

FEED ADDITIVES IN DAIRY NUTRITION AN INDUSTRY AND FARM PERSPECTIVE

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Introduction

Feeding high producing cows continues to challenge dairy farmers and nutritionists. Also, dairy profit margins vary as milk prices and feed costs shift yearly. Feed costs represent the largest input cost to produce milk (estimated to be 35 to 50 percent). Goals of a successful feeding program are listed below.

- Optimize milk yield
- Produce desirable milk components
- Maximize rumen microbial yield
- Stimulate dry matter intake
- Produce key nutrients for mammary gland synthesis

Feed additives are a group of feed ingredients that can cause a desired animal response in a non-nutrient role such as pH shift, growth, or metabolic modifier (Hutjens, 1991). Several feed additives contain nutrients such as sodium in sodium bicarbonate or protein in yeast culture. A survey of 61 high producing US herd managers in 1992 (averaging 24,418 pounds of milk) revealed variable use of feed additives in Table 1 (Jordan and Fourdraine, 1993) compared to an earlier survey of top herds. Feed additives are not a requirement or guarantee for high productivity or profitability.

Evaluating Feed Additives at the Farm Level (4 R's)

Four factors can be considered to determine if a feed additive should be used: anticipated response, economic return, available research, and field responses (Hutjens, 1991). Response refers to expected performance changes the user could expect or anticipate when a feed additive is included. Several examples are listed below.

- Higher milk yield (peak milk and/or milk persistency)
- Increase in milk components (protein and/or fat)
- Greater dry matter intake
- Stimulate rumen microbial synthesis of protein and/or volatile fatty acid (VFA) production
- Increase digestion in the digestive tract
- Stabilize rumen environment and pH

- Improve growth (gain and/or feed efficiency)
- Minimize weight loss
- Reduce heat stress effects
- Improve health (such as less ketosis, reduce acidosis, or improve immune response)

Returns reflect the profitability of using a selected additive (Table 2). If milk improvement is the measurable response, a breakeven point can be calculated. For example, a consultant recommends an additive that raises feed cost 10¢ per day. If milk is valued at 12¢ per pound, every cow must produce 0.8 pound more milk to cover the added cost associated with the additive. Another consideration is if all cows receive the additive, but only cows fresh less than 100 days respond. Responding cows must cover the additive costs for all cows (responsive and non-responsive cows). One guideline is an additive should return two dollars or more for each dollar invested to cover non-responsive cows and field conditions which could minimize the anticipated response.

Research is essential to determine if experimentally measured responses can be expected in the field. Studies should be conducted under controlled and unbiased conditions, have statistically analyzed results (determines if the differences are repeatable), and have been conducted under experimental designs that would be similar to field situations.

Results obtained on individual farms are the economic payoff. Dairy managers and nutritionists must have data to compare and measure responses. Several tools to measure results (to evaluate responses on a farm) include DHI milk records (peak milk, persistency, milk components, and milk curves), reproductive summaries, somatic cell count data, dry matter intake, heifer growth charts, body condition graphs, and herd health profiles which will allow critical evaluation of a selected additive.

Evaluating Feed Additives at the Industry Level (7 R's)

Feed industry personnel and consultants may evaluate feed additive using a slightly different approach; the seven "R's" including and basic four R's as listed above plus reliability, repeatability, and relativity. Reliability is based on the research data base that has been published on a feed additive.

- The ability to predict that the product can have a positive response of a wide range of feeding
- Establish a normal curve of response in various studies
- Minimize the risk of not obtaining a positive benefit to cost ration

Repeatability represents the statistical data results (mean and standard deviation). Each feed consultant must determine what level of risk she or he will assume when selecting each feed additive. The bottom line is the probability of a profitable response. Relativity refers to other products, management changes, or on-farm practices that could replace the feed additive being used. For example, an anionic product could be removed if the nutritionist could reduce close ration levels of potassium to less than one percent, adapt a "no dry period" for third and over lactation cows, and/or drench each three lactation cows with a calcium gel product.

A second aspect of industry selection of a feed additive is which commercial product should be purchased. “Me too syndrome” is a term referring to a products that have limited research and results, but market on the concept that their products are identical to the industry base standard. One example is sodium bicarbonate, a chemical defined product that has no unique processing to make it more soluble or rumen active vs. inert.

A Look at New Research and Products

Biotin

Biotin has been associated with formation of hoof horn. Deficiency signs in calves include soft hooves, skin lesions, and hair loss. In swine and horses, a deficiency has resulted in cracks and fissures in the foot and toe. Biotin is required by ruminants and is synthesized by rumen bacteria. If rations are high in concentrate, the synthesis of biotin in the rumen is reduced due to the acid environment and shift in rumen microbes. Recent studies with beef and dairy cattle fed supplemental biotin are summarized below (Seymour, 1998).

- White line separation was reduced by 17 percent (27 verse 10 percent) in the rear lateral claw and 18 percent (20 verse 2 percent) in the rear medial claw when 20 mg of biotin was fed to first lactation Holstein cows after 100 days of supplementation.
- Sole ulcers were reduced in 180 dairy cows receiving 10 mg per day of biotin by 2.6 percent (3.3 verse 0.7 percent) compared to unsupplemented cows after 24 months of supplementation.
- Heel warts were reduced 20.2 (after 11 months) to 37.3 (after 4 months) percent in 56 dairy cows fed 20 mg of supplemental biotin per head per day during an 11 month study.
- Claw lesions (236 claws in 160 cows in 82 dairy herds) were improved and short term healing was enhanced when 20 mg of biotin were fed per day. Plasma biotin concentrations were correlated with faster new horn formation over lesions in biotin-supplemented cows.
- Vertical fissures or sand cracks were reduced 15.1 percent (29.4 verse 14.3) in 265 Hereford cows fed 10 mg per cow per day. Biotin-supplemented cows were 2.5 times less likely to develop sand cracks compared to unsupplemented cows.

Besides the improvement in foot health, an Ohio study reported 314 kilograms more milk (11,794 kg in control cows versus 12,108 kg in biotin-supplemented cows) ($P < 0.05$). In another study, biotin supplemented cows experienced fewer days to conception (116 versus 99) and services per conception (3.02 versus 2.69). In a second Ohio State study, a milk increase of 2.3 kilograms of milk per day was reported suggesting the role of biotin may enhance a metabolic route mediated by enzymes, increased glucose synthesis, and/or improved fiber digestion (Weiss and Zimmerly, 2000).

The recommended level for biotin supplementation is 10-20 mg per day starting at 15 months of age for heifers. Cows should be supplemented with 20 mg per day throughout lactation and 10 mg per day during the dry period. Target animals include chronic hoof problems cows, high producing cows, cows fed high grain rations, and heifers from breeding to calving. The cost is typically 8 to 10 cents per cow per day. The benefit to cost ratio is 3:1 based on a milk yield increase of two kilograms. The economics is more favorable if reproduction improves and lameness is reduced. Foot-related response to biotin supplementation may take several months before changes and improvements occur.

Protected Choline

Choline is usually classified as a B vitamin, but does not fit in the traditional role of a vitamin. Its roles in dairy nutrition include minimizing fatty liver formation, improving neurotransmission, and serving as a methyl donor. The lack of response to dietary choline is due to extensive rumen degradation estimated to be 85 to 95 percent of supplemental choline. When choline was infused postruminal (15 to 90 grams per day), the average milk response to choline was 1 kg milk per day, .17 percent fat, and 1.5 kg fat corrected milk per day (Erdman, 1990). The primary mechanism of interest in dairy cows is choline's effect on triglyceride transfer from the liver, especially in early lactation when free fatty acids from adipose tissue are mobilized and formed into lipoproteins requiring a methyl donor (Erdman, 1990). Choline could also spare methionine (10g of choline would provide the equivalent methyl groups found in 44g of methionine). Diets low in methionine may be improved by adding 30g of rumen-protected choline (Grummer et al, 1987). Choline is more difficult to protect in the rumen than amino acids because it is extremely hygroscopic.

Recently, sources of rumen-protected choline have been manufactured by encapsulation and fat coating. Cornell workers have reported rumen-protected choline significantly reduced NEFA conversion to stored triglyceride and increased glycogen in livers of dairy cows at calving and in early lactation (Overton et al, 2000). These metabolic changes can reduce the risk of clinical ketosis. New York field studies have also measured an average increase of 2.2 kg of milk per cow per day during the postpartum feeding period. One commercial product is feed at the rate of 15 gram of protected choline (in a 60 gram encapsulated product) starting 21 days prepartum to 50 days postpartum at a cost of 30 cents per cow per day. Improved encapsulation allows protected choline to be mixed with dry feed ingredients without loss of protection.

Anionic Salts and Products

Anionic salts and products (ammonium chloride, ammonium sulfate, aluminum sulfate, magnesium sulfate, calcium chloride, and commercial acid treated feeds) cause rations to be more acidic, increasing absorption of dietary calcium, and stimulating mobilization of bone calcium due to improvement in parathyroid hormone receptor sites (NRC 2001). When more calcium is available, the cow is able to maintain blood calcium levels caused by the calcium drain due to milk synthesis. Canadian workers (Block, 1984) reported 48 percent milk fever when cationic (control) diets were fed and no milk fever with anionic diets. Colorado researchers (Oetzel, 1988) reported a 13 percent decrease (from 17 to 4 percent) in milk fever when cows received anionic salts with calcium intakes as high as 150 grams per day. Feeding 100 grams of ammonium chloride and 100 grams of magnesium sulfate for 2 to 3 weeks prepartum has resulted in favorable responses

reducing milk fever and hypocalcemia, lowering retained placenta, and increasing dry matter intake postpartum (Beede et al, 1991). Anionic salts are unpalatable and should be mixed with 1 to 2 kg of a palatable carrier (such as distillers grain, molasses, or heated soybeans), and pelleted to avoid separation (Oetzel et al, 1992). Additional research is needed to determine optimal combinations of anionic salts, levels, and length of feeding. Monitoring urine pH is an effective way to determine if adequate levels of anionic product are being consumed relative to dietary potassium levels (Jardon, 1995). Target values for Holsteins are a pH from 6.2 to 6.8. For Jerseys, a pH from 5.5 to 6.0 may be needed for optimal response. If urine pH is over 7, the benefit of anionic products is not occurring. If urine pH is too low, excessive metabolic acidosis is occurring which can lead to kidney and health problems. Recently chlorine sources of anionic salts have proven to be more aggressive acidifiers compared to sulfates when monitoring urine pH. Hydrochloric acid (sprayed on feed) improves feed palatability compared to salts while reducing urine pH. Several commercial products are available with field reports of improved palatability.

Ionophores

Monensin (common brand name is Rumensin) and lasalocid (common brand name of Bovatec) are antibiotics that can change rumen fermentation patterns (higher propionic acid and less methane) by reducing gram positive bacteria. The initial research was conducted with beef cattle. In trials with monensin involving dairy animals, growth improvement ranged from 6 to 14 percent with no negative effects on reproduction, calving ease, or calf size. Pennsylvania data indicated heifers calved 38 days earlier due to improved growth and feed efficiency resulting in a savings of \$62. The cost of monensin was 1.2¢ per day or \$5 per animal resulting in a benefit to cost ratio of 12:1 (Hutjens, 1991). Both ionophores are labelled as a coccidiostats in growing heifers. The mode of action for ionophores include a shifting of VFA and methane production in the rumen favoring growth and feed efficiency, sparing dietary protein, and changing rumen fill and rate of passage. The benefit of ionophores as a coccidiostat would improve growth and health in young animals. In Canada, monensin has been cleared for lactating and dry cows as a coccidiostat and a 50 percent decrease in subclinical ketosis as been reported (Duffield et al, 1998). Levels varied from 8 to 24 mg per kg of dry matter (300 to 350 milligrams per cow per day). Dry matter intake is modestly decrease (< 1 kg) with milk slightly increases (<1 kg of milk) was reported by Canadian workers (Symanowski et al, 1999).

With the FDA clearance to use monensin for dry and lactating dairy cow, dairy managers have a new tool to improve feed efficiency and herd health. Table 3 is a summary nine studies in the U.S. and Canada including 357 first lactation cows (primiparous) and 609 second and great lactation cows (multiparous) starting 21 days prepartum through the entire lactation. The following points should be considered by dairy managers, nutritionists, and veterinarians.

- Efficiency of milk production increased 2 to 4 percent with recommended level of 11 grams to 22 grams per ton of total ration dry matter (TMR) on a dry matter basis.
- With higher milk yield and lower components at higher levels, the amount of solids-corrected milk did not change.
- Dry matter intake did not change in early lactation and dropped in the later stages of lactation.

- Body weight was not different between controls and supplemented cows.
- The benefit to cost ratio for monensin for lactating cows was 5 to 1.

Based on these data and Canadian research results, monensin should be feed to dry cows (300 to 350 mg per day) reducing displaced abomasum, increasing glucose precursors lower ketosis risk, and allowing transition of dry cows. Lactating cows should receive monensin to increase feed efficiency, reduce methane losses, improve protein status, and reduce bloat risk for cows on pasture. Growing heifers should be feed 40 to 200 mg per day (depending on body weight) to improve feed efficiency and reduce the risk of coccidiosis.

Yeast Culture

Yeast culture is a live culture of yeast (a fungi) and the media on which it was grown and dried so as to preserve the yeast's fermenting capacity. Several other types of yeast products are available from fermentation processes (such as brewers and distillers yeast). A summary of 7 yeast studies concluded cows fed yeast averaged 25.1 kg of 4% FCM compared to control cows at 23.5 kg (Hutjens, 1991). Early lactation cows had a significant increase in milk yield while mid lactation cows had no response (Harris and Lobo, 1988). Milk composition (fat and protein levels) response is also variable. Illinois (Dann et al, 2000) and Canadian workers (Robinson and Garrett, 1999) have reported significant increases in dry matter intake when yeast culture was fed to transition cows resulting in higher milk yields and less weight loss postpartum.

The main effect of yeast culture is to stabilize the rumen environment. Concentrations of cellulolytic and anaerobic bacteria were higher in vitro and in vivo systems. Rumen pH has been elevated in some studies with yeast cultures, but pH changes are not consistent. A reduction in rumen lactic acid concentrations has been reported (Williams, 1989). Yeast cultures are being studied to determine mode of action, optimum level, and correct stage of lactation to feed. Early lactation (2 weeks prepartum to 4 weeks post partum) appears to be an optimum time to feed yeast culture to stabilize the rumen environment as cows are shifted from dry cow to high-energy diets. Various forms and concentrations of yeast culture products are commercially available.

Zinc Methionine

Zinc methionine is a compound composed of zinc and methionine. The additive is resistant to degradation by rumen microbes. Zinc methionine was absorbed to similar extent as zinc oxide, but zinc methionine appears to be metabolized differently after absorption with lower urinary excretion and slower rate of decline in plasma zinc (Speers, 1989). In eight lactation studies, somatic cell counts averaged 320,000 and 217,000; and milk yield was 30.3 and 31.9 kg for control and zinc supplemented cows, respectively (Schugal, 1988). However, Ohio researchers found zinc methionine supplementation did not have an effect on wound healing, mastitis, immune response, or plasma zinc levels (Heinrichs et al, 1984). Zinc methionine has been reported in the field to harden hoof surfaces and reduce foot disorders. Several concentrations of zinc methionine are commercially available (feed labels must be checked to avoid excessive consumption).

Conclusions

Interest in feed additives will continue and will be influenced by new research results, advertising, and profit margins. Table 4 outlines additives in six categories that will assist dairy farmers, consultants, feed company nutritionists, and veterinarians in deciding if an additive should be included. Current status is classified in the following ways.

- Recommended: Include as needed
- Experimental: Additional research and study are needed
- Evaluative: Monitor on individual and specific situations
- Not recommended: Lacks economic responses to currently use.

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Table 1. Feed additives used in diets fed to high producing herds in 1992 compared to 1983.

Additive	----- report ---	
	% 1992	-- 1983
Sodium bicarbonate	75	70
Magnesium oxide	66	Na
Yeast/Yeast culture	51	17
Niacin	38	16
Zinc methionine	48	Na
No additives	na	10

Table 2. Required increase in milk yield to recover various additive costs with different milk prices.

Additive Cost (\$/cow/day)	----- Milk price (\$/100 lb) -----		
	10	12	14
	----- pounds of milk / cow / day -----		
.02	.2	.2	.1
.06	.2	.5	.4
.10	1.0	.8	.7
.30	3.0	2.5	2.1

Table 3. Summary of effectiveness of monensin by level (nine studies).

Level of monensin (g/ton)	Control	11g/t	15g/t	22g/t
Dry matter intake (lb/day)	43.9	43.4	42.8	42.3
Milk yield (lb/day)	65.0	66.7	66.8	67.5
Milk fat (%)	3.65	3.53	3.49	3.38

Milk protein (%)	3.15	3.13	3.13	3.10
Solids corrected milk (lb)	58.2	58.6	58.0	58.0
3.5% FC milk (lb)	66.1	66.8	66.7	66.0
Feed efficiency (lb 3.5%/lb DM)	1.50	1.54	1.56	1.56
Improvement milk efficiency (%)	control	+ 2.0	+2.5	+4.0

Table 4. Feed additive guidelines for dairy cows.

Anionic salts and products

1. Function: Cause the diet to be more acidic increasing blood calcium levels by stimulating bone mobilization of calcium and calcium absorption from the small intestine
2. Level: Reduce DCAD to -50 meq/kg using chloride sources (calcium chloride, ammonium chloride, Bio Chor, Animate, Soy Chor 44, Soy Chor 16, Nutro Clor, and hydrochloric acid treated feeds)
3. Cost: 40 to 75 cents per dry cow per day depending on product used
4. Benefit to Cost Ratio: 10:1
5. Feeding strategy: Feed to dry cows two to three weeks before calving. Adjust dietary calcium levels to 150 g per day (50 g inorganic). Raise dietary magnesium levels to 0.4 percent.
6. Status: Recommended

Aspergillus oryzae

1. Function: Stimulate fiber-digesting bacteria, stabilize rumen pH, and reduce heat stress.
2. Level: 3 g per day
3. Cost: 3 cents per cow per day
4. Benefit to Cost Ratio: 6:1
5. Feeding Strategy: High grain diets, low rumen pH conditions, and under heat stress (cows) and calves receiving a liquid diet
6. Status: Evaluative

Biotin

1. Function: Improve hooves by reducing heel warts, claw lesions, white line separations, sand cracks, and sole ulcers and increase milk yield through a metabolic route
2. Level: 10 to 20 milligrams per cow per day for 6 months to one year
3. Cost: 8 to 10 cents per cow per day
4. Benefit to Cost Ratio: 4:1
5. Feeding Strategy: Herds with chronic foot problems, may require supplementation for 6 months before evaluation, and company recommends beginning supplementation at 15 months of age.
6. Status: Recommended

Beta-carotene

1. Function: Improve reproductive performance, immune response, and mastitis control

2. Level: 200 to 300 mg per day
3. Cost: 30 cents per cow per day
4. Benefit to Cost Ratio: Not available
5. Feeding Strategy: In early lactation and during mastitis-prone time periods
6. Status: Not recommended

Calcium propionate

1. Function: Increase blood glucose and calcium levels
2. Level: 120 to 225 grams
3. Cost: 80 cents per pound
4. Benefit to cost ratio: Not available
5. Feeding Strategy: Feed 7 days prepartum to 7 days postpartum or until appetite responds; unpalatable
6. Status: Recommended

Protected choline

1. Function: A methyl donor used to minimize fatty liver formation and to improve fat mobilization
2. Level: 15 to 30 g per day
3. Cost: Not available
4. Benefit to Cost Ratio: 2:1 (when protected)
5. Feeding Strategy: Feed two weeks prepartum to eight weeks postpartum to cows experiencing ketosis, weight loss, and high milk yield
6. Status: Experimental (rumen protected)

Enzymes (fibrolytic)

1. Function: Increase fiber digestibility by reducing fiber (cellulase and xylanase enzymes) and DM intake
2. Level: Not clearly defined (enzymatic units per unit of feed dry matter)
3. Cost: 15 to 25 cents per cow per day
4. Benefit to Cost Ratio: 2 to 3:1 (Canadian data)
5. Feeding Strategy: Increase fiber digestibility, treated 12 hours before feeding, spray on product more effective when applied to dry diets, and may be diet specific
6. Status: Experimental

Magnesium oxide

1. Function: Alkalinizer (raises rumen pH) and increases uptake of blood metabolites by the mammary gland raising fat test
2. Level: 45 to 90 g per day
3. Cost: 21 cents per pound
4. Benefit to Cost Ratio: Not available
5. Feeding Strategy: With sodium-based buffers (ratio of 2 to 3 parts sodium bicarbonate to 1 part magnesium oxide)
6. Status: Recommended

Methionine hydroxy analog

1. Function: Minimize fatty liver formation, control ketosis, and improve milk fat test
2. Level: 30 g
3. Cost: 10 cents per cow per day (\$1.60 per pound)
4. Benefit to Cost Ratio: 2:1
5. Feeding Strategy: Feed to cows in early lactation receiving high levels of concentrate and limited dietary protein
6. Status: Evaluative

Monensin

1. Function: Improve feed efficiency for lactating cow, reduce ketosis and displaced abomasums in transition cows by shifting rumen fermentation and microbial selection
2. Level: 11 g to 22 g per ton of total ration dry matter consumed (250 to 400 mg / cow / day)
3. Cost: 2 cents per cow per day
4. Benefit to Cost Ratio: 5 to 1
5. Feeding Strategy: Feed to dry cows (reduce metabolic disorders) and lactating cow (feed efficiency) while monitoring milk components to evaluate optimal levels of monensin.
6. Status: Recommended

Niacin (B₃, nicotinic acid, and nicotinamide)

1. Function: Coenzyme systems in biological reactions, improve energy balance in early lactation cows, control ketosis, and stimulate rumen protozoa
2. Level: 6 g per cow (preventive and prepartum) and 12 g per cow (treatment and postpartum)
3. Cost: One cent per gram (6 to 12 cents per cow per day)
4. Benefit to Cost Ratio: 6:1 (6 grams level)
5. Feeding Strategy: High producing cows in negative energy balance, heavy dry cows, and ketotic-prone cows fed two weeks prepartum to peak dry matter intake (10-12 weeks postpartum)
6. Status: Evaluative

Probiotics (Bacterial direct-fed microbes)

1. Function: Produce metabolic compounds that destroy undesirable organism, provide enzymes improving nutrient availability, or detoxify harmful metabolites
2. Level: Not clearly defined
3. Cost: 5 to 15 cents per cow per day
4. Benefit to Cost Ratio: Not available
5. Feeding Strategy: Feed to calves on liquid diet, transition cows, and during stress conditions
6. Status: Evaluative for cows; recommended for milk fed calves

Propylene glycol

1. Function: Source of blood glucose, stimulate an insulin response, and reducing fat mobilization
2. Level: 8 to 16 ounces per cow per day
3. Cost: \$1.25 per pint or pound

4. Benefit to Cost Ratio: Not available
5. Feeding Strategy: Drench cow starting at one week prepartum (preventative role) or after calving when signs of ketosis are observed (treatment role). Feeding not as effective as drenching.
6. Status: Recommended

Silage bacterial inoculants

1. Function: To stimulate silage fermentation, reduce dry matter loss, decrease ensiling temperature, increase feed digestibility, improve forage surface stability, and increase VFA (lactate) production
2. Level: 100,000 colony forming units (CFU) per gram of wet silage. Recommended bacteria include *Lactobacillus plantarium*, *Lactobacillus buchneri*, *Lactobacillus acidilacti*, *Pediococcus cerevisiae*, *Pediococcus pentacoccus*, and/or *Streptococcus faecium*.
3. Cost: \$0.60 to \$2.00 per treated ton of silage
4. Benefit to Cost Ratio: 3:1 (feed recovery) to 7:1 (milk improvement)
5. Feeding Strategy: Apply to wet silage (over 60 percent moisture); corn silage, haylage, and high moisture corn; low natural bacteria counts (first and last legume/grass silage and frost damaged corn silage); and under poor fermentation situations
6. Status: Recommended

Sodium bentonite

1. Function: A clay mineral used as a binder, shifts VFA patterns, slows rate of passage, and exchanges mineral ions. Field claims to tie up mycotoxins have been reported
2. Level: 450 to 700 g per day (rumen effect), 110 grams for mycotoxin effect
3. Cost: 15 cents per pound
4. Benefit to Cost Ratio: Not available
5. Feeding Strategy: With high grain diets, loose stool conditions, presence of mold, low fat test, and dirt eating
6. Status: Evaluative

Sodium bicarbonate/sodium sesquicarbonate (buffer)

1. Function: Increase dry matter intake and stabilize rumen pH.
2. Level: .75 percent of total ration dry matter intake
3. Cost: 6¢ per cow per day (bicarb = \$0.19/lb; S Carb = \$0.18/lb)
4. Benefit to Cost Ratio: 4:1 to 12:1
5. Feeding Strategy: Feed 120 days postpartum with diets that are high in corn silage (over 50%), wet rations (over 55% moisture), lower fiber ration (<19% ADF), little hay (<5 lb), finely chopped forage, pelleted grain, slug feeding, and heat stress conditions.
6. Status: Recommended

Yeast culture and yeast

1. Function: Stimulate fiber-digesting bacteria, stabilize rumen environment, and utilize lactic acid.
2. Level: 10 to 120 g depending on yeast culture concentration
3. Cost: 4 to 6 cents per cow per day
4. Benefit to Cost Ratio: 4:1

5. Feeding Strategy: Two weeks prepartum to ten weeks postpartum and during off-feed conditions and stress
6. Status: Recommended

Yucca extract

1. Function: Decrease urea nitrogen in plasma and milk by binding ammonia to t glycofraction extract of Yucca shidigera plant improving nitrogen efficiency in ruminant animals.
2. Level: 800 milligrams to 9 grams per day (depending on source)
3. Cost: 2 to 4 cents per cow per day (\$1.28/ lb for Micro Aid 1X)
4. Benefit to Cost Ratio: Not available
5. Feeding strategy: To cows with high BUN and MUN levels
6. Status: Evaluative

Zinc methionine

1. Function: Improve immune response, harden hooves, and lower somatic cell counts.
2. Level: 9 g per day (Zinpro 40 trademark product)
3. Cost: 2 to 3 cents per cow per day
4. Benefit to Cost Ratio: 14:1
5. Feeding Strategy: To cows experiencing foot disorders, high somatic cell counts, and wet environment
6. Status: Recommended