM as the output and feed dry matter as the input. In the above example, DE would be:

$$\begin{aligned} \text{DE} &= \frac{(44290/2) [(.4324 + (16.218 \cdot \text{Fat \%} \cdot .01)]}{(54 \cdot 300)} \\ \text{DE} &= \frac{(22145 \cdot 1.021)}{16,200} \\ \text{DE} &= 1.3960 \end{aligned}$$

*Hutjens (2003) suggests for large breeds, DE under 1.3 is considered poor, 1.3 - 1.5 desirable, and over 1.5 excellent.

An increase in DE of 2 % with Rumensin changes DE to 1.424 (1.396 * 1.02)

$$\begin{aligned} \text{Improvement with Rumensin} &= 1.424 \times 16,200 \text{ (DMI of feed)} \\ &= 23065 \end{aligned}$$

An extra 453 pounds of 3.5% FCM shipped.

Rumensin is effective and approved by FDA for use in dairy cows to increase milk production efficiency (production of marketable solids-corrected milk per unit of feed intake) at doses between 11 g/ton and 22 g/ton on a 100% dry matter basis.

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Table 1. Effect of monensin on the lactational performance of dairy cows.

Parameter	No. Studies	Control	Monensin	Difference (%)	Significance
MONENSIN PREMIX¹					
Milk yield (l/d)	11	27.5	28.8	+4.7%	P<0.01
Fat content (%)	11	3.98	3.78	-5.0%	P<0.01
Fat yield (kg/d)	9	1.037	1.032	-0.5%	NS
Protein content (%)	11	3.25	3.20	-1.5%	P<0.05
Protein yield (kg/d)	9	0.846	0.872	+3.1%	P<0.01

¹Erasmus et al 1993; Thomas et al 1993; Walker et al 1996; van der Werf et al 1998; McGuffey and Giner 1998; Symanowski et al 1999; Phipps et al 2000

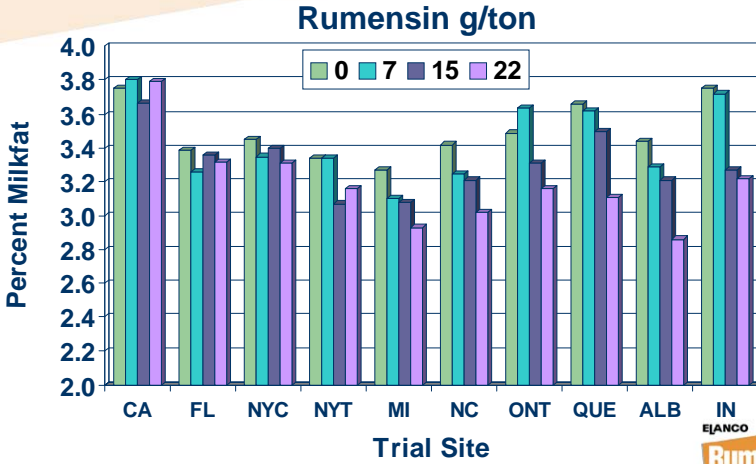
Table 2. North American Efficacy Study

North American Efficacy Study

Parameter	0 (Control)	11 g/ton	15 g/ton	22 g/ton
Average dry matter intake (lbs/day)	43.9	43.4	42.8 ^a	42.3 ^b
Daily milk yield (lbs)	65.0	66.7	66.8	67.5 ^a
Milkfat %	3.65	3.53 ^a	3.49 ^b	3.38 ^b
Daily milkfat yield (lbs)	2.34	2.34	2.33	2.27
Protein %	3.15	3.13	3.13	3.10 ^a
Daily milk-protein yield (lbs)	2.03	2.09	2.07	2.09
Daily solids-corrected milk yield (lbs)	58.2	58.6	58.0	58.0
Improvement in milk-production efficiency ¹		2%	2.5%	4%

Figure 1.

Effect of Rumensin Dose on Milk Fat Percent by Trial Site



N.A. Rumensin Dairy 9-trials, cows >100 DIM



Figure 2.

Determination of Minimum Effective Dose

