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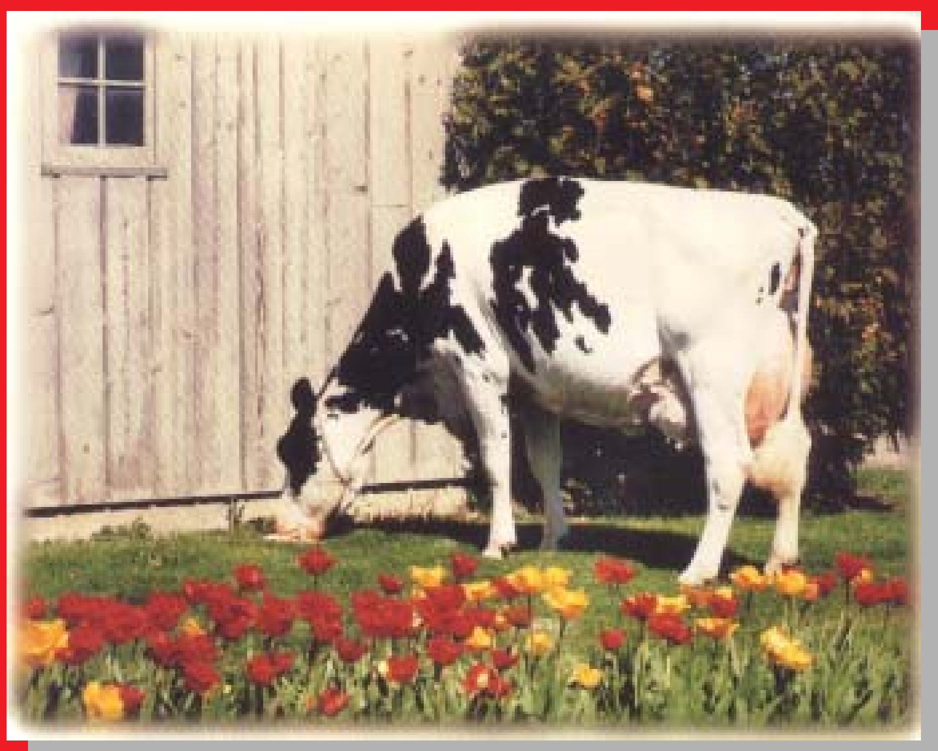

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Proceedings

Tri-State Dairy Nutrition Conference

April 17 and 18, 2001

Grand Wayne Center
Fort Wayne, Indiana

M. L. Eastridge, Editor

Mark your calendar for future dates of the
Tri-State Dairy Nutrition Conference

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The Conference Planning Committe extends appreciation to Mrs. Amanda Hargett for her assistance in organizing the Conference and acknowledges Mrs. Michelle Milligan for assistance with preparation of the *Proceedings*.

Proceedings orders: Contact Mrs. Amanda Hargett at The Ohio State University (614) 688-3143; email: hargett.5@osu.edu

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10th Anniversary
2001
Tri-State Dairy Nutrition Conference

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The Tri-State Dairy Nutrition Conference, Fort Wayne, IN is a yearly conference for feed industry professionals who have direct contact with dairy producers. The conference began in 1992 as a spin-off from the 1991 Ohio Dairy Nutrition Conference. In September 1991, a meeting to discuss planning a tri-state conference was held with faculty and Extension staff from Purdue, Michigan State, and The Ohio State Universities. The first Conference was held May 20 - 21, 1992 on the Purdue campus in Fort Wayne, IN. A planning committee was formed after the 1992 conference. The present committee consists of five feed industry personnel, one consultant, one veterinarian, one Extension staff, and a faculty member from each of the three universities. An ad hoc member who represents the company hosting the pre-conference, and an OSU conference assistant meet with the planning committee. The faculty have continuous committee membership, but the other eight members serve 3-year staggered terms. The committee meets twice each year. Presentations and proceedings papers are oriented to timely, in-depth, and practical dairy nutrition topics to meet on-farm nutritionists' needs. Participation and support by industry have been very important to the success of the Conference. Due to a continuous expansion of attendance, the conference moved in 1996 from the Purdue campus to the Grand Wayne Convention Center that is located downtown. A tradeshow and rotating industry-sponsored pre-conference are a part of the annual Conference. A conference web page http://www.ag.ohio-state.edu/ansci/tristate/ was launched in 1997. Continuing education credit is offered to veterinarians and members of the American Registry of Professional Animal Scientists (ARPAS). The success of the Conference is demonstrated by attendance and citation or reprinting of proceedings manuscripts in the scientific, international, and popular press. Multi-state programs similar to the Tri-State Dairy Nutrition Conference can serve a vital role in bringing research and Extension faculty from different universities and allied-industry professionals together to meet the educational needs of a rapidly changing dairy industry. [see J. Dairy Sci. 82(Suppl. 1):56].

Table 1. Attendance at the Tri-State Dairy Nutrition Conference.

Total Attendance	2000	1999	1998	1997	1996	1995	1994	1993	1992
	399	436	450	350	358	337	275	265	152
Distribution (%) of attendance by state:									
Ohio	28.7	28.9	30.2	32.6	41.6	37.4	42.4	36.9	45.6
Michigan	23.0	25.2	24.9	30.0	22.9	24.0	26.9	25.8	27.2
Indiana	17.5	16.6	19.2	16.9	20.1	16.6	17.0	21.3	19.9
Illinois	1.7	4.3	3.1	4.0	3.4	4.2	2.7	2.3	
Kentucky	1.7	2.9	5.0	4.0	2.8	1.5	1.9	2.3	
New York	6.6	6.6	4.1	5.1	1.1	3.0			
Pennsylvania	6.0	4.6	4.3	2.0	2.5	3.3	2.7	6.1	
Wisconsin	2.9	2.3	3.9	1.4	2.5	3.6	1.5	1.9	
Canada	3.7	1.3							
Other States	8.0	5.3	4.0	3.1	6.4	4.9	3.4		
Distribution (%) of attendance by job affiliation:									
Feed Industry - sales/nutrition advisor	56.4	65.7	61.0	53.1	57.8	56.1	60.8	50.0	47.7
Feed industry - management/research	10.0	8.9	8.5	8.8	7.5	11.1	8.4	10.5	9.1
Private Nutrition Consultant	7.9	5.3	4.3	8.2	6.8	6.6	7.8	3.2	12.5
Veterinarian	5.7	9.5	6.4	8.8	8.0	7.6	4.8	16.9	8.0
Government Agency - e.g. regulatory	0.7					0.5		0.8	
Dairy Producer	4.3	4.7	5.9	5.4	7.5	2.0	3.6	2.4	
University - campus	8.6	3.6	10.7	12.3	6.8	11.1	9.6	11.3	14.8
University - county/district	6.4	2.4	3.2	3.4	5.6	5.1	4.8	4.8	8.0

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Adjusting to Industry Changes

Nutrition of Dairy Goats

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Abstract

Although there are relatively few large commercial dairy farms with goats, many small herds exist and many youth use goats for 4-H projects. Adequate nutrition is critical for animal health and productivity and for maximizing animal performance for genetic selections. Accurate estimation of dry matter intake is critical, and rations need to be adjusted for nutrients based on maintenance (degree of activity), growth, pregnancy, production level, and environmental factors, such as heat stress. Goats possess eating behavior that is much different than for cattle - they are browsers when grazing and more apt to sort through feed mixtures. Proper feeding management is very critical in prevention of some nutritionally related health problems.

Introduction

Although goats are a low percentage of total agricultural receipts in the tri-state area, they may be a primary source of revenue for a few livestock producers, they serve as a source of revenue and as for pets/hobby for many small farm operations, and they are popular animals for 4-H projects. As of January 1997, Ohio ranked second to California in number of does (n = 1,426; Indiana and Michigan with 341 and 466 does, respectively) enrolled in the Dairy Herd Improvement **(DHI)** program and fourth to Oregon, California, and Wisconsin (ranked in descending order) in number of herds (n = 51; Indiana and Michigan with 11 and 40 herds, respectively) enrolled in the DHI program (Wiggans, 1997a). The 1996 average US production per lactation for does on the official testing program with DHI was 1,750 lb milk, 3.75% milk fat, and 3.22% milk protein (Wiggans, 1997b). Table 1 provides average milk yield and composition for some of the most common breeds of dairy goats. As of March 2001, 17, 534 herds, 976,311 animals, and 289,987 DHIR lactations were registered with the ADGA (2001). Meat goat production is increasing in the Midwest with the introduction of the Boers and Spanish goats, and market goat projects are increasing in the 4-H programs.

With the presence of a large number of goat herds in the tri-state area, many questions often arise on their nutrition, and information on the nutrition of goats is often limited because less research is done with the small ruminants than with beef, dairy, poultry, and swine. It has been 20 years since the publication of the NRC (1981) for goats. This paper will focus on the nutrition and nutritionally related health problems of goats.

Dry Matter Intake

The first principle of feeding animals is knowing approximate amounts of feed consumed. This is necessary to determine nutrient intake per day

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and appropriateness of dietary nutrient densities. The estimated dry matter intake (**DMI**) based on percentage of body weight **(BW)** for lactating dairy goats is provided in Table 2. Heat stress decreases DMI of goats, and dietary changes need to be made during such periods to minimize negative effects on milk production (Lu, 1989a). The DMI for dry does will be 3.0 to 3.5% of BW. Figure 1 provides the expected DMI for goat kids differing in BW and average daily gain (**ADG**). Market goat kids will eat similarly to dairy kids based on ADG (0.25 to 0.50 lb/day), but market goats usually have a higher rate of gain than dairy kids.

Nutrients

Energy and Protein

The net energy requirement for lactating does can be calculated using the following equation (Eastridge and Lemon, 1995):

$$NE_L \text{ (Mcal/day)} = (0.076 * BW_{kg}^{0.75}) + (0.70 * 4\% \ FCM_{kg/day}).$$

The crude protein **(CP)** requirement for lactating does can be calculated by:

$$CP \text{ g/d} = 4.15*BW^{0.75} + ((milk_{kg/day} *(\% \text{ milk protein}/100)/0.35)*1000).$$

Depending on milk yield, lactating does generally need 14 to 16% CP in the diet.

The milk urea nitrogen **(MUN)** generally ranges from 12 to 16 mg/dl in dairy cows and may be affected by dietary concentrations of CP, rumen degradable protein (**RDP)**, and nonfiber carbohydrates. Limited data are available for MUN in dairy goats but appears to follow similar patterns as observed for dairy cows. Brun-Bellut et al. (1991) observed, with a limited number of animals, MUN of 14.4 and 18.2 mg/dl when does were fed diets with 65 or 76% RDP (% of CP), respectively. Milk samples from a goat dairy farm in Ohio revealed MUN of 14.2 mg/dl (standard deviation **(SD)**; = 3.1) in May, 1998 and 19.9 mg/dl (SD = 3.1) in September, 1998; thus, the variation was similar to data for dairy cows (n = 294 cows, mean =12.4 mg/dl, SD = 3.1) in the study by Lyatuu (1997).

Dry does need 11 to 12% CP in the diet, and the daily protein requirement can be calculated using the following equation (Sahlu et al., 1992): $CP \text{ (g/day)} = 9.8 * BW \text{ kg}^{0.75}$. Energy needed by dry does can be calculated using the following equation:

$$NE_L \text{ (Mcal/day)} = 0.124 * BW_{kg}^{0.75};$$

(about 0.60 Mcal/lb of dietary DM).

The energy and protein requirements for growing kids can be calculated using the following equations:

$$NE \text{ (Mcal/day)} = (0.1357 * BW_{kg}^{0.75}) * e^{(0.00018 * ADG \text{ g/day})}$$

$$CP \text{ (g/day)} = (0.284 * ADG_{g/day}) + (5.19 * BW_{kg}^{0.75}).$$

Protein level in the diet for growing kids should range from 14 to 16%.

Adequate dietary fiber is essential for maintaining ruminal fermentation. Dietary levels of fiber usually do not become questionable except when high grain diets are fed to lactating does and finishing kids. Diets for lactating does should contain 26 to 28% NDF or 21% of the diet being NDF from forage. Diets for finishing kids often contain > 85% concentrate, with level of forage depending on forage type (corn silage versus legume or grass), particle size of grain (whole, cracked, or pelleted), and presence of other fibrous by-products.

Minerals and Vitamins

Confined animals should have supplemental minerals added to the grain mixture at appropriate levels to complement the type of forage being fed. Animals on pasture may only need access to trace-mineralized salt. Goats are not as prone to copper toxicity as occurs with sheep. Animals consuming harvested and stored feeds may benefit from supplemental vitamins. If this is the case, a vitamin premix should be added to the grain mixture. General guidelines for dietary concentrations of minerals and vitamins for goats are provided in Table 3.

Water

Lactating dairy goats require 2 to 3 gallons of water per day plus another 2 quarts for every quart of milk produced. Water should be available at all times for goats. Quality of the water is very important; some general guidelines are provided in Table 3.

Eating Behavior

Goats are more of a browser than are cattle and sheep, and goats eat grass much closer to the ground than cattle and caution needs to be taken in avoiding damage to the established pasture with overstocking of animals. Goats have a narrow mouth, mobile upper lip, prehensile tongue, agile front legs, and extensible hind legs which aid them in browsing and feed selection (Lu, 1989b). Goats appear to tolerate bitterness in plants more than do other ruminant species (Lu, 1989b). Goats may be less susceptible in general to toxic plants than cattle and sheep; however, their browsing nature increases their likelihood that they will consume potentially toxic plants. With their apt ability to select feeds, grain mixtures much be pelleted or well textured, otherwise fine particles, e.g. mineral and vitamin supplements, and unpalatable ingredients will not be consumed. Adding molasses to a textured feed may also help to minimize separation of the fine particles.

Feeding Guidelines

Forages

Pasture is an excellent means of providing forage. However, fertility of the pastures need to be maintained, and productivity of the pasture can be improved by grazing animals in small paddocks. Animals are moved off the grazed paddock to a new paddock to allow for regrowth. Animals are returned to the grazed paddocks after sufficient regrowth has occurred. Stocking rate will vary with pasture quality and productivity. Goats also should be rotated among pasture areas as a control measure for internal parasites, allowing at least three weeks between rotations to break the growth cycle of the parasites. In addition, a veterinarian should be consulted on establishing an effective anthelmintic program.

Whether the forage is available as pasture or stored feed, quality and species of the forage will affect grain supplementation. When sufficient supply is available, a feed analysis should be conducted. It is useless to analyze forage that will either be gone or little remaining when the lab results return. In such case, expected composition should be used from tabular values.

Fermented forages can be fed to goats. The most common problem is that herds are so small that the investment for silage storage is too large or that a sufficient amount (2" in winter and 4" in summer off silo surface) of silage can not be fed to keep the feed fresh. Corn silage can be fed but must be limited because of the energy concentration which could result in overconditioned animals.

Grain

1. Many different commercial grain supplements are available for goats.

2. For custom blending, some common grains and byproducts used are: corn, barley, oats, wheat, soybean meal, cottonseed meal, soybean hulls, dried brewers grains, distillers dried grains, corn gluten feed, and corn gluten meal.

3. Limited amount of wheat should be fed because of the rapid rate of ruminal fermentation.

4. Urea (45% N; 281% CP) should be limited to about 1% of dietary DM or used to supply one-third of the dietary protein to mature animals, should be introduced slowly, and should be fed with a grain mixture containing starchy grain sources.

5. Highly productive animals may respond to rumen undegradable protein. Special supplements are available, but the first approach should be to replace some oilseed meal in a ration with dried brewers grains, distillers dried grains, or roasted soybeans.

6. Excess fat, especially unsaturated fat, in the diet can reduce ruminal fiber digestibility and feed intake. Starchy grains are a cheaper source of energy, but energy concentration of the diets can be increased with fat supplementation. Highly productive animals may respond to additional energy provided from fat. Natural fat sources (soybeans, cottonseed, and tallow) are less expensive than commercial sources. Total dietary fat should not exceed 6% of DM, with 2 to 3% supplemental fat being common. The distinct flavor of goat's milk is attributed to some short-chain fatty acids. Feeding supplemental dietary fat reduces short-chain fatty acids and increases long-chain fatty acids, and therefore may alter the flavor of goat's milk.

7. Off-flavors in goat's milk may be caused by feed, e.g. wild onions, wild garlic, silage, weeds, etc. Goats should be removed from possible off-flavor sources four hours prior to milking.

Animal Health

Proper feeding management is very critical in prevention of some nutritionally-related health problems. Some common health problems with goats and nutritional implications of these problems are listed in Table 5.

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Wiggans, G.R. 1997b. USDA Summary of 1996 Herd Averages. Fact Sheet K-3, NCDHIP Handbook, National DHIA, Columbus, OH.

Other resources on dairy goats:

National Goat Handbook
http://www.inform.umd.edu/EdRes/topic/AgrEnv/ndd/goat

New York State 4-H Goat Projects
http://www.ansci.cornell.edu/4H/goats.html

Empire State Meat Goat Producers Association
http://www.ansci.cornell.edu/extension/esmgpa.html

Meat Goat Production and Marketing Handbook
http://goats.clemson.edu/NC%20Handbook/Default.htm

Caprine Supply (DeSoto, KS)
http://www.caprinesupply.com

Dairy Goat Journal
http://www.dairygoatjournal.com

United Caprine News
http://www.unitedcaprinenews.com

Table 1. Milk yield and composition for some of the most common goat breeds based on individual doe lactations during 1999 (ADGA, 2001).

Breed	Number of does	Age at Start of Lactation	Milk Yield (lb/lactation)[1]	Milk Fat (%)	Milk Protein (%)
Alpine	1044	2 yr, 11 mo	2198	3.4	3.0
Lamancha	362	2 yr, 10 mo	2084	4.0	3.4
Nubian	682	2 yr, 10 mo	1815	4.7	3.9
Oberhasli	100	2 yr, 4 mo	1932	3.6	3.0
Saanen	567	2 yr, 6 mo	2351	3.4	3.1
Toggenburg	384	3 yr	2113	3.2	2.9

[1]Based on 275 to 315 days in milk.

Table 2. Dry matter intake (% of body weight) for lactating dairy goats.

FCM[1] (lb/day)	Body weight (lb)							
	50	75	100	125	150	175	220	225
2	4.1	3.5	3.2	3.0	2.8	2.7	2.6	2.5
4	5.5	4.4	3.8	3.5	3.3	3.1	3.0	2.8
6		5.3	4.5	4.0	3.7	3.5	3.3	3.1
8			5.2	4.6	4.2	3.9	3.6	3.4
10				5.1	4.6	4.2	4.0	3.7
12					5.1	4.6	4.3	4.0
14						5.0	4.6	4.3
16							5.0	4.6

[1]4% Fat-corrected milk (FCM) = (0.4 * lb milk) + (15 * lb fat)

Table 3. General guidelines for dietary mineral concentrations for goats (DM basis).

Mineral	Lactating Does	Dry Does	Kids
Calcium, %	0.70	0.42	0.55
Phosphorus, %	0.36	0.24	0.30
Magnesium, %	0.25	0.16	0.16
Potassium, %	1.00	0.65	0.65
Sulfur, %	0.20	0.20	0.20
Iron, ppm	50	50	50
Manganese, ppm	40	40	40
Copper, ppm	12	12	12
Zinc, ppm	50	50	50
Selenium, ppm	0.3	0.3	0.3
Vitamin A, IU/lb	1800	1800	1000
Vitamin D, IU/lb	450	450	140
Vitamin E, IU/lb	10	40	11

Table 4. General guidelines for quality of water for livestock.

Item	Suggested Level	Comments
pH	6 to 9	Low or high pH may decrease water intake
Chloride	< 250 ppm	
Sulfates	< 300 ppm	High S may affect palatability of water and decrease absorption of selenium and copper
Phosphates	< 1.5 ppm	
Calcium	< 200 ppm	High levels may reduce water intake
Magnesium	< 200 ppm	High levels may reduce water intake
Sodium	< 300 ppm	Water softener may be in use with high levels
Iron	< 0.3 ppm	High levels may reduce water intake and decrease copper absorption
Copper	< 0.5 ppm	
Nitrate nitrogen	< 100 ppm	Nitrate toxicity may occur at elevated levels
Zinc	< 25 ppm	
Bacteria:		
Adult animals	< 1000 fecal coliforms/100 ml	
Young animals	< 1 fecal coliform/100 ml	

Table 5. Health problems with goats that have some relationship with nutrition.

Health Disorder	Comments and Nutritional Relationships
Enterotoxemia	1. Consult vet for vaccination strategy 2. Introduce grain slowly and avoid feeding an excessive amount of grain
Acetonemia	1. Occurs during later pregnancy and most likely with does carrying twins or triplets 2. Higher risk with over-conditioned does (limit energy intake before pregnancy and during early gestation) 3. Prevent by increasing grain intake during late pregnancy; providing molasses in grain mixture may be helpful 4. High-producing does with low DM intake are also at risk 5. Treat by drenching with 200 to 300 ml of propylene glycol and/or IV of glucose
Urinary calculi	1. More common in castrated males 2. Feedlots: Dietary Ca:P > 1.5:1, limit P intake, decrease cation (Na + K) - anion (Cl + S) balance by feeding 0.5% ammonium chloride or ammonium sulfate in the complete diet. Avoid feeding high quality legumes 3. Range: Caused by high silica content of forages, provide sodium chloride at 4% or more of the total diet
Hypomagnesemia	1. Treatment: IV of calcium-magnesium solution; drench or enema with Mg may also be effective 2. Prevention: Increase magnesium in diet (maximum 0.4%); provide dietary K/(Ca + Mg) at 1 to 2.2
Parturient paresis	1. Prepartum: Avoid feeding high levels of calcium (e.g. avoid feeding high quality legumes); maintain Ca:P at 1.5:1 to 2:1; feed adequate vitamin D 2. Treat with IV of calcium
Posthitis	1. Occurs occasionally in the prepuce (sheath) of males 2. Likely caused by a high protein intake, resulting in increased urea concentration in urine which creates a favorable environment for the urea-hydrolyzing organism, *Corynebacterium renale* 3. Inflammation and infection of the prepuce occurs 4. Prevent by limiting protein level in the diet

Table 5. (Continued)

Health Disorder	Comments and Nutritional Relationships
Urea toxicity	1. Limit urea to 1% of dietary DM or 1/3 of dietary protein 2. Introduce the feeding of urea slowly 3. Make sure feed-grade urea is used
Bloat	1. Feed hay before animals turned out to legume pasture 2. In feedlot situations, prevent by increasing dietary fiber 3. Feed 2 to 4 oz/day of poloxalene as a preventive
White muscle disease	1. Use injectable Se for kids 2. Make sure supplemental selenium is at 0.3 ppm of ration 3. Use some feeds naturally high is Se, such as brewers dried grains or linseed meal
Ruminal acidosis or laminitis	1. Most likely to occur near parturition 2. Increase grain slowly after parturition 3. Decrease grain, increase forage 4. May replace some starchy grain with by-product grain sources relatively high in fiber 5. Increase particle size of grain (coarsely cracked or whole) 6. Add buffer to concentrate (15 lbs/ton of sodium bicarbonate or sodium sesquicarbonate)
Mycotoxins	1. Primary source would be grain and corn silage 2. Ruminants less susceptible than nonruminants 3. Maximum tolerable level of 0.5 ppb of aflatoxin for milk 4. Deoxynivalenol primarily reduces intake 5. High concentrations of fumonisins and zearalenone can affect animal health and performance 6. Dilute by feeding less of the contaminated ingredient 7. Feeding commercially available binders at manufacturer's suggested rates or bentonite at 0.5% of dietary DM may lower absorption of mycotoxins
Low reproduction	1. Poor body condition; increase energy intake 2. Too high (especially rumen degradable protein) or too low dietary protein 3. Inadequate phosphorus, or vitamins A or D 4. Inadequate Se and vitamin E

Table 5. (Continued)

Health Disorder	Comments and Nutritional Relationships
Abortion	Undernutrition during rapid fetal development
Mastitis	1. Ensure a clean environment. Make sure milking equipment is properly cleaned, parts are maintained and replaced as needed, and the pulsation system is properly functioning. 2. Inadequate Se and vitamin E may exist
Listeriosis	1. Symptoms include abortion and the animal may walk in circles, thus referred to as “circling disease” 2. Caused by the bacterium *Listeria monocytogenes* which is present in many areas of the environment; however, the organism appears to grow well in corn silage that has not undergone adequate fermentation 3. Prevent by harvesting corn silage at proper maturity and moisture so that pH drops to < 4.5 and do not feed corn silage until at least two weeks after ensiling, or longer if the environmental temperature drops sharply soon after ensiling. Low pH in the silage limits growth of the organism. 4. If clinical signs arise, consult with a veterinarian.
Toxic plants	1. Many different plants contain toxic substances 2. Become familiar with plant species accessible to livestock; identify potentially toxic plants and their toxins. Cornell University provides a website for identification of poisonous plants (http://www.ansci.cornell.edu/plants/plants.html). 3. Restrict problem grazing areas as needed, make sure feed is not limited, and limit the feeding of harvested forage containing toxic weeds

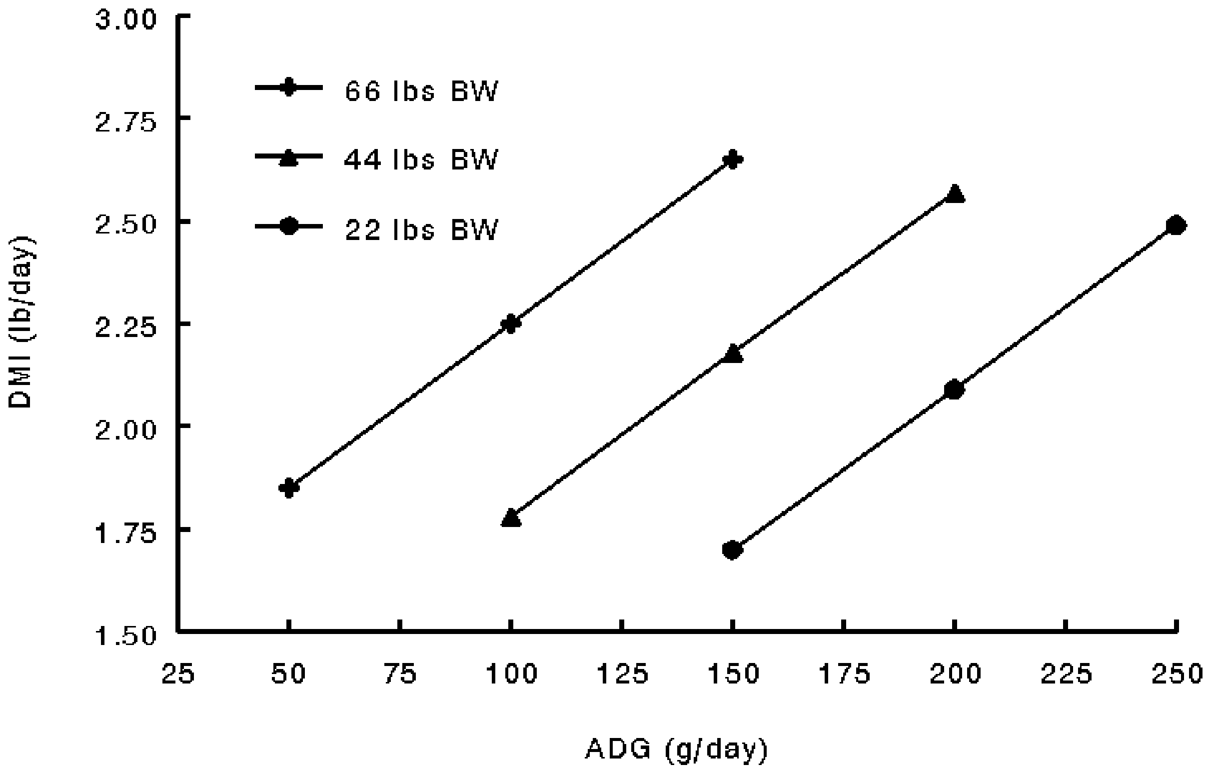

Figure 1. Dry matter intake of goat kids differing in body weight (BW) and average daily gain (ADG).

The 100-Day Contract with the Dairy Cow: 30 Days Prepartum to 70 Days Postpartum

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Abstract

During the transition period, the dairy cow is undergoing numerous changes in endocrine, nutritional, metabolic, and physiological status as she prepares for calving and initiation of lactation. These changes result in a dramatic decrease in dry matter intake that worsens the negative energy balance already present after calving. If the negative energy balance during transition becomes excessive, metabolic diseases, such as fatty liver and ketosis, can result. Disruption of mineral balance during the periparturient period leads to mineral balance disorders, especially milk fever. These diseases are costly in terms of their affect on milk production, reproduction, and the cow's susceptibility to other periparturient disorders. Intensive management of the nutrition, feeding system, and environment of the periparturient dairy cow reduces the odds of disease and increases the odds of success.

The '100 day contract' is a series of delicate negotiations that encompass the full impact of the transition cow. Unsuccessful negotiations at any point increase the risk of overall failure. Getting the details right and ensuring adequate intake of all nutrients are the key elements of the '100-day contract'.

Introduction

In evaluating the production cycle of the dairy herd, a 100-day period of critical importance exists. The '100-day contract' with the dairy cow begins 30 days before calving and continues through first breeding at 70 days postpartum. The terms of the contract include the birth of a live calf, with the cow remaining healthy during the transition period, high peak milk production, controlled loss of body condition, and high fertility at first breeding (Figure 1). The momentum toward successful achievement begins in the close-up dry cow group and builds through calving to first breeding. Getting the cow off the track at any point disrupts the momentum and can lead to 'wrecks'. Wrecks include metabolic disorders during the periparturient period that can have long-term impact on production and reproduction. This paper will focus on a phase-by-phase look at the negotiations required to successfully fulfill the 'contract', as well as the long-term consequences of cows getting off track.

The Transition Period

Goff and Horst (1997b) defined the transition period of a dairy cow's productive cycle as the change from the pregnant, nonlactating state to

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the nonpregnant, lactating state during the interval from three weeks prepartum until three weeks postpartum. The transition period is characterized by numerous changes in physiological, metabolic, and endocrine status to accommodate parturition and lactogenesis (Grummer, 1995). If nutritional management does not meet these challenges, the transition cow is at risk of developing a wide range of health problems soon after parturition (Bell, 1995). These problems include milk fever, fatty liver, ketosis, retained placenta, displaced abomasum, and severely suppressed immune function (Goff and Horst, 1997b). Proper management during the transition period affects the well being of the dairy cow by decreasing the incidence of metabolic and infectious diseases, increasing production, and improving reproductive performance during the subsequent lactation. Achieving successful transition should have a positive impact on the profitability of a successful dairy farm.

To successfully manage the transition cow, we must first understand the changes the cow is experiencing and the impact of a poor transition. Then we must implement strategies that address the challenges of the transition cow.

The Transition Cow : Understanding the Challenge

During the dry period, the cow must be prepared for calving and initiation of lactation. The concept of preparing the dry cow is different from the traditional view of the dry period as a 'rest' phase (Gerloff, 1988). Goff and Horst (1997b) concluded that the periparturient period should adapt the rumen while maintaining normal energy and calcium metabolism, as well as supporting a strong immune system.

Changes in Endocrine Status

As parturition approaches, the transition cow undergoes a variety of changes in endocrine status. Plasma prolactin levels increase sharply the day prior to calving, resulting in initiation of lactation and increased colostrum synthesis. Progesterone concentration, which is elevated during gestation for maintenance of pregnancy, drops to nearly undetectable levels on the day before calving (Figure 2). Plasma estrogen concentration rises sharply at the same time in response to secretion of fetal cortisol. Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) concentration begins to rise and peaks at parturition, causing luteolysis and further inhibition of progesterone synthesis (Goff and Horst, 1997b). High levels of estrogen are thought to contribute to the decline in dry matter intake **(DMI)** that occurs around parturition (Bell, 1995; Grummer, 1995). Goff and Horst (1997b) reported that DMI declines by as much as 30 to 40%, or from 2% to less than 1.5% of the animal's body weight. Severe decreases in intake put the animal at risk for a number of metabolic disorders.

Changes in Nutritional and Metabolic Status

Although not producing milk, the prepartum cow is undergoing numerous changes that result in significantly higher nutrient requirements. Bell et al. (1995) measured energy and protein deposition in the uterus and fetus. Their research clearly illustrated the increased nutrient requirements during the final 30 days of gestation (Table 1). However, as shown in Figure 3, the increased nutrient requirements occur concurrently with declining appetite and nutrient intake.

To compensate for the negative energy balance caused by decreased DMI around parturition (Figure 4), the stress of calving, increased energy demands resulting from fetal growth and lactogenesis, and other unknown endocrine-related factors, mobilization of adipose tissue increases. Adipose tissue provides energy in the form of nonesterified fatty acids **(NEFA)** (Grummer, 1995). Plasma NEFA concentration increases approximately two-fold during the last 17 days of gestation, peaks around parturition, and remains higher than prepartum levels until about two weeks postpartum (Figure 5). The liver oxidizes NEFA to ketone bodies and carbon dioxide via the tricarboxylic acid cycle **(TCA)** or esterifies them to triacylglycerols **(TG)**, which are exported from the liver as very low density lipoproteins **(VLDL)** (Rukkwamsuk et al., 1998). If these changes become too dramatic, they can lead to ketosis and fatty liver disease.

In short, there is a significant increase in the cow's nutrient requirements during the final 30 days of gestation, and thus, there is a critical need to maintain intake and provide support for a proper plane of nutrition. A key to successful transition cow management is a nutritional management system (diet and feeding system) that provides nutrients in the proper balance and maximizes intake.

Changes in Physiological Status of the Reticulorumen

Significant physiological changes also occur during the transition period. Because of significant fetal growth during the last 60 days of gestation, ruminal capacity decreases by as much as 20%, then increases again within 8 days after calving. Ruminal dry matter and fluid fill also decrease just before calving and remain low until about 20 days postpartum (Table 2). Decreased capacity of the rumen limits the amount of feed the cow can consume, however, it does not account for the magnitude of the decrease in dry matter intake that occurs around calving (Stanley et al., 1993).

Absorptive capacity of the rumen also changes during the dry and transition periods. Beginning at dry-off, cows are most often fed a high-forage, low-concentrate diet that is higher in neutral detergent fiber **(NDF)** and less energy dense than the lactation diet. The lower energy diet causes a decrease in length and surface area of rumen papillae (Figure 6). This physiological change in rumen papillae corresponds to a 50% loss of absorptive capacity of volatile fatty acids **(VFA)** during the first 7 weeks of the dry period (Dirksen et al., 1985).

Postpartum, the papillae must increase in length and surface area to achieve maximum absorption of VFA. Feeding a diet higher in fermentable organic matter stimulates development of the papillae. However, this growth process requires 4 to 6 weeks after changing to a high-energy diet (Dirksen et al., 1985). If the amount of fermentable organic matter is increased too rapidly after parturition and before the papillae have reached adequate surface area, the cow cannot absorb VFA efficiently. Volatile fatty acids can build up in the rumen, causing pH to fall, and resulting in rumen acidosis. Protozoa and some bacteria in the rumen are killed, releasing endotoxins that are absorbed into the bloodstream (Goff and Horst, 1997b). These endotoxins cause systemic changes in blood flow and affect the growth and health of the hooves. These changes can result in the painful condition of laminitis. Cows with laminitis have limited mobility, and therefore, limited intake. Lameness, combined with the rumen papillae's limited ability to absorb VFA from the rumen, may worsen the transition cow's negative energy balance, increasing the risk of metabolic disorders. Successful transition cow programs are designed to accommodate the endocrine and physiological changes in the cow while minimizing costly metabolic diseases.

Metabolic Disorders

The transition from late gestation, non-lactating to nonpregnant, lactating presents significant challenges to the cow's system. When nutrition management does not meet these challenges, a wide range of health problems can result. Metabolic diseases are disorders that are nutritional in origin and often result in acute symptoms, require treatment. Incidence is highest during the period just prior to calving through peak lactation (Shearer and Van Horn, 1992). As shown in Table 3, most of the periparturient diseases, such as milk fever, ketosis, retained placenta, and displaced abomasum, occur within the first 2 weeks postpartum. Many infectious diseases, such as mastitis, also become clinically apparent at this time as a result of the animal's depressed immune function. Other health disorders that become evident later in lactation, such as laminitis, can be traced back to complications during the first two weeks after parturition (Goff and Horst, 1997b). The majority of metabolic diseases are related to either energy balance or mineral balance. The diseases commonly associated with severe negative energy balance include fatty liver and ketosis. Milk fever is the most common mineral balance disorder (Shearer and Van Horn, 1992).

Energy Balance Disorders

During late gestation and early lactation, the cow becomes anorexic. This condition severely limits consumption of energy in amounts necessary to meet demands for maintenance and milk production. Fatty acids are mobilized from adipose tissue as an additional energy source, however, the bovine liver has limited capacity for the amount of fatty acids that can be oxidized or exported as VLDL. When this limit is reached, TG accumulate in the liver, and acetyl coenzyme-A (from oxidation of fatty acids) that is not utilized in the TCA cycle is converted to ketone bodies, such as acetone, acetoacetate, and b-hydroxybutyrate. These ketones appear in the blood, milk, and urine (Goff and Horst, 1997b).

Fatty liver occurs when the rate of TG synthesis exceeds the rate of TG hydrolysis and TG export as VLDL (Grummer, 1993). Excessive accumulation of TG in the liver impairs its normal function and, in severe cases, can result in liver failure (Shearer and Van Horn, 1992). Because rate of TG synthesis is proportional to plasma NEFA concentration, fatty liver is likely to develop during periods of high plasma NEFA, such as the periparturient period. As shown in Figure 5, NEFA concentration increases approximately two-fold between 17 days prepartum and two days prepartum and increases two-fold again, reaching peak concentration by calving (Grummer, 1993). Because the accumulation of fat in the liver impairs its function, the liver of an overconditioned cow has a more limited ability to oxidize fatty acids than that of a thinner cow (Goff and Horst, 1997b). As a result, excessive body weight gain during late lactation or the dry period predisposes cows to the development of fatty liver following parturition (Rukkwamsuk et al., 1998).

Another major factor contributing to the formation of fatty liver is the inherently slow rate of VLDL secretion by the liver in ruminant animals compared to other species (Bertics et al., 1992). The elevated estrogen levels around parturition can also enhance TG deposition in the liver, escalating the problem even more (Grummer , 1993; Goff and Horst, 1997b). Fatty liver is best prevented by nutritional management during the dry period that minimizes TG deposition in the liver and maximizes liver glycogen stores (Grummer et al., 1993). This balance can be accomplished by monitoring and managing body condition through the late lactation and dry period diets so cows approach calving in proper body condition (Shearer and Van Horn, 1992). There is also evidence that propylene glycol administration prevents fatty liver by improving energy balance during the last days of gestation and first few weeks of lactation (Formigoni et al., 1996). Data from work done by Grummer et al. (1994) revealed that 296 ml of propylene glycol given as an oral drench once daily was effective for reducing plasma NEFA concentrations.

Fatty liver is thought to precede spontaneous clinical ketosis. Fatty liver is most common by the first day after calving, but cows are most susceptible to ketosis at 3 weeks postpartum. In addition, development of fatty liver may have a direct effect on carbohydrate metabolism and influence susceptibility to ketosis. Gluconeogenic activity of liver tissue has been found to be impaired under conditions conducive to fatty liver development. Reduction in gluconeogenesis by the liver may lower blood glucose levels and decrease insulin secretion, which would support greater lipid mobilization and increased rate of fatty acid uptake by the liver and increased ketogenesis (Grummer, 1993).

Ketosis results from impaired metabolism of carbohydrates and VFA, leading to hypoglycemia. Formation of ketones is the result of incomplete metabolism of mobilized fat. Fatty acids accumulate in the liver as acetyl-CoA because the liver has reduced ability to utilize them. Excess acetyl-CoA is converted to ketones that can be metabolized by peripheral body tissues. When ketones are produced in excess of peripheral tissue's capacity to use them, they accumulate in the bloodstream, resulting in ketosis. Cows with clinical ketosis exhibit reduced feed intake, reduced milk yield, loss of body weight, central nervous system involvement (staggering, lack of coordination, and appearance of staring or blindness), and, in severe cases, acetone odor on the cow's breath (Shearer and Van Horn, 1992). Ketosis can be prevented by implementing the same nutritional management strategies used to prevent fatty liver. Additional prevention strategies include avoidance of fermented feeds, such as certain silages containing ketogenic precursors, increased frequency of concentrate feeding, and use of specific additives during the dry and transition periods (Kronfeld, 1982; Grummer, 1993). Additives include daily niacin supplementation, which has been shown to reduce plasma concentration of the ketone b-hydroxybutyrate (Duffield et al., 1998) and daily oral administration of propylene glycol, which provides glucose precursors (Shearer and Van Horn, 1992; Grummer et al., 1994).

Mineral Balance Disorders

A second major cause of metabolic disease is a disruption of mineral balance, primarily calcium balance, around parturition. Lactogenesis and colostrum synthesis place a large demand on calcium homeostasis mechanisms so that almost all cows develop some degree of hypocalcemia at parturition (Beede and Pilbeam, 1998). When plasma calcium concentration drops too low to support nerve and muscle function, parturient paresis, or milk fever, develops (Goff and Horst, 1997a).

Milk fever affects up to 9% of dairy cows around calving (Joyce et al., 1997). Risk of milk fever increases with age and parity. Cows of third or greater parity are at the highest risk, while milk fever is rare in first-calf heifers. Increased risk is also likely related to higher milk yield (Shearer and Van Horn, 1992; Horst et al., 1997; Rajala-Schultz et al., 1999).

The most widely used treatment for milk fever is intravenous infusion of 23% calcium borogluconate solution. However, this treatment can cause cardiac arrest by raising plasma calcium concentrations to dangerous levels. Also, approximately 25% of cows treated for milk fever relapse and require additional treatment (Horst et al., 1997). Prevention can be a more cost-effective alternative in managing milk fever.

Traditionally, limiting calcium intake during the dry period was used to prevent milk fever. The goal of this strategy is keep dietary calcium low enough so that calcium mobilization mechanisms move calcium from body stores and are functional at calving when calcium demand for milk synthesis suddenly increases. Dietary calcium intake should be limited to less than 50 g/day; however, diets containing such a low calcium concentration are often difficult to formulate because many forages commonly used in dairy diets, especially legumes, contain a substantial amount of calcium (Shearer and Van Horn, 1992).

Another concept in milk fever prevention is utilization of dietary cation-anion difference **(DCAD)**. When the amount of calcium in the blood drops below normal, parathyroid hormone **(PTH)** is secreted to stimulate release of calcium from body tissues into the blood pool. Cows that have a relatively high blood pH are less responsive or non-responsive to secretion of PTH, but cows that have relatively low blood pH are more responsive to PTH. The number of equivalents of cations and anions present ultimately determines blood pH. Blood pH decreases when more anions than cations enter the blood from the diet and digestive tract. The goal in utilizing DCAD in diet formulation and anion supplementation should be to reduce blood pH enough to affect calcium mobilization in response to hypocalcemia. An appropriate DCAD can be achieved by reducing the number of cations or increasing the number of anions in the diet. The number of cations in the diet can be controlled by selecting feeds, especially forages, that are as low in potassium and other cations as practically possible (Beede and Pilbeam, 1998). Goff and Horst (1997a) have provided evidence that increasing potassium in the prepartum diet increases the incidence of milk fever. However, current guidelines for forage production are inadequate for providing dairy producers with low potassium forages.

Sources of anions include Cl^- and SO_4^{-2} salts of calcium, ammonium, and magnesium. Phosphate salts are weakly acidifying and are not commonly used. However, only a limited amount of anionic salts can be added to the diet because of palatability problems that can affect intake (Horst et al., 1997). When DCAD is sufficiently reduced, increased calcium content of 180 to 210 g per cow per day does not cause milk fever and appears to have some benefit to the cow (Beede and Pilbeam, 1998).

Diets containing anions must be properly mixed in order for each cow to receive the correct amount of anions to affect blood pH. Anions are ineffective in component feeding situations because the cow’s DCAD cannot be controlled. For the DCAD approach to be most effective, anion/cation content of feedstuffs, intake of the diet, and urine pH (an indicator of blood pH and acid-base status) of cows must be closely monitored (Beede and Pilbeam, 1998). If management requirements cannot be met, other options for preventing milk fever are available. These include feeding a prepartum diet low in calcium (less than 50 g/day) and administration of readily available calcium sources at calving to increase plasma calcium (Horst et al., 1997). Sources of calcium include commercially available oral supplements, such as gels and pastes.

Parturition Disease Complex

Severe losses of body stores or a more general lack of properly balanced nutrients increase the risk of the cow experiencing a number of metabolic diseases. Markusfield (1993) describes these as a parturition disease complex. It is important to understand that these disorders are not independent but are related. For example, milk fever is a significant risk factor for several other transition cow problems, including dystocia, ketosis, retained placenta, mastitis, and displaced abomasum.

Grohn et al. (1995) reported the incidence of these diseases for Holstein cows in New York (Table 3). As the median day of occurrence indicates, these diseases are most likely to occur during the period immediately after calving. However, these disorders have an impact on production and reproduction during the entire lactation. Cows experiencing any one of these disorders are at much greater risk of suffering from a number of the other periparturient dysfunctions. Furthermore, these peripartuient disorders disrupt the cow's metabolic momentum toward high peak milk yields and also have negative carryover effects on reproductive performance.

Effects of Metabolic Diseases

The culmination of periparturient disorders is lost milk production and decreased reproductive efficiency, both of which reduce income. Cows with fatty liver exhibit depression, loss of appetite, rapid loss of body weight in severe cases, and marked decrease in milk production. Fatty liver is frequently associated with most of the other periparturient disorders, including ketosis, milk fever, displaced abomasum, retained placenta, and metritis. Fatty liver cases do not respond well to treatment, with mortality rates of up to 50% (Shearer and Van Horn, 1992) Cows that do recover have a lengthened interval to first estrus and days to first service (Morrow, 1975).

Ketosis also causes appetite depression, decreased milk yields, and weight loss (Shearer and Van Horn, 1992). Deluyker et al. (1991) reported that clinical ketosis caused losses in milk production of 557 lb during the first 119 days in milk for cows that were diagnosed within the first 21 days postpartum. These cows also had peak milk production of nearly 6 lb less than healthy animals. Clinical ketosis has been associated with increased risk of metritis, displaced abomasum, and mastitis. Subclinical ketosis has been associated with decreased milk yield, increased risk of clinical ketosis, metritis, and cystic ovarian disease, and impaired reproductive performance (Duffield et al., 1998).

Energy balance disorders, such as fatty liver and ketosis, indicate that the parturient cow is in a state of severe negative energy balance. During this period of negative energy balance, luteinizing hormone pulse frequency and growth rate and size of the dominant follicle are decreased. As a result, cows have a longer interval to first ovulation, which causes an increase in days to first service, days open, and services per conception, as well as decreased first service conception rate (Table 4). Achieving high energy intake during the transition period is critical to normal resumption of ovulation and normal corpus luteum development, and therefore, high reproductive efficiency (Roche et al., 2000).

Milk fever is another important periparturient disorder. Rajala-Schultz et al. (1999) found that milk fever alone caused a milk loss of between 2.42 and 6.38 lb/day during the first 4 to 6 weeks following parturition. It can also reduce the productive life of the cow by as much as 3.4 years.

The average cost per case of milk fever has been estimated at $334, based on direct treatment cost and estimated production losses (Horst et al., 1997).

Milk fever also increases the risk of other metabolic diseases, primarily because it has a detrimental affect on smooth muscle function. Muscle tone decreases in most body systems, particularly in the cardiovascular, reproductive, and digestive systems, and possibly in the mammary system. Blood flow to the extremities is reduced, causing the characteristic cold ears of a cow suffering from milk fever. Jonsson and Daniel (1997) found that there was also a significant reduction in blood flow to the ovaries of sheep with induced hypocalcemia. This would result in suppressed ovarian function, including progesterone synthesis and follicular development. Unfortunately, the highest incidence of hypocalcemia is during the first 6 weeks after calving, a critical time for resumption of ovarian activity.

As shown in Table 5, hypocalcemia also predisposes the cow to calving disorders, including retained placenta, dystocia, and metritis, as well as other periparturient disorders. Calving disorders are detrimental to postpartum reproductive function because they slow the rate of uterine involution and resumption of a normal estrous cycle (Risco, 1992). Reproductive efficiency is decreased as a result of a longer interval to first service and first conception and a lengthened calving interval.

Hypocalcemia affects the digestive system by reducing rumen contractility and increasing the risk of displaced abomasum. As a result, feed intake may be suppressed, worsening the negative energy balance already present around parturition and putting the cow at a greater risk for ketosis (Goff and Horst, 1997b). Hypocalcemia may also put the cow at greater risk for mastitis by affecting the teat end sphincter. If the teat end cannot close sufficiently following milking, the cow is more susceptible to bacterial invasion that causes mastitis. In addition, hypocalcemic cows have increased plasma cortisol concentrations that may worsen the immunosuppression normally present at parturition. This leaves the cow with decreased ability to fight infectious diseases, including mastitis (Goff and Horst, 1997b).

Transition Cow Management

Dry Cow Nutrition

The decreases in milk production and reduced reproductive efficiency associated with the periparturient diseases indicate that the incidence of these diseases must be closely monitored. Retained placenta and related reproductive tract infections are often assumed to be caused by nutritional deficiencies. More specifically, since researchers reported the relationship between vitamin E, selenium, and retained placenta, many producers first react to cows calving with retained placenta by increasing vitamin and mineral supplementation of the dry cow diet. Vitamin E and selenium are antioxidant substances that aid in the removal of reactive oxygen metabolites **(ROM)**, or free radicals, that are generated during normal metabolism. When ROM are not effectively removed, they can impair the health and productivity of the cow by damaging cells and tissues, altering metabolism and inducing changes in steroidogenesis. Membrane permeability, enzyme function, and muscle tone can be affected by reactions involving ROM. In addition, ROM alter metabolism by reducing the supply of essential cofactors, such as nicotinamide adenine dinucleotide phosphate **(NADPH)**, and diverting glucose from the important metabolic pathways. The ROM also cause inactivation of steroidogenic enzymes that are necessary for the synthesis of reproductive hormones, such as progesterone and estrogen. Vitamin E is a chain-breaking antioxidant that terminates reactions involving ROM by reacting directly with the radicals after they have been formed. Glutathione peroxidase, an enzyme containing selenium, prevents the formation of ROM by removing the reactants O_2^- and H_2O_2. Research has shown that the levels of antioxidants in the blood are higher for cows that shed the placenta within 12 hours of parturition (Figure 7). Several other studies have shown that supplementation of vitamin E and selenium reduced the incidence of retained placenta. In addition, supplementation seems to be more effective when vitamin E and selenium are both added to the diet than when one or the other is lacking (Table 6) (Miller and Brzezinska-Slebodzinska, 1993).

Correct vitamin and mineral supplementation to enhance immunity is certainly a goal of proper transition cow management. However, French researchers more completely described retained placenta as an under-nutrition disease. Chassagne and Chacornac (1994) reported that cows that retained the placenta were on a lower plane of nutrition prior to calving. Blood metabolite measurements showed higher fat mobilization and lower blood glucose, as well as lower blood calcium and amino acids (Table 7). These results show the importance of the overall nutritional balance of the transition cow.

Levels of crude protein **(CP)** and amino acids in the dry cow diet also affect performance in the subsequent lactation. During pregnancy, the cow requires protein for maintenance, fetal growth, and, in the case of a primiparous heifer, growth of the dam. The National Research Council (NRC, 2001) recommends feeding 12.4% CP in the late dry period, or 2.8 lb of CP for a mature 1500-lb (without conceptus) cow consuming 22.2 lb/day of DM. Approximately 9.6% of the diet should be in the form of rumen degradable protein **(RDP)**. Levels above or below these recommendations can have detrimental effects. Greenfield et al. (2000) found that cows fed 12% CP for 28 days prepartum had a higher DM intake and produced more milk during the first 56 days in milk when compared to cows fed 16% CP. On the other hand, lower protein levels in the dry cow diet can restrict the growth of the fetus, resulting in low calf birth weight. In addition, amino acids from protein can be oxidized for energy during the late dry period, when energy demands for fetal growth are high and DM intake is depressed (Greenfield et al., 2000). Without this additional energy source, the transition cow's negative energy balance may worsen.

There are also a variety of feed additives available to help make the transition period more successful. Anionic salts and oral calcium supplements can be given to alleviate milk fever problems. Daily oral doses of propylene glycol and/or daily niacin supplementation during the transition period help decrease the severity of negative energy balance. Other feed additives, such as yeast culture and probiotics, have been used to aid cattle in the transition from low starch diets ted to dry cows to high starch diets fed to lactating cows.

Feeding Management

The environment in which cows are fed is important when evaluating the transition program and the ability to successfully achieve the 100-day contract. Much has been written pertaining to the feeding environment of lactating cows, but comparatively, little information is available relative to the periparturient cow. Adequate bunk space to allow all cows equal access at feeding time is important, as is the availability of water relative to distance from feed (less than 50 feet) and the number of animal spaces. In managing the transition cow group, there can be large fluctuations in the number of cows on a day-to-day basis. The amount of feed delivered must be carefully monitored as group size changes when fresh cows are moved out after calving and late gestation cows are added. Age and body weight of the cows entering and leaving the transition group will also affect the amount fed. These details of where and how feed is offered to the transition cow group can determine the success or failure of the early lactation cow.

Environment

Another factor critical to a successful transition cow contract is housing. The dry cow experiences significant stress with calving and initiation of lactation. The housing system is key to minimizing exposure to environmental stress. Housing should protect the animal from injury and disease. This is especially important for the dry cow in late gestation. Harmon and Crist (1994) reported that the incidence of environmental mastitis is highest during the first two weeks and the last two weeks of the dry period. Voermans (1997) recommended evaluating the housing system in terms of ability to reduce exposure of the animals to pathogens. Furthermore, Voermans (1997) concluded that the important benefits of good housing in minimizing animal stress were manifested in improved immune function and increased resistance to challenge by pathogenic microorganisms. Clean, dry bedding is essential to improved animal health, especially in the periparturient transition phase.

High environmental temperatures result in significant thermal stress for the transition cow. Exposure to heat during the third trimester of gestation shifts blood flow to the extremities and away from the uterus, compromising placental and fetal growth. Calves often have lower than normal birth weights, putting them at higher risk for mortality (Shearer and Beede, 1990). In addition, researchers in Georgia found that the incidence of retained placenta increased from 12% during the warm, humid months of May through September to 24% during the cooler months (Dubois and Williams, 1980). Hormone alterations due to heat stress affect mammary development and lactogenesis, reducing milk yield in the subsequent lactation (Table 7) (Shearer and Beede, 1990). Strategies to keep cows cool and comfortable during the transition period include providing shade for cows on pasture or utilizing sprinklers, misters, and/or fans in free-stall structures. Cows should also be provided with an easily accessible source of clean drinking water.

Summary

During the transition period, the dairy cow is undergoing numerous changes in endocrine, nutritional, metabolic, and physiological status as she prepares for calving and initiation of lactation. These changes result in a dramatic decrease in DM intake that worsens the negative energy balance already present after calving. If the negative energy balance during transition becomes excessive, metabolic diseases, such as fatty liver and ketosis, can result. Disruption of mineral balance during the periparturient period leads to mineral balance disorders, especially milk fever. These diseases are costly in terms of their affect on milk production, reproduction, and the cow's susceptibility to other periparturient disorders. Intensive management of the nutrition, feeding system, and environment of the periparturient dairy cow reduces the odds of disease and increases the odds of success.

The '100 day contract' is a series of delicate negotiations that encompass the full impact of the transition cow. Unsuccessful negotiations at any point increase the risk of overall failure. Getting the details right and ensuring adequate intake of all nutrients are the key elements of the '100-day contract'.

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Table 1. Energy and protein deposition in the uterus and fetus during pregnancy in Holstein cows.[1]

	Energy (kcal/day)		Protein (g/day)	
Gestation (days)	Uterus	Fetus	Uterus	Fetus
210	631	500	76	54
230	694	601	90	73
250	757	703	103	91
270	821	805	117	110

[1]Adapted from Bell et al., 1995.

Table 2. Periparturient changes in ruminal water-holding capacity and fill.[1]

	Average days from calving[2]						
	-61	-48	-34	-20	-6	+8	+22
Rumen Capacity, gal	33.5	31.4	28.5	28.0	26.9	37.5	35.1
Total fill/capacity, %	46.5	51.9	57.3	55.5	53.1	51.0	58.9
DM fill/capacity, %	6.7	6.2	6.6	6.0	6.2	6.4	7.4
Fluid fill/capacity, %	39.9	45.7	50.7	49.5	47.0	44.6	51.5

[1]Adapted from Stanley et al., 1993.

[2]Negative values indicate days prior to calving; positive values indicate days after calving.

Table 3. Lactational incidence risks and median days postpartum of disorders in 8070 multiparous Holstein cows in New York state.[1]

Disorder	Lactational Incidence: Risk (%)	Lactational Incidence: Median day of occurrence
Retained placenta	7.4	1
Metritis	7.6	11
Milk fever	1.6	1
Ketosis	4.6	8
Displaced abomasum	6.3	11
Mastitis	9.7	59

[1]Adapted from Grohn et al., 1995.

Table 4. The effects of early postpartum energy status on reproductive performance.[1]

	Days to first service	Days open	Services per conception	First service conception rate (%)
Normal	70.5	80	1.2	75
Subclinical ketosis	75.8	102	2.0	44
Ketotic	78.0	100	1.9	40

[1]Adapted from Miettinen, 1990.

Table 5. Influence of hypocalcemia on risk of other periparturient disorders.[1]

Disease	Odds ratio	*P*-value
Dystocia	2.8	<0.0001
Retained placenta	6.5	<0.0001
Left displaced abomasum	3.4	0.06
Ketosis	8.9	<0.0001
Mastitis	8.1	<0.0001

[1]Adapted from Table 2 in Curtis et al., 1983.

Table 6. Incidence of placental retention in dairy cows fed diets containing > 0.12 ppm of Se with or without 1000 IU of supplemental vitamin E during the last 40 days of gestation.[1]

Year	Reference	Treatment	
		Control	Vitamin E
		(% of group)	
1988	Mueller et al., 1988	26.7	6.9*
1989	Mueller et al., 1989	34.4	10.8**
1990	Thomas et al., 1990	52.9	22.0*
1991	Brzezinska-Slebodzinska and Miller, 1992	32.3	21.9

*$P < 0.05$
**$P < 0.01$
[1]Adapted from Miller and Brzezinska-Slebodzinska, 1993.

Table 7. Measurements of blood metabolites and nutrients between normal cows and cows with retained placenta.[1]

Item	Retained	Normal
Glucose, ng/dl	59.6	61.8
NEFA[2], meq/dl	0.494	0.340*
Amino acids, moles/dl	2.34	2.48*
Calcium, mg/dl	96.3	98.5*
Monocytes, 10^3/ml	225	310*

*$P < 0.05$
[1]Adapted from Chassagne and Chacornac (1994)
[2]NEFA = non esterified fatty acids.

Table 8. Effect of prepartum heat stress on postpartum milk yield.[1]

Production	Cooled	Heat stressed	Difference (%)
305-d milk yield, lbs.[2]	5878.4	5623.2	255.2 (4)
150-d milk yield, lbs./d	89.5	81.8	7.7 (8.5)
Peak milk yield, lbs./d[3]	91.0	87.4	3.6 (4)

[1]Adapted from Shearer and Beede, 1990.
[2]305-d predicted yield adjusted for age, month of calving, and Estimated Relative Producing Ability (ERPA).
[3]Means of peak milk production taken from three herds.

1. Birth of a live calf
2. Healthy cow during the transition period
3. High peak milk production
4. Controlled loss of body condition
5. High fertility at first breeding

Figure 1. Terms of the 100-day contract

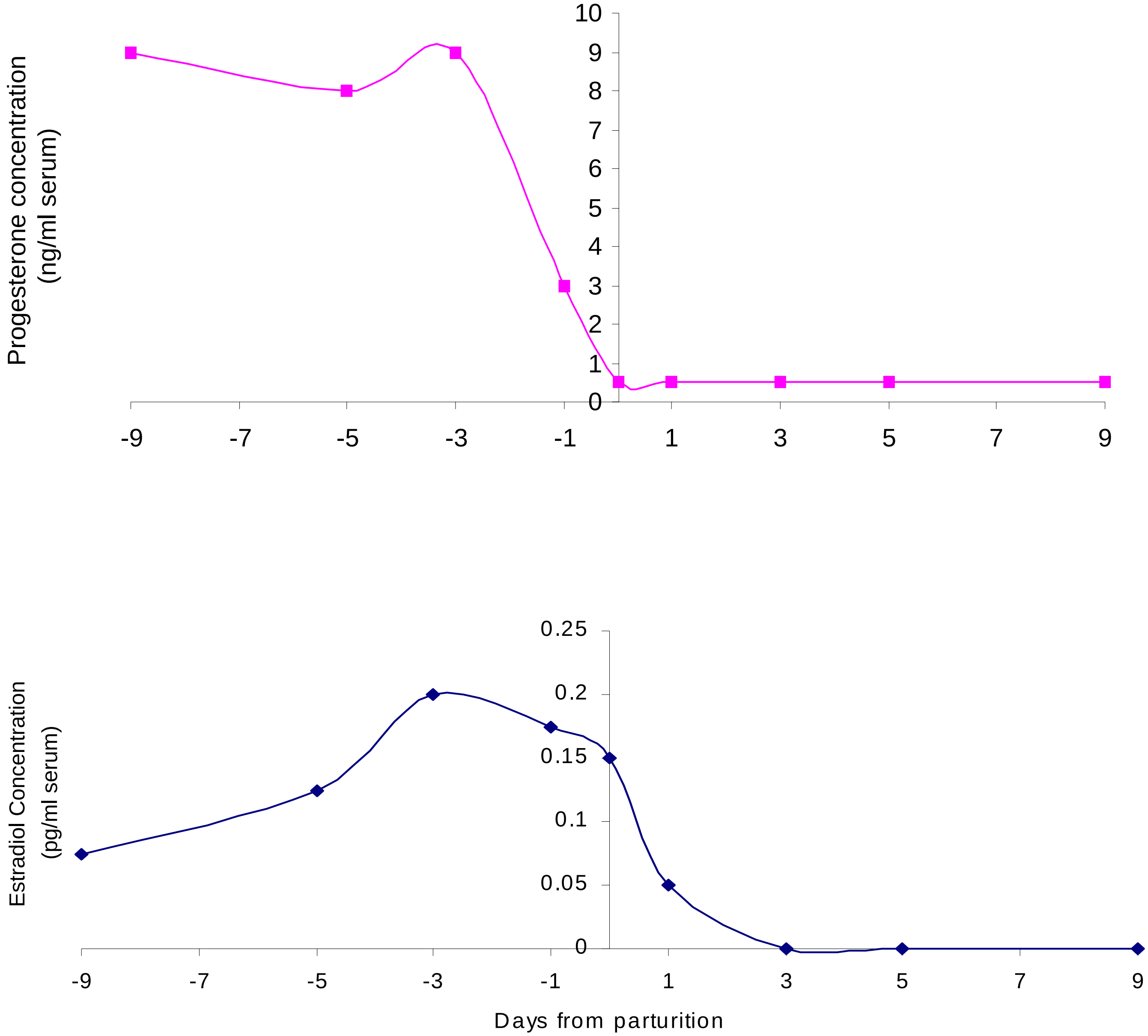

Figure 2. Changes in serum concentrations of hormones in cows during the periparturient period (adapted from Bell, 1995).

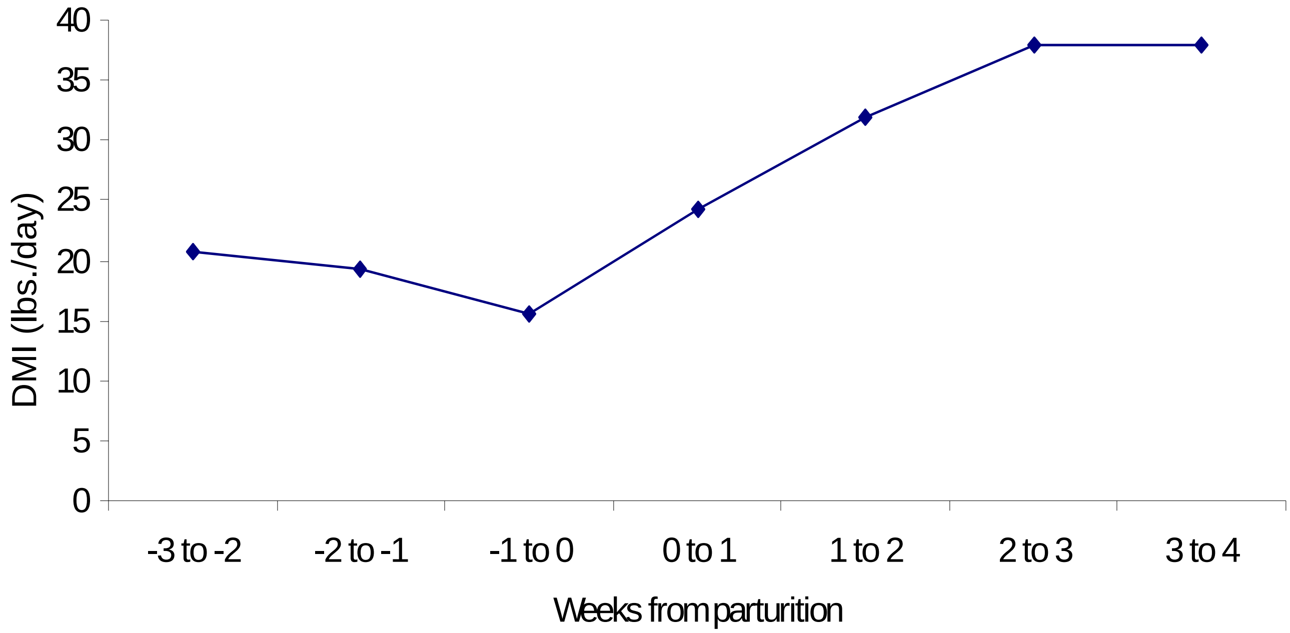

Figure 3. Dry matter intake of transition cows (Adapted from Underwood, 1998).

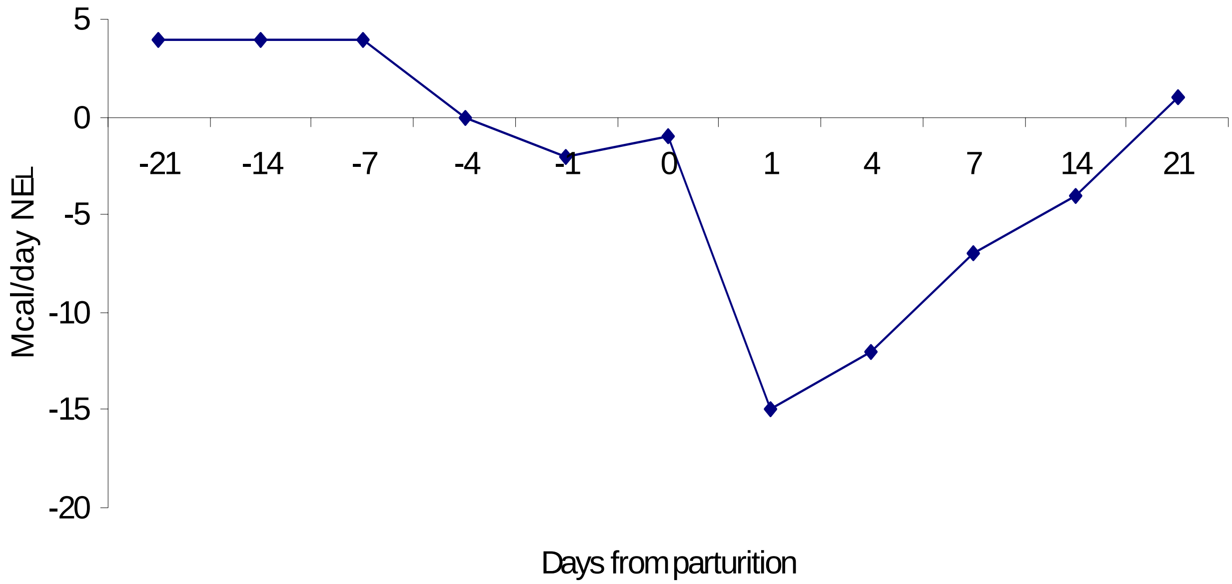

Figure 4. Estimated prepartum energy balance of transition cows (Adapted from Grummer, 1995).

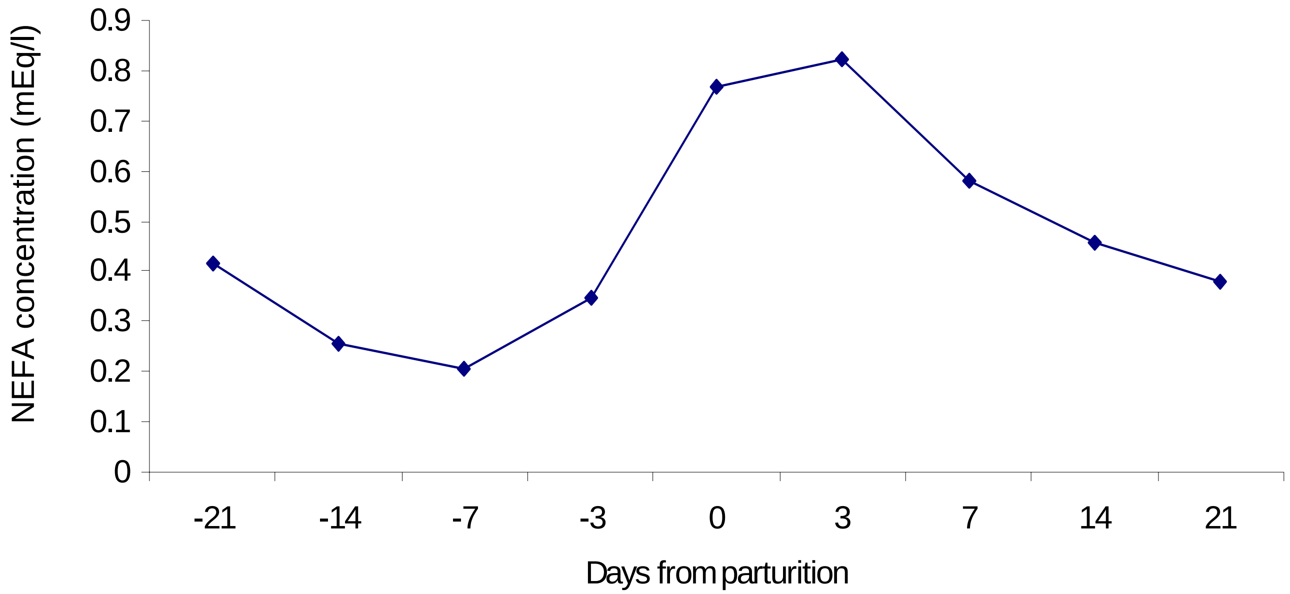

Figure 5. Serum non-esterified fatty acid concentration of transition cows (Adapted from Underwood, 1998).

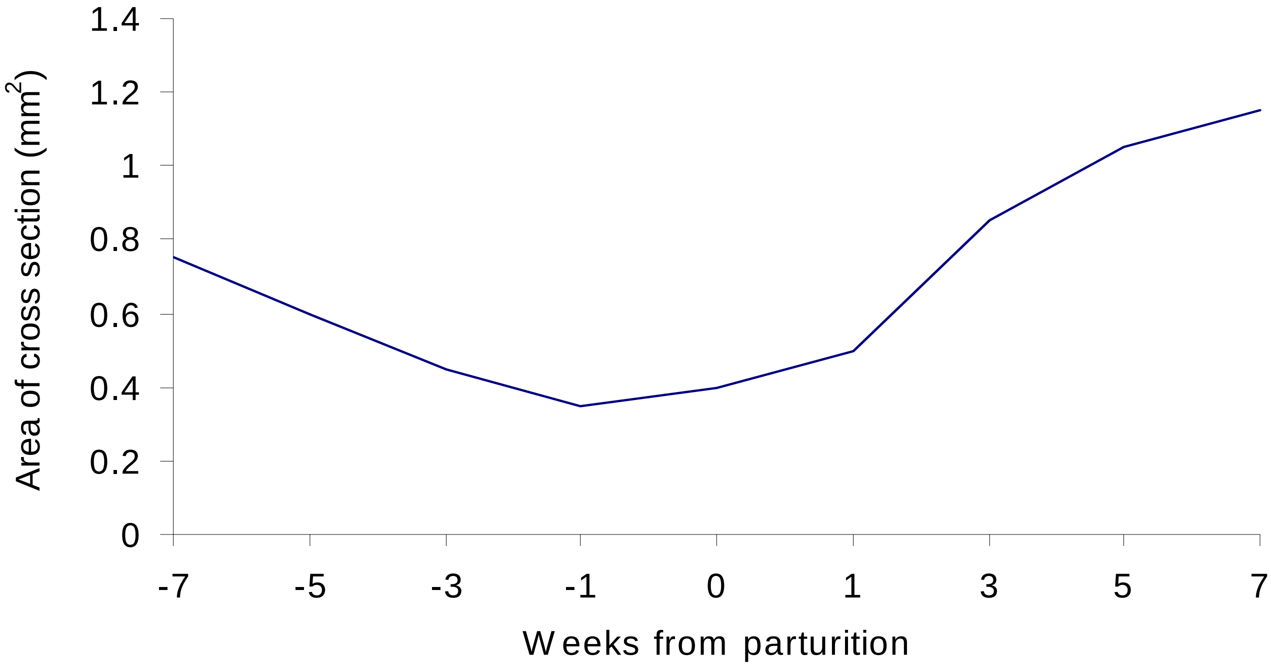

Figure 6. Changes in the area of cross sections of rumen papillae of cows fed low-energy diets prepartum and high-energy diets postpartum (Adapted from Dirksen et al., 1985).

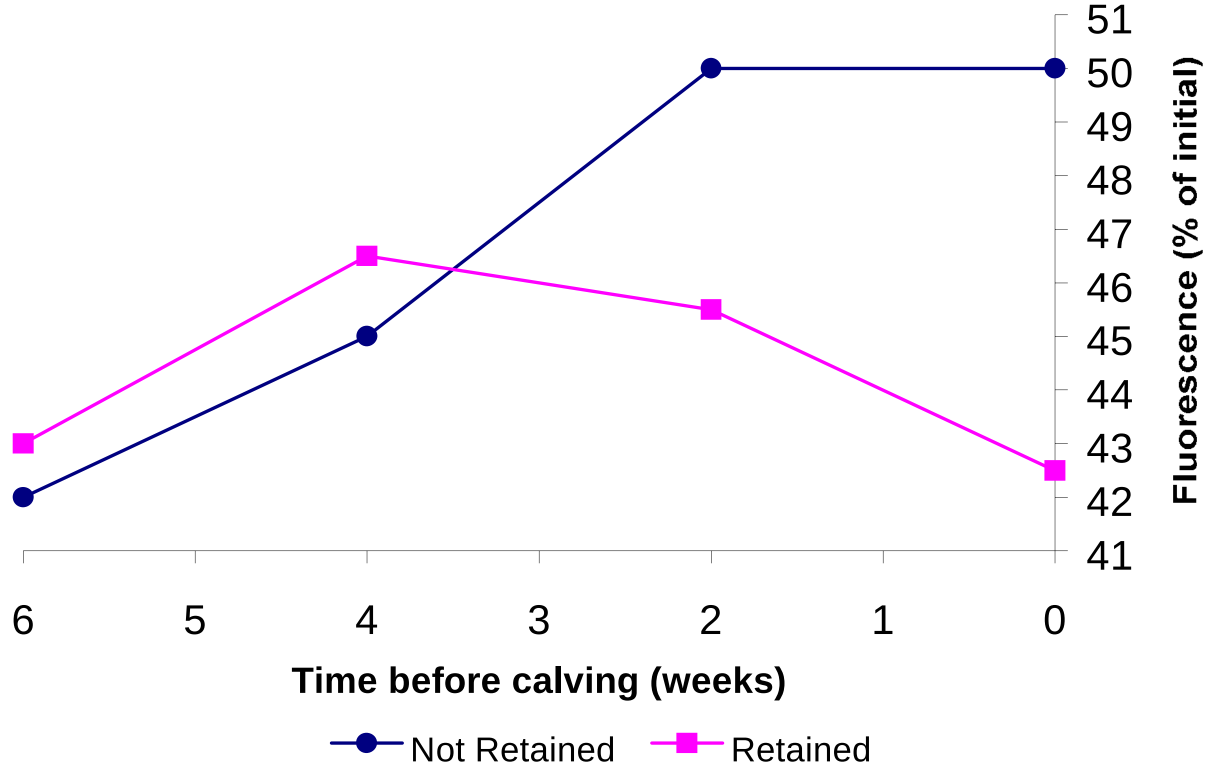

Figure 7. Total antioxidants in bovine plasma as measured by their protection of phycoerythrin fluorescence in vitro (Adapted from Miller and Brzezinska-Slebodzinska, 1993).

Prevention of Displaced Abomasum

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Abstract

Because of intake depression prior to calving and slow intake ascent post-calving, the transition period is the major risk period for abomasal displacements. Feeding and management practices that prevent other calving-related disorders reduce the risk of abomasal displacements. Cows that have excess body condition at calving are at increased risk of ketosis and abomasal displacements. Both excessive and minimal feeding of concentrates pre-calving may increase the risk of abomasal displacements. Feed bunk management is an important risk factor for abomasal displacements. Inadequate bunk space, high competition at the feed bunk, restricted bunk access time, and restricted feed availability may limit intake. Poor environmental and social adaptation of transition cows may limit feed intake. Low feed intake may lower rumen fill, providing greater opportunity for migration of the abomasum. The importance of bunk management practices that limit feed intake in causing left displaced abomasum **(LDA)** is likely greatest during the early post-calving period, because of the coinciding events of the transition period. Feed delivery practices can alter the actual nutrient densities of the consumed ration relative to nutrient specifications of the formulated ration. Sorting of the total mixed ration **(TMR)** in the feed bunk can also cause this problem. Fiber densities of the consumed ration that are below minimum recommended allowances may result. Excess TMR mixing may grind coarse particles and cause a lack of fiber physical form. Transition programs and feed bunk management practices should be monitored closely when investigating LDA problem herds.

Introduction

Shaver (1997) published a review of nutritional risk factors for abomasal displacements. The purpose of this paper is to summarize the important findings from that review, update any new information, and discuss the management practices necessary for the prevention of abomasal displacements.

Abomasal displacements cause economic loss in dairy herds through treatment costs, premature culling, and production loss. Current treatment costs range from \$100 to \$200 per case, and 10% of cows diagnosed with displaced abomasum are culled or die before the next test day. Treated cows that remain in the herd produce about 800 lb less milk the following month than cows without a displaced abomasum.

Eighty to 90% of all abomasal displacements are left sided. Estimates in the literature of average incidence rates for LDA range from 1.4 to 5.8%. We (Pehrson and Shaver, 1992) reported an average LDA incidence rate of 5% (range 0 to 21.7%) from a survey of 71 commercial dairy

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herds with 5,742 cows. Jordan and Fourdraine (1993) reported an average LDA incidence rate of 3.3% (range 0 to 14%) from a survey of 61 high-producing commercial dairy herds averaging about 24,000 lb of milk per lactation.

Transition Period

Eighty to 90% of LDA are diagnosed within one month post-calving. Estimates in the literature of the proportion of LDA diagnosed within two weeks post-calving range from 52 to 86%. This denotes the transition period of 2 to 4 weeks pre-calving through 2 to 4 weeks post-calving as the major risk period for LDA.

The transition period is characterized by intake depression pre-calving and slow intake ascent post-calving. Low feed consumption during the transition period is a risk factor for LDA through reduced rumen fill and increased incidence of other calving-related disorders. Low rumen fill may provide greater opportunity for migration of the abomasum. Decline of dry matter intake (**DMI**) is about 35% over the last week pre-calving and causes increased liver tri-glyceride immediately post-calving (Bertics et al., 1992). Concurrent calving-related disorders have been implicated as risk factors for LDA.

Post-Calving Disorders

Cows with uncomplicated ketosis, retained placenta, metritis, or subclinical milk fever are at an increased risk of LDA. This suggests that feeding and management practices that prevent other calving-related disorders will reduce the risk of LDA.

Conversely, LDA has been found to increase the risk of other calving-related disorders. Cows with LDA are at increased risk of complicated ketosis and metritis. This suggests that feeding and management practices that prevent LDA will reduce the incidence of some other calving-related disorders. Ketosis and LDA are closely related calving-associated disorders.

Body Condition Score

Cows with excess body condition score (**BCS**) at calving are at increased risk of LDA; incidence rates for cows (n = 1401, 95 commercial dairy herds) with low (2.75 to 3.25), medium (3.25 to 4), and high (> or = 4) BCS at calving were 3.1, 6.3, and 8.2%, respectively (Dyk, 1995). Increased risk of ketosis and fatty liver, greater pre-calving intake depression, and slower post-calving intake ascent for cows are associated with over-conditioned at calving.

Cows with excess BCS at calving were at increased risk of ketosis; incidence rates for cows with low, medium, and high BCS at calving were 8.9, 11.5, and 15.7%, respectively (Dyk, 1995). Higher ketosis incidence in cows with greater BCS at calving may have predisposed them to the higher observed incidence of LDA.

European workers (Garnsworthy and Topps, 1982) fed cows to a BCS (adjusted to a 1 to 5 scale) at calving of 2 to 3 (low), 3 to 4 (medium), and 4 to 5 (high) in two trials. During the first 16 weeks postcalving, cows with higher BCS at calving consumed less dry matter (**DM**) and reached maximum DMI later. Similar results were reported by Treacher et al. (1986) using two groups of cows with BCS at calving of 3 and 5 (adjusted to a 1 to 5 scale).

Lead Feeding

Lead feeding, the practice of increasing concentrates during the last few weeks prior to calving, is a common practice on commercial dairy farms. Lead feeding energy and protein have been shown to lower the risk of LDA and ketosis (Curtis et al., 1985).

Coppock et al. (1972) fed TMR containing 75, 60, 45, and 30% forage (DM basis) to 40 Holstein cows from 4 weeks pre-calving through 4 weeks post-calving. No LDA were observed in cows fed the high forage diet. Incidence rates for LDA in cows fed the 60, 45, and 30% forage diets were 16.7, 40, and 36%, respectively. This study involved an abrupt switch to TMR with higher levels of concentrate at 4 weeks pre-calving rather than a gradual increase in the amount of concentrate fed during the last few weeks prior to calving. This abrupt dietary switch may have aggravated the LDA response to higher concentrate feeding, but it reflects lead feeding practices in commercial dairy herds that feed TMR.

European workers (Dirksen et al., 1985) reported that the cross-sectional area of ruminal papillae declined when cows were placed on a low-energy dry cow diet, reaching a low point 1 to 2 weeks prior to parturition. The ruminal papillae cross-sectional area increased gradually after cows were placed on a high-energy diet starting 2 weeks prior to calving but was not maximized until 6 to 8 weeks post-calving. This suggests that capacity for ruminal VFA absorption is lowest during the transition period.

Minimal lead feeding pre-calving may increase the risk of acidosis and LDA through failure to increase the absorptive capacity of the ruminal papillae prior to the feeding of high-energy post-calving diets. Pre-calving adaptation of the rumen microbial population prior to the feeding of high-energy postpartum diets may also be important. Further, pre-calving concentrate lead feeding may increase energy intake and reduce fatty acid mobilization from adipose tissue, which may reduce the incidence of fatty liver and ketosis.

Both excessive and minimal lead feeding of concentrates pre-calving may increase the risk of LDA. After considering that intake depression during the close-up period results in a total DMI of 1.5% of body weight (**BW**), then guidelines for concentrate DM lead feeding of up to 0.75% of BW restricts the close-up TMR to 50% concentrate or less. This rate of concentrate feeding should allow for adequate ruminal conditioning, along with sufficient energy intake to address the fat mobilization issue if a high-starch concentrate is supplemented. We recommend that pre-fresh diets be formulated for 0.70 to 0.72 Mcal of net energy lactation (**NE_L**) per lb of DM. Cameron et al. (1998) implicated pre-fresh diets with >0.75 Mcal NE_L/lb DM as a risk factor for LDA.

Another supplementation strategy being used in the field for pre-fresh cows is the feeding of high-fiber rather than high-starch concentrates. One Midwest-based feed company reports, from in-house research trials and field experiences, good success with their pre-fresh diet recommendation of 5 lb grass hay (as-fed basis) and 12 lb high-fiber concentrate (as-fed basis) with the rest of the diet from corn silage. There is a lack of published research data comparing high-starch concentrates versus high-fiber concentrates as supplements in pre-fresh diets. Fiber sources with high ruminal fermentability (i.e. soy hulls or beet pulp) should be used if the high-fiber concentrate supplementation strategy is employed. This approach may offer some advantages from the standpoint of LDA prevention, but research data are lacking.

Post-Calving Concentrate Feeding

A special TMR for early post-calving cows is becoming more common, especially on large commercial dairy farms. We do not recommend formulation of post-fresh diets with less than 21% neutral detergent fiber (**NDF**) from forage. Ohio State workers (Wang et al., 2001) compared post-fresh diets that contained 17%, 21%, or 25% NDF from forage. Milk production and DMI of post-fresh cows (first 30 days in milk) were highest on the 21% NDF from forage diet. We recommend 35 to 40% non-fiber carbohydrate (**NFC**; DM basis) in post-fresh diets. Whole cottonseed, soy hulls, and beet pulp are good ingredients for limiting starch concentrations in post-fresh diets. Whole cottonseed also contributes a significant amount of effective fiber. These recommendations should offer some advantages from the standpoint of LDA prevention, but research data are lacking. Dietary supplementation of sodium bicarbonate lessens the decline in ruminal pH that is observed post feeding (Erdman, 1988). This may help prevent laminitis and LDA. The recommended inclusion rate for sodium bicarbonate is 0.75 to 1.0% of dietary DM.

Hypocalcemia

From a study with 510 Holstein cows in a commercial dairy herd, Florida workers (Massey et al., 1993) reported that cows hypocalcemic at parturition (total serum calcium < 7.9 mg/100 ml and serum ionized calcium < 4.0 mg/100 ml) were at increased risk of LDA. This increased risk of LDA for cows that are hypocalcemic at calving may be due to reduced ruminal and abomasal motility (Goff and Horst, 1997). There may be a role for strategies to prevent hypocalcemia at calving, such as formulation of pre-calving diets for dietary cation-anion difference, in the prevention of LDA.

Ration Physical Form

Oklahoma workers (Dawson et al., 1992) reported that cows fed ground alfalfa hay (1/4" hammer-mill screen) and concentrate in a pelleted (1/8") experimental TMR starting at calving were at increased risk of LDA (17.4 vs. 1.6%) compared with cows fed the standard herd ration of sorghum silage (1/2" theoretical length of cut) and concentrate mixed plus loose alfalfa hay. Cows that developed LDA were diagnosed within 8 to 18 days post-calving.

These results demonstrate that an extreme alteration in ration physical form (i.e. pelleted TMR) during the early post-calving period increases LDA. Lack of physical form reduces chewing activity and ruminal fill, motility, and fiber-mat formation and increases ruminal VFA concentration, which all may play a role in causing LDA. The importance of physical form as a risk factor for LDA is likely greatest during the early post-calving period, because of the coinciding events of the transition period.

Data are lacking with regard to the impact of varying silage and TMR physical form within typical field ranges on the incidence of LDA. We recommend that transition diets should contain adequate coarse particles to support good chewing activity and rumen fill. Diets with 8 to 10% of particles on the top screen of the Penn State – Nasco shaker box are recommended for both pre-fresh and post-fresh cows. Inclusion of 3 to 5 lb/cow/day of hay in the TMR for transition cows can help meet this coarse particle recommendation. Evidence of sorting of the transition-cow TMR should be monitored closely.

Dry Cow Forages

A wide variety of forages are used for dry cows on commercial dairy farms, but data are limited regarding their impact on the incidence of LDA. Purdue workers (Zamet et al., 1979) reported LDA incidence rates of 1/29 (LDA/n), 3/30 and 3/30 for chopped hay, haycrop silage, and corn silage in dry cow forage programs, respectively.

Agway workers (Nocek et al., 1983) evaluated dry cow forage programs consisting of long hay, 50% long hay and 50% corn silage (DM basis), and corn silage DM restricted to 1% of BW plus 2.0 lb/cow/day of liquid protein supplement. Incidence rates for LDA were 3.0, 4.3 and 6.3% for hay, hay - corn silage, and corn silage, respectively. Incidence rates for ketosis were highest for hay (9.1% vs. 6.3 to 6.4%). Higher incidence of LDA for corn silage may have been due to low rumen fill related to limit-feeding and lack of physical form. Higher incidence of ketosis for hay may have been due to lack of energy. The lowest incidence of LDA plus ketosis was observed with the hay - corn silage diet (10.6% vs. 12.1 to 12.7%). It appears that all corn silage rations should not be fed to dry cows. If all corn silage rations are limit-fed, rumen fill may not be sufficient to prevent LDA. If they are not limit-fed, excess energy consumption may cause over-conditioning and associated metabolic disorders.

However, controlled use of corn silage as a component of forage programs for dry cows may be beneficial. We generally recommend limiting corn silage to 50% or less (DM basis) of the dry cow forage program. Corn silage comprised 50 to 80% (DM basis) of the close-up dry cow forage programs in the trials of Mashek and Beede (2000 and 2001) with LDA incidence rates of 4.3% vs. 8.3% for 3 versus 6 week pre-fresh feeding periods and 7.5% vs. 10.3% for pre-fresh diets without or with corn grain supplementation. It is unknown whether feeding pre-fresh diets with a lower proportion of corn silage in the forage program would have reduced the incidence of LDA observed in these trials.

Transition Cow Environment

Bazeley and Pinsent (1984) reported that herds with a high incidence of laminitis tended to put cows through more abrupt changes at calving than low incidence herds. Although not evaluated in their field survey, the same relationship also likely applies to LDA. Their observation underscores the importance of specific feeding and management programs that allow prepartum and early postpartum cows to adapt gradually to social, environmental, and nutritional changes. Cow comfort, ventilation, and bunk management are especially important for transition cows.

Feed Bunk Management

Cameron et al. (1998) implicated that feed bunk management is a risk factor for LDA. Feed bunk management is a risk factor for LDA through effects on feed consumption and actual nutrient densities of the consumed ration.

Feed analysis

Errors in nutrient delivery can occur because of errors in the nutrient composition assigned to feed ingredients. The use of tabular values for nutrient composition of feed ingredients can be a source of error.

Error in the nutrient analysis of feed ingredients can result from poor sampling technique on the farm, infrequent feed sampling and testing, or inaccurate laboratory analyses. Variation in the layering of forages into bunker silos (i.e. alfalfa silage versus corn silage or silage of different qualities) and the relative uniformity of sample and feed removal from the face can lead to a discrepancy between the forage test and what is actually fed. Switching between silo bags before forage tests are received and a new ration is formulated can cause wide swings in nutrient delivery. To ensure consistent and accurate nutrient delivery, effort should be made to assess and control these sources of error.

Procedures are available to evaluate forage and TMR particle size in commercial testing laboratories (ANSI, 1988) or on the farm (Lammers et al., 1996) and should be employed to evaluate physically effective fiber. Dietary NDF from forage should also be included in the evaluation of physically effective fiber.

Ingredient DM adjustments

Errors in nutrient delivery can occur because of failure to routinely determine the DM content of wet ingredients and adjust the rations accordingly to maintain correct and consistent DM proportions of ingredients. This is especially true for the DM proportion of forage to concentrate.

There may also be an error in the on farm determination of DM content. Considerable care and time must be taken to drive off all of the water to reach a stable endpoint weight before calculating the DM content of samples when using the microwave-oven and Koster-tester methods, or otherwise, DM content will be over-estimated.

Ingredient feeding rates

Errors in nutrient delivery can occur because incorrect amounts of ingredients have been added to the TMR. This can be due to an error in communication between the nutritionist, herd manager, and the feeder. More often it is due to a feeder that free lances from the formulated ration, attempts to cover up an error by adding more or less of another ingredient later on in the batch, or simply makes an honest mistake in batch preparation.

Computer programs (i.e. Easy Feed, Feed Watch, Dairy Tracker, and Feed Supervisor) are now available that lock the desired recipe for each batch in the scale, record the amount of each ingredient actually added to the batch, and record the total batch amount delivered to each pen. These programs have the potential to dramatically reduce the operator error that is associated with feed mixing and delivery. They can also help ensure batch-to-batch and day-to-day consistency of the TMR.

Feeding a partial TMR or some portion of the daily allotment of forage or concentrate separate from the mix can be a large source of variation in nutrient consumption among cows within a group. Adding forage to a set mixer volume rather than a scale weight can not be done accurately enough. Floating the amount of forage that is added to the batch mix depending on the amount of feed refusal is not accurate either.

Scale error can occur and the calibration of scales should be done routinely. Faulty scales should be either fixed or replaced.

Feed mixing

Incorrect and inconsistent TMR mixes can arise from mismanagement of the mixing process. Sampling the bunk mix and performing a nutrient and particle size analysis can assess this. Mixing error can occur for the following reasons:

- batch size too small (common problem with transition rations),
- batch size greater than the mixing capacity of the mixer,
- trying to mix too much hay in the batch (this may also cause dispensing problems),
- improper sequencing of ingredients into

the mixer,

- under mixing or mixing for too short a period of time (causes inadequate mixing), and
- over mixing or mixing for too long a period of time (causes unmixing of some ingredients and particle size reduction of the batch mix).

Feed delivery

Cows that slug feed the TMR may be more prone to laminitis and LDA. Cows with reduced DMI may be more prone to LDA. Factors that may cause slug feeding of the TMR or that may limit feed consumption include:

- limited bunk space,
- limited feed access time,
- restricted feeding versus feeding for 5 to 10% refusal,
- inconsistent feeding schedule,
- infrequent TMR push up, and
- bunk competition.

The combination of limited bunk space (< 1.5 feet per cow) and feed access time (< 16 to 20 hours per day) is worse than either situation alone. The use of lock-ups in situations of limited bunk space and feed access time exacerbates the problem because each lock up and the cow in it takes up 2 feet of bunk space. When overcrowding of free stalls coincides with limited bunk space, as is often the case, the potential for laminitis is greater because cows may spend more time standing on concrete rather than lying in stalls (Colam-Ainsworth et al., 1989). Cows which develop laminitis would be expected to have reduced DMI, and therefore may be more prone to LDA. First lactation heifers fed in a separate group spent 10 to 15% more time eating and consumed 0.5 to 2.0 more meals per day than herdmates grouped with mature cows (Krohn and Konggaard, 1979). Bunk competition may play a role in laminitis and LDA.

Sorting

Armentano and Leonardi (1999) and Martin (1999) observed extensive TMR sorting in the feed bunk in university and on-farm trials, respectively. Data on particle size of TMR and orts (ANSI, 1988) and intake indicated that cows sorted against the coarse particles (Armentano and Leonardi, 1999). This was more evident for TMR containing 40% compared to 20% alfalfa hay (DM basis). The variation in sorting among cows was large. Martin (1999) determined particle size of the TMR and bunk mix (Lammers et al., 1996) at 6-hour intervals post feeding on a commercial dairy. The percentage on the top screen of the Penn State – Nasco shaker box for the TMR and bunk mix at 6, 12, 18, and 24 hours post feeding were 9.3, 13.7, 21.5, 27.5, and 58.7%, respectively. Cows sorted against the coarse particles. From a projection of the coarse particle intake at each time period, it appeared that intake of coarse particles was less than predicted during hours 0 to 12 post feeding and more than predicted during hours 13 to 24 post feeding. An on-farm evaluation of sorting should include particle size determination (Lammers et al., 1996) of the TMR, bunk mix, and orts.

Factors that may make a TMR prone to sorting include:

- DM content of forage and mix,
- particle size of forage and mix,
- cobs in corn silage,
- amount of hay added to mix,
- quality of hay,
- frequency of feeding,
- bunk space,
- feed access time.

If sorting is a problem, then one or more of the following may need to be considered:

- feeding smaller amounts of TMR more frequently,
- adding less hay to the mix,
- processing hay finer,
- using higher quality hay,
- using hay that is more pliable,
- processing corn silage,
- addition of water to the dry TMR, and
- addition of a liquid-molasses product to the TMR to tie up fines.

Summary

Herds with inadequate feeding and management programs for transition cows are at an increased risk of developing LDA. Over-conditioned cows are more likely to develop LDA. Feed bunk management is a risk factor for LDA. There is a myriad of errors in feed delivery and bunk management that can occur on commercial dairies to cause a variation in nutrient intake relative to the formulated ration. This variation is particularly evident for coarse particles that are prone to sorting in the feed bunk. Feed sorting may be a major risk factor for LDA, and it merits investigation.

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Dietary Factors that Affect Dry Matter Intake

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Abstract

Physical and chemical characteristics of diets can have a large effect on feed intake and milk yield of dairy cows. The main dietary factors that affect feed intake are the filling effect of diets, the ruminal fermentability of diets, type and amount of fat in the diet, and nutrients that limit maximum milk yield. Distension in the rumen is a major factor affecting dry matter intake **(DMI)** of high producing cows and it becomes a more dominant mechanism regulating feed intake as milk yield increases. The filling effect of diets is determined primarily by concentration and digestion characteristics of forage neutral detergent fiber **(NDF)** in the diet. Feed intake is also regulated by fuels provided by the diet, but regulatory mechanisms are much more complex than the common assumption that animals eat to meet their energy requirements. Site of starch digestion affects the type of fuel absorbed by the animal and can dramatically affect DMI with relatively little effect on energy content of the diet. In addition, fat sources that provide unsaturated fatty acids to the small intestine can result in lower DMI and possibly lower energy intake, while other fat sources that provide more saturated free fatty acids to the small intestine might increase energy intake. Forage NDF content can be used to formulate diets and the optimal forage NDF for a group of cows with available dietary ingredients depends upon the fermentability of starch and fiber, variation in DM and NDF content of forages, forage particle size, the feeding system used, and other factors. The goal of formulating diets for high producing cows is to provide low fill, highly fermentable diets that result in consistent fermentation over time. Diets with high forage NDF will limit feed intake, particularly for the highest producing cows. However, high forage NDF diets might be necessary to maximize energy intake and animal health given the dietary ingredients and feeding system available.

Introduction

Feed intake is a function of meal size determined by satiety and the time interval between meals determined by hunger. The brain receives many different signals that affect satiety and hunger. It has been proposed that animals eat the amount of a particular diet that minimizes the total discomfort produced by signals from various receptors in the body to the brain. Distension in the rumen causes discomfort and can reduce feed intake, but high producing animals might tolerate a greater degree of discomfort from physical fill to offset discomfort from hunger. Manipulating diets to increase meal size and increase frequency of meals can lead to greater feed intake. A greater understanding of the mechanisms regulating feed intake along with evaluation of animal responses to diet changes allows dietary adjustments to be made to optimize feed intake as well as to optimize allocation of dietary ingredients to animals. Although regulation of feed intake is very com-

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plex, the main dietary factors influencing DMI are:

- Filling effect of diets,
- Ruminal fermentability of diets,
- Unsaturated fat reaching the intestines, and
- Other nutrients limiting milk yield.

This paper addresses the major dietary factors affecting feed intake and how to formulate diets to increase energy intake and maximize yield for lactating cows.

Distension in the Rumen

Ruminal fill can limit intake of high producing cows and other cows fed high forage diets. As milk yield increases, ruminal fill becomes a greater limitation on feed intake, and the highest producing cows within a group generally have feed intake limited by ruminal fill to the greatest extent. Reformulating the diet to decrease its filling effect might increase feed intake of the highest producing cows in the group while decreasing feed intake of lower producing cows in the group, resulting in no noticeable difference in feed intake on a group basis. Feed intake might decrease for the lower producing cows in the group because the reformulated diet that is less filling might be more fermentable and(or) have greater energy density which might result in smaller meal size and(or) longer time between meals. The extent to which feed intake is limited by ruminal fill for cows in the peri-parturient period is not known. It is important to note that the rumen doesn't have to be full for ruminal fill to limit intake; there are receptors in the rumen wall that signal the brain when the rumen is stretched. Diets with a greater filling effect limit meal size, but hunger occurs sooner and the number of meals consumed per day might partially or completely compensate for the decreased meal size.

The filling effects of feeds are related to the amount, form, and digestion characteristics of forage fiber. Coarse fiber particles (effective fiber, mostly from forage) are needed in the diet to maximize production in at least three different ways: 1) stimulation of chewing which results in the secretion of salivary buffers, 2) formation of a rumen mat that entraps small particles, increasing their ruminal digestibility, and 3) providing a consistent source of fuels to the microbes in the rumen which functions to provide a steady supply of fuels to the liver and mammary gland. Some sources of fiber are very effective at stimulating chewing and causing mat formation in the rumen (long and coarsely chopped forages) while others are not (most high fiber byproducts). Also, sources of fiber vary greatly in NDF digestibility and retention time in the rumen. All three of these functions mentioned above are important to maximize milk yield, and the most valuable sources of fiber are those that are effective at stimulating chewing and formation of the rumen mat and are also highly digestible with a rapid ruminal turnover (less filling).

Filling Effect of Diets

The filling effect of a diet is determined primarily by initial bulk density of feeds, as well as their filling effect over time in the rumen. The overall filling effect is determined primarily by:

- Forage NDF content,
- Forage type (legumes, perennial grasses, and annual grasses), and
- NDF digestibility (within a forage family).

Forage NDF is less dense initially, digests more slowly, and is retained in the rumen longer than other dietary components. Feed intake of high producing cows is often reduced dramatically by increasing the forage NDF concentration of the diet. Several studies in the literature reported a decrease in DMI of ~ 5 to 9 lb/day when dietary NDF content was increased from 25 to 35% by substituting forages for concentrates. Although most studies reported a significant decrease in DMI as forage NDF increased, the DMI response was variable, depending on the degree to which intake was limited by ruminal fill. Higher producing cows are limited by fill to the greatest extent, and the filling effect of forage fiber varies depending on particle size and fermentation characteristics.

Experiments that have evaluated effects of forage particle size have generally shown small effects on DMI. However, one experiment showed little effect of particle size of alfalfa silage when fed in high grain diets but a large reduction in DMI occurred for the diet containing longer particle size for alfalfa silage when fed in a high forage diet. Feed intake might have only been limited by ruminal fill in the high forage diet, which could explain the interaction observed.

Increasing dietary NDF content by substituting non-forage fiber sources **(NFFS)** for concentrate feeds has shown little effect on DMI in studies reported in the literature. The NFFS include byproduct feeds with significant concentrations of NDF, such as soyhulls, beet pulp, cottonseed, corn gluten feed, and distiller's grains. Fiber in NFFS is probably much less filling than forage NDF because it is less filling both initially (smaller particle size) and over time in the rumen because it is digested and passes from the rumen more quickly.

Forage NDF has a much longer ruminal retention time than other major dietary components. Retention time in the rumen is longer because of longer initial particle size and greater buoyancy in the rumen over time, which differs greatly across forages. As forages mature, the NDF fraction generally becomes more lignified. Lignin is a component of plant cell walls that helps stiffen the plant and prevent lodging. It is also essentially indigestible by ruminal microbes and limits fermentation of cellulose and hemicellulose. Within a forage type, the degree to which NDF is lignified is related to the filling effects of the NDF. Fiber that is less lignified clears from the rumen faster, allowing more space for the next meal. However, ruminal retention time of NDF from perennial grasses is generally longer than for legume NDF in spite of being less lignified. Because of this, it is more filling and should not be included in high concentrations in diets of cows for which feed intake is limited by ruminal fill, unless it is of exceptionally high quality. Corn is an annual grass, and corn silage NDF digests and passes from the rumen quickly and can be an excellent source of forage NDF for high producing cows.

The extent of lignification of NDF is a useful way to estimate the filling effects of forage NDF. To calculate lignification of NDF, divide the lignin content as a percentage of DM by the NDF content as a percentage of DM and multiply by 100. Data from the upper Midwest of the U.S. indicate that the lignin content of alfalfa NDF ranges from ~11 to 20%, and the lignin content of corn silage NDF ranges from ~ 3 to 9% when measured as acid-detergent sulfuric acid lignin. Forages with low lignified NDF are especially valuable (except perennial grasses) and should be targeted to the highest producing cows to allow them to consume more feed and attain higher milk yield. This is true even if the forage has low protein content or high NDF content, both of which can be compensated for by diet formulation. Forages with greater lignification of NDF and forage mixtures with higher perennial grass content should be targeted to animals whose DMI is not limited by ruminal fill, such as cows in late lactation, dry cows (except those close to calving) and heifers. The relative amount of grass in older stands of alfalfa can be determined by the ratio of acid detergent fiber **(ADF)** to NDF; ADF represents 50 to 60% of the NDF for grasses but over 75% of the NDF for legumes. Target alfalfa with the highest ADF as a percentage of NDF and the lowest lignin as a percentage of NDF to the highest producing cows. Besides forage maturity, the extent to which NDF is lignified is also greatly affected by growing conditions, such as light, heat, and water stress. Lignification of NDF is not related to NDF or protein content for either alfalfa or corn silage. Because alfalfa is priced in some markets based upon NDF or protein content or relative feed value **(RFV)**, and not on the lignification of NDF, this presents an opportunity to purchase a valuable dietary ingredient (effective, digestible NDF) inexpensively.

When a group of cows is offered a diet, feed intake of the highest producing cows are most limited by ruminal fill and these cows present the greatest opportunity to increase energy intake by diet formulation. However, when the filling effect of the diet is decreased, problems can occur with slug feeding because low-fill diets can be consumed rapidly. This is a common problem when cows compete for feed bunk space in overcrowded facilities and requires diets that are either more filling or less fermentable to prevent ruminal acidosis.

Low ruminal pH from highly fermentable feeds can decrease rate of fiber digestion and increase the filling effects of the diet, which might increase distension in the rumen. Although low ruminal pH is generally associated with high grain diets for which distension is less likely to be a constraint on feed intake, ruminal fermentability of grains are highly variable and daily means for ruminal pH of less than 5.7 have been reported for diets with high (> 40%) NDF content. Fat can also inhibit fiber digestion in the rumen and can decrease rumen emptying, both of which can increase distension in the rumen. The CP content of diets is often related positively to DMI of lactating cows; this is at least partly because of increased ruminally degraded protein effects on digestibility of feeds. The mechanism involved is presumably a reduction in distension as fiber and DM digestibilities increase. Moisture content of silages has been reported to be negatively related to feed intake, but feed intake of high moisture forages is more likely limited by fermentation products than moisture content per se.

Ruminal Fermentability of Diets

Rapid fermentation of ingested feed during a meal produces volatile fatty acids **(VFA)** that can cause satiety. Although acetate is the VFA produced in the greatest quantity in the rumen, propionate has a greater effect on limiting intake. When dietary NDF is held constant, increasing the fermentability of the diet by substituting a rapidly fermentable starch source, such as ground high moisture corn, for a starch source with a more moderate rate of fermentation, such as dry corn, will likely reduce meal size and possibly decrease daily DMI. The fermentability of diets depends on digestion and passage characteristics of individual feed ingredients and interactions among them. Starch is generally fermented faster than NDF but passes from the rumen more quickly. Although nonfiber carbohydrates **(NFC)** are often used as a proxy for the fermentability of diets, it is poorly related to fermentability because fermentability of both starch and NDF vary greatly by source.

Factors affecting ruminal fermentability of fiber include extent of lignification, rate of fermentation, and ruminal retention time. As discussed above, rate of fermentation is dependent on intrinsic characteristics of the feed and on ruminal pH over time. Rate of passage is related to particle size and fermentation characteristics that affect buoyancy in the rumen. Retention time of forage NDF ranges from 24 to over 40 hours for lactating cows, depending on the amount of feed intake, dietary characteristics and source of NDF.

Ruminal fermentation of starch is affected by particle size, gelatinization of starch, and amount and solubility of endosperm proteins. Dry rolling and grinding decrease particle size of grains, which increases surface area of the grain available to microbes and therefore, rate of fermentation. Steam rolling or flaking increase surface area and also gelatinize starch, which increase accessibility by microbes and rate of fermentation. Endosperm proteins surround starch granules and inhibit accessibility to starch by ruminal microbes. Different grain types such as wheat, barley, corn, and sorghum have major differences in amount and solubility of endosperm proteins that dramatically affect rate of fermentation. Wheat and barley have low concentrations and greater solubility of endosperm proteins, resulting in greater rates of fermentation than corn or sorghum. There is also great variation in amount and solubility of endosperm proteins among corn hybrids. Some hybrids have floury endosperm with soluble proteins and are more readily digested, and others have more vitreous endosperm with insoluble proteins and are more resistant to digestion. High moisture fermentation results in proteolysis and an increase in the solubility of endosperm proteins, increasing rate of starch digestion. Rate of starch fermentation and protein solubility has been shown to increase with time after ensiling. Therefore, corn silage and high moisture corn are expected to have lower starch digestibility immediately after ensiling compared to several months later after endosperm proteins have become more soluble.

Ruminal starch fermentation ranges from less than 40% to greater than 90% depending on source. Ruminal fermentability depends on rate of digestion and rate of passage from the rumen, which, in turn depends on intrinsic characteristics of individual feeds, other dietary components, and on characteristics of the animals fed. For instance, rate of starch digestion for a particular feed depends on the population of starch digesting microbes in the rumen. Rate of starch fermentation (percentage per hour) can increase dramatically when the fermentable starch content of the diet is increased. Rate of passage is affected by the size and density of particles and by the filtering effects of the rumen mat and by level of intake. The major limitation to fermentation rate of sugars is accessibility by rumen microbes. Although sugars from whey or molasses are fermented very quickly and completely, sugars in fresh forages are less accessible and probably fermented more slowly but completely because of the long retention time of forage particles in the rumen.

Fermentation of organic matter **(OM)** in the rumen results in the production of acetic, propionic, butyric, and other VFA. Lactic acid is also produced, but its rate of utilization by microbes is usually sufficient to keep concentrations low. If a diet suddenly becomes more fermentable, lactic acid concentrations can increase and ruminal pH can drop rapidly because lactic acid is a much stronger acid than the VFA. This happens when abrupt changes occur in the diet, such as when a much more fermentable starch source is substituted for one that is less fermentable, or when heavy rains result in more moisture and less forage DM and NDF added for silage in bunker silos when total mixed rations **(TMR)** are mixed. When cows have clinical ruminal acidosis, it is because of elevated lactic acid concentrations. Increasing consistency in all aspects of your feeding program and paying particular attention to mixing and to variation in forage DM and NDF contents will help prevent lactic acidosis and allow diets with lower forage NDF content to be fed. Lactic acid is not usually a factor in sub-clinical acidosis, which results in lower energy intake and poor microbial efficiency. This happens when production of VFA exceeds the buffering capacity of the ruminal contents, resulting in a decline in ruminal pH.

The optimal ruminal pH to maximize milk yield and efficiency of milk production is unknown. It probably varies for different cows and feeding conditions. However, we do know that fiber digestion decreases as pH is reduced from ~ pH 6 to pH 5.5 and below. This is because growth of fiber-digesting microbes becomes inhibited as pH declines. We also know that once populations of fiber digesting microbes are reduced, it can take many days to restore their numbers. On the other hand, the starch-digesting microbes have shorter doubling times and their populations can increase quickly. The implication of slower fiber digestion in the rumen is that fiber becomes more filling and feed intake might decrease. Fermentation acids are also absorbed from the rumen more quickly as pH declines and this might result in smaller meal size. While this might benefit cows "on the edge" of ruminal acidosis, it might result in lower DMI for others. The average ruminal pH throughout a day is much less meaningful than the fraction of time ruminal pH is below a threshold value, such as pH 5.7. Therefore, feeding management decisions should be made to minimize variation not only from day-to-day but also within a day. Factors affecting variation in ruminal pH throughout a day include those that affect the number and size of meals discussed above and the fermentability of diets.

The production rate of fermentation acids depends upon the amount of OM fermented per unit time and the efficiency at which microbes utilize this OM for growth. When large amounts of highly fermentable OM are quickly provided to ruminal microbes, they sometimes uncouple growth from fermentation. This is called energy spilling and is undesirable for two reasons. The first is that less microbial protein will be produced per pound of OM fermented. The second is that much more acid will be produced per pound of OM fermented, which adds to the acid load in the rumen that must be neutralized or buffered. This also results in increased rate of propionate production and absorption, which can decrease meal size, increase the interval between meals, and decrease feed intake. Reductions in ruminal pH from excess fermentation acid production can also result in lower fiber digestion and further lower efficiency of microbial protein production.

Consistency of Ruminal Fermentation

There are many benefits to a high level of ruminal fermentation that is consistent over time. This can be attained by feeding highly fermentable effective NDF, and starch with moderate rate of fermentation with a moderate to slow passage rate from the rumen. It is also important to feed ad libitum, and avoid over-crowding to decrease slug feeding. Starch sources that ferment rapidly result in a more variable fermentation over time with a much greater production of fermentation acids immediately following a meal than prior to the meal. Less variation in fermentation acid production over time translates to higher minimum ruminal pH and allows more fermentable diets to be fed. A consistent supply of available carbohydrate in the rumen will increase efficiency of microbial protein production, reducing the need for expensive sources of bypass protein. This will ensure consistent production and absorption of VFA into the blood which will help increase feed intake and possibly result in less insulin release, and therefore, greater partitioning of energy to milk.

Effects of Fat Source

Effect of added fat on energy intake is a function of its effect on feed intake, on digestibility of dietary DM, and the digestibility of the fatty acids in the fat source. Effects of fat on feed intake vary greatly by source with no consistent effect observed for oilseeds or hydrogenated fat sources, but a linear reduction in feed intake of over 2.5% for each 1% added fatty acids from calcium soaps of palm fatty acids and a reduction of about one half of that observed for unprocessed animal fat, including tallow and grease occurs. Unsaturated fatty acids reduce feed intake more than saturated fatty acids when infused into the small intestine. It appears that unsaturated fatty acids reaching the intestines is a major factor reducing feed intake and that more unsaturated fat reaches the intestines from calcium soaps of palm fatty acids than from unprocessed animal fat and relatively little unsaturated fatty acids reach the intestines with hydrogenated fat and with oilseeds which contains fatty acids that are extensively biohydrogenated in the rumen. Although large quantities of unsaturated fat in the diet that is rapidly released, such as vegetable oil, can result in decreased fiber digestion, unsaturated ruminally available fat from oilseeds can be included in the diet at moderate levels (~3% added fat) without inhibiting ruminal fermentation. Whole oilseeds are an excellent source of fat because the fat is released slowly in the rumen, hydrolyzed to free fatty acids, and biohydrogenated. The saturated free fatty acids reaching the small intestine have little effect on feed intake and are only slightly less digestible than unsaturated free fatty acids reaching the small intestine, which has been shown to reduce feed intake. Hydrogenated free fatty acids have no consistent effect on feed intake, have little or no effect on ruminal fermentation, and can be used to further increase energy intake further.

Other Nutrients Limiting Milk Yield

Low availability of nutrients that limit milk yield can reduce feed intake. This might be glucose, individual amino acids, fatty acids, or other nutrients. The mechanisms involved are complex and differ by the limiting nutrient, but evidence suggests that feed intake can be "pulled" by increased milk yield. For instance, increased supply of limiting amino acids could increase rate of clearance of metabolic fuels from the blood, increasing hunger and reducing the inter-meal interval.

Diet Formulation for High Producing Cows

Ultimately, the usefulness of the information presented above is dependent upon how it is used to formulate diets. Although the type and characteristics of carbohydrate must be considered when formulating diets for all cows, it is especially important when formulating diets for cows with high daily milk yield because ruminal fill limits DMI of these cows to the greatest extent. A balance must be attained for ruminal carbohydrate fermentation. Carbohydrate fermentation in the rumen is desirable to provide fuels for microbial growth and production of microbial protein, yet the fermentability of the diet must be limited to prevent excessive production of fermentation acids. Inadequate effective fiber or excessive fermentability of the diet can decrease ruminal pH, feed intake, diet digestibility, and microbial protein production. This is a major problem on many dairy farms that results in poor health, and reduces milk yield and farm profitability. On the other hand, diets with excessive effective fiber that are more filling and diets that are poorly fermentable can also result in lower milk yield and profitability because of reduced energy intake and microbial yield. Both situations can be thought of as lost opportunity for maximization of farm profits. Understanding the complex factors that interact to determine energy intake and microbial protein production in the rumen can pay off generously by allowing increased milk yield and reduced dietary costs. The goal of formulating diets for carbohydrates is to provide low fill, highly fermentable diets that result in consistent ruminal fermentation.

Forage NDF **(FNDF)** content should be used as the primary basis for diet formulation because it best represents the filling effects of diets and is the primary source of effective fiber in diets. Diets should be formulated based on concentration of FNDF, and not on the amount consumed per day, because dietary characteristics affect DMI, and carbohydrates must be balanced for optimal effective fiber and fermentability of carbohydrate. Balanced is the key word; when diets are formulated for an amount of FNDF or effective NDF (which might be based on a percentage of body weight), the assumption is made that there is a requirement that must be met that is independent of the rest of the diet. Unfortunately, this concept doesn't incorporate much of what we know about factors affecting energy intake and microbial protein production.

The optimum concentration of FNDF that will maximize energy intake of lactating cows ranges from ~ 17 to 28 % of DM. Figure 1 illustrates how several primary factors affect the optimal FNDF content of the diet.

Because intake may be limited by physical fill as the FNDF content of the ration increases and FNDF is generally less digestible than other feed components, the goal to increase energy intake should be to formulate diets with lower FNDF concentrations, while preventing excessive production of fermentation acids. The concentration of FNDF within this range is dependent on the cow or group of cows, the feeds available, and the feeding system used. The minimum FNDF content (17%) would be optimal in relatively few situations because of one or more limiting factor(s). Beginning at the minimum FNDF content, several factors will require a higher optimal FNDF content to maximize energy intake and microbial protein production.

Recommendations

- Starch sources with high ruminal digestibility can result in excess fermentation acid and lower ruminal pH. High propionate production from highly fermentable diets can also limit DMI. These sources include rolled barley and wheat, ground high moisture corn, steam-flaked corn, finely rolled corn silage, bakery waste, and sugar sources, such as molasses, whey, and citrus pulp. Adjust site of starch digestion by altering the ruminal degradability of starch. This is easily accomplished by substituting a starch source with lower ruminal degradability for one with higher ruminal degradability. It is important to use starch sources with high whole tract digestibility to maximize energy intake. Finely ground dry corn is generally less fermentable than barley, low-density steam-flaked corn, or ground high moisture corn and can be used to manipulate site of starch digestion because it has high whole tract digestibility. Coarsely rolled corn or sorghum is less desirable because whole tract digestibility is lower for these starch sources. Substitution of a less fermentable starch source, such as dry ground corn for high moisture corn, can increase DMI when it is limited by propionate production and increase microbial efficiency.

• Concentrations of very rapidly degraded carbohydrates (sugars and starch sources, such as wheat and barley) should be limited in the diet. Rapid fermentation of carbohydrates can reduce efficiency of microbial protein production and limit meal size. Adequate ruminally degraded protein should be provided to maximize microbial efficiency.

• Avoid rolling corn silage too finely. Adjust the rollers so that the cobs and most of the grain is in the middle sieve of the Penn State Particle Size Separator. Rolling corn silage too finely can result in excessive ruminal starch fermentation.

• Diet fermentability can also be adjusted by substituting NFFS, such as beet pulp or soyhulls, for starch in the diet. This might be a reasonable alternative to altering site of starch digestion, depending on the relative prices of the NFFS to starch sources. Rate of fermentation of NDF from NFFS is generally slower than that of starch and sugars, and less propionate is produced. Also, fermentation rate of fiber (NDF and pectin) declines with ruminal pH. This has the benefit of limiting the decline in ruminal pH following meals, but it might reduce digestibility of the NFFS. Because effectiveness of NFFS is generally very low and because they are generally highly fermented, they are not filling like FNDF and have little effect on DMI when substituted for grains. Addition of NFFS can result in large reductions in optimal FNDF of diets. While this is desirable to minimize the filling effect of diets, it might not maximize energy intake because of possible rapid passage from the rumen, which results in decreased digestibility.

• Avoid feeding starch sources that are poorly fermented, such as dry corn silage, or coarsely rolled corn or sorghum, to high producing cows. Diets that are poorly fermented can result in decreased microbial yield and fuels for the production of glucose and milk lactose. This is a common occurrence in the upper Midwest when corn is harvested too mature and many kernels pass from the rumen and through the cow undigested. Feed intake is not limited by propionate under these conditions because the fermentability of the diet is reduced, and feed intake increases until ruminal fill becomes a limitation. This can result in increased passage rate, decreasing digestibility and feed efficiency. Milk yield often decreases in spite of greater feed intake because of decreased diet digestibility. The remedy is to increase fermentation in the rumen by minimizing the amount of poorly fermented corn and adding fermentable carbohydrate to the diet. Often, the fermentability of the dry corn increases over time in the silo as endosperm proteins are solubilized.

• An alternative to limit diet fermentability is to increase the diet FNDF content. However, unless the FNDF digests and passes from the rumen quickly, this approach will increase the filling effect of the diet and reduce DMI when limited by ruminal fill.

• Feeding forages with highly fermentable NDF with high ruminal NDF turnover will require higher FNDF in the diet but will allow greater energy intake and provide a more consistent source of energy to the cow throughout the day. Forages with high ruminal NDF turnover include alfalfa with low lignification of NDF (< 16% for Midwestern data) and corn silage with low lignification of NDF (< 6% for Midwestern data). Brown midrib corn silage has been shown to have high rates of clearance from the rumen that allows higher DMI when fill limitations exist. In one recent experiment, response in milk yield to brown midrib corn silage was much higher for high producing cows, presumably with DMI limited by ruminal fill, than for lower producing cows.

• The NDF content of forages influences the fermentability and the optimal FNDF concentration of the diet. Forages, such as grasses or mature alfalfa, with high NDF contents require much more grain or NFFS to optimally formulate diets. Because supplements are generally more fermentable than forages, FNDF concentrations must be higher, but this might lower DMI. However, immature alfalfa or corn silage with low NDF contents (< 36%) require very high forage in the diet. Because forages have lower energy density than most grains and NFFS, energy density of the diet is lower for diets containing high concentrations of low NDF forages. Unless the forage has high NDF digestibility, energy intake might be restricted, limiting milk yield.

• Variation in DM and (or) NDF of forages will cause great variation in ration FNDF and fermentability. Cows consuming low FNDF diets are not able to deal with this variation. If ration FNDF content decreases and fermentability increases, ruminal acidosis might occur. However, if forage NDF or DM contents increase and are undetected and uncorrected, energy intake will be somewhat reduced, and this is not a great problem for animal health. Therefore, when variation is expected, higher dietary FNDF levels must be fed to lower the risk of acidosis.

• Effort should be made to reduce variation when forages are harvested (or purchased) and stored. Identify individual lots of forage and have them tested. Avoid sending fresh forages to labs to be tested because respiration of sugars in transit results in increased fiber concentration and lower predicted energy content compared to what is offered to animals. Freezing fresh forage before shipping to labs is not an alternative because the fiber content of fresh-frozen samples increases during thawing. Variation in forage DM and quality is often a problem for silage. Bunker silos have less daily variation than upright silos or bags because the silo is filled in layers that tend to be mixed when removed from the silo. In contrast, abrupt shifts in DM and NDF can occur when removing silage from upright silos or silage bags. Silage DM concentration should be tested routinely. Frequency of testing depends on the amount of variation and the type of silo. Silage DM in upright silos should be tested twice weekly and when changes are noticed, while silage in bunker silos can be tested less frequently. Mixing loads of silage from wet and dry parts of the bunker face when removed from the silo can help reduce variation, particularly after a substantial rainfall.

• Restrict the concentration of individual ingredients with variable quality or DM. Variation in ingredients that comprise a large fraction of the diet can have a great effect on FNDF and fermentation characteristics of the entire diet. Variation in forages or other feeds can be accommodated if they have relatively little effect on the total diet.

• Sorting can cause variation in diets consumed throughout the day. Sorting can be reduced by chopping forages more finely, rolling corn silage, avoiding dry rations, and feeding more than one time per day.

• Feeding TMR will allow lower FNDF concentrations. The TMR have a great advantage because rapidly fermented carbohydrates are consumed along with effective fiber, which limits the size of meals and the decline in pH following meals. Concentrates can be fed separately, but they should be fed four or more times per day and rapidly degraded starch sources should be limited.

• Provide diets with adequate particle length. Reduction in particle length starts when forages are chopped. Further reduction occurs when corn silage is processed and when forages are ensiled in bags by augers during filling. Particle size is also reduced when diets are mixed in some TMR mixers. A constant mixing time that is sufficient to adequately mix the TMRs, while avoiding excessive particle length reduction, should be used. Finally, particles are reduced still further when eaten by the cow. Effective fiber is needed to form a rumen mat to selectively retain small particles in the rumen and to stimulate rumination. While there is little to be gained in effectiveness of NDF by having particle length beyond a certain point, particle size in the TMR consumed by cows is sometimes inadequate. The Penn State Particle Size Separator, available from NASCO (Fort Atkinson, WI), is useful to monitor changes in particle size from mechanical treatment and to ensure adequate particle length in the TMR. Less than 40% of the TMR should be recovered in the bottom box following sieving to provide adequate particle length. When more than 10 to 15% of the TMR is recovered on the top sieve, the TMR will be more subject to sorting. This leaves over 45% on the middle sieve, which provides most of the effective NDF in the diet. Diets containing silages that are chopped too finely can benefit by including 2 to 3 lb. of long-chopped hay in the diet to improve the effectiveness of NDF.

- Addition of buffers to the diet can increase the buffering capacity of rumen fluid and help attenuate the reduction in pH following a meal. However, they will not have a great effect on optimal FNDF concentration in the diet.

- Diets with added fat require somewhat less FNDF because fat isn't fermented in the rumen to form acids. Although fat can be included in diets to increase energy intake beyond what can be attained by diet formulation for carbohydrates, some fat sources have been shown to reduce DMI and might not improve energy intake. The best sources of fat to increase energy intake are those that provide more saturated free fatty acids, less unsaturated fatty acids, and less saturated triglycerides to the small intestine. These sources include oilseeds, such as cottonseed and whole soybeans, in limited quantities and products containing hydrogenated free fatty acids. Fat sources providing high quantities of saturated triglycerides should be limited because of low digestibility of fatty acids. Sources that provide unsaturated fat in a ruminal bypass form can result in reduced feed intake. An additional consideration when feeding fat sources with polyunsaturated fatty acids is that milk fat content might be reduced because of the trans fatty acids produced in the rumen.

- Grouping cows by milk yield will help increase energy intake because diets can be more closely formulated to meet their needs. High producing cows should be fed low fill diets to maximize energy intake. However, lower producing cows can be offered diets with higher FNDF content, which provides the benefit of a more consistent supply of fuels throughout the day. A more consistent supply of nutrients might help partition more fuels to milk and help prevent excessive body condition. Wide variation in DMI and milk yield of cows within groups makes it difficult to optimize FNDF concentration for all cows in the group.

Conclusions

The different factors discussed above are important to formulate diets to maximize energy intake and microbial protein production. The complex interactions among these factors prevent accurate prediction of optimal FNDF concentration for cows or groups of cows. Diets should be formulated by evaluating cow response to dietary changes and adjusting the diet based on this response. Lower FNDF contents will generally allow higher energy intake and higher milk yield. Exceptions are when FNDF is highly fermentable, which will allow higher FNDF contents and higher energy intakes, and when passage rates of NFFS in low FNDF diets are excessive and digestibility is reduced. Diets with low optimal FNDF content will have starch sources that have moderate ruminal fermentation, forage particles that are sufficiently long, moderate to low FNDF content, be fed as a TMR, and have little daily variation. Diets with high FNDF content will limit energy intake of high producing cows. However, high FNDF content might be required when rapidly fermented starch sources or finely chopped forages are used or when feed bunk space is limited, grain feeding is infrequent, or when variation in feed ingredients is large. The information presented here can be used to develop a strategy to maximize energy intake and microbial protein production and should be refined with experience.

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More specific information and references regarding dietary factors affecting DMI are available in the following reference:

Allen, M. S. 2000. Effect of diet on short-term regulation of feed intake by dairy cows. J. Dairy Sci. 83:1598-1624.

17% --28%

Highly fermentable starch and sugar sources >

< Nonforage fiber sources

Fast ruminal clearance rate of FNDF >

High NDF forages >

High daily variation in diet composition >

Limited feed bunk space >

No total mixed ration, grain fed infrequently >

Finely chopped forages >

< Added fat

< Added buffers

Figure 1. Optimal dietary forage NDF (FNDF) concentration (% of dietary DM).

Feed Born Pathogens of Cattle

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Abstract

Several important diseases of cattle in the United States may be spread by the ingestion of contaminated feed, including Salmonella spp., Johne's disease, Listeria, Anthrax, and Botulism. Bovine spongiform encephalopathy and foot and mouth disease are examples of diseases that are not currently found in the United States but are potentially transmitted to cattle through contaminated feed. The source of pathogens in feedstuffs may include fecal contamination from animals shedding specific organisms or the inclusion of animal products containing the organism. Some pathogens are naturally present in feedstuffs but replicate to higher concentrations or produce harmful toxins when feeds are improperly harvested and/or stored. An understanding of potential feed born pathogens is necessary to effectively control them and their effects on cattle.

Introduction

The primary role of the dairy nutritionists is focused on meeting the metabolic needs of cattle in an efficient and economical manner. An often-overlooked aspect of feeding cattle is the potential for feedstuffs to contain pathogens that are detrimental to the health of the animal. Several important pathogens of cattle may be transmitted by ingestion of contaminated feed; however, disease associated with contaminated feed is rare. However, the seriousness and potential human health consequences of some of these diseases, such as bovine spongiform encephalopathy **(BSE)**, have led to specific laws and regulations on the manufacturing and handling of feeds destined for animal use. The source of pathogens in feedstuffs may include fecal contamination from animals shedding specific organisms (e.g. Salmonella and Johne's) or the inclusion of animal products containing the organism (BSE, Anthrax, or Foot and Mouth disease). Some pathogens are naturally present in feedstuffs but replicate to higher concentrations (Listeria) or produce harmful toxins (Botulism) when feeds are improperly harvested and/or stored.

Another important aspect that should be considered is the potential for cattle feedstuffs to be contaminated with pathogens that are in themselves not harmful to cattle but may be of human health concern if they enter the food chain. Examples of these would include E. coli O157:H7 and Salmonella.

This paper will review some of the important pathogens of cattle found in feedstuffs in the United States. A brief review of BSE and foot and mouth disease is also included.

Salmonella

There are over 2000 serologically distinct serotypes of Salmonella. The most common Salmonella serotypes infecting cattle include *S.*

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dublin, S. typhimurium, S. newport, and *S. montevideo* (Ekperigin and Nagaraja, 1998). Clinically, salmonellosis usually manifests itself as a severe diarrhea that can lead to septicemia, fever, dehydration, shock, and death. Salmonella has also been associated with abortions, arthritis, and pneumonia. Cattle that recover from infection with *S. dublin* often become carriers and shed large numbers in their feces (up to 1,000,000 cfu/gram) and milk (up to 100,000 cfu/ml) (Smith, 1990). Cattle become infected by oral ingestion of the bacteria. Sources include feed, water, bedding, and other inanimate objects that are contaminated with feces containing the bacteria. Feedstuffs of animal and plant origin can be contaminated with Salmonella (Williams, 1981); however, the overall level of contamination is reported to be low (Nabbut et al., 1982; Smith et al., 1994; Harris et al., 1997). Rendered products may have higher rates of Salmonella contamination (Allred et al., 1967; Pelzer, 1989). In a study of risk factors associated with Salmonella infection in feedlot operation, feeding of tallow, cottonseed, or cottonseed hulls significantly increased the risk of finding Salmonella in a pen of cattle (Losinger et al., 1997). Practices that have been recommended to reduce the risk of spreading Salmonella through feedstuffs include routine cleaning and disinfection of animal feeding equipment, avoiding the use of common equipment for feeding and manure handling, controlling of rodents, providing clean water sources that are at low risk of fecal contamination, and avoiding high risk feedstuffs such as animal or vegetable fats. Keeping feedstuffs dry is important, as Salmonella is more likely to survive and replicate under moist conditions. Irrigation of forage crops with lagoon water or spreading of manure slurry immediately prior to harvest should also be avoided.

Listeriosis

Listeriosis is caused by the bacteria *Listeria monocytogenes*. This bacterium is common in soil and on vegetation. It can survive in silage at low pH (< 4.0) and multiply in poorly fermented silages where the pH is greater than 5.0 (Cooper et al., 1998). The development of disease associated with Listeria is often associated with the feeding of silage (Fenlon, 1986). Isolation of *L. monocytogenes* is greatest in silages that are poorly fermented and spoiled (Fenlon, 1985). Infection in cattle can result in several clinical outcomes, including encephalitis, abortion, keratitis, and mastitis. Encephalitis results in a neurological syndrome that is commonly referred to as circling disease because of the often-demented circling behavior of affected animals. Abortions caused by Listeria are sporadic and may occur at any stage of gestation. Exposure to Listeria through diet and the environment is common and unavoidable. Under normal conditions, the bacteria can replicate in and pass through the gastrointestinal tract with no adverse affects. It is theorized that breaks in the mucosal surfaces of the gastrointestinal tract may allow for the bacteria to penetrate the mucosal surface and invade the central nervous system (Cooper et al., 1998). Conditions that increase concentration of the bacteria would increase the odds of this occurring. In addition, immunosuppressive conditions may be contributory in allowing the bacteria to replicate once it has gained entry into the body. The ubiquitous presence of Listeria in the environment precludes complete avoidance of the bacteria. However, precautions to reduce exposure should be taken. Efforts should be made to limit soil and fecal contamination of forages harvested for ensilage. Care should be taken to ensure proper fermentation of ensiled feeds. Listeria is more likely to be found in silage with a pH of greater than 5.6, as well as silage that is moldy.

Johne's Disease

Johne's disease is caused by the bacterium *Mycobacterium paratuberculosis*. Recent surveys suggest that up to 50% of dairy farms may be infected with Johne's disease (Johnson-Ifearulundu and Kaneene, 1999). Young calves are most susceptible to infection. Following infection as a calf, a long lag period ensues and clinical disease may not appear for years. Signs of clinical disease include chronic diarrhea and weight loss that are unresponsive to treatment. Infected cattle in later stages of the disease shed large numbers of the bacteria in their feces that may serve as a major source of infection for susceptible calves. Infected cows may also shed the bacteria in colostrum and milk. Avoiding fecal contamination of feed fed to replacement breeding cattle is essential to controlling the spread of Johne's disease (Rossiter and Burhams, 1996). The practice of feeding weigh back or bunk waste from adult cattle to young heifers should not be practiced. In addition, use of common equipment for both manure and feed handling (i.e. skid loader) should be avoided. Feeding of pooled waste milk or colostrum to calves should not be done unless the milk is from known Johne's negative cows or has been properly pasteurized. Pasteurization of milk at 72^o C (162^{o}F) for 15 seconds or at 65^{o}C (146^{o}F) for 30 minutes has been shown to be capable of killing of *M. paratuberculosis* under experimental conditions (Stabel et al., 1997; Stabel, 2001).

Neosporosis

Neosporosis is caused by the protozoan parasite *Neospora caninum.* The definitive host of this parasite is thought to be members of the canine family (McAllister et al., 1998). Other species, including cattle, are likely to be intermediate hosts. After infection of cattle, the parasite essentially becomes dormant in certain tissues, and cattle rarely become sick. However, when latently infected cattle become pregnant, their fetuses often become infected. Fetal infections may result in abortion or the birth of calves with neurological disorders. This essentially is the only clinical sign seen in cattle. Initial transmission to cattle is likely to occur from ingesting the organisms that are shed in the feces of the definitive host, that being dogs. Feed and water contaminated with dog feces has been theorized as the source of Neospora associated abortion outbreaks (Yaeger et al., 1994; McAllister et al., 1996; McAllister et al., 1998). Vertical transmission from infected cow to fetus can also occur. Cow-to-cow transmission is not thought to occur. Prevention of Neospora infections should include protection of feedstuffs from contamination with canine feces.

Botulism

Botulism is a rare disease of cattle caused by the ingestion of a neurotoxin released by the bacteria *Clostridium botulinum*. The disease is rapidly fatal and is characterized by paralysis. *Clostridium botulinum* is a spore forming bacteria and can survive in the environment for long periods of time. It replicates in decaying animals and plant material. Botulism invariably occurs following the ingestion of feedstuffs that contain the toxin. The source of the toxin may include dead rodents in feed or water sources and rotted vegetation. Outbreaks have also been traced to the feeding of poultry waste, brewer's grain, and improperly fermented grass silages (Blood and Radostits, 1989). A recent report of the death of 11 Holstein cows in Tennessee was linked to the feeding of round bale barley haylage (Kelch et al., 2000). Prevention of botulism includes avoiding the contamination of feedstuffs with dead animals and proper fermentation and storage of vegetative feedstuffs. Feeding of any spoiled material should not be recommended.

Anthrax

Anthrax is caused by the bacteria *Bacillus anthracis*. Similar to *Cl. botulinum*, *B. anthracis* is a spore forming bacterium that survives for long periods of time in the environment. It is a rapidly fatal disease that can affect most mammals, but cattle appear to be most susceptible. The occurrence of the disease is sporadic; although there are regions of the country and world where the disease is much more common. The most common route of infection is the ingestion of feedstuffs contaminated with the bacteria (Hinton and Bale, 1990). Bone meal has historically been implicated as a source of the bacteria. Contamination of forages during harvest by soil containing the bacteria spore may also be an important source of the disease. The reduction of feeding high risk feeds, such as bone meal, has reduced the incidence of anthrax in some countries. Harvesting of feedstuffs from areas know to be at risk for containing anthrax spores should be limited. Vaccines are available for immunization of cattle in high-risk areas.

Bovine Spongiform Encephalopathy

The BSE, also known as "mad cow disease", was first recognized in the UK in 1986 and has since been found in several European countries. Ongoing surveillance has not found the disease in the United States. The BSE is caused by a prion, an agent that is similar to that which causes scrapie in sheep. The disease is characterized by a degeneration of the neurological system that is invariably fatal. A similar disease is found in humans called Creutzfeldt-Jakob disease **(CJD)**. A form of CJD, called new variant Creutzfeldt-Jakob disease **(nvCJD)** was first described in Great Britain in 1996 (Will et al., 1996) and has been associated with the consumption of products contaminated with central nervous tissue of BSE-infected cattle (Schonberger, 1998). Transmission of the disease to cattle was believed to initially occur through diets containing sheep-derived protein sources contaminated with scrapie and then subsequently through diets containing bovine derived protein sources contaminated with BSE (USDA:APHIS-VS, 2001). It is also believed that changes in the rendering process in the United Kingdom might have added to the amplification of the disease. The feeding of mammalian protein from at-risk species (sheep and cattle) has been banned in the United States since 1997. Although no BSE is known to exist in the United States, this action is necessary to reduce the risk of this disease from entering the cattle population.

Foot and Mouth Disease

Foot and mouth disease is a highly infectious disease that primarily affects cloven-hoofed animals, including cattle, sheep, and swine. It has been eradicated from the United States since the early 1900's. The disease is endemic in many regions of the world, and recent outbreaks in the United Kingdom have emphasized the potential economic devastation that this disease could have if introduced into the United States. The virus that causes foot and mouth disease can survive in products made from infected animals, and the disease can be readily transmitted by the feeding of animal proteins contaminated with the virus. Of the 627 outbreaks of foot and mouth disease worldwide between 1870 to 1993 in which a source of virus was reported, 66% were attributed to contaminated meat, meat products, or garbage (USDA:APHIS-VS, 1994). It is believed that the recent outbreak in the UK was introduced by the feeding of meat scraps obtained from airline companies. The importation of animals and animal products into the United States from countries known to have foot and mouth disease is strictly regulated and covered under Title 9 of the Code of Federal Regulations, Parts 94-98 (http://www.access.gpo.gov/nara/cfr/index.html).

Summary

Feed can serve as a source of pathogens known to cause disease in cattle. The occurrence of food born disease in cattle is rare but should not be overlooked. Precautions to reduce the risk of feed contamination with cattle pathogens should be part of normal biosecurity protocols. In addition, protocols put in place to improve the safety of feedstuffs ingested by cattle also help to insure the safety of human food products produced from cattle.

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Making the Transition from Ration Formulation to Farm Nutrient Balancing

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Abstract

Ration formulations for dairy cows traditionally neither involve agronomic considerations of the resulting manure effects on soils nor the manured soils' effects on the quality of the forages grown from these soils. Because of the high proportion of forages utilized in dairy feeding programs, there is opportunity to maximize the use of these "home-grown" products and achieve overall farm nutrient balance that is not as easily achievable with other animal feeding programs. As nutrient management regulations pervade US agriculture, the responsibilities of persons directing feeding programs will increase. The paper presents various scenarios detailing the importance and effects that dairy feed ration planning potentially has on soil and feed quality.

History

Livestock and poultry farms have trended toward fewer farms that have larger numbers of animals than prior years. For example, total US dairy cow numbers increased by 54,800 cows from 1998 to 1999, while the number of dairy farms decreased by 5,960 farms. The largest percentage of growth in farm numbers was in the 500+ cow sized herds (1.9%); in all categories less than 200 cows, there was negative growth. For herds between 200 to 499 cows, there was a modest 0.8% growth in number of farms (USDA-NASS, 2001).

Prior to the early 1960's, many US livestock farms were relatively small facilities that raised a variety of animals and produced most of the grains, forages, and bedding materials needed for these animals. These farms generally employed manure management systems where the animals were raised on bedding materials, such as straw, which would absorb free liquids (i.e., urine) resulting in manure that was handled as a solid. In most cases, this manure was recycled by application to the crop land that produced the feed for the animals. Additionally, many animals were also pastured year-round, or at least certain times of the year. This uncollectable manure was directly recycled for pasture fertilization.

An economy of scale resulted in production efficiencies that favored farms where animal numbers were increased without increasing crop land acreage. This occurred first on poultry farms and was followed in more recent years by swine producers. Implementation of scale-efficient technologies not only saved labor costs but produced healthier, uniform food products. It was also discovered that specializing in one type of production, i.e. animal husbandry instead of crop production, allowed for other production efficiencies and economies of scale. Dairy farms are now following that trend in the Midwest.

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Nutrient Distribution Challenges Emerge

As farm sizes grew, some animal agriculture operations increased feed grain acreages, but many increased reliance on others who specialized in feed grain production or on commercial mills that provided feed made from purchased grains. At the point where more feed ingredients were being imported to the farm than the farm could raise itself for its own needs, nutrient distribution for recycling back to the cropland where the feed grains were grown became an increasing challenge, and in many instances, never happened.

Feedstuff imports were easier for poultry and swine production, and to lesser extent beef feedlots, because of the large proportion (up to 100%) of grain used in these animals' diets. Grain is easily grown is most farm areas of the US and is easily transported nearly anywhere, even from other countries. However, dairy cattle use a relatively high proportion of forage in their diets (generally 50 to 75% depending on their production stage). Because of the physical form of forages (silages, baled hays, etc.), they neither are as easily stored or transported as grains nor are they grown as ubiquitously. In spite of this, it is not unusual for Ohio dairy farms to be feeding Kansas alfalfa or for southwest dairies to bring corn silage from 100 miles away.

Because of this specialization of crop and animal production and the ability of an efficient US transportation system, nutrient distribution inequities have emerged. Much of this unequal recycling of crop nutrients has been positive. In some areas, crop production potential has increased due to the higher fertility from manure applications to soils that previously had inadequate levels of plant food. For those areas where the feedstuffs are grown, but animals are not produced, regular applications of chemical fertilizers must be made to replenish the nutrients being shipped off the farm.

In some areas of concentrated livestock and/or poultry production, whether large general areas like Lancaster County, PA or even small isolated farms that could be located anywhere, nutrients through manure applications have exceeded those needed to optimize crop production and may exceed the assimilative capacity of the crop and the soil. It is these situations that concern the public, who in turn have asked various levels of government to oversee these activities to ensure that the environment is not compromised. Concerns arise from the possibility of nutrients leaking from the farm site through various mechanisms, such as leaching, soil erosion, or soluble nutrients in rain-water run-off. The major nutrients of concern are nitrates in drinking water supplies, which can result from supplying more nitrogen annually than crops will utilize, and phosphorus, which can enter surface waters and provide a stimulus for algae growth.

Animal Species and Feedstuff Differences

Forages, in most all cases, are higher in potassium (K) content than phosphorus (P) (corn silage = 4.4:1 K:P, alfalfa hay = 8.8:1 K:P) while grains have a much narrower ratio (corn grain = 1.3:1 K:P, soybeans = 2.8:1) (NRC, 1989). In general, fertilization practices on these crops reflect this: forages require a higher proportion of K fertilization to P, and grains generally require a narrower ratio. Logic follows that the more the crop removes of a particular element, the more of that element that must be replaced.

Because non-ruminants cannot as easily digest the P that is in grains (as phytate-P) as can ruminants, extra mineral P is added to all poultry and swine rations to provide sufficient available P for the animals needs. This results in a manure that has a K:P ratio that is even narrower than that of the grains in the diet (poultry layer manure K:P = 1.1:1 with about 2.3% P, swine finisher manure K:P = 1.4:1 with about 2.5% P). As manure from mostly grain-fed animals is applied to grain-producing cropland, a general build-up of P in the soil will occur at many manure application rates. This is desirable up to the point where the crop fails to increase yields and the soil may become saturated with P, enabling it to leave the site through soluble P contained in run-off or in leachate water. Several states have set standards identifying "critical" soil test P levels beyond which it is believed that an unacceptable amount of P may be contained in run-off waters. A variety of methods are available and are being proposed to scientifically examine the risks from excessive P levels in soils. These excess levels may pose risks to water quality and are thoroughly discussed in the US EPA (2001) document, "Proposed Regulations to Address Water Pollution from Concentrated Animal Feeding Operations".

Because of the number of animals that may be on any one site, the acreage from which the grain came from may be extensive, further increasing the nutrient distribution challenge. For example, a 125,000-bird standard-size layer barn utilizes approximately 800 acres of corn and 550 acres of soybeans. A facility may have 8 or more of these buildings, representing nutrients from over 10,000 acres of cropland.

On the other hand, ruminants and dairy cows specifically, not only utilize phosphorus much more efficiently from grains than non-ruminants but also the P in forages is more available to the animal (as non-phytate P). This limits the need for adding more mineral P to the cow's diet compared to non-ruminant diets. This, in conjunction with the fact that a high proportion of the cow's diet consists of forages which are high in K, leads to a manure that is high in K in relationship to P (dairy cow manure = 3.7:1 K:P at approximately 0.7% P).

Care must be exercised when applying excess dairy manure nutrients to soils that will grow forages, particularly grasses such as orchard grass, which are known K accumulators. These types of forages grown on over-fertilized soils can create severe ration imbalances that may affect animal health and performance, particularly in dry cows and heifers, which are limited in their ability to flush K from their system through milk flow.

The Dairy SPAN Opportunity

Dairy farms, regardless of size, have the opportunity to meet sustainable soil, plant and animal nutrition **(SPAN)** requirements, and minimize environmental, production, and regulatory challenges. The following summary statements confirm this:

1. Dairy cows have a high proportion of forages in their diets which have a high K:P ratio and thus utilize more K than P from the soil reserve.

2. Dairy cow rations can be supplemented with lower levels of P because of the ruminant is digestion of phytate-P and high proportion of non phytate-P in forages.

3. Dairy cow manure has a K:P ratio more in line with forage K:P ratios (manure nutrients more balanced with the crops that will be fertilized with the manure.

4. Forage transportation and general availability is not as favorable as is grain.

5. Because of transportation and quality concerns

due to timeliness of harvest (esp. silages), there is an advantage in growing most all of the forages and some of the grain necessary for dairy cow rations in close proximity to the dairy farm.

6. When more feedstuffs are imported from areas where manure nutrients cannot be redistributed back to the soil where the feeds were grown, nutrient imbalances may occur and environmental quality and animal health may suffer in the long term.

SPAN Scenarios

A computer spreadsheet program was developed to evaluate various scenarios under different ration, herd management, and crop production management schemes. The model takes into account all nutrients imported onto the farm, the utilization of nutrients on the farm, nutrients exported from the farm. The rationale behind this dairy farm model is the following simplified equation:

FARM NUTRIENT INPUTS =
FARM NUTRIENT OUTPUTS +
RETAINED/RECYCLED NUTRIENTS+
NUTRIENT LOSSES

Examples of nutrient inputs include items such as feed ingredients purchased and fertilizers; nutrient outputs include milk and cattle sold or otherwise removed from the farm. Retained/recycled nutrients are those that are recycled through the crops grown while utilizing manure nutrients and those retained in the bodies of the animals, and nutrient losses include items such as volatile nitrogen losses and nutrients leaving the farm that may be carried in run-off water or soil leachate.

By looking at various scenarios, soil and agronomic effects can be predicted. They demonstrate that feed ration planning along with the utilization of forages produced on land receiving dairy manure applications can provide for long-term sustainable production.

Milking Herd Information

The examples used all include the same following herd information:

675 cows in the milking herd with no heifers or calves being raised on the farm. Milk production RHA is 24,500 lb of milk, the cull rate is 30%, and 100% of the manure goes to a liquid manure retention basin. All milk cow rations (Table 1) were balanced for 59 lb/day of DM intake **(DMI)**, 17.45% crude protein (**CP,** DM basis), and 35% neutral detergent fiber (**NDF**, DM basis). Dry cow rations (Table 1) were balanced for 29.6 lb/day of DMI, 12.6% CP, and 43.7% NDF.

Scenario 1:

Forages home grown:	All except dry cow grass hay
Grains home grown:	None
Fertilizer program:	No adjustment for manure

In this scenario, corn silage, alfalfa haylage, and alfalfa hay are grown by the producer, but all grains and grass hay are purchased. Acres of crops grown for each scenario can be found in Table 2. In this case, no adjustments have been made to compensate for crop nutrients provided by the manure generated by the dairy cows. A list of purchased nutrient inputs for this example is found in Table 3. This is not a long-term sustainable situation with annual excesses of 129.5 lb/acre of P and 455 lb/acre of K, as well as 10,593 lbs of total nitrogen. The over-all nutrient balance for Scenario 1 is found in Table 5. The logical first step would be to eliminate most of the purchased fertilizers, which is presented in Scenario 2 (Table 5).

Scenario 2:

Forages home grown:	All except dry cow grass hay
Grains home grown:	None
Fertilizer program:	Limited purchased nitrogen only

With the normal fertilization program now eliminated, except for some limited additional nitrogen, the P excess per acre has been reduced by 47% at +68.5 lb/acre and the K excess by 72% at +126.4 lb/acre (see Tables 3 and 5). This still is not sustainable if the same acreage is continuously used for manure applications and forage production. Scenario 3 (Table 6) looks at a way of utilizing more manure nutrients and importing less by growing all the corn grain that is fed as well as the dry cow grass hay.

Scenario 3:

Forages home grown:	All
Grains home grown:	All corn only
Fertilizer program:	Limited purchased nitrogen only

When growing all of the forage and corn grain needs, a much more sustainable situation is presented (Tables 2, 4, and 6). The P excesses are now at +26.9 lb/acre and K excesses are +35.9 lb/acre. The SPAN analysis of Scenario 3 also shows the amount of N, P, and K that is retained and recycled in the animals and the feeds. Most nutrient management analysis programs fail to consider this considerable pool of nutrients that is always in the system but not part of the soil nutrient supply.

Because these soil nutrient additions are exclusive of the forage acres, modest build-up is desirable if the forage portion of the rotation can be planned to “mine” these excesses by judicious use of fertilizers during the production phase. Based on this premise, a hypothetical idealized rotation is provided in Table 7. This was a rotation developed to meet the forage needs of a 675 cow milking herd in an eight-year corn and alfalfa rotation (with limited amount of small grain) on 688 total cropland acres. When consideration is given to the total nutrients applied to the soil over this period and the total nutrients utilized through anticipated crop removals, it is calculated that soil test P values would increase only a modest +2.8 ppm and that soil test K values would decrease approximately -91.9 ppm (Table 8). This assumes no P or K fertilizer would be applied during this 8-year rotational period. Depending on initial soil test levels, P and K fertilization may be necessary to optimize crop production until a maintenance program can be developed through full manure utilization.

Scenario 4:

Forages home grown:	Corn silage only
Grains home grown:	All corn only
Fertilizer program:	Limited purchased nitrogen only

An additional scenario was examined where only corn silage and corn grain needs were grown on manured acreage (Tables 2, 4, and 6). The P excesses are now at +43.5 lb/acre and K excesses are +186.2 lb/acre with an excess of 16,628 lbs of N. In this example, not only are less nutrients utilized by not growing hay forages, additional N, P, and K are being imported onto the farm, causing nutrient application imbalances once again. This demonstrates the critical nature of growing forage hay in the dairy farm rotation in order to achieve nutrient balance. Corn silage production is limited by the needs of the cows. Growing excess corn grain for commodity marketing will utilize additional N and P but not nearly enough K to prevent extensive soil build-up of this element.

Ration Mineral Effects on Soils

Table 9 demonstrates the effect of additional P mineral [(calcium phosphate monobasic **(CPM)**, 21% P)] has on soil P build-up potential. Utilizing Scenario 3 (Table 6) as a constant (all forages and corn grain produced on the farm land receiving manure through the rotation) and varying the amount of CPM fed, it can be demonstrated that lowering the amount of CPM from 0.30 to 0.10 lb/head/day lowers the ration content from 0.46% to 0.39% of DMI (lower ration P levels by 15%). This assumes that all excess P fed to the milk cows will be excreted in the manure. Theoretically, this has the potential to lower the excess P that will eventually be land-applied through the manure by 37% (-11.8 lb/acre/year of P). If lower levels of P can be utilized effectively in the dairy rations, higher soil test levels of P can be avoided.

Milk Production Effects

Milk contains significant amounts of N, P, and K. A 675-cow dairy herd with a 24,500 lb RHA for milk yield will annually export 62,016 lb of N, 11,312 lb of P, and 19,196 lb of K. Significant variations in milk production will also have a significant effect on nutrient exportation from the farm.

Summary

Persons directing feeding strategies on dairy farms can have a large influence on the long-term viability of the operation. They should understand that basic feed program changes can have a tremendous effect on manure quality, which in turn affects the soils that the manure is applied to and the crops grown on these soils. There are provisions for the signature of persons responsible for feeding programs in Comprehensive Nutrient Management Plans that are being developed in many states as requirements for regulatory and cost-sharing benefits. Nutritionists and agronomists need to think about the whole SPAN cycle and should consult with other professionals who are proficient in crop production and manure nutrient management to assist with some basic planning and on-going assistance. Growing all forages needed for the dairy herd is a balanced approach that not only provides for environmental sustainability of the operation but more than likely has many economic benefits as well.

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Table 1. Rations for lactating and dry cows used in the different scenarios discussed in the paper.

Milk Cow Ration			
DM intake, lb/head/day	59.05		
CP intake, lb/head/day	10.31	17.45% CP	
NDF intake, lb/head/day	20.84	35.28% NDF	
P intake, lb/head/day	0.25	0.43% P	
K intake, lb/head/day	0.86	1.46% K	
Home Grown:		Purchased:	
	lb/head/day (as fed basis)		lb/head/day (as fed basis)
Grains:		Grains:	
shelled corn		shelled corn	10
Protein feeds:		Protein feeds:	
soybean meal		soybean meal	6
whole cottonseed		whole cottonseed	4
fishmeal		fishmeal	0.4
bloodmeal		bloodmeal	0.2
dried distiller’s grain		dried distiller’s grain	2.5
soybean hulls		soybean hulls	3
Forages:		Forages:	
alfalfa hay	2	alfalfa hay	
corn silage	65	corn silage	
alfalfa silage	25	alfalfa silage	
		N-P-K Mineral feeds:	
		Calcium Phos. Mono.	0.22
Dry Cow Ration			
DM intake, lb/head/day	29.66		
CP intake, lb/head/day	3.75	12.66% CP	
NDF intake, lb/head/day	12.95	43.67% NDF	
P intake, lb/head/day	0.135	0.46% P	
K intake, lb/head/day	0.507	1.71% K	
Home Grown:		Purchased:	
	lb/head/day (as fed basis)		lbs/head/day (as fed basis)
Grains:		Grains:	
shelled corn		shelled corn	3
Protein feeds:		Protein feeds:	
soybean meal		soybean meal	1
fishmeal		fishmeal	0.25
dried distiller’s grain		dried distiller’s grain	1.5
soybean hulls		soybean hulls	3
Forages:		Forages:	
grass hay		grass hay	8
corn silage	35	corn silage	
alfalfa silage	5	alfalfa silage	
		N-P-K Mineral feeds:	
		Calcium Phos. Mono.	0.2

Table 2. Crop information for the different scenarios.

Scenario 1 & 2 Crop Information			
Corn for silage		354	acres
yield	20 tons/acre		@ 65% moisture
Corn for grain		0	acres
yield	150 bu/a		@ 15% moisture
Alfalfa hay or haylage		291	acres
yield	5 tons/acre		@ 15% moisture
Grass hay or haylage		0	acres
yield	4 tons/acre		@ 15% moisture
Scenario 3 Crop Information			
Corn for silage		354	acres
yield	20 tons/acre		@ 65% moisture
Corn for grain		242	acres
yield	150 bu/acre		@ 15% moisture
Alfalfa hay or haylage		291	acres
yield	5 tons/acre		@ 15% moisture
Grass hay or haylage		62	acres
yield	4 tons/acre		@ 15% moisture
Scenario 4 Crop Information			
Corn for silage		354	acres
yield	20 tons/acre		@ 65% moisture
Corn for grain		242	acres
yield	150 bu/a		@ 15% moisture
Alfalfa hay or haylage		0	acres
yield	5 tons/acre		@ 15% moisture
Grass hay or haylage		0	acres
yield	4 tons/acre		@ 15% moisture

Table 3. Purchased inputs for Scenarios 1 and 2.

SCENARIO 1	**PURCHASED INPUTS**	
Grains:		
	shelled corn	36,296 bu
Protein feeds:		
	soybean meal	585 tons
	whole cottonseed	370 tons
	fish meal	45 tons
	blood meal	18 tons
	dried distiller's grain	277 tons
	soybean hulls	370 tons
Forages:		
	grass hay	246 tons
N-P-K Mineral feeds:		
	mineral 1 Calcium Phos. Mono.	26 tons
Fertilizers:[1]	Anhydrous 82-0-0	40 tons
	DAP 18-46-0	26 tons
	TSP 0-46-0	28 tons
	Muriate of Potash 0-0-60	97 tons

SCENARIO 2	**PURCHASED INPUTS**	
Grains:		
	shelled corn	36,296 bu
Protein feeds:		
	soybean meal	585 tons
	whole cottonseed	370 tons
	fish meal	45 tons
	blood meal	18 tons
	dried distiller's grain	277 tons
	soybean hulls	370 tons
Forages:		
	grass hay	246 tons
N-P-K Mineral feeds:		
	mineral 1 Calcium Phos. Mono.	26 tons
Fertilizers:[1]	Anhydrous 82-0-0	8 tons
	DAP 18-46-0	0 tons
	TSP 0-46-0	0 tons
	Muriate of Potash 0-0-60	0 tons

[1]DAP = Diammonium phosphate and TSP = triple super phosphate.

Table 4. Purchased inputs for Scenarios 3 and 4.

SCENARIO 3	PURCHASED INPUTS	
Grains:		
	shelled corn	0 bu
Protein feeds:		
	soybean meal	585 tons
	whole cottonseed	370 tons
	fish meal	45 tons
	blood meal	18 tons
	dried distiller's grain	277 tons
	soybean hulls	370 tons
Forages:		
	grass hay	0 tons
N-P-K Mineral feeds:		
	mineral 1 Calcium Phos. Mono.	26 tons
Fertilizers:[1]		
	Anhydrous 82-0-0	14 tons
	DAP 18-46-0	0 tons
	TSP 0-46-0	0 tons
	Muriate of Potash 0-0-60	0 tons

SCENARIO 4	PURCHASED INPUTS	
Grains:		
	shelled corn	0 bu
Protein feeds:		
	soybean meal	585 tons
	whole cottonseed	370 tons
	fish meal	45 tons
	blood meal	18 tons
	dried distiller's grain	277 tons
	soybean hulls	370 tons
Forages:		
	alfalfa hay	185 tons
	grass hay	246 tons
	corn silage	0 tons
	alfalfa silage	246 tons
N-P-K Mineral feeds:		
	mineral 1 Calcium Phos. Mono.	26 tons
Fertilizers:[1]		
	Anhydrous 82-0-0	14 tons
	DAP 18-46-0	0 tons
	TSP 0-46-0	0 tons
	Muriate of Potash 0-0-60	0 tons

[1]DAP = Diammonium phosphate and TSP = triple super phosphate.

Table 5. Analysis of SPAN (soil, plant, and mineral nutrition) for Scenarios 1 and 2.

SCENARIO 1 SPAN ANALYSIS			
NUTRIENT GAINS:			
	lb N	lb P	lb K
from cattle entering herd:	6,148	1,750	462
from purchased feeds:	195,871	36,069	63,483
from fertilizers:	74,960	21,600	116,400
Totals in =	276,978	59,419	180,345
NUTRIENTS LEAVING FARM:			
	lb N	lb P	lb K
from cattle leaving:	7,854	2,238	591
from crop/manure export:	0	0	0
from milk sales:	62,016	11,312	18,605
Totals out =	69,869	13,550	19,196
	lb available N	lb P	lb K
ANNUAL NET GAIN OR LOSS:	10,593	45,869	161,149
ANNUAL EXCESS OR DEFICIT PER ACRE EXCLUDING LEGUMES PER ACRE ON 354 TOTAL ACRES	30	129.5	455.0

SCENARIO 2 SPAN ANALYSIS: REDUCED FERTILIZER			
NUTRIENT GAINS:			
	lb N	lb P	lb K
from cattle entering herd:	6,148	1,750	462
from purchased feeds:	195,871	36,069	63,483
from fertilizers:	13,120	0	0
Totals in =	215,138	37,819	63,945
NUTRIENTS LEAVING FARM:			
	lb N	lb P	lb K
from cattle leaving:	7,854	2,238	591
from crop/manure export:	0	0	0
from milk sales:	62,016	11,312	18,605
Totals out =	69,869	13,550	19,196
	lb available N	lb P	lb K
ANNUAL NET GAIN OR LOSS:	151	24,269	44,749
ANNUAL EXCESS OR DEFICIT PER ACRE EXCLUDING LEGUMES PER ACRE ON 354 TOTAL ACRES	0	68.5	126.4

Table 6. Analysis of SPAN (soil, plant, and mineral nutrition) for Scenarios 3 and 4.

SCENARIO 3 SPAN ANALYSIS: RAISE ALL FORAGE & CORN

NUTRIENT GAINS:			
	lb N	lb P	lb K
from cattle entering herd:	6,148	1,750	462
from purchased feeds:	163,186	29,506	42,323
from fertilizers:	22,960	0	0
Totals in =	192,294	31,256	42,785
NUTRIENT LEAVING FARM:			
	lb N	lb P	lb K
from cattle leaving:	7,854	2,238	591
from crop/manure export:	0	0	0
from milk sales:	62,016	11,312	18,605
Totals out =	69,869	13,550	19,196
	lb available N	lb P	lb K
ANNUAL NET GAIN OR LOSS:	496	17,706	23,589
ANNUAL EXCESS OR DEFICIT EXCLUDING LEGUMES PER ACRE ON 658 TOTAL ACRES	1	26.9	35.9

SCENARIO 3 RETAINED/RECYCLED NUTRIENTS

	lb N	lb P	lb K
NUTRIENTS RECYCLED THROUGH CROPS:	128,208	27,538	145,424
NUTRIENTS RETAINED IN HERD:	17,949	5,108	1,348
TOTAL RECYCLED/RETAINED N-P-K:	146,156	32,646	146,772

SCENARIO 4 SPAN ANALYSIS: ALL CORN AND NO HAY

NUTRIENT GAINS:			
	lb N	lb P	lb K
from cattle entering herd:	6,148	1,750	462
from purchased feeds:	252,591	37,766	129,765
from fertilizers:	13,120	0	0
Totals in =	271,859	39,516	130,227
NUTRIENT LEAVING FARM:			
	lb N	lb P	lb K
from cattle leaving:	7,854	2,238	591
from crop/manure export:	0	0	0
from milk sales:	62,016	11,312	18,605
Totals out =	69,869	13,550	19,196
	lb available N	lb P	lb K
ANNUAL NET GAIN OR LOSS:	16,628	25,966	111,031
ANNUAL EXCESS / DEFICIT PER ACRE ON 596 TOTAL ACRES	28	43.5	186.2

Table 7. Hypothetical rotation of corn (C), alfalfa (A), and wheat (W) for forage during eight years using eight fields (F).

Rotation Analyses

Herd size = 675 cows

8 YEAR ROTATION

FIELD(each is 86 acre block)

year	F1	F2	F3	F4	F5	F6	F7	F8
2002	C	C	A	A	A	C	C	W
2003	C	A	A	A	C	C	W	C
2004	A	A	A	C	C	W	C	C
2005	A	A	C	C	W	C	C	A
2006	A	C	C	W	C	C	A	A
2007	C	C	W	C	C	A	A	A
2008	C	W	C	C	A	A	A	C
2009	W	C	C	A	A	A	C	C

357	acres of corn
249	acres of alfalfa
81	acres wheat/small grain silage
688	total acres

(dark shading)	manure prior to crop, full rate =	19,000 gal/acre
(light shading)	manure prior to crop, 1/2 rate =	9,500 gal/acre

Total manure/wastewater/solids applied per year = 7,489,800 gal/year

Table 8. Nutrient balance from crop rotation shown in Table 7.

Crop Rotation:	Corn Silage	Alfalfa Haylage	Corn Silage	Wheat Grain
rotation no. of years	2	3	2	2
yield, tons/acre	22.4	14.6	22.4	2.4
total manure P_2O_5 applied	102,632	0	102,632	5,819
manure P_2O_5 lb/acre applied/year	144	0	144	72
total manure K_2O applied	197,932	0	197,932	11,223
manure K_2O lb/acre applied/year	277	0	277	139
P_2O_5 lb/acre removed/year	90.16	58.65	90.16	40.35
total P_2O_5 removed	64,400.00	43,887.98	64,400.00	3,268.45
K_2O lb/acre removed/year	206.98	348.84	206.98	23.99
total K_2O removed	147,839.99	261,038.07	1,943.22	

Total Rotation P_2O_5 Applied: 211,082 lb Total Rotation P_2O_5 Removed: 175,956 lb
Total Rotation K_2O Applied: 407,087 lb Total Rotation K_2O Removed: 558,661 lb
Total acres = 688

Net P, lb/acre after full rotation = 22.2 8 years
Net K, lb/acre after full rotation = -183.7 8 years

Net soil test P value/acre
after full rotation = 5.6 lb/acre P
2.8 ppm P

lb/acre P to apply per year to alfalfa: 0
lb/acre K to apply per year to alfalfa: 60.8

Table 9. Ration mineral effects on soils.

Milk Cows (Table 6; Scenario 3)			
CPM[1] (lb/cow/day)	Ration P (% of DM)	Annual Soil P Excess (lb/acre)	Soil P (% Reduction from highest level)
0.30	0.46	31.6	
0.27	0.45	29.9	5
0.25	0.44	28.7	9
0.22	0.43	26.9	15
0.20	0.42	25.7	19
0.18	0.42	24.6	22
0.15	0.40	22.8	28
0.12	0.39	21.0	34
0.10	0.39	19.8	37

[1] Calcium Phosphate Monobasic, 21% P.

Phosphorus Regulations and Feeding Requirements for Dairy Farms

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Abstract

Nutritionists and dairy farmers are the 'critical control points' to make certain that phosphorus (P) excretion is minimized. Careful feed analysis, prudent diet formulation, and monitoring and control of dietary P can be done so that just enough P is fed to meet the animals' requirements for optimum performance. These aspects are becoming increasingly important as state and federal governments develop and (or) re-write guidelines and regulations for manure P management on dairy farms. When dairy manure is applied to cropland, the maximum application rate for P (that amount that can be removed by the next crop grown) is reached before the maximum application rate for N or K. This paper summarizes some of the key aspects of current guidelines and regulations of manure P management in Michigan, Ohio, and Indiana.

Additionally, the new NRC (2001) requirements for P are examined and compared with previous NRC (1989) requirements. For lactating and dry, pregnant dairy cows, the recommended P concentrations in typical rations are lower in the 2001 compared to the 1989 NRC.

Introduction

The purpose of this paper is two-fold: 1) to briefly review and compare the current (as of April 1, 2001) phosphorus (P) management guidelines and regulations for dairy farms in Michigan, Ohio and Indiana and, 2) to compare the new (NRC 2001) P requirements for dairy cattle with the 1989 NRC requirements.

Phosphorus Guidelines and Regulations for Dairy Farms (as of April 1, 2001)

A major source of manure P on dairy farms is from purchased feeds. Only about 20 to 30% of total feed P consumed by dairy cattle actually is exported from farms in milk and marketed animals (Klausner, 1993). Therefore, 70 to 80% of feed P is excreted in manure and must be recycled in the feed production system or exported from the farm for some other purpose. In a comparison of models to predict P excretion by dairy cows, it was noted that by far the most influential factor determining how much manure P is excreted is the amount of dietary P consumed (Beede and Davidson, 1999). By far, the vast majority of P consumed by cattle when fed in excess of requirement is excreted in the manure. Dairy nutritionists and producers must feed to optimize animal performance, while minimizing P excretion in manure. Dairy nutritionists and producers are the 'critical control points' to be sure that no more P than is absolutely necessary is excreted. This can be done by prudent diet formulation, careful control of the feeding operation, and monitoring of dietary P, so that just enough P is fed to meet the animals' requirements for optimum performance.

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In many instances, between 2 and 3 acres of tillable land per dairy cow and her replacement heifer are required on an annual basis to maintain “zero P balance” of the whole farm system. An effective plan to recycle manure P can accrue economic benefits to dairy producers by reducing use of commercial fertilizer, reducing build-up of P in soils, and reducing the risk of P contamination of surface and ground waters. The ratio of P-to-N in dairy manure typically is about 2-to-1, whereas non-legume crops require P-to-N in a ratio of 1-to-2. Therefore, P takes “center stage” as the primary nutrient of interest in manure application. Phosphorus must be the first nutrient considered to effectively utilize dairy manure in cropping systems because the maximum amount of P that can be applied and removed by a crop will be reached first, before maximum N or K amounts are reached.

As a result of the above considerations, state and federal governments, agricultural organizations, and agencies in Michigan, Ohio, and Indiana are in the process developing and (or) modifying existing and future guidelines and regulations about management of manure P on dairy farms. The information provided in Table 1 is an attempt to summarize and compare some of the key information for each state. It is imperative that dairy nutritionists and producers be fully informed and current with these guidelines and regulations as they formulate and feed rations to dairy cattle. Please review and compare the information in Table 1 for important aspects about whole farm P management in Michigan, Ohio, and Indiana. At the end of this article are website addresses that can be accessed in the future to receive the most recent information; new information is evolving rapidly!

Phosphorus Requirements: Comparison of NRC (2001) and NRC (1989)

Recently, the NRC subcommittee on dairy cattle nutrition reviewed the worldwide scientific literature and established up-to-date requirements for P (NRC, 2001). The factorial method was used to establish requirements for P and most other dietary essential mineral elements. By this method, the amounts (grams/day) of P needed by the animal for maintenance, lactation, growth, and pregnancy were determined and summed; this value is the ***Absorbed P Required*** by an animal of a particular body size, milk production level, growth rate, and pregnancy status. The ***Absorbed P Required*** is the amount of P that must be absorbed into the animal’s body to meet its needs; in other publications, this amount may be known as the true or net requirement. The ***Absorbed P Required*** (grams/day) is then divided by an absorption coefficient to determine the ***Total Dietary P Required*** (grams/day). The ***Total Dietary P Required*** is the grams of P that the animal must consume on a daily basis in order to acquire the ***Absorbed P Required.*** Unique and different absorption coefficients were assigned, based on information from the scientific literature, to each feed ingredient and mineral element source that may be used to build a diet (NRC, 2001). Therefore, each complete diet has its own unique overall absorption coefficient for P depending upon the unique set of feed ingredients that make up that particular diet. This is a different approach than was used previously (NRC, 1989). It is especially noteworthy that the P requirements **--*Absorbed P Required*** or ***Total Dietary P Required*** --- are expressed as grams/day per animal. Though the dietary concentration of P (% of DM) is often thought of as “the requirement” in the field, this is not appropriate because the actual dietary requirement ***(Total Dietary P Required)*** may or may not be accurately provided depending on the rate of intake of a diet with a specific P content (%). Having an accurate estimate of feed intake (dry matter intake, **DMI**) becomes very important to exactly meet the animals' actual P requirement ***(Total Dietary P Required)***.

Lactating Cows

Figure 1 (Panels A – D) provides a graphic comparison of the NRC (2001) with NRC (1989) P requirements as milk yield of a non-pregnant Holstein cow (700 kg [1540 lb] body weight) varies from 10 to 60 kg/day [22 to 132 lb/day]. The example cow was fed a basal diet containing corn silage, alfalfa haylage, high moisture corn, ground dried corn, soybean meal, blood meal, calcium carbonate, dicalcium phosphate, and a mineral and vitamin premix (NOTE: a diet must be entered into the NRC (2001) model in order for the correct absorption coefficient **(AC)** to be computed for that particular diet). Panel A shows the ***Absorbed P Required (grams/day)***, Panel B the ***Total Dietary P Required (grams/day)***, Panel C the dietary DMI (kg/day) as predicted from the model (NRC, 2001) for varying milk yields or from information in Table 6-1 (NRC, 1989), and Panel D shows the dietary P content (% of DM) computed as ***Total Dietary P Required*** divided by the respective predicted DMI. Over the total range of milk yields, ***Absorbed P Required (grams/day)*** is about 35% greater for NRC (2001) compared with NRC (1989) (Figure 1, Panel A). This is primarily because of the higher absorbed P requirement for maintenance in 2001 compared with 1989. ***Total Dietary P Required (grams/day)***, on average across the range of milk yields, is about 5% lower for NRC (2001) compared with NRC (1989) (Figure 1, Panel B). This primarily is because of the higher AC (0.72) in this particular diet formulated according to NRC (2001) compared with the universally applied AC (0.50) of NRC (1989). Panel C compares the predicted DMI (kg/day) across milk yields; at 10 kg milk yield/day, DMI is about 11% greater in NRC (2001) than NRC (1989), but 4% less at 60 kg/day milk yield. Therefore, dietary P percentages, computed as ***Total Dietary P Required*** divided by predicted DMI to meet the ***Absorbed P Required (grams/day)*** and ***Total Dietary P Required (grams/day)*** for this example Holstein cow over the range of 10 to 60 kg/day milk yield are about 7% less overall for NRC (2001) compared with NRC (1989) (15% less with 10 kg/day to 5% less with 60 kg/day milk yield in NRC 2001 versus 1989). Overall, the amount of dietary P (grams/day) fed to cows to meet NRC (2001) requirements is less compared with the previous NRC (1989). There is no evidence in the scientific literature that feeding amounts or concentrations of dietary P greater than that needed to meet requirements improves lactational or reproductive performance (Beede and Davidson, 1999; NRC, 2001).

Pregnant, Non-lactating Cows

The comparison of the P requirements computed according to NRC (2001) and NRC (1989) for a mature, pregnant Holstein cow (700 kg [1540 lb] body weight) from 170 to 290 days of pregnancy is shown in Figure 2. The basal diet is composed of corn silage, alfalfa haylage, high moisture corn, ground dried corn, soybean meal, blood meal, calcium carbonate, dicalcium phosphate, and a mineral and vitamin premix. Feed DMI varied by days pregnant according to the NRC (2001) feed intake prediction equation or as back-calculated from the NE_L requirement (NRC, 1989). The ***Absorbed P Required (grams/day)*** is greater according to NRC (2001) compared with NRC (1989) across days of pregnancy (Figure 2, Panel A); this is primarily due to the greater amount of absorbed P required for maintenance. Additionally, in NRC (1989) no attempt was made to vary the P requirement as stage of gestation increased; thus, the ***Absorbed P Required (grams/day)*** (Panel A) and the ***Total Dietary P Required (grams/day)*** (Panel B) were constant across days of pregnancy in the 1989 NRC. Shown in Panel C is dietary DMI (kg/day) across days of pregnancy as predicted by the new model (NRC, 2001) or back-calculated based on the NE_L requirement of a dry pregnant cow (NRC, 1989) with the characteristic reduction in DMI often observed in late pregnancy (NRC, 2001). Across the range of days pregnant (170 to 290), DMI as predicted by NRC (2001) is greater than that computed from information available to back-calculated it in NRC (1989). During approximately the last trimester of pregnancy and based on the ***Total Dietary P Required (grams/day)*** and the computed DMI, the total dietary P content (% of DM) to meet the ***Absorbed P Required (grams/day***) is lower in NRC (2001) compared with the previous NRC (1989). Therefore, although the ***Absorbed P Required (grams/day)*** and ***Total Dietary P Required (grams/day)*** are greater for a pregnant dry cow as computed by NRC (2001) compared with NRC (1989), the dietary P concentration (Figure 2, Panel D) to supply the requirement is less in the 2001 versus 1989 NRC because the estimate of DMI is greater in 2001. The key points are: 1) to determine the ***Absorbed P Required*** and the ***Total Dietary P Required*** (grams/day) for a particular ration with specific feeds (so that the appropriate AC is computed; NRC, 2001), and 2) to have as good an estimate of actual DMI as possible so one can deliver the ***Total Dietary P Required*** in the daily ration. The total P concentration of the diet is not the "requirement".

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Ohio State University Extension. 2001. Fact Sheet AS-9-01. Questions pertaining to large dairy enterprises in Ohio: Environment. Department of Animal Sciences, 2029 Fyffe Road, Columbus, OH 43210-1095. Available on-line at: http://ohioline.ag.ohio-state.edu.

Pertinent Website Addresses

Michigan Manure Management:
http://www.msu.edu/user/manure/index.htm

Ohio Manure Management:
http://ohioline.ag.ohio-state.edu/lines/stock.html#Dairy;
http://oh.nrcs.usda.giv/fotg/OhioNRCSstandards1.htm#T2Z

Indiana Manure Management:
http://www.anr.ces.purdue.edu/anr/anr/swine/manure/regulate.htm

Nutrient Requirements of Dairy Cattle:
http://www.nap.edu/new.htm; one can read the new NRC publication free and (or) order a hardcopy of the publication and model (on compact disk) from this site.

Table 1. Comparison of the current (as of April 1, 2001) guidelines and regulations for manure phosphorus (P) management on dairy farms in Michigan, Ohio, and Indiana.

1. What are the names of the service and governmental regulatory agencies?

Michigan: The Michigan Department of Agriculture **(MDA)** facilitates development and recommends manure management system plans for dairy operations. For example, Michigan's Agricultural Environmental Assurance Program **(MAEAP)** has created a voluntary program for livestock producers to develop management plans and implement practices to protect the environment while maintaining economic viability of farm operations. Development of a farm-specific Comprehensive Nutrient Management Plan is an integral part of MAEAP. Michigan State University Extension provides recommended fertilization rates for different crops.

The Michigan Department of Environmental Quality **(DEQ)** is responsible for enforcing the laws and regulations delineated in the Michigan's Natural Resources and Environmental Protection Act **(NREPA)**.

Ohio: The Ohio Environmental Protection Agency **(EPA)** administers the Animal Waste Pollution Abatement Program and permits livestock operations over 1,000 animal units. The Division of Soil and Water addresses operations smaller than 1000 animal units. Several voluntary programs exist at the state and university (The Ohio State University) levels to help farmers address pollution problems. Later in 2001 or early 2002 permitting responsibility will be transferred to the Ohio Department of Agriculture **(ODA)** - Livestock Environmental Permitting Program. The Ohio Department of Natural Resources **(ODNR)—** Division of Soil and Water Conservation along with local Soil and Water Conservation Districts **(SWCD)** have authority regarding water quality on and from farms. The Ohio Livestock Coalition **(OLC)** has been conducting the Livestock Environmental Assurance Program **(LEAP)** since 1997.

The Ohio State University Extension provides recommended fertilization rates for different crops.

Indiana: Indiana Department of Environmental Management **(IDEM)** is responsible for and administers the permitting and approval of confined animal feeding operations.

Purdue University Extension provides recommended fertilization rates for different crops.

2. What are the names and general characteristics of applicable guidelines or regulations for management of P in manure?

Michigan: The state operates under a set of guidelines defined by the Michigan Right to Farm Act (Act 93, 1981, as amended). Under the Act, a comprehensive set of scientifically based practices -- Generally Accepted Agricultural and Management Practices (GAAMP) --- were developed to protect natural resources (air, soil, and surface and ground waters) from pollution and to protect farm operations from harassment and nuisance complaints if the GAAMP are followed. The GAAMP are referenced in Michigan's NREPA, which defines a "zero discharge" standard for release of pollutants into surface and ground waters. Additionally, the GAAMP use the nationally recognized construction and management standards to provide control of runoff in a 25-year, 24-hour rainfall event. There are specific GAAMP for Manure Management and Utilization (MDA, 2000).

Ohio: Comprehensive Nutrient Management Plans **(CNMP)** are required for all permitted operations (see response in question 3 below); development and implementation of CNMP are encouraged strongly for all other dairy operations not formally required to have a permit.

Indiana: The new confined feeding operation rule does not directly regulate P, but the Commissioner of the IDEM can implement a P application restriction at any time. Guidelines for limits on manure P application have not been set. This currently is being considered, perhaps as a P index.

3. What is the current status of regulatory programs and guidelines for management of P (e.g., voluntary, involuntary, pending, in-effect, etc.)?

Michigan*:* Currently, the GAAMP that are in effect are considered voluntary guidelines. However, dairy producers are strongly encouraged to develop a farm-specific CNMP as an integral part of MAEAP. Any livestock unit that pollutes the environment and has not effectively adopted and implemented the GAAMP for Manure Management and Utilization is liable under Michigan's NREPA.

Ohio: Prospective dairy farms of greater than 1000 animal units - Concentrated Animal Feeding Operations **(CAFO)** are required to file for a Permit to Install **(PTI)** from Ohio EPA. A new PTI must be applied for any time the intention is to increase animal numbers beyond those of the original permit. Application for PTI is open to the public for review. Dairy facilities of less than 1000 animal units currently are not required to submit a plan or apply for a PTI.

Indiana: Educational programs are focusing on reducing P levels in feed and using agronomic rates to apply P to land. A Manure Management Plan computer program assists producers to plan application of manure. There are no other regulations currently, except the potential for enforcing limits on high P concentrations in soils (e.g., 400 lb/ acre Bray P1). The IDEM has published a guidance document to interpret the rule and establish guidelines for compliance.

4. Are the state's manure nutrient management guidelines or regulations based on manure spreading standards for P, nitrogen (N), or both?

Michigan: A P standard has been in effect since 1987 for the spreading of manure on cropland.

Ohio: A P standard has been in effect for about 2 years.

Indiana: The state currently uses N-based application rates. However, appropriate information is being collected about Indiana soils and topography so that a change to a P index (P-based application rates) could be implemented.

5. What are the specific key features of the guidelines or regulations in each state for manure nutrient management and distribution (e.g., quantity/per acre, quantity/per year, etc)?

Michigan: Emphasis is on manure nutrient utilization for crop production rather than on waste disposal because: 1) efficient use of manure nutrients will accrue economic benefits by reducing use of commercial fertilizer, and 2) application of nutrients (e.g., P) at agronomic rates reduces the potential risks of contamination of surface and ground waters.

Recommended management practices include:

1) soil fertility testing for P, N, and K every 3 years to determine where manure nutrients can best be used;
2) use of Michigan State University fertilizer recommendations to determine total P needs of specific crops being produced on each field to which manure is to be applied; fertilizer and manure P recommendations are given in, and fertilizer P is sold as, pounds of phosphate [P_2O_5];
3) analysis of the nutrient content of manure to be applied (P, ammonia-N, total N, and K); agronomic rates of P application always should be used to reduce the risk of P accumulation in the upper soil profile and contamination of surface waters with P where runoff and (or) erosion could occur; if the soil test level for P reaches 150 lb/acre (75 ppm) (Bray P1) the manure applications should be reduced to a rate where manure P added does not exceed the P removed by the harvested crop (if this manure rate is impractical due to manure spreading equipment or crop production management, a quantity of manure P equal to the amount removed in 2 crop years can be applied in year 1, if no additional P fertilizer or manure P is applied in year 2); if the Bray P1 soil test reaches 300 lb/acre (150 ppm) or higher, manure applications should cease until crop removal reduces soil test levels to less than 300 lb/acre Bray P1; to protect surface water against discharges of P, adequate soil and water conservation practices should be practiced to control runoff and erosion from fields where manure is applied;
4) to avoid reaching soil test P levels of 300 lb/acre (150 ppm; (Bray P1), manure application rates should be reduced to provide the P needs of crops rather than providing all of the N needs of crops and adding excess P, and
5) a rate of manure P application that can be removed by crops in 2 years can be applied the first year as long as this rate does not exceed the N fertilizer recommendation for the first crop grown after the manure is applied; at this higher rate of manure application, no fertilizer or manure P should be applied in the second crop year.

Ohio: The amount of manure that can be applied to cropland depends on the concentrations of P, and sometimes N, in the manure and how much of these nutrients already are in the soil where the manure is to be applied. The Natural Resources and Conservation Service **(NRCS)** bases application rates on the most restrictive nutrient, which typically is average P (as P_2O_5) removal rate for the next crop rotation, but not to exceed the N requirement of the next crop. Manure application to land is an acceptable practice, but The Ohio State University Extension **(OSUE)** does not recommend application of manure to cropland if it will increase the soil P concentrations in the plow layer above 250 to 300 lb/acre (Bray P1). Raising P concentrations above these levels provides no agronomic benefit and may increase the risk of surface water pollution. Detailed recommendations for manure application can be found in OSUE Bulletin 604 *Ohio Livestock Manure and Wastewater Management Guide* (http://ohioline.ag.ohio-state.edu/b604/index.html). Besides nutrient concentrations in manure and soil, other factors such as setbacks for drainage ditches, homes, wells, and maximum rates of liquid manure to be applied at any one time based on “Available Water Capacity” are considered. Additionally, both the Ohio EPA and the ODNR have regulations and guidelines for land application of animal manure for specific situations (http://oh.nrcs.usda.giv/fotg/OhioNRCSstandards1.htm#T2Z).

Indiana: Specifications are based on agronomic rates, specific setback requirements, slope, soil conditions, temperatures, etc. A detailed set of records must be kept on all manure application activities.

A minimum number of acres for manure application must be maintained and documented in the written record at all times based on: 1) agronomic rates for potentially available N provided by laboratory tests of manure and soil, or 2) application rates not to exceed 150 lb/acre of potentially available N per year, for controlled feeding operations and other animal feeding operations that have not received test results on the soil and manure. Currently, there are no application rate specifications of any kind for P.

The following information must be included in the operation record: type of manure applied; results of manure tests; soil tests for all manure application sites; amount of manure applied; type of application method used; identification of locations and number of acres on which manure is applied; dates manure was applied; and, determination of agronomic rates for potentially available N used to apply manure to each field.

6. Are permits and a permitting process required with respect to P to site, locate, and build a dairy facility in the state?

Michigan: Currently there is not a statewide permitting process established by law for approval to site and build a dairy facility.

Local (e.g., county or township) considerations on land use and zoning may come into play in certain instances.

Ohio: Permits to install (PTI) are required for dairy operations with greater than 1000 animal units (700 mature dairy cows). Dairy farms planned for less than 1000 animal units are not required to obtain a PTI. However, voluntary development of a plan with the local SWCD is highly encouraged; this plan should consider both P and N for crop needs, tillage practices, crop rotations, yield records, available water holding capacity of the soil, and manure application methods.

Local (e.g., county or township) considerations on land use and zoning may come into play in certain instances.

Indiana: A new rule has been adopted where any operation with 300 animal units (1 animal unit = 1000 lb live weight) or more is required to get a permit renewable every 5 years. A Manure Management Plan must be submitted with the renewal.

Local (e.g., county or township) considerations on land use and zoning may come into play in certain instances.

7. For the latest information on P guidelines and regulations in each state go to the following web sites:

Michigan: http://www.msu.edu/user/manure/index.htm

Ohio: http://ohioline.ag.ohio-state.edu/b604/index.html;
http://oh.nrcs.usda.giv/fotg/OhioNRCSstandards1.htm#T2Z

Indiana: http://www.anr.ces.purdue.edu/anr/anr/swine/manure/regulate.htm

Figure 1 -Panel A.
Total Absorbed P vs. 3.5% FCM Yield

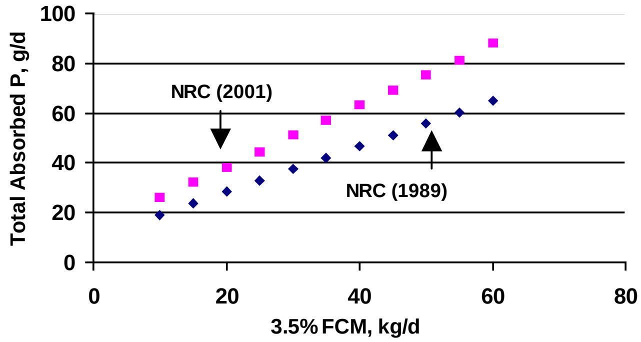

Figure 1 -Panel B.
Total Dietary P vs. 3.5% FCM Yield

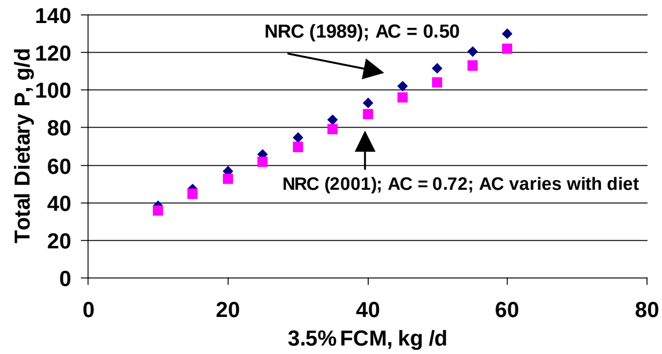

Figure 1 – Panel C.
DMI (kg/d) vs. 3.5% FCM Yield

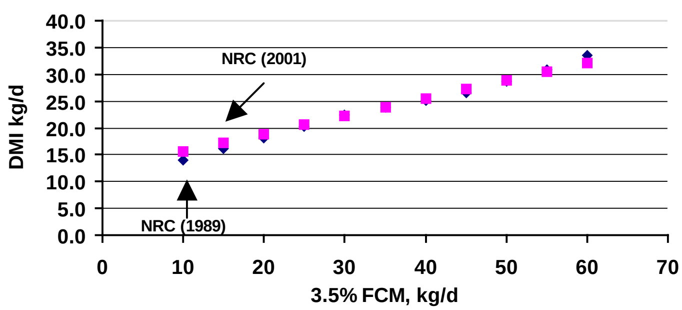

Figure 1 – Panel D.
Dietary P% vs. 3.5% FCM Yield

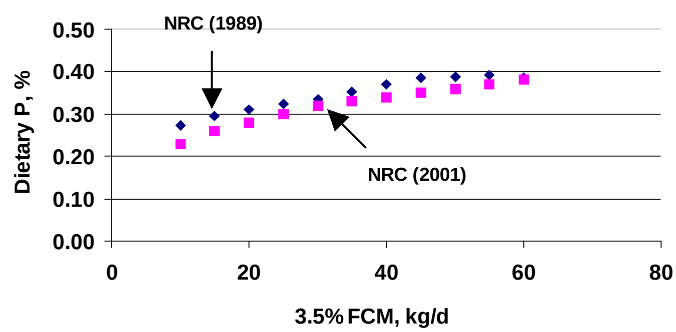

Figure 1. Comparison of the NRC (2001) versus NRC (1989) requirements for phosphorus for a non-pregnant, lactating Holstein dairy cow (700 kg [1540 lb] body weight) when milk yield varies (10 to 60 kg/day, in 5 kg increments [22 to 132 lb/day, in 11 lb increments]; milk contains 3.5% fat and 3.2% total protein). The cow is not gaining or losing body weight. The basal diet is composed of corn silage, alfalfa haylage, high moisture corn, ground dried corn, soybean meal, blood meal, calcium carbonate, dicalcium phosphate, and a mineral and vitamin premix. Dry matter intake (DMI) varies with milk yield according to the NRC (2001) feed intake prediction or according to computed feed intake (Table 6-1; NRC, 1989), respectively. Comparing NRC (2001) with NRC (1989) P requirements: Panel A is the ***Absorbed P Required (grams/day)***; Panel B is ***Total Dietary P Required (grams/day)***; Panel C is the dietary DMI (kg/day) predicted as described above for varying milk yields; and, Panel D is the dietary P content (% of DM) computed as Total Dietary P Required divided by the respective predicted DMI. FCM = fat-corrected milk and AC = absorption coefficient (1.0 kg = 2.2 lb).

Figure 2 - Panel A.
Absorbed P vs. Days Pregnant

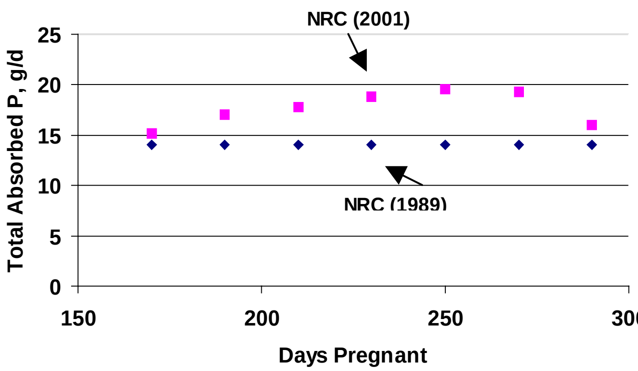

Figure 2 - Panel B.
Total Dietary P vs. Days Pregnant

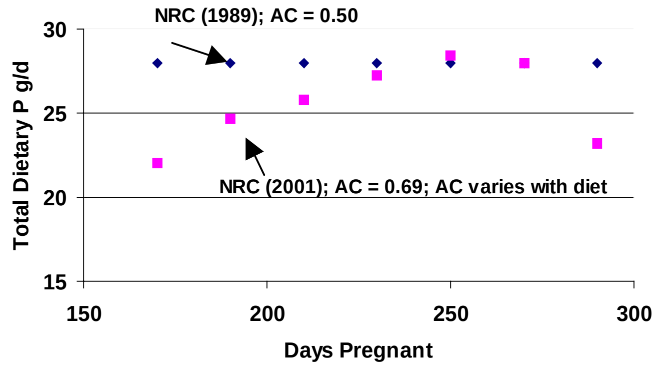

Figure 2 - Panel C.
Dry Matter Intake vs. Days Pregnant

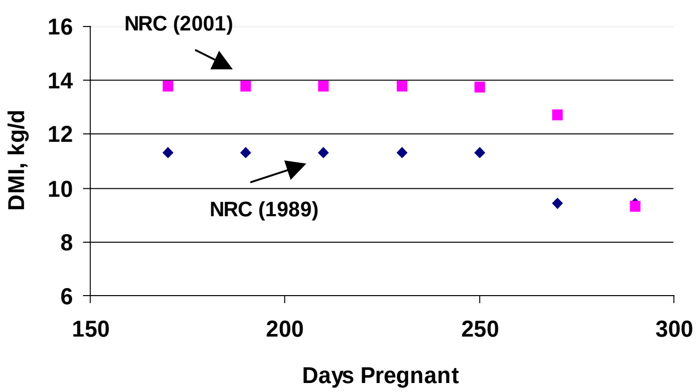

Figure 2 - Panel D.
Dietary P% vs. Days Pregnant

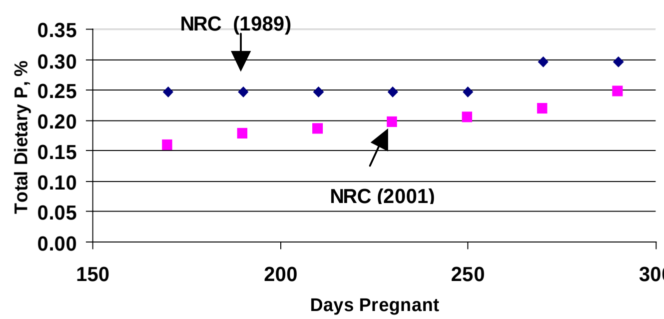

Figure 2. Comparison of the NRC (2001) versus NRC (1989) requirements for phosphorus for a pregnant (170 to 290 days pregnant), mature Holstein dairy cow (700 kg [1540 lb]). The basal diet is composed of corn silage, alfalfa haylage, high moisture corn, ground dried corn, soybean meal, blood meal, calcium carbonate, dicalcium phosphate, and a mineral and vitamin premix. Dry matter intake (DMI) by days pregnant was determined according to the NRC (2001) feed intake prediction model or back-calculated from the NE_L requirement (NRC, 1989). Comparing NRC (2001) with NRC (1989) P requirements: Panel A is the ***Absorbed P Required (grams/day);*** Panel B is ***Total Dietary P Required (grams/day),*** *AC = absorption coefficient*; Panel C is the dietary DMI (kg/day) predicted as described above for varying days pregnant; and, Panel D is the dietary P content (% of DM) computed as ***Total Dietary P Required*** divided by the respective predicted DMI (1.0 kg = 2.2 lb).

Assessing the Merits of Different Corn Hybrids for Silage

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Abstract

Hybrid selection for corn silage should involve comparing differences in yield, production costs, and the economic value of the resulting silage. Seed costs are easily compared, and data from silage yield trials are available from seed companies and some universities. Comparing the nutritional value of different silage hybrids is much more difficult. This paper outlines a proposed method to compare the nutritional and economic value of different silage hybrids based on nutrient composition data, in vitro neutral detergent fiber **(NDF)** digestibility, and the cost of nutrients. The effect of in vitro NDF digestibility on dry matter intake **(DMI)** intake is estimated based on a 0.3 lb/day increase in intake per percentage unit increase in in vitro NDF digestibility. The costs associated with increased intake and the value of the increased milk production are then calculated. The differences in the value of the nutrients provided by different silage hybrids are calculated using composition data, the NRC (2001) model, and a computer program (SESAME 2000). The value of the silage (as a source of nutrients and potential effects on intake) should then be compared to expected differences in seed costs and yields.

Introduction

Hybrid, agronomic practices, growing conditions, harvesting and storage methods, and diet formulation affect the nutritional value of corn silage. This paper will discuss only hybrid effects, but those other factors influence the ultimate value of corn silage, and interactions among hybrid and those other factors can greatly affect the value of different hybrids. This paper will not discuss agronomic characteristics of corn hybrids. Silage growers must select hybrids that are adapted to their specific growing conditions. Because corn genetics are constantly changing this paper will use only data published during the last 4 years.

Corn Silage Evaluation: General Concepts

The best hybrid to use is the one that is most profitable. Profitability is a function of the cost of the silage, and its nutrient content and DMI potential.

Production Costs

Hybrid selection affects the cost of the silage mainly through differences in yield and seed costs. Seed costs are easily compared. Seed companies and some universities[2] conduct yield trials so that silage yields of different hybrids can be compared. This paper generally will not discuss yield differences, but yield should not be ignored when selecting hybrids. Based on Ohio State Extension budgets, a 10% reduction in yield increases production costs about $1.80/ton (35% DM).

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Economic Value

Economic value is much more difficult to compare among hybrids than are differences in yield. Several seed companies and some universities provide some nutrient composition and in vitro digestibility data. Nutrient composition data and in vitro NDF digestibility should be used to estimate economic value. However, users must carefully evaluate the data provided by the seed companies and universities. If two hybrids have numerically different in vitro NDF digestibility but the differences are not statistically significant, the NDF digestibility of the two hybrids should be considered as equal.

Feeding trials are the ultimate measure of the nutritional value of a silage. The number of research trials conducted to compare the nutritional value of different corn silage hybrids has increased substantially during the past few years; however, the data base still is very limited. Furthermore, most studies only compare two or three hybrids, whereas the number of potential comparisons is almost endless. When evaluating lactation data comparing two hybrids, one must ask the question, would the answer be the same if a different 'control' hybrid was used?

A Potential Method to Evaluate Hybrids

Feedstuffs, including corn silage, are simply delivery vehicles for nutrients. The feedstuffs that provide the lowest priced nutrients should be selected for inclusion in diets. For this approach to work, the concentrations of the nutrients must be measurable, the economic value of the nutrients must be known, and differences in the concentrations of nutrients must completely describe differences in animal response when fed different feedstuffs. At this time, none of these requirements are met completely; however, this fundamental approach with some modifications can still be used to choose silage hybrids.

Corn silage provides energy (expressed as net energy for lactation, **NEL)**, rumen degradable protein (**RDP**), rumen undegradable protein (**RUP**), effective NDF (**eNDF**), and several minerals and vitamins (for this discussion, minerals and vitamins will be ignored). Substantial differences in RDP and RUP concentrations among hybrids have not been observed, and corn silage generally does not have high concentrations of those nutrients. Corn silage is a major source of both NEL and eNDF, and these components should be part of the hybrid selection process. The weight placed on these components will vary depending on the needs of a specific farm. If alfalfa is plentiful, NEL may be more important; if forage is limited, eNDF becomes more important.

Measuring Nutrient Concentrations

Laboratory assays that directly measure NEL, eNDF, RDP, and RUP do not exist. Methods are available, however, that can be used to estimate concentrations of these nutrients. For hybrid comparisons in this paper, NEL concentrations will be estimated using the approach outlined in the new NRC (2001). The NEL concentrations of feeds are estimated based on nutrient composition (NDF, protein, lignin, fat, and ash), DMI, and estimated digestibility of the diet. The concentration of eNDF is a function of NDF concentration and particle size. For comparisons in this paper, all NDF provided by corn silage will be considered effective. This assumption is valid for comparing hybrid because particle size is largely determined by chop length, not hybrid. The concentrations of RDP and RUP are not available for different hybrids; therefore, the data published for 'normal corn silage' (NRC, 2001) will be used for all hybrids (adjusted for differences in CP content).

Economic Value of Nutrients

St.-Pierre and Glamocic (2000) developed a method to determine the economic value of different nutrients. An economic value is given to NEL, eNDF, RDP, and RUP. Based on feed prices in late February, 2001, 1 Mcal of NEL is worth $0.05 and 1 lb of eNDF, RDP, and RUP are worth $0.02, 0.00, and 0.35, respectively. The average composition of 'normal corn silage' (NRC, 2001) is 0.66 Mcal/lb NEL (at 3 X maintenance), 45% NDF, 5.8% RDP, and 3.0% RUP (DM basis); therefore, 1 ton of corn silage (35% DM) would have a maximum economic value to a buyer of $23.10 for NEL, $6.30 for NDF, and $7.35 for RUP for a total of $36.75 (this includes all costs including storage and shrink). The economic values used in this paper should not be considered constant, and different results would likely be obtained with different prices. A computer program (SESAME, 2000) can be purchased from Ohio State University Extension that calculates the economic value of feedstuffs based on their nutrient composition and current feed prices.

Effect of Nutrient Concentrations on Animal Performance

Differences in concentrations of NEL, eNDF, RDP, and RUP of feeds, especially forages, do not account for all the differences observed in animal performance when different feeds are included in diets. A major determinant of animal performance when fed a particular forage is the DMI potential of the forage. Cows consume more DM when fed diets that contain forages with high in vitro NDF digestibility. Oba and Allen (1999b) determined that when in vitro or in situ NDF digestibility was statistically different between compared forages, a 1 percentage unit increase in in vitro NDF digestibility resulted, on average, in a 0.38 lb/day increase in total DMI. That data base included only one study comparing different corn silage hybrids (brown midrib versus isogenic control). An additional study has been reported using brown midrib corn silage. When data from only corn silage studies (Oba and Allen, 1999a; Oba and Allen, 2000) was used, mean increase in DMI per percentage unit increase in in vitro NDF digestibility was 0.33 lb (range was 0.19 to 0.48 lb). For this paper, 0.3 lb of increased DMI (total diet, not just the silage fraction) is assumed for every one percentage unit increase in in vitro NDF digestibility. That value should only be used when in vitro NDF digestibility of two hybrids are statistically different.

The proposed method (Table 1) to compare the economic value of different hybrids is to first determine potential differences in DMI (and ultimately milk production) based on differences in in vitro NDF digestibility. The economic value of the nutrients provided (using chemical composition data, the NRC (2001) program to calculate NE_L values, and SESAME (2000) to calculate economic value of the nutrients) is then calculated. The sections below entitled *Economic value* use this approach. However, the economic value of the specialty hybrids are compared only to the control hybrids used in the study. Different results might be obtained if a different control hybrid was selected. The economic value must then be compared to potential changes is production costs (yield and seed costs).

Brown midrib hybrids

This topic was reviewed recently by Eastridge (1999) and will not be discussed in detail.

Nutrient Composition

Brown midrib (**bmr**) corn silage has similar CP contents and similar to slightly lower concentrations of NDF than typical hybrids. At equal DMI, bmr corn silage is more digestible than its isogenic control (Tine et al., 2001). When nonlactating cows were fed a diet of 98% corn silage at maintenance DMI, the measured NEL concentrations were 0.70 and 0.64 Mcal/lb for bmr and isogenic control (Tine et al., 2001). That would mean that 1 ton of bmr corn silage (35% DM) would contain 42 Mcal of NEL more than control silage with an approximate value of $2.10/ton. However, digestibility decreases as DM intake increases and cows consume more DM when fed bmr corn silage (discussed below). A recent study (Tine et al., 2001) measured (not estimated) the NEL content of diets with 60% corn silage (bmr or isogenic control) and found both diets contained 0.73 Mcal NEL/lb of DM.

Cow Responses

Dry matter intake was higher for cows fed bmr corn silage in all 12 studies reviewed by Eastridge (1999), with a mean increase of 3.6 lbs/day. Milk yield was higher for cows fed bmr corn silage in eight of 12 studies (mean response for the 12 studies was 2.1 lb/day increase). Since that review, four more studies (Ballard et al., 2001; Moreira et al., 2000; Oba and Allen, 2000; Tine et al., 2001) were found comparing bmr corn silage to other hybrids. When all data were combined, a pound for pound replacement of bmr corn silage with another hybrid resulted in an average increase in milk yield of about 3 lb/day and an increase in DMI of 3 to 4 lb/day. All the recent studies, however, have been short term experiments (lasting a few weeks). Data with long term comparisons (months) are not available. The available data strongly suggests that the increased milk production observed when bmr corn silage replaces an equal amount of conventional corn silage is caused by increased DMI, not by changes in NEL, NDF, or CP concentrations.

Economic Value

Based on nutrient composition (NDF, CP, and NEL concentrations), the economic value of bmr corn silage is similar to conventional hybrids; however, bmr silage clearly has a higher intake potential which results in higher milk production. Based on the data from short term lactation trials, cows produce about 3 lb more milk and consume about 3 lb more DM than cows fed conventional corn silages (diets contained 30 to 40% of the DM as corn silage). Assuming feed costs (control diet) of $0.055/lb of DM and assuming a $4/ton increase in production cost for bmr corn silage (Eastridge, 1999), feed costs would increase about $0.27/cow/day and gross milk income (assumed $12.50/cwt) would increase about $0.375/cow/day. Income over feed costs would be about $0.10/cow/day higher for bmr silage than conventional silage. The big unknown is whether this return would hold for the entire 305-day lactation. The lower yield (approximately 10%) and higher intake of diets with bmr silage will increase the land needed to produce corn silage.

Leafy Hybrids

Corn hybrids have been developed that have two to four more leaves above the ear than conventional corn hybrids. One study reported that about 13% of the total plant DM was provided by leaves for a leafy hybrid (TMF 94) compared to about 11% for conventional hybrids (Kuehn et al., 1999).

Nutrient Composition

Three studies (Bal et al., 2000; Ballard et al., 2001; Kuehn et al., 1999) were found that reported nutrient composition of different leafy hybrids (control hybrids varied among experiments). No differences were reported in CP concentration (leafy hybrid mean = 7.4% of DM). The NDF content was variable (42 to 48%) and tended to be 1 to 3 percentage units higher than the control hybrids. The NEL concentration of leafy hybrids has not been measured. In vivo DM digestibility data are inconsistent but generally differences have been small between leafy and control silages (Kuehn et al., 1999; Bal et al., 2000). This implies that the NEL content of leafy hybrids was probably similar to that of the control hybrids. Published in vitro digestibility of leafy hybrids is extremely limited. Kuehn et al. (1999) reported that in vitro NDF digestibility of a leafy hybrid was about 4 percentage units higher (not statistically different) than control hybrids. Ballard et al. (2001) reported that in vitro NDF digestibility of a leafy hybrid stored in laboratory silos was 4 percentage units higher (not statistically different) than the control hybrid, but in samples from silage stored in a farm scale bag silo, the leafy hybrid had 4 percentage units lower (not statistically significant) in vitro NDF digestibility than control silage.

Cow Responses

Four studies (Bal et al., 2000; Ballard et al., 2001; Kuehn et al., 1999; Moreira et al., 2000) have been published comparing leafy hybrids to different control hybrids, and no statistical differences in milk yield or DMI have been found (Table 2). The lack of an intake response fits the small differences reported in in vitro NDF digestibility.

Economic Value

The concentrations of CP and NEL (based on in vivo digestibility data) in leafy hybrids appears similar to that of the control hybrids used in the studies. Data from lactation trials show no difference in DMI potential for the leafy hybrid. Leafy hybrids tend to have higher NDF concentrations (approximately 2 percentage units). Assuming a 2 percentage unit increase in NDF concentration, 1 ton of leafy corn silage (35% DM) will have about 14 lb more NDF than conventional hybrids. The approximate value of the additional NDF is $0.02/lb x 14 lb = $0.28/ton of corn silage (35% DM) compared to the control silages used in the studies.

High Oil Hybrids

Nutrient Composition

Silage made from high oil hybrids have approximately 1 percentage unit more CP, equal NDF concentrations, and 1 to 2 percentage units more fatty acids than conventional hybrids (LaCount et al., 1995; Weiss and Wyatt, 2000). Experiments have not been conducted to measure the NE_L content of high oil corn silage, but diets with high oil corn silage (62% of dietary DM) had 0 (processed corn silage) and 5% (unprocessed corn silage) more measured total digestible nutrients **(TDN)** than a conventional hybrid. Based on that study, the NE_L content of high oil silage is assumed to be 5% higher than conventional unprocessed corn silage.

Cow Responses

One recent short term (28 days) study (Moreira et al., 2000) and two recent long term (>12 weeks) studies (Dhiman et al., 1999; Weiss and Wyatt, 2000) are available that compared high oil corn silage to conventional hybrids (Table 3). No differences were observed in DMI among hybrids. In two studies, no statistical differences were observed in milk production, and in one study, a trend toward higher milk production with high oil corn silage was reported. The study that reported a trend toward higher production used diets with 62% corn silage; the other studies used 22 to 37%

corn silage.

Economic Value

One ton of high oil corn silage (35% DM) would have about 2.5 lb more RUP and approximately 23 Mcal more NEL than normal unprocessed corn silage (no difference in NEL between high oil and processed corn silage). The increased RUP is worth $0.87/ton and the increased NEL is worth $1.16/ton. No difference in intake potential has been reported. Therefore, one ton (35% DM) of high oil corn silage, on average, would currently be worth approximately $2 more than a conventional unprocessed hybrid, but only about $0.87/ton more than a processed conventional hybrid. These expected increases in economic value must be compared to expected differences in yield and production costs.

Hybrids with Different NDF Concentrations

Hybrids with NDF concentrations significantly higher and lower than normal corn silage are available. The need for hybrids with NDF concentrations higher or lower than normal will vary based on the forage base of the farm. Cows need a certain amount of forage NDF (NRC, 2001). If the diet for a specific farm relies heavily on corn silage, corn silage with above average NDF may be useful, but if the farm relies heavily on hay crop forage or the hay crop forage has a high NDF concentration, corn silage with lower than normal NDF may be beneficial.

Nutrient Composition

Published data comparing corn silages with widely differing NDF concentrations are extremely limited. Bal et al. (2000) conducted a study with a corn silage with low NDF (Cargill 3677) and a more typical hybrid (Garst 8751). The NDF content of the two hybrids was 32.8 and 39.2%, respectively, and CP content was similar (7.2 vs. 7.7). Weiss (unpublished) conducted a study with a conventional hybrid (Novartis B52-B2) and a high NDF hybrid (Novartis N48-V8). The NDF content of the two hybrids was 42.4 and 49%, respectively, and CP content was similar (8.6 and 8.5%). Dry matter digestibility was similar between hybrids (within experiments), suggesting that the NEL content of the low and high NDF silages were similar to the control hybrids.

Cow Responses

Bal et al. (2000) compared a corn silage with about 33% NDF to one with 39% NDF. In one set of treatments, diets contained 35% corn silage (diets were not equal in NDF), and in another set of treatments, the amount of forage fed was increased when low NDF corn silage was fed (40 vs. 44% corn silage) so that diets were equal in NDF. Hybrid had no effect on DMI when corn silage concentrations were kept the same, but when substituted to maintain equal dietary NDF, the low NDF corn silage reduced DMI about 2 lb. Milk production (96 lb) and milk composition were not affected by hybrid in any of the comparisons. In an unpublished study (Weiss), cows fed diets with about 45% corn silage that had high or normal NDF concentrations (diets contained 29 and 31% NDF for the normal and high NDF corn silage, respectively) produced similar amounts of milk (74 lbs) and had equal DMI (52 lb).

Economic Value

In the two available studies, CP content did not differ between hybrids with significantly different NDF concentrations. Based on in vivo digestibility, NEL concentrations did not differ, and no differences were reported in DMI. The difference in NDF, however, has economic value. In both studies, NDF concentration differed by about

6 percentage units. Therefore, the high NDF silages in both studies would be worth about $0.84/ton (35% DM) more than the low NDF silages.

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Table 1. Proposed method to compare the economic value of different corn silage hybrids.

1. Evaluate potential differences in production costs.

   1. Obtain yield data from seed companies and university trials.
   2. If yields are statistically different, estimate differences in production costs [$1.80/ton (35% DM silage) increase per 10% decrease in yield].
   3. Calculate differences in seed costs per ton.

2. Evaluate differences in intake potential.

   1. Obtain in vitro NDF digestibility data from seed company or university trials.
   2. If values are statistically different, estimate potential differences in total DMI between diets with the different hybrids (0.3 lb increase in DMI per percentage unit difference in in vitro NDF digestibility). Estimate cost of increased DMI.
   3. Estimate potential increased income (higher milk production) from increased DMI. Based on Oba and Allen (1999b), when DMI increases because of increased in vitro NDF digestibility, 4% fat-corrected milk yield increases approximately 1.5 lb per pound of increased DMI (increased milk yield should only be considered when in vitro NDF digestibility is statistically different). Then calculate increased net income (increased milk income - increased feed costs).

3. Evaluate potential differences in economic value of nutrients.

   1. Obtain nutrient composition data (NDF, CP, lignin, and ash).
   2. Calculate NEL using NRC (2001) and the assumed differences in DMI (if any).
   3. Calculate any difference in economic value of nutrients using SESAME (2000).

Table 2. Production responses when dairy cows were fed leafy hybrids.

Study	Milk yield (lb/day)	DM intake (lb/day)
Kuehn et al. (1999). 22 week lactation trial; 40.6% corn silage in diet, 13 first-lactation and 8 multiparious cows per treatment, no statistical differences among treatments.		
High grain hybrid (Dekalb 442)	73.3	47.3
Blended seed (Dahlco No. 2 blend)	76.2	46.3
Leafy hybrid (TMF 94)	73.7	47.1
Bal et al. (2000). Latin square, 33.5% corn silage in diet, 24 multiparious cows, no statistical differences among treatments, means averaged over planting population treatments.		
Control (Pioneer 3563)	89.1	60.6
Leafy (TMF 106)	88.7	59.3
Moreira et al. (2000). 4 week lactation trial, 32.5% corn silage in diet, 24 early lactation cows per treatment, no statistical differences among treatments.		
Control (Asgrow RX 5888)	76.8	46.4
Leafy (TMF 99)	78.3	46.9
Ballard et al. (2001). 4 week lactation trial, 31.1% corn silage in diet, 25 pen-fed multiparious cows per treatment, no statistical differences among treatments.		
Control (Pioneer 3861)	68.6	Not reported
Leafy (TMF 94)	68.4	Not reported

Table 3. Production responses when cows were fed high oil corn silage.

Study	Milk yield (lb/day)	DM intake (lb/day)
Dhiman et al. (1999). 21 week lactation trial with 27 cows per treatment starting at 3 week postpartum. Diets were 22.5% corn silage. The diet with high oil corn silage also contained high oil corn grain (31.5%). No statistical differences between treatments.		
Control (Dekalb DK-512)	88.9	60.9
High oil (LOL-671)	95.7	62.5
Moreira et al. (2000). 4 week lactation trial, 32.5% corn silage in diet, 24 early lactation cows per treatment, no statistical differences among treatments.		
Control (Asgrow RX 5888)	76.8	46.4
High oil (RX 5888TC)	77.2	46.2
Weiss and Wyatt (2000). 12 week lactation trial with 8 cows per treatment starting at 23 weeks of lactation. Diets contained 62.5% corn silage. Significant ($P < 0.10$) effect of hybrid on milk yield and significant hybrid by processing interaction on DMI.		
Control (Doebler's 636XY) unprocessed	59.0	38.9
Control processed	61.2	41.4
High oil (Doebler's 637T6) unprocessed	62.9	42.2
High oil processed	61.8	39.8

Management Guidelines During Harvest and Storage of Silages

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Abstract

Management techniques during harvest and storage can have marked effects on the quality of forages stored as silage. Wilting to correct moistures and chopping forages to recommended particle lengths will help during the silo packing process. High cutting of corn silage may be an option for some producers to consider in the future. However, no recommendations can be made until more research is completed. Mechanical processing of corn silage can help to improve its nutritive value by improving starch and fiber digestion. Rapid packing to recommended densities and excluding air from the forage mass stimulates a more optimal fermentation in the silo. To help with the ensiling process, microbial inoculation encourages a more efficient fermentation. When forages are drier than 40% DM, inoculants are more effective if applied in a liquid form. All silage additives should be added such that they are distributed evenly throughout the forage mass. Covering bunk and pile silos with plastic is a cost efficient mechanism to save nutrients during storage. Finally, good feedout and silo face management can also help to maintain silages with a high nutritive value.

Introduction

High quality forage drives milk production by stimulating dry matter intake. Therefore, insuring the availability of quality forage throughout the year is important. Assuming that forage is at the optimum stage of maturity, the next challenge is to harvest that forage and to store it so that it retains its nutritive value. Harvest and storage management can have marked effects on silage quality. The objective of this paper will be to briefly discuss some recommended management practices to make high quality silage.

Preharvest Preparation

The condition of equipment to be used during harvest and silo filling should be optimized. Knives should be sharpened on the chopper. Silos and forage wagons should be cleaned before filling and moldy and spoiled silages should be removed so that they do not contaminate fresh forage. Bag silos should be placed in an area with good drainage and a slight slope away from the feeding end of the bag. We preferably like to put bags on a poured concrete pad. Although this can be costly, it speeds up silage removal and results in less waste, especially during rainy/muddy weather. The ground around bag silos should also be kept clean and free of weed growth to deter damage to the bags by animals.

Chop Length

Cut forages at optimal theoretical length for the specific crop (e.g. alfalfa - 3/16 inch; unprocessed corn silage - 3/8 inch; processed corn silage - ¾ inch). This is also a good time to measure actual particle size. In diets where corn silage

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makes up the majority of the forage, 15 to 20% of the particles should be greater than 1.5 inches long. If using a Pennsylvania State Forage Separator, 5 to 10 % of the corn silage should be retained on the top screen to ensure optimum levels of effective fiber in the diet. If corn silage is not the major forage in the diet, 2 to 4% of the top screen may be sufficient. For processed corn silage, 15 to 25% of the forage should be on the top screen.

Cutting Height

Corn Silage

Corn silage is normally harvested to leave 4 to 6 inches of stalk in the field. Typically, the only time that cutting height should be higher is during drought years when the potential for nitrate accumulation in the lower third of the stalk may occur. However, some dairy farmers have been high-cutting their corn silage as a normal practice. Preliminary research shows that when compared to normal-cut corn silage, high cutting (leaving 18 to 20 inches of stalk) results in silage with slightly lower concentrations of fiber and lignin, but higher concentrations of starch and net energy (Table 1). Leaving more of the stalk in the field that contains high concentrations of fiber and lignin may also help to improve soil conditioning. However, as expected, there is a small yield drag from high cutting. On-going research is evaluating this practice on different varieties and interactions with stage of maturity. The ultimate success of high-cutting corn silage will depend on milk produced per ton of forage and milk produced per acre of forage. No recommendations are currently being made relative to high cutting of corn silage until more research has been completed.

Alfalfa

A recommended 1-inch cut height for alfalfa is dictated by yield and stand life. Although cutting at 3 or 4 inches may improve nutritive value, this is usually not justifiable because of the loss in yield. Belesky and Fedders (1997) reported that cutting alfalfa at 1 to 2 inches resulted in 38% more yield than alfalfa cut at 4 inches. For healthy alfalfa, short cutting height does not reduce stand longevity. Leaving a 4-inch stubble may be justifiable under certain conditions. For example, leaving more stubble at fall cutting may allow for better snow cover to protect plants during cold winters. In addition, reserve of carbohydrate in the roots of stressed crops (excess moisture or too early of a cut) may benefit from a higher cut (Wiersma, 2001).

Mechanical Processing of Corn Silage

Mechanical processing of whole plant corn has been an accepted method to improve the quality of corn silage. Whole plant processing crushes the entire plant through rollers and can be accomplished in the field during harvesting, at the silo but prior to storage, or after ensiling and just prior to feeding. Processing corn silage improves starch and fiber digestion and allows for good packing in silos, even with a longer length of particle chop. Rollers should be set at 1 to 3 mm (or follow manufacturer's guidelines for specific machines). Care should be taken to monitor the effectiveness of the processing. When large amounts of acreage require harvesting, there may be a tendency to open the rollers more than what is recommended in order to speed up the harvest and to reduce wear on equipment. As a rule of thumb, adequate processing is occurring if more than 90 to 95% of the kernels are crushed or cracked. The theoretical cut of corn silage can be increased to ¾ of an inch when corn silage is mechanically processed. This is useful because it improves effective fiber. Improvements in milk production appear to be about 1.5 to 2.0 lb/day, with larger improvements when more mature corn silage (e.g., black layer) is processed. However, we still recommend to target harvest for 35% DM (whole plant DM). If, however, there are reasons out of your control (inclement weather, equipment problems, or scheduling problems with a contractor) that results in corn being harvested at later stages of maturity, processing should be considered. A common observation by producers switching to processed corn silage is the reduction in cobs in the feed bunk and a reduction in kernels in the manure. There is insufficient data to support the use of whole plant processing in immature whole plant corn if a premium is to be paid for the processing. If brown midrib (low lignin) corn silage is chopped at less than 3/4 inch theoretical length, it should not be processed. However, the chop length on brown midrib corn can be increased to 1 to 1 1/2 inch and should then be processed but with rollers set to 5 to 8 mm. A key goal of good processing for brown midrib corn is to have all cobs at least broken into quarters (Rich Bennek, Mycogen Seeds, Indianapolis, IN, personal communication).

Keys to Making Good Silage

The keys to making quality silage are to 1) rapidly exclude air from the forage mass, which will result in 2) a rapid production of lactic acid and reduction in silage pH, and 3) to prevent the penetration of air into the silage mass during storage.

Excessive air, due to slow silo filling or poor packing (overly dry forage or forage chopped too coarsely) allows the plant to respire for prolonged periods of time. This results in utilization of sugars and excessive degradation of plant protein. Delayed filling can result in a clostridial fermentation that is characterized by high concentrations of butyric acid and ammonia-N and poor digestibility (Table 2; Mills et al., 2000). Air also encourages the growth of undesirable microbes, such as yeasts and molds.

Silo Packing

Rapid filling and adequate packing are crucial regardless of silo type. Exclusion of air limits heating and encourages the ensiling process. A low packing density can lead to significant losses of DM during storage (Ruppel et al., 1995). In a recent study from our lab, tightly packed alfalfa forage ensiled more quickly (Figure 1) than did loosely packed forage. Loosely packed forage also had more yeasts and molds at the end of ensiling than did tightly packed silage.

Air can be eliminated by fast filling (but not too fast), even distribution of forage in the storage structure, chopping to a correct length, and ensiling at recommended DM for specific storage structures. The density of bag silos can be monitored via density gauges or by monitoring the diameter of the bag. Bunk silos should be filled as a progressive wedge to minimize exposure to air. The recommended optimal packing density for bunk silos is 14 lb of DM per cubic foot. An Excel spreadsheet can be downloaded from the University of Wisconsin Extension web site that provides guidelines for bunker silo filling (www.uwex.edu/ces/crops/uwforage/storage.htm). Users can input silo dimensions, tractor weight, forage delivery rate, forage DM, and packing time to estimate packing density.

The Ensiling Process

Under anaerobic conditions (lack of air), silage fermentation is dominated by microbial activity. Fermentation is controlled primarily by a) type of microorganisms that dominate the fermentation, b) available substrate (waster soluble carbohydrates) for microbial growth, and c) moisture content of the crop. Lactic acid-producing bacteria utilize water-soluble carbohydrates to produce lactic acid; the primary acid responsible for decreasing the pH in silage. Undesirable fermentations from microorganisms, such as Enterobacteria and Clostridia, can occur if the pH does not drop rapidly. Clostridia can be eliminated by harvesting forage at less than 68 to 70% moisture (more than 30 to 32% DM). Lack of air prevents the growth of yeast and molds and a low pH prevents the growth of most bacteria after fermentation is done. Silage can be kept for prolonged periods of time if these conditions prevail.

Form and Location of Microbial Inoculation

Research has proven that microbial inoculants can be useful by improving silage fermentation and resulting in more DM and nutrient recovery and improved animal performance (Muck and Kung, 1997). However, several factors can affect how well an inoculant may work.

Silage inoculants are applied in a dry or liquid form and thus a logical question is: Does the form of application change the effectiveness of an inoculant? A recent study from our lab showed that both a dry granular or liquid application of a commercially available silage inoculant were equally effective in improving the rate of fermentation of alfalfa with 30% DM (Whiter et al., 1999). In alfalfa from the same field, but wilted to about 54% DM, again both forms of inoculation stimulated the fermentation process when compared to untreated silage. However, the liquid-applied inoculant caused an even faster decline in pH than did the dry-applied inoculant (Figure 2). Similar results have been reported by German researchers on grass silage with a DM content of about 40%. Why did this happen? Inoculants applied in a dry form rely solely on moisture in or on the crop to resuscitate the organisms. In contrast, dried bacteria begin to resuscitate in the water used for a liquid application. Thus, it may take longer for the bacteria in an inoculant applied in a dry form to revive, resulting in a slower rate of fermentation than with an inoculant applied in water. We suggest that if all other things are equal, apply an inoculant that has been mixed in water to forage with ^{3} 40% DM. To help with this recommendation, new high pressure/low volume liquid applicators require fewer refilling of inoculant tanks. Do not mix an inoculant that has been designed for a dry application into water for a liquid application.

The location of applying a microbial inoculant is also important. Common sense suggests that there are preferred locations for applying an inoculant depending on the situation a producer is faced with. For example, if silage is to be stored in a bunk, pile, or pit silo, I would recommend that the inoculant be applied at the chopper for a more even distribution. Remember that these bugs neither have legs nor do they swim! If all the inoculant gets put on in one spot, it will probably stay there; some distribution will occur during tractor movement and packing, but this is not efficient. For silage that will be stored in a tower or bag silo, application at the chopper or blower/bagger will probably make a difference. In a few instances, forage is chopped and harvested far away from where it is ensiled. Under these circumstances, I would prefer to have the inoculant applied at the chopper so that the microorganisms can begin their work right away. Don’t forget to properly calibrate your applicators to match forage delivery and don’t increase the dilution or reduce the application rate!

Sealing Silos and Fermentation

Bunks, pits, and drive over piles should be covered immediately with 6 mil plastic tarp and weighted with old tires (tires should be touching) to exclude air. Split tires are a good alternative because they are easier to handle and are undesirable for animals to nest in. The return on investment (labor and plastic) is extremely high for covering bunk and pile silos (Bolsen et al., 1993). Conventional cement stave silos should be leveled and sealed with a silo cap immediately after filling.

When conditions allow for it, silage should ferment for about 3 to 4 weeks before feeding. A gradual transition over a 10 to 14 day period from old silage to new silage is also recommended. Unfermented feed is the equivalent of feeding green-chop that is high in fermentable sugars and can cause cows to go off feed and have loose manure. For dairy farms that store silage primarily in tower or bunk silos, putting some forage into a bag silo that can be fed during silo filling (especially in the case of corn silage in the Fall) is a good idea. This will allow for emptying of bunk or tower silos before filling and also allows for a uniform source of silage during this time. If possible, store bale and bag silos where they will be shaded from the hot afternoon sun. This will help to maintain silage quality for a longer period of time.

Silage Feedout

Proper management for removal of silage from silos and management at the feed bunk can help producers to maximize profits and production. Removal of about 3 to 4 inches of silage from conventional cement stave silos will help to prevent silage from heating in the silo. Because the density of pack is usually less in bunk and bag silos, it is recommended that 4 to 6 inches be removed from the face of the silo during warm weather. Lesser amounts may be removed in areas of the country where ambient temperatures never rise about 40 to 45^{o}F during the winter months. Removal of silage should be such to minimize loose silage on the ground between feedings. Cows respond best when offered fresh feed 3 to 4 times per day. Hot, moldy feeds should not be fed because it is low in nutritive value and digestibility and depresses intake. Feed bunks should be kept full but clean of decaying feed.

Summary

Good management practices during harvest and storage can help to maintain the high quality forage brought in from the field for storage. Moisture content, particle length, packing density, and covering silos eliminates air from the forage mass and encourages a good fermentation. Microbial inoculants can also help to improve the ensiling process. When forage is > 40% DM, an inoculant applied in a liquid form is more effective than a dry-applied inoculant. Care must be taken to also distribute the inoculant evenly throughout the forage mass for maximum effectiveness.

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Table 1. Effect of cutting height on the composition and yield of corn silage.[1]

Cut Height	DM (%)	NE_L (Mcal/lb)	ADF (%)	ADL[3] (%)	NDF (%)	Starch (%)	CP (%)	Tons per ace[2]
Normal[4]	35.3	0.72	24.6	3.58	45.3	31.5	7.50	26.5
High[5]	37.3	0.75	21.2	2.16	40.8	33.7	7.63	23.3

[1]Neylon and Kung, 2001; preliminary data, University of Delaware
[2]Adjusted to 30% DM basis.
[3]ADL = Acid detergent lignin.
[4]Four inches of stalk left in the field.
[5]Eighteen inches of stalk left in the field.

Table 2. Effect of delayed filling on composition and in vitro dry matter digestibility of barley silage (Mills et al., 2000).

Item	Control[1]	Delayed Filling[2]
DM, %	36.3	36.2
pH	3.98	4.61*
Lactic acid, %	8.57	4.96*
Acetic acid, %	2.65	1.85*
Butyric acid, %	0.00	1.65*
Ethanol, %	0.96	1.29*
Yeasts, cfu/g	3.09	5.12*
IVDMD,[3] %	71.7	64.7*

*Different from control, $P < 0.05$.
[1]Forage chopped and immediately packed into silos.
[2]Forage chopped and exposed to air for 24 hours prior to packing into silos.
[3]48 hour in vitro DM digestibility.

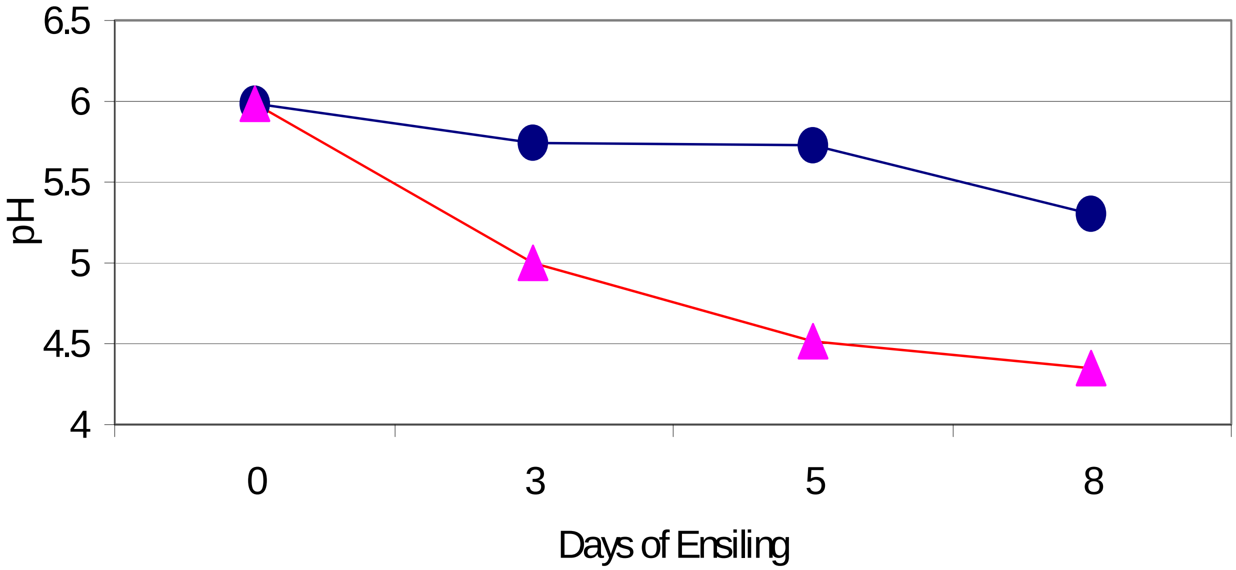
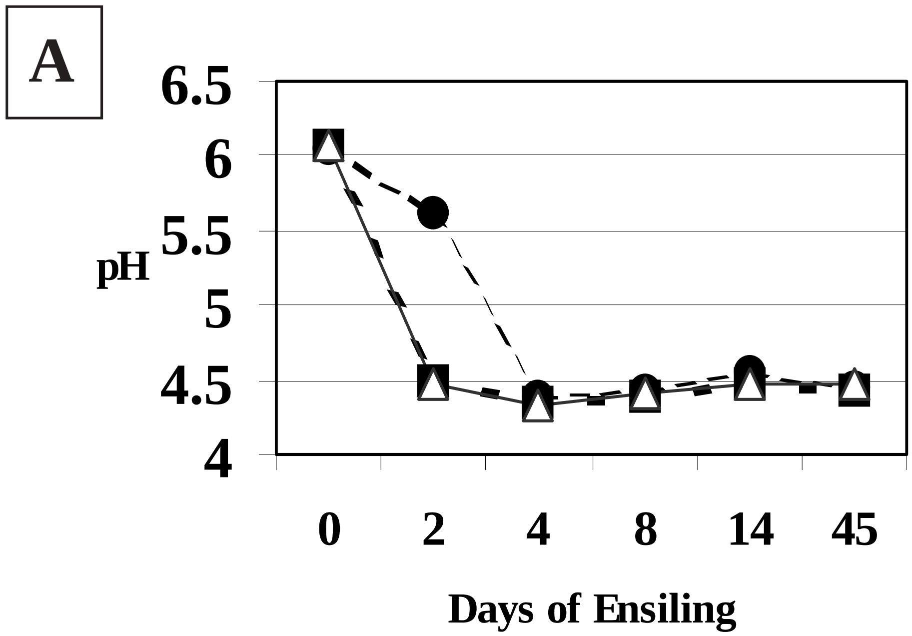


Figure 1. The effect of a tight (14 to 15 lbs of DM/cubic ft., s) or loose (11 to 12 lbs of DM/cubic ft., ●) pack on the decline in pH of alfalfa silage (Lynch and Kung, 2001; unpublished data, University of Delaware).



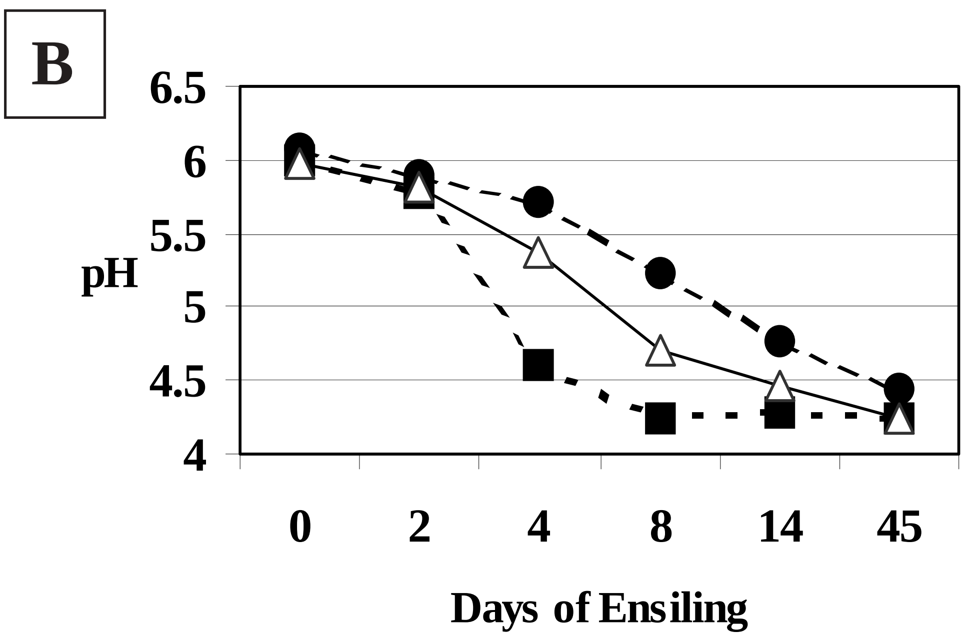


Figure 2. The effect of form of application of a microbial inoculant on the decrease in pH of low DM (A, 30% DM) and high DM (B, 54% DM) alfalfa silage. Untreated silage (●), silage treated with *Lactobacillus plantarum* MTD1(Ecosyl Products, Ltd., Stokesley, England) in a dry form (∆), and silage treated with *Lactobacillus plantarum* MTD1 in a liquid form (n) are shown. (SE < 0.05; Whiter et al., 1999).

Requirements for and Regulation of Growth of Holstein Calves – Implications for Decreasing Age at First Calving

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Abstract

Reducing the age at first calving **(AFC)** is the primary means by which producers can reduce the costs associated rearing dairy replacements. Virtually none of the studies that explored the concept of "accelerated growth" initiated treatments prior to three or four months of age, and therefore, these studies might have missed an opportunity to reduce the AFC without detrimental effects on mammary development. Further, protein deposition per unit of gain and thus feed efficiency is potentially the highest at this stage of life when the calf is still a functional non-ruminant. Data from recently completed slaughter and metabolism studies with Holstein calves from birth to 240 lb of body weight **(BW)** indicated that tissue energy and protein depositions are higher than predicted by the 1989 Dairy and 1996 Beef NRC. Further, the growth appears to be normally regulated via the growth hormone/somatotropic axis as early as the second week of life, and this regulation is sensitive to level of nutrient intake and exogenous somatotropin. Application of these data indicates that enhancing the growth rate of neonatal calves might be beneficial for long-term development and productivity.

Introduction

For several years, our laboratory has been investigating nutritional and management practices in an effort to reduce the age at first calving. Interest in this area stems from several factors, primary of which is the economic investment required for the heifer replacement program by the dairy industry which is equivalent to 15 to 20% of the costs to produce milk. Several observations were made by our group in 1996 that precipitated a series of ongoing experiments that will be discussed in this paper. Without significant referencing, those observations were:

1. Studies that had investigated pre-pubertal "accelerated growth" in an effort to lower the AFC started treatments well into the ruminant phase of growth and as late as 8 months of age. Thus, we might have lost a significant amount of time and opportunity with regard to lowering the AFC. Additionally, early postnatal growth is the most efficient time to deposit protein and develop skeletal growth.

2. Recent evaluations of nutrient requirements for Holstein heifers suggested that our current system of equations did not adequately represent the composition of gain and thus the energy and protein requirements for growth during the pre-pubertal phase of life. Further, this inability to meet the "true" requirements might have confounded our expectations and interpretation of accelerated growth studies (e.g. when evaluated among experiments, feeding for a particular growth rate might not lead to a simi-

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lar composition of gain).

3. On farm management of calf rearing typically follows nutrition programs developed for early weaning and thus employed restricted liquid feeding levels in an effort to encourage dry feed intake. Considering this practice, in light of the 1996 National Animal Health Monitoring Service **(NAHMS)** data indicating that neonatal calf mortality was greater than 10%, led us to think about calf raising from a different perspective. The paradigm shift revolved around the following questions: 1) do standard calf nutrition programs contribute to the observed morbidity and mortality, and 2) is the practice of restricting liquid feed intake the most biologically sound approach to achieving calf growth and health.

4. We know of no other neonatal system that is successful at enhancing future productivity by restricting milk intake in an effort to force weaning, humans included.

Based on these observations, we have conducted several studies to more clearly elucidate the energy and protein requirements for tissue growth from birth to approximately 240 lb of BW. In addition, we have explored the relationship between amount and type of nutrient intake and the functioning of the somatotropic axis. Finally, we have begun to evaluate the role of nutrition in the development of the immune system in order to determine what role the supply of specific nutrients has on immune competency.

Not surprisingly, one of our most relevant discoveries was the imperative link between the realization of the calf's biological potential and the systematic management of nutrient delivery. In other words, not only did we discover that the nutrient requirements used for current calf feeding systems are poorly described, but it became clear that calf management practices had adapted themselves to a form practices far from what would be considered biologically normal. Dr. Jim Drackley has also discussed the concept of what is considered normal by current standards versus what we understand about the biology (Drackley, 2000). This system adaptation apparently occurred in order to compensate for inadequate nutrition or nutrient delivery. Therefore, as we recommend the use of more accurately described nutrient requirements for growing calves, we must also recommend adjustments to current management protocols so that optimization of growth is a systematic integration of nutrients and nutrient delivery. Application of biological principles is not "plug-and-play" technology; more accurately described nutrient requirements of growing calves cannot be met by "conventional" calf management practices.

Growth Studies

In the first study (Diaz et al., 2001; Smith et al., 1998), sixty calves were assigned randomly among three treatments (TRT) after a three to five day period of adjustment. Treatments were designed to achieve three targeted daily rates of live weight gain **(LWG)** (TRT 1 = 1.1, TRT 2 = 2.1, and TRT 3 = 3.1 lb) (Table 1). There is an interpretation here that is important to understand. In order to conduct a study of this nature, there must be a range in slaughter weights and growth rates to have enough animals and variation represented to develop mathematical equations that can be used with other populations across a range in growth rates and BW. This should not be interpreted as a study focusing on "accelerated growth." However, the study did reveal the growth potential of calves under good management conditions that could then be translated into an "on farm" program and used to challenge producers to set new goals for their calf rearing programs.

The milk replacer (Milk Specialties Co., Dundee, IL) was formulated to contain 30% CP and 20% fat (DM basis) (Table 1). The milk replacer was an all-milk protein formulation. This dietary CP content was selected based upon previous studies (Donnelly and Hutton, 1976a,b; Gerrits et al., 1996) that indicated a plateau in daily protein accretion might be achieved at near maximal dry matter intake **(DMI)** with a CP concentration of 30%. The goal of the diet formulation was to ensure that protein would not be the most limiting nutrient. The initial estimated energy requirements were derived from the available data (Donnelly and Hutton, 1976a,b; Gerrits et al., 1996; NRC, 1989; NRC, 1996). The vitamin and mineral contents of the milk replacer were formulated based upon the expected amount of DMI, thus their concentrations were decreased in TRT 2 and 3 to prevent excessive intake.

The calves assigned to TRT 1 and 2 were fed their respective milk replacer reconstituted to 15% DM; TRT 3 calves received milk replacer reconstituted to 18% DM. Calves were fed individually in buckets three times per day (0700, 1400, and 2100 h), and water was offered for ad libitum intake throughout the study. No dry feed was offered. All amounts of feed and water offered and refused were recorded at each feeding. The calves were weighed twice weekly prior to feeding, and if the LWG of a calf exceeded the target growth rate, then the animal's calculated DMI was reduced. Calves were allowed 30 min, to consume the meal. If the milk replacer was not consumed within 30 min the refusal was quantified and recorded.

Calves were purchased from four local dairy farms and the Cornell Dairy. Upon arrival at the calf barn, calves were given a physical examination and received 2 ml of vitamin B complex subcutaneously (The Butler Co., Dublin, OH), 2.5 ml of BoSe intramuscular (1 mg of selenium and 50 mg (68 IU) of vitamin E per ml; Schering-Plough Animal Health Corp., Union, NJ), and 2 ml of iron dextran intramuscular (100 mg/ml of elemental iron; The Butler Company, Dublin, OH). Calves were vaccinated intranasally against infectious bovine rhinotracheitis **(IBR)** and parainfluenza **(PI-3)** (2 ml TSV-2; Pfizer Animal Health, Exton, PA) at approximately 3 days of age, against Pasteurella multocida and P. hemolytica (2 ml Once PMH; Bayer Corp., Shawnee Mission, KS) at approximately 7 and 28 days of age, against BVD, BRSV, IBR, and PI-3 i.m. (2 ml BRSV Vac 4; Bayer Corp.) at 7 and 28 days of age, and against five Clostridial diseases with a toxoid (2 ml Vision Seven; Bayer Corp.) at days 14 and 35. Indices of calf health were monitored and recorded several times per day. Since all calves remained generally healthy and there were no differences among treatments, no health data will be presented.

On the same set of calves, we simultaneously investigated the relationship between DM intake, growth rate, and the development of the somatotropic axis. We were interested in determining how early in life the somatotropic axis is expressed and functional. To test functionality, we administered exogenous somatotropin (120 mg/kg BW) for 3 days prior to slaughter and then sampled plasma and various tissues for analyses of insulin-like growth factor-I **(IGF-I)** and messenger RNA for IGF-I and the somatotropin receptor.

Significant findings from these studies were:

1. Growth rates of calves fed a milk replacer that more closely meets their requirements are difficult to control; calves have a tremendous capacity for growth.

2. Calves fed a milk replacer mixed at a lower dilution rate (18%) at less than 14 days of age have difficulty consuming adequate DM in order to meet specific growth targets (Table 2). Dilutions to 15% solids appear to be more acceptable at early ages.

3. Feed efficiencies were relatively high compared to traditional on farm efficiencies, most likely a result of more adequate protein levels that allowed for greater protein deposition, levels of DM intake well above maintenance, and no transition to dry feed during the course of study (Table 2).

4. Composition of gain of calves on this study differed from that predicted by either the 1989 Dairy or 1996 Beef NRC equations (Table 3), and this has significant implications for proper growth and development of replacement heifers.

5. Increased milk replacer feeding did not result in any observable negative health consequences, which suggests our management was adequate and that the milk replacer was formulated properly to allow for adequate digestibility. We believe data indicating that general health is decreased and scours are increased with increased liquid feed intake are related to lapses in management or are observations made from older data where milk replacer manufacturing methods were not as refined as they are today.

6. The somatotropic axis is functional as early as 21 days of age and is responsive to level of nutrient intake (Table 4). In addition, the liver specific somatotropin receptor, which is responsible for normal growth, is also sensitive to nutrient intake and is expressed by 21 days of age. This is significant in that it demonstrates normal regulation of endocrine and possibly paracrine signals of growth early in life. This raises the question of whether traditional feeding strategies with conventional nutrient densities in our industry standard milk replacers are adequate to allow full expression of the somatotropic axis.

7. Our data suggest that the protein requirement is not fixed and that the level of energy intake drives the requirement for protein. Equations generated from these data indicate that to meet the energy allowable protein requirement when calves are gaining in excess of 1.5 lb/day, the protein content of the diet must be at least 26 to 28% CP on a DM basis. This is in agreement with levels predicted in a summary of the literature (Drackley, 2000). His review suggested that the minimum level of protein required to meet maintenance requirements and 0.5 lb/day gain to be 18.1% on a DM basis (Table 5). Higher protein content would be necessary to achieve high rates of gain without increased fat deposition.

A subsequent study by Tikofsky et al. (2001) was conducted to determine the effect of varying levels of dietary fat and carbohydrate for dairy calves fed under isocaloric and isonitrogenous intake conditions. In addition, in the study of Tikofsky et al. (2001), we wanted to assess the effect of carbohydrate or fat as a fuel source for growth under conditions where calculated protein intake as a function of the energy intake was not considered to be limiting growth (Davis and Drackley, 1998; Diaz et al., 2001). Previous work was confounded by varying fat and/or protein levels and allowing intakes to remain similar, thus creating diets that were not isocaloric or isonitrogenous. This lack of control confounds interpretation of the primary effect of fat or carbohydrate on the efficiency of use of the energy source on growth rate or body composition. The receiving protocol was similar to the study of Diaz et al. (2001).

Milk replacer formulations were manufactured according to protein and fat specifications determined by the investigators so that target DMI for each treatment would enable isocaloric and isonitrogenous intake conditions among treatments (Table 6). Treatment diets consisted of three specially formulated milk replacers (Milk Specialties, Co., Dundee, IL). The protein of all milk replacers was derived from all-milk sources, and the fat content was primarily tallow. Fat and lactose contents of all diets were formulated to deliver treatments that are defined as low fat, high lactose (LF); medium fat, medium lactose (MF); and high fat, low lactose (HF).

Dry matter intake for calves on all treatments was calculated to deliver 0.24 Mcal/kg $BW^{0.75}$ for treatment day 1 through 14 and then increased to 0.28 Mcal/kg $BW^{0.75}$ from day 15 until final slaughter weight was reached. Targeted energy intakes for individual calves were adjusted every 7 days based on changes in animal weight. Dry matter intake targets were intended to create isocaloric and isonitrogenous dietary intake conditions. Feed consumption was measured at each feeding for each calf by subtracting the refused milk replacer from the total fed. Calves rarely refused any feed from any of the treatment diets. Free choice water was offered at all times. Dry feed was not offered.

Mean slaughter weights and days on treatment are shown in Table 7. Mean days on treatment were similar for calves among treatments (P = 0.9). Mean initial BW and mean final BW were similar among treatments (P = 0.83 and 0.91, respectively), and consequently average rate of BW gain was similar among treatments (P = 0.66). Gross energy **(GE)** and protein intakes of milk replacer diets are shown in Table 7. No differences were detected for protein intake (P = 0.79) and GE intake (P = 0.63), thereby sustaining the desired effect of isocaloric and isonitrogenous intakes among treatments. There was a higher intake of fat as fat percentage in the diets increased from LF to HF (P = 0.001). Compositional results are shown in Table 8.

Results expressed as a percentage of whole empty body **(EB)** demonstrate the same pattern as weight results for all measured components. However, in this analysis, it is apparent that water, as a percentage of whole EB, is different between the LF and HF treatments (P = 0.04). Therefore, means of dry EB composition among treatments were analyzed to determine if there was a tendency for a lower fat diet to promote the development of a leaner animal. On a water-free basis, protein and fat contents of the dry EB composition were different between LF and MF, and LF and HF treatments (P = 0.006 and 0.003, respectively). Therefore, animals on LF deposited less fat, resulting in the development of leaner animals.

Significant results from the study of Tikofsky et al. (2001) were:

1. Treatments remained isocaloric and isonitrogenous throughout the course of the study, thus providing us with better interpretive data than previous studies.

2. Increasing the level of carbohydrate (~55%) and lowering the fat (~15%) to levels within this experiment was not detrimental to digestive capacity and suggests that there is a critical upper level of carbohydrate intake that affects digestion and scours.

3. Although diet composition was dramatically different, when fed under iso-caloric and iso-nitrogenous intake conditions, daily growth rate was not different.

4. Increasing dietary fat intake increased body fat deposition and was not used any more efficiently as a fuel source for protein retention (or "you are what you eat").

5. Under conditions of isocaloric and isonitrogenous intakes, body composition could be altered by diet composition, independent of growth rate; therefore, rate of gain should not be a sole means of assessing the efficacy of a nutrition regimen for milk replacer-fed calves.

Based on the results of the study by Smith et al. (1998), a follow-up study was conducted to determine if calves fed an industry standard milk replacer (20% CP; 20% fat) at conventional rates (1.4% BW as DM per day) developed an active somatotropic axis compared to calves fed a higher protein (30% CP; 20% fat) milk replacer at 2.4% BW as DM per day (Bork et al., 2000). Calves were fed twice daily and weighed twice weekly. Intake was adjusted weekly. No dry feed was offered. Additionally, blood was sampled weekly and sent to Dr. Brian Nonnecke at the National Animal Disease Center in Ames, Iowa for evaluation of immune competency. Separate blood samples were taken weekly for analyses of plasma urea nitrogen, IGF-I, and other metabolites.

Growth rates were significantly different between treatments and were directly related to DM intake (Table 9). There was an 85 lb advantage at the end of 63 days of treatment for calves fed at 2.4% BW. Calves fed under a more conventional system did not respond as well to a bovine somatotropin **(bST)** challenge at 5 weeks of life as those fed an accelerated amount of milk replacer (Table 10). A surprising observation was the increase in growth rate observed with the TRT 2 calves the week following the bST challenge. There was no change in DM intake during this period. The implication of this study is that current strategies for calf nutrition might not allow for normal expression of growth via the somatotropic axis. In lactating dairy cattle, this same condition would be considered very poor nutritional management. It is interesting to note that the plasma IGF-I levels correlated (r = 0.97 with growth rate in the TRT 2 calves, but the correlation in the TRT 1 calves was less (r = 0.70).

Data on the effects on the immune system are still developing but suggest that higher levels of intake early in life have positive effects on the maturation of the immune system (Nonnecke et al., 2000). Previous data have indicated that lower levels of intake can impair the responses of the immune system in neonatal calves (Williams et al., 1981; Pollack et al., 1993, 1994).

Recognizing that in order for this programmatic approach to calf rearing to succeed, a successful weaning program must be developed. One of the historical challenges to calf programs that included the feeding of increased amounts of milk or milk replacer was a phenomenon called "post-weaning slump." To overcome this situation, we rationalized the problem as such: if a calf stopped growing, it is either ill or the diet provided to the calf is inadequate and is not meeting the requirements for maintenance and growth at that specific time. We approached the problem from the perspective that the diet did not supply the amount and type of nutrients to support the rate of gain the calf had been accustomed to, and thus, growth was reduced. The data describing the development of the rumen suggests that basic rumen function is occurring by three weeks after dry feed intake has been initiated (Warner, 1991).

We formulated a new starter diet the had ingredients and nutrient profiles known to enable both adequate ruminal fermentation for rapid development at low levels of intake and supply the calf with a good profile of post-ruminally available nutrients in order to maintain an adequate growth rate while rumen function is developing. We then conducted a study to determine how well our weaning "system" worked. In order to fully test the system, we again employed the use of somatotropin challenges to determine if the somatotropic axis comes uncoupled during the weaning phase. If nutrient supply was inadequate, we would anticipate that the response to somatotropin would be relatively non-existent, and there would be no rise in circulating IGF-I. Therefore, our objectives in this study were: (1) to compare the responses to repeated somatotropin challenges during the weaning period, and (2) to compare the response to a somatotropin challenge between heifer and bull calves.

Calves fed solely a high protein (30% CP) milk replacer are responsive to short-term somatotropin challenge by 3 weeks of age (Smith et al., 1998, 1999). In terms of circulating IGF-1, responsiveness is related to rate of gain and BW. Milk-fed animals commonly go through a growth slump at weaning. If so, the response to somatotropin challenge may be depressed at that time. Our first objective was to measure the change in circulating IGF-1 in calves following bST challenge prior to, during, and after weaning (Smith and Van Amburgh, 2000).

Calves received 4 L colostrum initially, then were fed a 30% CP, 20% fat milk replacer twice daily (milk replacer DM at 2% of BW per day) and free choice water. Calves were weighed weekly and feed amounts adjusted accordingly. Calves were first offered starter (26.5% CP, 0.50 Mcal NE^g/lb, DM basis; Table 11) after reaching 220 lb BW. When starter was introduced, milk replacer DM was offered at 1% BW per day for one week, then at 0.5% BW per day for one week before being discontinued. The challenge protocol consisted of injecting 120 mg/kg BW of bST once daily for three days. The first bST challenge was performed when calves weighed about 235 lb. Two weeks later, which was 10 days after starter was first offered and milk replacer restricted, the second bST challenge was performed. The third bST challenge took place two weeks after the second challenge and 10 days after calves had been completely weaned from milk replacer.

- Although heifers had a significantly decreased rate of gain the first week of weaning (Figure 1), they still gained nearly one pound per day (0.95 lb/day).
- By the third week after the start of the weaning protocol, gains had returned to their preweaning level (Figure 1).
- Total DM intake dipped slightly the first week of weaning, then increased rapidly once milk replacer feeding was discontinued (Figure 2).
- Circulating IGF-1 was not different (P = 0.61) between heifers and bulls.
- The response to bST challenge was not different (P = 0.9) among the three challenge periods.
- The response to challenge was greater in heifers than bulls (P = 0.04).
- Growth rates for heifers and bulls across the challenge periods were not significantly different (P = 0.18), averaging 2.2 and 2.4 lb/day, respectively.

The step-down weaning protocol followed in this study minimized the occurrence of a post-weaning “slump” in growth despite the fact that starter was first introduced as milk replacer was reduced (Smith and Van Amburgh, 2000). Weaning had no significant impact on the IGF-1 response to somatotropin challenge in this study and is likely related to the capacity of the starter to deliver adequate nutrients. With the small number of calves in this study, biological variation between calves was greater than gender-related differences in response to somatotropin when weaned at 235 lb. Thus, we conclude that calves can be weaned without uncoupling the somatotropic axis and results of studies of milk-replacer-fed bull calves can be applied to heifers.

Integration

Recent work has suggested that the mammary gland of replacement heifers is not affected by growth rates up to 200 lb of BW (Sejrsen et al., 2000) so that should not be a concern for this early stage of growth. To further the approach of feeding greater nutrients during the milk feeding phase, a study compared the performance of calves from birth through the first lactation when they were fed either milk replacer (23% CP, 18% fat) or allowed to suckle the dam for 15 min three times a day for the first 6 weeks of life (Bar-Peled, et al., 1997). Both treatments were designed to deliver the same amount of intake on a weight basis. Growth rates were higher for the calves allowed to suckle for the first 6 weeks; however, the calves fed milk replacer adapted to dry feed faster and gained more weight by 12 weeks of age than the suckling calves. But the suckled calves, bred at the same weight, conceived and calved 30 days earlier than the milk replacer fed calves, were 3 inches taller, 80 lb heavier, and produced 998 lb more milk in the first lactation. The only known treatment difference between those calves was the dietary composition and amount of nutrients consumed during the first 6 weeks of life.

Our understanding of the nutrient requirements of calves and the management of that nutrient delivery has increased in the last few years. Similar work exploring body composition of neonatal calves has been underway at the University of Illinois by Dr. Jim Drackley and demonstrates similar responses to nutrition and dietary composition to the data discussed in this paper (Barlett, 2001). The data generated allows us to develop nutritional programs in early life that can enhance not only growth rate but deliver what we consider to be more appropriate body composition early in life. With this increased understanding comes the ability to improve on-farm management of calf programs.

Based on the endocrine responses (i.e. increased responsiveness to bST challenge and higher basal circulating levels of IGF-I), more biologically normal growth appears to be that in excess of our current industry practice for the first 6 to 8 weeks of life. We have developed weaning programs and diet formulations that enhance growth rates through this approach to feeding calves. Subsequently, further work is currently underway to determine if the application of this information will enhance lifetime profitability.

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Table 1. Chemical composition of milk replacer fed to calves at three levels of intake in the study of Diaz et al. (2001)[1].

Component	Treatment 1	Treatment 2	Treatment 3
DM, %	96.2	95.8	96.0
Protein, % of DM	31.2	29.5	30.6
Fat, % of DM	20.0	21.0	20.2
Lactose, % of DM	42.9	43.4	43.0
Ash, % of DM	5.90	6.10	6.30
Calcium, % of DM	1.10	1.03	1.24
Phosphorus, % of DM	0.71	0.70	0.77
Gross energy, kcal/g	4.97	5.19	4.92
Vitamin A[2], KIU/kg	60.0	30.0	15.0
Vitamin D_3[2], KIU/kg	20.0	15.0	10.0
Vitamin E[2], IU/kg	200	150	100

[1]Each treatment represents a separate batch of milk replacer.
[2]Vitamin levels were the formulated levels and were based on the expected level of DM intake (1, 3, and 4% of body weight per day for treatments 1, 2 and 3, respectively) necessary to achieve the target growth rates.

Table 2. Body weights, feed intake, and growth performance of calves fed three levels of milk replacer and slaughtered at three different body weights in the study of Diaz et al. (2001)[1].

	Treatment 1			Treatment 2			Treatment 3			SE	*P* TRT[2]
n	6	6	6	6	6	6	6	6	6		
Target slaughter weight, lb	143	187	231	143	187	231	143	187	231		
Birth weight, lb	98.5	98.8	105.4	97.9	99.6	98.1	100.9	97.0	97.0	2.8	0.9
Actual slaughter weight, lb	144.4^{a}	187.0^{b}	232.5^{c}	149.8^{a}	189.5^{b}	225.9^{c}	149.8^{a}	185.1^{b}	229.2^{c}	2.8	0.9
Days on treatment	40.0^{a}	67.0^{b}	98.5^{c}	25.0^{a}	39.0^{b}	62.0^{c}	24.0^{a}	34.0^{b}	50.0^{c}	1.9	0.02
Total DMI, lb	70.5^{a}	131.4^{b}	196.0^{c}	66.1^{a}	127.4^{b}	209.4^{c}	59.5^{a}	110.9^{b}	186.2^{c}	7.8	0.04
Daily DMI, lb	1.76^{a}	1.90^{b}	1.98^{b}	2.64^{a}	3.26^{b}	3.37^{b}	2.49^{a}	3.26^{b}	3.72^{c}	0.02	0.04
DMI, % of BW	1.62^{a}	1.44^{b}	1.23^{c}	2.46^{a}	2.45^{a}	2.15^{b}	2.39^{a}	2.67^{b}	2.48^{c}	0.05	0.001
Gain/feed, lb/lb	0.65^{a}	0.65^{a}	0.42^{b}	0.57^{a}	0.60^{b}	0.62^{b}	0.78^{a}	0.76^{a}	0.70^{b}	0.03	0.001
ADG, lb/day	1.15^{a}	1.32^{a}	1.30^{a}	2.07^{ab}	2.30^{b}	2.07^{a}	2.05^{a}	2.58^{b}	2.67^{b}	0.09	0.003
Plasma urea nitrogen[8], mg/dl	12.0^{a}	9.3^{b}	10.2^{c}	12.5^{a}	13.1^{b}	9.4^{c}	10.1^{a}	12.4^{b}	10.2^{a}	1.29	0.4

[1]SE = Standard error of the mean, DMI = dry matter intake, BW = body weight, and ADG = average daily gain.
[2]Probability of differences among treatment (TRT).
[abc]Values with different superscripts differ ($P < 0.05$) by slaughter weight within treatment.

Table 3. Comparison of observed energy and protein retained and composition of gain in calves in the study of Diaz et al. (2001) with prediction equations used in the 1989 Dairy (NRC,1989) and 1996 Beef NRC (NRC, 1996)[1].

	Retained Energy, (Mcal/day)			Retained Protein, (g/day)			Fat in Gain, %		Protein in Gain, %	
	Observed	Predicted Dairy[2]	Predicted Beef[3]	Observed	Predicted Dairy[4]	Predicted Beef[5]	Observed	Predicted Beef[6]	Observed	Predicted Beef[7]
Treatment 1	1.17	1.17	0.92	136.9	98.8	130.0	7.6	0.0	24.3	21.7
Treatment 2	2.48	2.12	1.72	199.4	160.6	213.1	15.2	15.5	20.2	18.3
Treatment 3	2.82	2.45	2.01	244.4	183.3	244.0	13.8	19.6	21.8	17.4

[1]The weight and weight gain units for the equations are expressed in kilograms.. The prediction of retained protein utilized the actual energy value of the gain of the calves on study as determined by bomb calorimetry.
[2]Calculated using the equation: NE (Mcal/day) = $(0.035*LW^{0.75})*(LWG^{1.119}) + LWG$, where LW = live weight and LWG = live weight gain.
[3]Calculated using the equation: RE (Mcal/day) = $0.0635*EBW^{0.75}*EBG^{1.0973}$, where RE = retained energy, EBW = empty body weight, and EBG = empty body gain.
[4]Calculated using the equation: RPN (g/day) = (211-(26.2*NE(Mcal/day)/LWG)*LWG, where RPN = net protein required for growth, NE = net energy, and LWG = live weight gain.
[5]Calculated using the equation: Net protein (g/day) = SWG*(268-(29.4*(RE (Mcal/day)/SWG))), where SWG = shrunk weight gain, and RE = retained energy.
[6]Calculated using the equation: Proportion of fat (g/100 g) = 0.122*RE (Mcal/day) - 0.146, where RE = retained energy.
[7]Calculated using the equation: Proportion of protein (g/100 g) = 0.248 - 0.0264*RE (Mcal/day), where RE = retained energy.

Table 4. Calf plasma insulin-like growth factor-I (IGF-I; ng/ml) concentrations from the study of Smith et al. (1998). Pre-challenge samples were taken four days prior to slaughter. Pre-challenge samples were taken either 14- or 24-hr after the third daily somatotropin injection.

		Target daily gain (lb/day)		
Plasma IGF-I values (ng/ml) summarized over all slaughter weights (143, 187, 231lb)		1.1	2.1	3.1
	Pre challenge (baseline)	143	243	267
	Post 14-hour	293	500	527
	Post 24-hour	230	367	430

Table 5. Effect of rate of body weight gain with constant initial body weight (100 lb) on protein requirements of pre-weaned dairy calves (adapted from Davis and Drackley, 1998) (From Drackley, 2000).[1]

Rate of gain (lb/day)	ME (Mcal/day)	ADP (g/day)	Required DMI[2] (lb/day)	CP required (% of DM)
0	1748	28	0.84	8.3
0.50	2296	82	1.11	18.1
1.00	3008	136	1.45	22.9
1.50	3798	189	1.83	25.3
2.00	4643	243	2.24	26.6
2.50	5532	297	2.67	27.2
3.00	6457	350	3.12	27.6

[1]ME = metabolizable energy, ADP = apparently digestible protein, and DMI = dry matter intake.
[2]Amount of milk replacer DM containing 2075 kcal ME/lb DM needed to meet ME requirements.

Table 6. Milk replacer diet specifications on a dry matter basis for calves fed on the study of Tikofsky et al. (2001).

	Low fat	Medium fat	High fat
Dry matter, %	97.2	96.9	96.3
GE[a], Mcal/kg DM	4.62	5.09	5.77
Protein, % of DM	23.54	24.80	27.00
Fat, % of DM	14.79	21.62	30.62
Lactose[b], % of DM	55.29	46.69	35.36
Ash, % of DM	6.37	6.89	7.02
Ca, % of DM	0.83	0.92	1.01
P, % of DM	0.67	0.73	0.74
Magnesium, % of DM	0.14	0.15	0.15
Potassium, % of DM	1.72	1.78	1.78
Sodium, % of DM	0.77	0.84	0.89
Vitamin A, KIU	16,500	18,117	20,060
Vitamin D, KIU	5,883	6,039	6,686
Vitamin E, IU	110	21	134

[a]Gross energy. [b]Lactose determined by difference.

Table 7. Days on treatment, initial and final full body weight, average daily gain for all treatments, and calculated dry matter intake and measured intakes of GE[1], protein, and fat for calves on the study of Tikofsky et al. (2001).

	Low fat	Medium fat	High fat	SEM[2]	*P*
n	8	8	8		
Days on treatment	54.6	56.1	55.1	2.7	0.90
Initial body weight, lb	105	104	102	2.2	0.83
Final body weight, lb	190	188	188	1.3	0.91
Average daily gain, lb	1.6	1.5	1.6	0.03	0.66
Intakes during respective days on treatment:					
Dry matter, lb	122[x]	116[xy]	103[y]	2.49	0.02
GE, Mcal	257.6	268.8	270.3	12.83	0.63
Protein, lb	28.7	28.8	27.8	0.62	0.79
Fat, lb	18[x]	25[y]	31.6[z]	0.60	0.001

[1]Gross energy.
[2]SEM = standard error of mean.
[x,y,z]Values with different superscripts are statistically different. Fisher's pairwise comparison used to determine differences between treatment means (individual error rate = 0.025). ANOVA used to calculate overall P-value from F-statistic.

Table 8. Whole empty body (EB) and dry EB composition of calves fed three milk replacers varying in carbohydrate and fat contents fed at isocaloric and isonitrogenous levels (Tikofsky et al., 2001).

	Low fat	Medium fat	High fat	SEM[1]	P
Whole EB composition:					
EB protein, %	17.54	17.21	17.38	0.151	0.69
EB fat, %	8.48[x]	9.91[y]	11.0[y]	0.253	0.002
EB ash, %	3.63	3.42	3.33	0.086	0.37
EB water, %	70.33[x]	69.43[xy]	68.25[y]	0.307	0.04
Dry EB composition:					
EB protein, %	59.18[x]	56.42[y]	54.85[y]	0.498	0.006
EB fat, %	28.58[x]	32.36[y]	34.63[y]	0.628	0.003
EB, ash %	12.24[x]	11.23[xy]	10.53[y]	0.275	0.06

[1]SEM = standard error of mean.
[xy]Values with different superscripts are statistically different. Fisher's pairwise comparison used to determine differences between treatment means (individual error rate = 0.025). ANOVA used to calculate overall P-value from F-statistic.

Table 9. Birth weight, final weight, average daily gain, and dry matter intake of calves fed to achieve two levels of performance on the study of Bork et al. (2000).[1]

	Treatment 1 (conventional)	Treatment 2 (accelerated)	SE	*P* value
Initial weight (lb)	101	101	2.9	0.94
Final weight (lb)	163	249	8.6	0.0001
ADG (lb/day)	1.0	2.42	0.1	0.0001
DM intake (% of BW)	1.4	2.4	ND	ND
Stature difference, inches		+3.5	0.6	0.0001

[1]SE = standard error, ADG = average daily gain, DM = dry matter, and ND = not determined.

Table 10. Plasma concentrations of insulin-like growth factor-I (IGF-I) in calves fed two different milk replacers at either 1.4 or 2.4% of body weight dry matter and challenged with bovine somatotropin (bST) at five weeks of age (Bork et al., 2000).

	IGF-I levels[1] (ng/ml)		P<
	Pre bST	14 hr post-bST	Pre vs. 14 hr
Treatment 1 (conventional) (20% CP:20% fat)	78	109	0.06
Treatment 2 (accelerated) (30% CP:20% fat)	152	215	0.001

[1]Pooled Standard Error = 11.7

Table 11. Calf starter nutrient profile.[1]

Dry matter (DM), %	91.8
Protein, %, of DM	26.5
Fat, % of DM	3.1
Ash, % of DM	7.7
Calcium, % of DM	1.16
Phosphorus, % of DM	0.68
NEm (kcal/g)	1.23
NEg (kcal/g)	1.10
Vitamin A (IU/kg)[†]	>15000
Vitamin D_3 (IU/kg)[†]	>5000
Vitamin E (IU/kg)[†]	>200
Lasalocid (g/kg)[†]	0.1

[†]Values shown for vitamin content are according to formulation.
[1]Partial ingredient list: Dextrose, plasma, blood meal, citrus pulp, soyhulls, wheat midds, soybean meal, roasted soybeans, steam-flaked corn, molasses, dried whey, corn gluten meal, alfalfa meal, methionine, and lysine. Values reported are measured values except those marked.

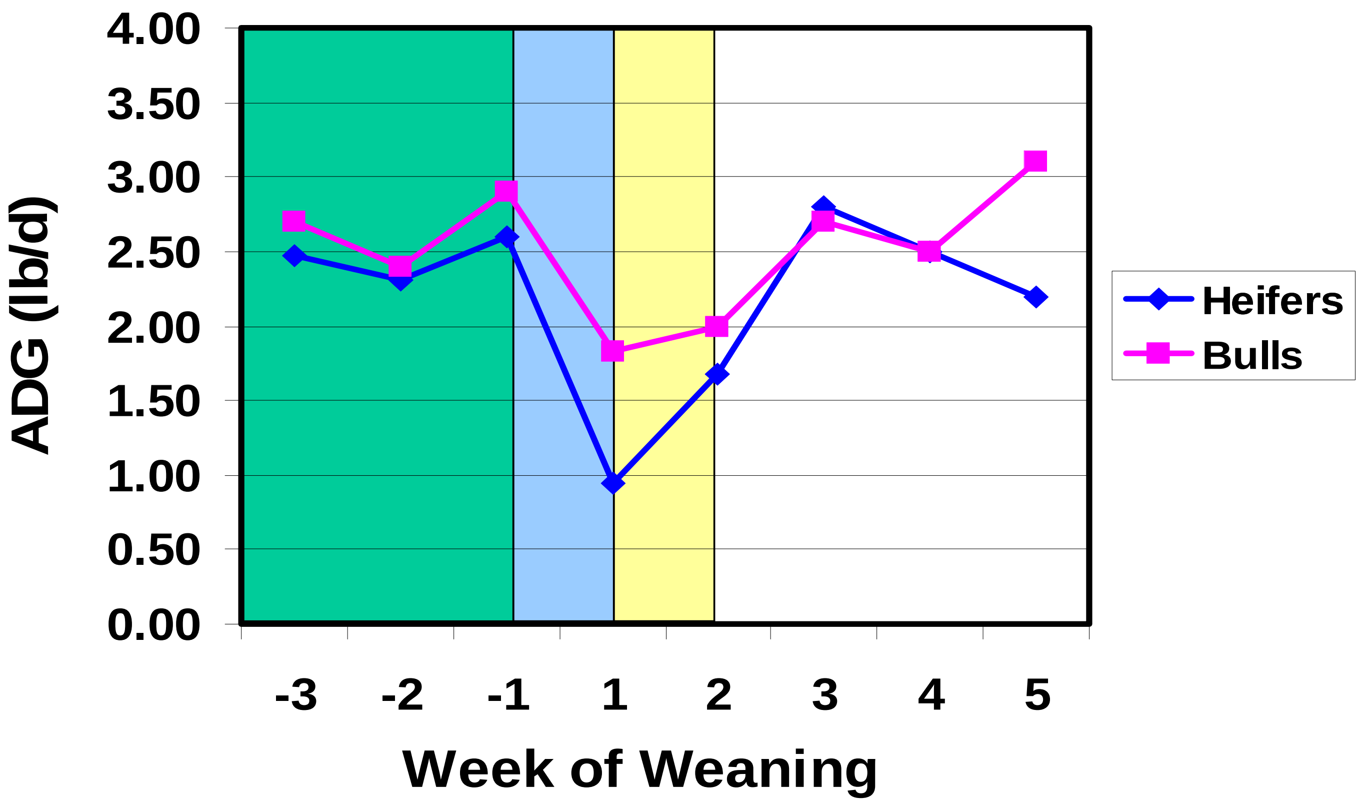

Figure 1. Growth response (ADG = average daily gain) of calves weaned to a specially formulated starter grain at 8 to 9 weeks of age at approximately 230 lb of body weight (Smith and Van Amburgh, 2000).

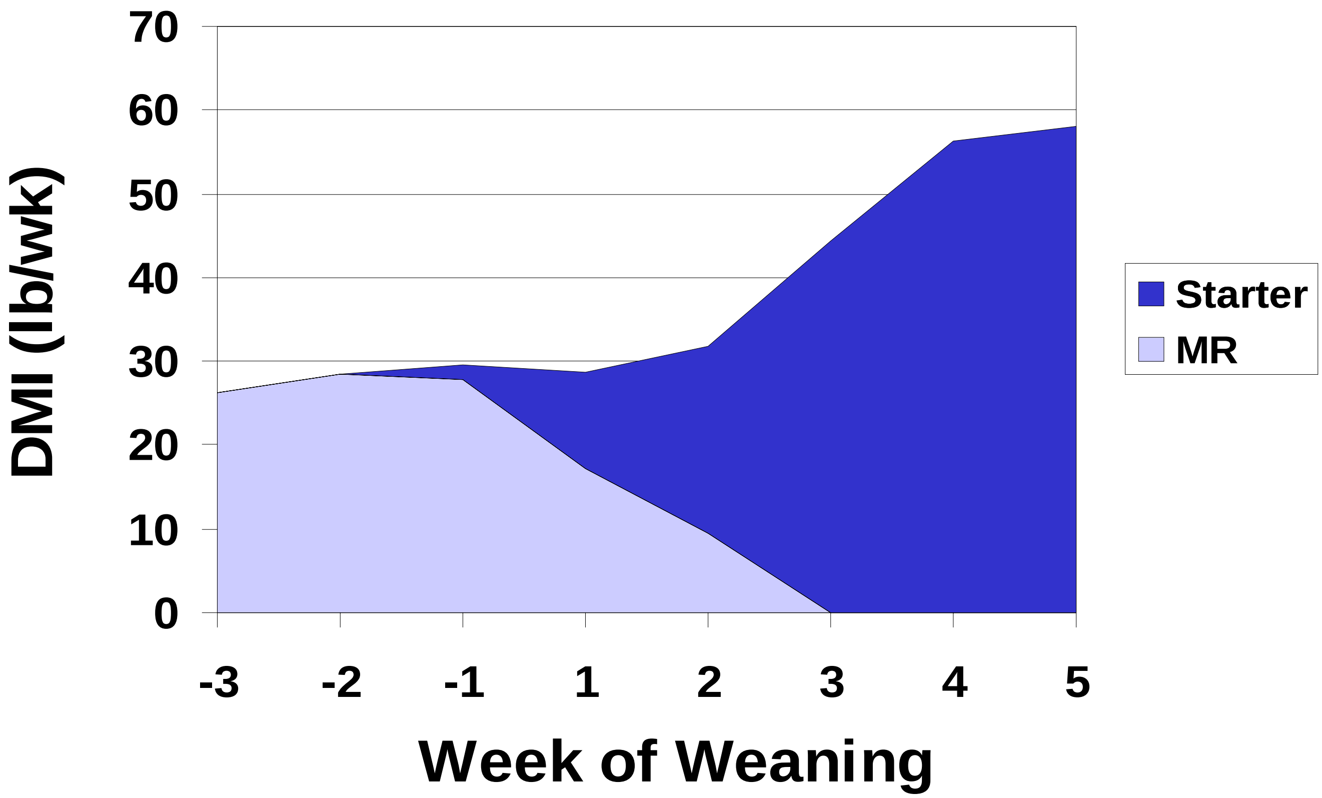

Figure 2. Dry matter intake (DMI) of milk replacer (MR) and starter grain of calves weaned at 8 to 9 weeks of age at approximately 230 lb of body weight (Smith and Van Amburgh, 2000).

Nutritional Intervention During Transportation of Heifers

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Abstract

Transporting neonatal and adult cattle can interrupt the homeostatic state, leading to depressed immunity and altered nutritional status. Neonates are sensitive because of enhanced metabolic needs. Surprisingly, the stress of unloading and feeding is greater than is an uninterrupted long journey. All animals are susceptible to altered plasma mineral concentrations, which is mostly a function of dehydration. Most animals return to eating by 3 days post-transport, but morbid animals can take greater than 7 days, and neonates still experience secondary infection up to 4 weeks post-transport. Energy and potassium supplementation have improved hydration and decreased nitrogen loss. Additionally, vitamin B_6, pantothenic acid, folic acid, and ascorbic acid are important in stress responses and their requirements are increased by stress. Vitamin E has not had a pronounced effect on transport stress, but zinc and chromium have both been beneficial following transport. Alternate therapies to return animals to normal eating patterns include the use of oral or subcutaneous electrolytes. Subcutaneously administered beta-glucan improved early morbidity following transport in heifers. Behavioral measures, such as the use of "trainer" cows (more so than trainer steers), have facilitated return to eating and reduced mortality. Interventions for improved nutritional status involve nutrient supplementation as well as changes in other management practices.

Introduction

The ultimate goal of management practices is to achieve physiological homeostasis for the animal. This state of balance allows the animal to attain optimum production. However, some disruptions of that balance are necessary, such as the process of transportation. Transportation consists of several elements, gathering and regrouping of animals, loading and handling by humans, confinement on a vehicle, and unloading and regrouping in novel surroundings.

The disruptions that transport causes include dietary changes, social and environmental stress, and exposure to new pathogens. Feed and water may be withheld prior to transport and are typically not available during transport. This has a two-pronged effect that can alter the nutritional state of the animal increase of stress and altered daily intake. The process of handling and the transport itself lead to decreased intake.

Depressed intake can immuno-compromise the animal, primarily because of altered antioxidant status. Similarly, the result of infection by a new pathogen can depress intake. Stress responses associated with handling, transport, and new environments also can alter immune competence. This results in a high mortality, especially in young calves, during the first three weeks following transport (Knowles, 1995).

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Adverse climatic conditions are stressors that animals have to cope with during transport. Depending on the age of the animal and the season of transport, the upper critical temperature or the lower critical temperature may be of greater concern (Hemsworth et al., 1995; Table 1). Neonatal calves have increased thermal requirements directly related to their increased energy metabolism, compared to older ruminating animals (Schrama et al., 1992; Schrama et al., 1993). But, the neonate also has decreased observable responses to stress (Knowles et al., 1997). Therefore, young calves are more affected by winter transport, but it may not be as evident.

Pre-Transit Fasting and Intervention During the Journey

Because of the greater metabolic needs of the young calf, it is critical that the calves are fed prior to loading. However, after 30 hours of food withdrawal and 12 hours of transport, 5- to 10-day-old calves were minimally affected for slaughter (Todd et al., 2000). Mid-journey feeding has also been shown to be minimally beneficial, but providing water alone was detrimental (Knowles et al., 1999). So, getting the calf quickly to the final destination is the least stressful scenario. In contrast, a 10-hour rest stop for ex ported calves was beneficial for their potassium and total protein concentrations (Atkinson, 1992). All blood constituent changes that were detrimental for the control calves in that study (increased skin thickness, increased total plasma protein, and decreased potassium) were associated with dehydration. Electrolytes are beneficial in reversing most of those alterations. Most measures took under 24 hours to stabilize, but body weight and creatine kinase (indicative of protein degradation) took 7 days to return to baseline levels. Similarly, with ruminating calves, fasting and transit caused mobilization of body nutrients and resulted in a BW loss, but those effects were quickly reversed during the recovery period after transport (Phillips et al, 1991). However, the physiological response of fasting alone differed considerably from that of fasting and transit together, suggesting that transit influenced ruminal fermentation and blood chemistry beyond the effects of fasting (Galyean et al., 1981).

Post-Transport Return to Feeding and Nutrient Balance

Animals should return to eating by 3 days post-transport (Hutcheson and Cole, 1986; Table 2). Morbid animals will take up to 7 days. However, be aware that neonatal calves will sometimes still succumb to pathogens (secondary infections) up to 4 weeks post-transport (Knowles, 1995). Feeding a 50% concentrate diet instead of hay and supplementing potassium at 24.7 g/100 kg of BW for 2 weeks after transport improved hydration and plasma urea-nitrogen (Cole et al., 1986). Urinary and total N excretion and non-evaporative water losses were greater than for cattle that had been fasted but not transported. A 50% concentrate diet diminished those effects. Crude protein requirements are not altered by transport, but the dietary concentrations need to be adjusted to compensate for decreased intake (Cole and Hutcheson, 1990).

Rumen microbe numbers decrease from controls for both fasted and fasted/transported cattle. However, some metabolic changes are associated with transport rather than just with fasting including decreased volatile fatty acid **(VFA)** concentrations (which suggests that rumen mobility is impaired), increased plasma glucose and glutamic oxaloacetic transaminase,and decreased blood iron and triglycerides (Gaylean et al., 1981).

With the altered ruminal flora, it is not surprising that B_6, folic acid, pantothenic acid, and ascorbate requirements are increased by stress. Vitamin B_6 is important in regulation of glucocorticoid function and ascorbate restores cortisol suppressed immune functions (Dubeski et al., 1996); therefore, those alternations in nutrient availability compromise the animal.

Vitamin E, given orally, 24 hours prior to a 3 hour transport decreased cortisol (Mudron et al., 1996; Mudron et al., 1994; Table 2), but surprisingly did not otherwise affect leukocyte function. Supplementation of alpha-tocopherol after transport resulted in plasma concentrations that indicated adequate alpha-tocopherol, but neutrophil and red blood cell alpha-tocopherol concentrations were undetectable (Sconberg et al., 1993; Table 2). Creatine kinase was also elevated, suggesting inadequate alpha-tocopherol. After 4 weeks of supplementation, plasma alpha-tocopherol was increased further and neutrophil and red blood cell alpha-tocopherol concentrations were detectable. This supports other alpha-tocopherol data that reveal a quicker response to injected alpha-tocopherol. However, injectable vitamins A, D, and E were not the magic bullet as had been subjectively observed; the combination did not decrease weight loss during transport (Jubb et al., 1993).

Serum zinc decreases and serum copper increases during morbidity following transport (Orr et al., 1990), supporting the notion that zinc and copper status may be useful indicators of well-being. Chromium has enhanced average daily gain **(ADG)** by 80 days post-transit in beef calves (Kegley et al., 1997). However, chromium did not affect neutrophil and lymphocyte ratios, infectious bovine rhinotracheitis **(IBR)** antibody following a challenge, immunoglobulin G **(IgG)** response to porcine red blood cells, or cortisol. Supplemental chromium decreased haptoglobin on day 7 when morbidity was greatest (Wright et al., 1995). Chromium linearly decreased cortisol with increased chromium by day 28 post-transport (Moonise-Shageer and Mowat, 1993), and chromium decreased morbidity and rectal temperatures at days 2 and 5. Additionally, antibody titers to horse red blood cells and IgG_1 increased by day 14 with chromium. These studies together suggest that supplemental zinc and chromium will benefit transported cattle.

Transport Therapies

Electrolytes have been shown to be somewhat beneficial for adult cattle, but they have been substantially beneficial in returning neonates to normal functioning and eating. Electrolyte therapy has been used successfully in treating transported and handled cattle (Hutcheson et al., 1984) but must be used judiciously (Schaefer et al., 1997). Electrolyte therapy used in conjunction with increased energy, although taking several days, is efficacious. However, for dairy transport purposes, the time required to be effective is not an issue as it is for beef cattle headed for sale barns or abattoirs.

Neonatal dairy calves demonstrated behavioral signs of earlier return to interest in feeding when given electrolytes (Eicher and Morrow-Tesch, 2000; Figure 1), and their plasma IgG concentrations were greater beginning at 8 days post-transport and continuing through the end of the trial at day 18 post-transport (Eicher and Morrow-Tesch, 1998). Beef heifers (265 day-old), given oral electrolytes, returned resting behavior toward control values (Smith and Wilson, 1999).

Another promising intervention has been the use of $-glucan (from Saccharomyces cerevisiae) to prevent shipping fever in imported heifers. Subcutaneous $-glucan, delivered during the first 12 hours after arrival, protected the treated heifers from infectious diseases (Pedroso, 1994; Table 3). A Saccharomyces cerevisiae product used with ascorbic acid has been beneficial for weight gain and improved fecal scores for neonatal calves in a stressful environment (McKee et al., 2000). This has yet to be tested under a transportation stressor.

The use of "trainer" animals has been suggested as a useful management tool to improve return to full feed and health following transport of feedlot cattle. This is an age-old dairy technique. Dairy farmers have used experienced cows to facilitate movement of new heifers into the parlor. However, this technique can be useful for newly arrived calves (Loerch and Fluharty, 2000; Table 4) and cows. Additionally, trainer cows resulted in lower morbidity for groups than for groups with trainer steers.

Summary and Conclusions

There are several interventions that have promise in assisting cattle, stressed by transport, to return to eating. The use of electrolytes in conjunction with energy supplementation is beneficial for both neonates and adults. Behavioral measures, such as the use of trainer cows, have been shown to be beneficial in several settings. Some anti-oxidant vitamins merit further investigation as potential stress and morbidity reducing agents. However, there are things that have been shown to be of limited use, including supplementation of protein and some anti-oxidant vitamin supplementation (except to compensate for decreased feed intake), feeding neonates en route, and providing water rather than electrolytes during and immediately after transport. There is still room for reduced morbidity and mortality in transported dairy animals; improved handling during loading and unloading may be the next area to assist in an earlier return to homeostasis and feed consumption.

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Table 1. Upper and lower critical temperature (°F) by age and physiological status. [1]

	LCT[2]	UCT[3]	Reference
Calf consuming 1 gallon/day of milk	55	79	Hahn, 1981
Calf 110 to 440 lb	23	79	Hahn, 1981
Cow, dry and pregnant	7	77	Webster, 1974
Cow, peak lactation	-13	77	Young, 1981

[1]Adapted from Hemsworth et al., 1995.
[2]Lower critical temperature (LCT) and upper critical temperature (UCT).

Table 2. Effects of nutrients on homeostasis following transport and when the intervention was given.

Nutrient	Benefit[1]	Administration	Reference
Energy	Increase	pre-trans, during	Hutcheson et al., 1984
Protein	NC	---	Cole and Hutcheson, 1990
Vitamins:			
B_6	necessary	injection prior to stressors	
Pantothenic acid	necessary		
Folic acid	NC		
C (ascorbic acid)	necessary		
E (alpha-tocopherol)	decreased CK and cortisol	oral post-transit, oral pre-transit	Sconberg et al., 1993 Mudron et al., 1996
Minerals:			
Cr	decreased: cortisol, APP, and morbidity	fed	Moonsie-Shageer & Mowat, 1993 Wright et al., 1995
Zn	altered with transit	---	
K	improved hydration	post-transit	Hutcheson et al., 1984

[1]NC = no change, CK = creatine kinase, and APP = acute phase protein.

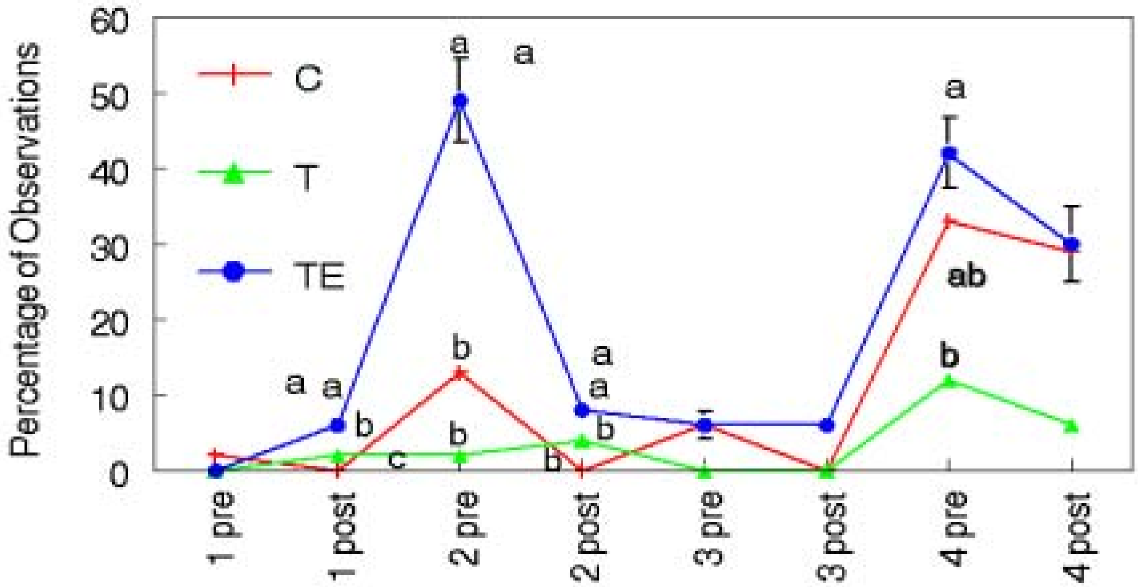
Table 3. Beta-glucan as an intervention following transport of 12-month-old heifers (Pedroso, 1994).

	Treated	Control	
Clinical signs	3/77	19/44	*P* < 0.001
Deaths	0/77	1/44	-----

Table 4. Effectiveness of trainer steers or cows in reducing morbidity, encouraging eating, and enhancing weight gain (Loerch and Fluharty, 2000).

	Week 1 gain	Morbidity (%)	day 1 to 2 eating	3 to 7 eating
Control		16.7	48.3	NS[1]
Trainer steer	increase	28.3	60.0	NS
Trainer cow	increase	8.3	81.7	NS
P value	0.10	---	0.05	---

[1]NS = not significant.



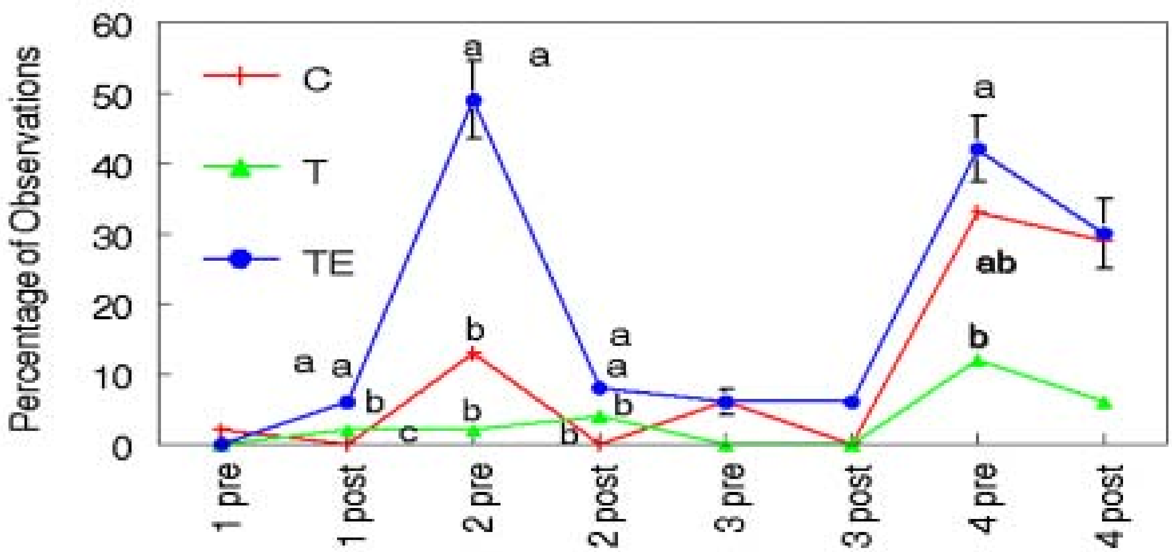


Figure 1. Vocalizations (bottom) and eating behavior (top) of non-transported (control), transported (T), or transported with subcutaneous electrolyte (TE) neonatal calves. Behaviors were observed for 4 days at 0.5 hours pre- and post-feeding (milk), with dry feed available ad libitum. (Eicher and Morrow-Tesch, 1998; Eicher and Morrow-Tesch, 2000).

Feeding Genetically Modified Crops to Dairy Cattle

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Introduction

It could be argued that the original genetically modified **(GM)** crops were created by Gregor Mendel in the late 1860's and led to the development of the science known as genetics. The work of Mendel on inheritance gene segregation is the foundation of classical animal and plant breeding programs. These concepts have been applied to agriculturally important crops in order to develop plants with traits leading to increased productivity, better environmental tolerance, and growth uniformity. Paul Berg of Stanford University generated the first modified DNA molecules in 1972. This pioneering work, which combined the DNA of two different organisms (human and E. coli bacteria), created the first recombinant DNA molecule. Berg was awarded the 1980 Nobel Prize in chemistry for this work which led to the development of the field of genetic engineering and the modern biotechnology industry. Unlike the work of Mendel, which until 1900 was largely ignored by his scientific peers, the field of genetic engineering and biotechnology has evolved rapidly to enable the genetic engineering of plants and animals. Likewise, the development and use of GM crops has been the subject of mounting scientific discussion, public debate, scrutiny, and concern. The purpose of this paper is not to highlight the attributes of GM crops or to debate the environmental and social concerns surrounding the technology. Instead, information is provided to help the reader understand the processes of genetic engineering of plants and identify some of the concerns that have been voiced with regard to feeding GM plants to livestock.

What are GM crops?

The genetic information (DNA) of an organism determines the mixture of proteins that are synthesized within specific cells of the organism. Under normal conditions, this is a highly regulated process that involves several control points. Genetic information, or DNA, is used to synthesize RNA which is used by the cell to make proteins that function to control cellular metabolism. The segments of DNA that encode these proteins are known as genes, which are organized onto chromosomes and aggregated within the nucleus of cells. The genetic code (DNA) is a sequence of sugars (deoxyribose units) containing either a cyclic purine or pyrimidine side chain. These nucleic acids code for the amino acids, which are the smallest components of proteins. For every protein, there is a specific segment of DNA that has a sequence that is complementary to the amino chain in that protein. This complementary segment of DNA (cDNA) is the minimal amount of genetic information needed to produce the protein that it encodes. Bacteria proteins are encoded in a single uninterrupted stretch of DNA that is copied without alteration to produce a RNA molecule. In eucaryotes, almost all of the DNA cod-

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ing regions are separated by noncoding sequences called introns. In the nucleus of cells, DNA is used as a template to make RNA. The RNA is a copy of DNA that is made using a different sugar base (ribose as opposed to deoxyribose). In generating RNA, the sequences corresponding to the noncoding regions of DNA are sliced out within the nucleus during synthesis. The RNA, known as messenger RNA (mRNA), is translocated to the cytoplasm and used as the template for synthesis of the corresponding protein. If the sequence of mRNA used to synthesize a protein is known, then the corresponding DNA sequence is the minimal amount of genetic material needed to make that particular protein.

The ability to find the minimal sequence of DNA for a protein were made possible by the discovery in 1970 by Howard Temin and David Baltimore of reverse transcriptase **(RT)**, a retroviral enzyme that copies RNA to DNA. As a consequence when mRNA is isolated from cells and reverse transcribed, it generates a DNA strand that is complementary (cDNA) to the proteins made by that cell (or tissue). Laboratory procedures have been developed that enable the isolation and propagation of cDNA for specific proteins.

Genetically modified crops are plants that contain a cDNA from an unrelated organism that results in the production of a protein that is not normally found within the cells of that plant. However, in order for a cDNA to result in the synthesis of a protein, it must also contain the other elements than enable the protein synthetic machinery of the cells to bind and initiate the process of translating the genetic code from RNA to protein. Other elements of the DNA segment will specifically direct expression of protein to specific cells or tissue. For example, one of the several Cry protein, that are native to the Bacillus thuringiensis **(Bt)** bacterium, can be expressed by combining the region of DNA that codes for the protein with the elements of genes in the corn plant that enable the protein to be made in that organism. Genetically modified plants are the result of splicing a piece of DNA from another organism, such as Bacillus thuringiensis, into the genomic DNA for the corn plant in such a way that it will be passed, through the gametes, to the next generation. Portions of DNA that flank the inserted gene can determine which cells within the organism will synthesize the corresponding RNA and protein. Therefore, the transferred gene (transgene) can be expressed specifically in leaves, seeds, or other plant parts by design.

Use of GM crops

Over 40 transgenic crop varieties have been cleared for commercial use in the United States. These include potato, corn, cotton, tomato, squash, papaya, canola, soybeans, and sugar beet. Since their introduction in 1995, the use of transgenic crops has been increasing rapidly. Plantings of transgenic crops has increased steadily from 20.3 million acres in 1997 to 50.5 million acres in 1998, to 70 million in 1999. Transgenic pest-protected crop varieties are the largest portion of this acreage, and plants containing one of the Bt genes are the most prevalent transgenes found in field crops. In 1999, approximately 25% of the cotton acreage and 21% of the corn acreage contained the Bt-gene. Of the total acreage of corn, soybeans, cotton, and canola, 37, 47, 48, and 35 % were transgenic, respectively (Adkisson et al., 2000).

The debate over the use of GM foods and GM crops is partly rooted in the uncertainty of long-term repercussions of use of this technology. Some of the concerns that have been voiced include enhanced evolution of pest strains, the toxicity or allergenicity of the products of the transgene, cross fertilization of the GM plants with wild relatives and propagation of the transgene in the wild, and adverse effects on non-target organisms.

Feeding studies

A growing number of studies have evaluated the use of GM crops for livestock. The main purpose of these tests are to evaluate the effects of the transgene when it is expressed in the edible parts of the plant. These experiments provide information on the direct effects of feeding large quantities of plant material containing the transgene and provide information relevant to human health effects. In conducting these experiments, the control feed should be the genetically closest material that does not contain the transgene.

Typically, the plant material should comprise substantial portion of the diet and be evaluated over a long enough time interval to provide an accurate assessment of its feeding value. Likewise, the chemical composition of the feed should be equivalent in order to minimize (or eliminate) differences in ration composition. This may not be a trivial task. For example, when testing a GM corn against the genetically closest corn, the crops need to be grown under the same agronomic conditions, in the same environments, and harvested at the same stage of maturity. The anticipated result is feeds with identical characteristics; however, due to slightly different genetic makeup of the plants and unexplained variation in growing conditions, it is possible that slightly different nutrient profiles are attained. In this event, the researcher must decide between formulating the diets to a specific nutrient profile (i.e., CP, energy, lipid, Ca, or P) or to identical ingredient composition. Additional complications are evident if the crops are subjected to pest pressure. Growing Bt-corn and the genetically closest corn hybrid in a field that are infested with European corn borer can result in two markedly different crops at harvest with respect to nutrient profile and susceptibility to invasion by fungal pathogens.

In assessing the safety of transgenic crops as foods, they are often compared with their traditional counterpart because the counterpart has a history of safe use as a food. The substantial equivalence test can also be applied to GM livestock feeds. This practical comparative approach to evaluating feeds is an accepted method of evaluating foods (and feeds) by the Food and Agricultural Organization **(FAO)** of the United Nations and the World Health Organization **(WHO)** (Hoover et al., 2000).

Testing a GM crop and the near-genetic control for substantial equivalence requires a slightly different mindset to the typical experiments that are conducted to evaluate a feed additive or two diets that differ with respect to ingredient profile. In the case of the latter, the hypothesis tested is that the additive acts to alter milk production, milk composition, or efficiency of production, and the experiment is designed accordingly. The number of cows used to test the hypothesis is based on the estimated difference in milk production between the treatments and the variation associated with the response to the treatment. If the magnitude of response to the treatment is large and relatively uniform, then few cows are needed to demonstrate a response to the treatment. The experimental design will also dictate the number of cows needed per treatment to test the hypothesis. Completely randomized designs require more cows per treatment to test for treatment differences than do Latin squares, single reversal designs, switchback designs, and other experimental designs that reduce variation due to cow(s). The hypothesis (that the treatments are equal) is either accepted or rejected. The probability of stating that the means are different when they are really the same is typically set at 5% ($P < 0.05$). Therefore, a lack of statistical difference between treatments may be observed when too few cows are used in an experiment. In evaluating substantial equivalence, the burden of proof is reversed. The experimenter must reduce the risk of concluding that there is no difference between the treatments when it really exists. Inadequate cow numbers in some cases might ensure a lack of difference between treatments when differences really are present.

There are published studies and preliminary reports evaluating GM crops for livestock. The primary GM crops evaluated in these studies are Bt-corn and glyphosate resistant crops. Growth performance was similar for beef cattle fed Bt-corn silage and grain compared with cattle fed a near-genetic control (Hendrix et al., 2000). Likewise, milk production and composition were similar in dairy cattle fed diets containing 60% corn silage and grain from Bt-corn or a near-genetic control (Donkin et al., unpublished).

Glyphosate is the active ingredient in Roundup, one of the most widely used herbicides in the world. Since 1996, glyphosate-tolerant, or Roundup Ready (**RR**; trademark of Monsanto Co., St. Louis, MO), cultivars have been developed for corn, soybean, canola, and cotton. Glyphosate acts by inhibiting the enzyme 5-enolpyruvylshikimate-3-phosphatsynththase **(EPSPS)**, which is involved in aromatic amino acid biosynthesis in plants. Expression of a modified EPSPS provides the transgenic varieties with herbicide resistance (Sidhu et al., 2000). Compositional analysis of grain and forage from glyphoshate-tolerant corn (Roundup Ready) are comparable to a near genetic control and a convention corn (Sidhu et al., 2000). Likewise, glyphosate-tolerant soybeans are equivalent to the parental conventional soybean cultivar with respect to compositional analysis.

Feeding studies that compared RR-soybeans with the parent line indicate a lack of differences in growth, feed conversion, and body composition due to the GM soybeans. Whole ground soybeans were fed at 10.2% of DM in diets containing primarily alfalfa hay, corn silage, and corn grain (Hammond et al., 1996). Production of 4% fat-corrected milk was increased 5.5 to 5.9 lb/day when RR soybeans were fed (Hammond et al., 1996). Despite these differences, there was no effect of RR soybean on rumen volatile fatty acids, digestibility of DM and nitrogen, or milk composition (Hammond et al., 1996). Studies conducted recently at Purdue University indicate equivalence of corn silage and corn grain at 60 and 18 % of the diet DM, respectively, on DM intake, milk production, and milk composition (Donkin et al., 2000).

Corn hybrids have been genetically enhanced to express proteins that are native to the Bacillus thuringiensis (Bt) bacterium, and therefore, they are resistant to damage caused by European corn borer infestation (Koziel et al., 1993). Bacillus thuringiensis is a soil borne bacterium that produces Cry proteins in the form of protoxins. When consumed by the larval stage of the European corn borer and other insects, the Cry proteins are activated and bind to the lining of the gut causing cellular swelling and lysis due to osmotic balance disruption (Feitelson et al., 1992). Expression of the Cry protein gene in corn hybrids provides protection against European corn borer infestation (Koziel et al., 1993; Pefersen, 1997; Rice and Pilcher, 1998). There are at least four different Cry proteins that have been expressed in plants; Cry9C, Cry1A(b), Cry1A(c), and Cry3A.

Commercial Bt corn hybrids can express at least three different Bt toxins. The most common form of the toxin is the Cry1Ab, which is produced as a full-length protoxin, the form of the protein found in the Bacillus thuringiensis organism. A second form is a truncated, preactivated toxin. Unlike the other Bt-toxins, the Cry9C form does not degrade rapidly in gastric fluids and is more heat stable. These findings have led to concerns regarding its allergenicity (Adkisson et al., 2000).

Screening for GM feeds

Consumer concerns about GM foods, particularly in Europe, have led to labeling regulations for foods that are GM. As a consequence, appropriate analytical methods have been developed that permit analysis of food (feeds) for the detection of GM food. Although one might argue that through conventional plant breeding and selection techniques that almost all field crops have been GM, the regulations specifically target genetically engineered foods. Despite a legal framework requiring identification of sources of GM crops, there is no internationally validated and accepted standard screening method for GM crops.

Two common methods used for the detection of GM crops are the polymerase chain reaction **(PCR)** and enzyme linked immunosorbant assays **(ELISA)**. The PCR method is based on a quantitative detection of the modified sequence of nucleic acid in the plant material, whereas the ELISA method specifically detects the protein that is synthesized as a result of the inserted gene. Methods for the detection of DNA are used predominantly because they are much more sensitive and robust than methods based on detection of the protein.

To detect specific GM crops, a unique DNA fragment is amplified from the DNA of the plant material using PCR. Fragments corresponding to regions of the promoter or terminator sequences of the transgene are frequently used in this assay. These DNA elements flank the segment of the transgene and are necessary for its expression in the crop. A segment of the cauliflower mosaic virus **(CaMV)** is present in about 75 % of the currently produced GM crops and is used in PCR screening. Another common sequence is the nos terminator bacterial sequence that is added to the transgene. The PCR method for detection of GM crops is reliable when applied directly to the crop plant but has the disadvantage of being qualitative in that the method detects the presence or absence of the transgene but not the quantity. Because these methods are so sensitive, false positives may result from simple contamination of laboratory equipment (Lipp et al., 1999) or the natural presence of CaMV or the nos terminator from the ubiquitous Agrobacterium tumefaciens. The use of real-time PCR methods provides quantitative data on the quantity of the modified DNA sequence present in transgenic feeds (foods) (Vaitilingom et al., 1999) but requires a separate assay to detect the presence and quantity of each transgene. Newly developed DNA micro-array (DNA chip) technology permits the simultaneous detection of more than 10,000 genes. As additional GM crops are developed, the complexity of testing for their presence will be substantially enhanced. It is likely that micro-array technology will be incorporated in future testing for the presence of GM crops in co-mingled feeds.

Fate of Ingested DNA in the Dairy Cow

The transfer of genes across species appears to be rare (Droge et al., 1998). However, a portion of the controversy surrounding the use of GM plants reflects the possibility that DNA introduced into crops could be transferred into bacteria, or into the cells of animals and humans that eat these crops. Other concerns involve the second party transfer of DNA to humans through animal products. Information relative to the fate of dietary and bacterial nucleic acids in the dairy cow fed conventional feeds is instructive in assessing these risks.

Feeds contain approximately 0.02% DNA on a DM basis. Therefore, the diet of a 1400 lb lactating dairy cow consuming feed at 3.8% of BW contains approximately 0.0106 lb of DNA. Corn genomic DNA is approximately 2.5 x 10^9 base pairs (bp); therefore, a transgene of 4000 bp in length would comprise 1.6 ppm of total corn plant DNA. If a diet containing 60% GM corn is fed at the intake given above, then the intake of the GM derived DNA is approximately 0.20 ppb or 4.8 ug/day. Approximately 85% of the plant DNA entering the rumen is degraded to nucleotides or smaller components (Beever and Kemp, 2000). The flow of bacteria nucleic acid to the duodenum is approximately 100 g/d of which 15% is DNA. Therefore, the flow of DNA from the rumen is approximately 15 g/d. If the DNA fragment for the Bt-gene in a diet containing 60% Bt corn was preferentially protected from ruminal degradation, it would comprise only 0.32 ppb of the DNA found in the abomasum and small intestine.

While it is possible for a DNA to be absorbed through the intestinal wall (Schubbert et al., 1998), simple laws of probability do not favor the transfer of the Bt gene. In controlled experiments when specific DNA (M13) was fed to mice, the specific DNA sequence could be detected in macrophages and spleen. It should be noted that in these studies, the quantity of DNA fed to the mice was 50 ug/day or approximately 0.0017 % of the total diet, which leads to questions regarding the relevance to normal dietary consumption. One study reported the detection of DNA for Rubisco, an abundant chloroplast protein, in DNA extracted from white blood cells and tissues of a cow (Beever and Kemp, 2000). However, attempts to detect the presence of DNA for a GM crop in the same experiment failed to detect any corresponding DNA fragments in blood. Neither Rubisco nor the GM specific gene were detected in milk (Beever and Kemp, 2000).

Summary

The use of GM crops for food and livestock feed has led to relevant debates regarding their safety, effects on the environment, and impact on the scope of agriculture. Horizontal gene transfer has enabled the production of corn and soybeans (and other crops) that resist pests and offer selected herbicide resistance to provide agronomic advantages. Opposition to use of GM crops, coupled with proliferating use of GM crops as livestock feeds, have necessitated development of testing protocols to verify crop segregation. Additional GM crops are likely in the future and may provide unique opportunities in dairy nutrition but will also bring forth challenges in public acceptance. Questions regarding the safety of milk, meat, and eggs from livestock fed GM crops have been raised. In this regard, the digestive tract of the dairy cow (and other ruminants) is aptly equipped to degrade DNA of microbial and plant origin. Based on simple mass transfer calculations, the maximal likelihood of transfer of DNA from GM plants to the cow is extremely low.

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Communicating in a Multifunctional, Multicultural Dairy Business Environment

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Dairy farms have become sophisticated small businesses that require a constant decision making process. These businesses are managed and operated with two to four tiers in their organizational structure. These tiers include most of the levels in the organization, from entry level employees to a general manager. In some cases, this general manager reports to the stockholders or to a board of directors. However, for the purpose of this manuscript, I will concentrate in the first two of the four tiers of these dairy businesses.

If we take into consideration a dairy farm with three tiers in the organizational structure, there are two different communication channels that will occur in the dairy. One communication process will occur between the general manager and middle managers and the second one between middle managers and the employees. The first process will require input from middle managers, such as the parlor manager and operation manager, as well as others in this tier. This process uses “Why” as the foundation to determine the “What”. Afterwards, these decisions have to be communicated to the other tier of the business that perform the job on a daily basis. Unfortunately, lack of communication, lack of alignment, and multicultural barriers deteriorate the communication process. This deterioration leads to start with the “What” with a minimal explanation of the “Why”. Changing this simple order leads to frustration, low employee morale, lack of motivation and high turnover that significantly reduces the profitability of the business.

Empowering employees with appropriate training and performance information to make daily decisions, such as determining if a cow is milked out or how often to push feed, will help them to understand the “Why” and then the “What”. Understanding the “Why” of a decision will eliminate some mutual frustrations and will lead to a better alignment in the business.

Another dimension that is creating a challenge in the second communication process is the multicultural environment that is very common in today’s dairy industry. This environment is made out of upper, middle managers and employees from many different cultures, educational levels, and ethnic groups that make this process more complex. Upper and middle management must invest time and effort to understand their systems and business model to be able to communicate it to the employees at the farm. Communication to employees has to be easy, and simple and must relate to their background and experiences.

Long documents, complicated manuals, and complex forms make the communication process very difficult. However, the use of summaries and graphics by upper and middle management can turn these documents into pivot tables, organizational charts, flow diagrams, and other documents

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that will make the process more simple.

If a dairy has determined a standard operating procedure to diagnose cows to be checked for mastitis, a flow chart will quickly and clearly explain the process. By using a flow chart with rectangles to determine each step in the process and diamonds for decision making points, you will facilitate the understanding of the process, the flow of information, and the translation of this document. Additionally, pictures and graphics can be used to better understand the process.

When employees are required to document problems or to establish a record of a sick cow, develop a form that is easy to understand and that can accomodate the same field for two different languages. For example, use column headings in one color to describe the information in one language and another color to describe it in another language. This will allow both parties to look at the same information in the same form at the same time.

When you are providing performance feedback to your employees, present information in a summarized and graphical way. Summarize daily reports of somatic cell counts for the bulk tank. There is no need to overwhelm employees with a lot of numbers; moreover, you will receive your premiums by the average of the month. Present the average and range for this period of time rather than a page with all the numbers. On the other hand, you can use a line graph with daily measurements to determine a visual trend in the data and create a sense of direction. Nowadays, most of this information can be obtained from the milk processor in an electronic format. Afterwards, you can incorporate this information into a simple spreadsheet to calculate these statistics and to generate a graph to determine performance over time.

If you are going to provide some training in a language that is not your mother tongue, you can use videos or publications to explain the generalities of the process; however, the specifics of your operation will have to be explained with customized resources and by a facilitator with a technical and spoken knowledge of both languages.

In summary, to better communicate among the different tiers of your operation, use the same approach for all levels. Explain the “Why” to determine the “What”. Also use simple communication forms, such as diagrams, flow charts, graphics, and summaries of data to facilitate the process. Logic, pictures, and numbers are universal, regardless of your mother tongue, ethnic background, educational level, or your position in the organizational chart of the business.

Am I on Board with the Rapid Changes?

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All of agriculture is undergoing rapid changes, from the production level, right on up to the board rooms of the major agricultural input suppliers. So, there is no reason to expect the feed industry to be any different. Ten years ago, who would ever have thought that Ralston Purina would ever consider selling off their feed division? In years past, it seemed like every town in western Ohio had at least one Purina elevator that made feed. Ralston Purina was the feed industry. Since then, this company has changed hands at least twice, gone bankrupt once, and are still there, doing the same things they have done for years. The company I started out with, Landmark Incorporated, ceased to exist back in the 1980's when it became Countrymark, which no longer exists either. Changes, changes, this is what it is all about these days. So the point here is not to document all the changes the feed industry has been through but to try to understand how people adapt to these changes and adjustments.

Professionals in our industry must be flexible to survive and prosper. Consider the feed salesperson, the one making farm calls for a living. Fifteen years ago, portable computers used in ration balancing were pretty much the exception, now they are the rule. A feed sales consultant with no computer skills is a dying breed. In the past, I worked with lots of sales representatives who had no computer skills, so my counterparts and me did their computer work for them. Now, I work with one guy who does not use computers. He is dying breed. He does a great job, but when he retires, he will be replaced with someone who is computer literate. I can teach almost anyone to use a computer and all the software needed, but I do not have the time. I need people who have the basic skills so that I can train them in software use only. Teaching a sales representative how to fire up a laptop just is not in my job description anymore. It was an important component in the mid and late 1980's but not anymore. At that time, computer use in our industry was pretty much confined to central offices. Main frames were used for our feed formulation systems. The company I worked with at that time was in the process of changing from mainframe based formulation systems to PC based systems. The reason for this change was flexibility and speed. Mainframe formulation and pricing systems were too cumbersome; they could not respond to change rapidly enough. In those days, adding a new feed required a computer programmer to go in to make some exotic change just so the price sheet could be printed out correctly. Sometimes, it might take a couple of weeks to get new products added to the price sheet. These changes caused a lot of pain for a lot of people. Some could not understand why we had to change because they liked things the way they were. They liked the status quo. To my knowledge, there is not a single one of these folks left in the industry!

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So how do we deal with change? For me, it is a matter of embracing it and driving it. There are all kinds of cliches that describe this: “If you’re not going forward, you’re going backward”. “If you’re happy with the results you’re getting, keep on doing the same thing”, etc. etc. The question remains, how do we adapt to change and still be productive? The answer is quite simple really and relates to being part of the change. To make change a satisfying part of a career, we must be part of the things that are changing, and in the best situation, be the one that is driving the change. We need to be able to recognize a good idea when you see one. Adopt it, apply it, and be part of its application to your business. One of the worst things that can happen to companies and their people is to be guilty of the “It wasn’t invented here” syndrome. An engineer friend of mine who used to work for Goodyear Tire and Rubber tells me that that is pretty much what happened to that company, which at one time was an industry leader. What this means is that many companies, which are obviously just groups of people who get paid to utilize capital and labor to produce something, fall into the trap of thinking that they are the only ones who know anything and that they are the only ones ever to have good ideas. This can be fatal! The list of companies that had this philosophy, applied it, and that are no longer with us is long indeed. The same things that happened to these companies can happen to individuals too. Take care not to be the one who continuously is opposed to new ideas, using new technologies and changing the way you do things. Think for a second who are the first ones to go in a downsizing or in a merger. It is the people who resist change and can not accept the fact that their company is changing. It is important to be sure that changes are well thought through and are going to result in positive things for the company, but do not get caught fighting and whining about changes that are inevitable.

Change can be very exciting and stimulating. Who wants to spend a career doing exactly the same thing the same way? Not me! One of the important changes that we must continually adopt in the feed industry relates to research developments. There is no telling how many experiments are going on today, to produce data that we can use to enhance our products and our business. Being on board with changes means keeping up with technological changes. Reading the journals is the obvious way to stay current. If you are going to stay in this industry, you had better be a member of the right scientific societies, and you had better be reading the journals as they arrive. You better believe that I am reading the journals, looking for new product ideas, looking to see who is doing what kind of work, and looking for the quality of the research (were appropriate controls used, etc.). When significant new work is published, are you prepared to change your product lines to adopt it? It takes a lot of work and study to be innovative; it’s a whole lot easier to stay with what we are doing. Being on board with change means being ready to adopt these new developments right away.

What about changes in your company? My previous company was bought out a couple of years ago. I went from working in a swanky headquarters building to my basement! Let me tell you about change! Going from working in a group setting to being all alone most of the time. This change has been good though, and I’m on board with it! Why, because I embrace change. I now work with a totally different group of people, running the business in a totally different way. It took a while to get used to this new company. The hardest part was just figuring out what it was they wanted. Sounds easy doesn’t it? It was not though. What people say and what they mean frequently are different. It took a while to figure out the corporate culture too. I’ve been able to do that and adapt my ways to what they expect and do things the way they want to have them done. Making these changes was pretty easy, once I figured out what changes were needed. That was the hard part. Adapting to change is not a matter of totally sublimating your ideas and personality. Make sure your ideas are presented in a fashion that your new employer understands and can accept. Do not forget that even though you may feel threatened and unsure about the new company, they may well have the same feelings about you. Thus to be a successful part of this change, you must become part of the new structure and continue to be productive while adapting. It is not that hard, if you have invested in the change and have decided not to resist it.

Look for changes that are coming in your company. If you are working hard and doing an outstanding job, you have nothing to worry about. Just be sure that you keep your eyes open for the changes; some are subtle, unlike a buy out, which trust me is like a freight train. If you are involved in being bought out, get ready to make big time changes because no company that I have ever seen does things like any other. To be on board with changes like this, you must first figure these things out, and chances are that no one will be able to tell you what they are going to be.

Be aware of changes that are occurring in your industry too. It may not always be the best to be the very first one to adopt new innovations. Sometimes it is better to let a competitor take that risk. But when it looks like something is going to work, be sure your plans are in place to make that change immediately. Do not ever be the last to make the change.

So how do you feel about change? Do you hate it? Do you love it? These are important questions to which you need to know the answers. If you hate change, try to understand why. Is it because you fear how it may affect you and your career? We all have these concerns, but if we can find ways to bring change into our lives and careers on an almost routine basis, bigger changes in our companies and industries are a lot easier to accept. I believe that most people who resist change do it out of fear. Few of them will admit it, but in my case, when I have been able to figure out why I am resistant, it is due to fear. I do not claim to be a psychologist, but I do know that understanding these fears goes a long way toward accepting and dealing with them. Then change becomes something to relish.

Being accepting and on board with change can be very exciting and stimulating. When we are enthused about changes, we become the agents of change ourselves. It is very easy to drive change when this great idea is our own. Be on the look out for great ideas coming from your co-workers or competitors. Recognize them when you see them, and put these ideas to work for you and your company. Most of us have great ideas from time to time, but to be totally on board with change, it is important to look for innovations coming from areas other than our own mind. Being on board with change will help us to be constantly looking for new ideas in our own industry and in others. Keep you eyes open, there are lots of bright and creative people out there coming up with new things all the time. We can all benefit from others thoughts and ideas, if we are on board with change and are aware that it is happening and are willing to be part of it.