Experiences with Free-access Acidified-milk Feeding in Ontario

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Abstract

Several Canadian producers have implemented an inexpensive free-access feeding system modeled on Finnish guidelines,[18] using formic acid as a milk preservative. The system mimics natural suckling and permits group social behavior. It allows for accelerated growth and changes labor requirements for calf rearing. Anecdotally, producers report less clinical cases of diarrhea and use of drugs for rearing milk-fed calves and kids. Free-access feeding provides freedom from hunger - the best medicine for milk-fed calves and kids. This paper answers questions about and describes ways to set up the feeding system.

Résumé

Un système d'alimentation lactée à libre accès et peu coûteux, s'inspirant du modèle finlandais, a été mis en place par plusieurs producteurs canadiens. Ce système, qui utilise l'acide formique comme agent de conservation, ressemble à l'allaitement naturel et permet le comportement social en groupe. Le système permet une meilleure croissance et modifie les besoins en main d'œuvre durant l'élevage des veaux. Sur une base anecdotique, les producteurs notent moins de cas cliniques de diarrhée et rapportent une utilisation moindre de drogues dans l'élevage des veaux de lait et des chevreaux. L'alimentation à libre accès permet d'éviter la faim, ce qui représente le meilleur traitement pour les veaux de lait et les chevreaux. Cet article donne des réponses concernant le système d'alimentation et sa mise en place.

Introduction and Concepts – Nature's Way and Conventional Feeding Systems

Nature's way of feeding calves includes free access, nursing until satiated, frequent meals per day and suckling. Conventional rearing systems often limit access, restrict milk intake per meal, encourage rapid feeding or gorging, restrict meals per day or provide milk in pails (non-suckling).

Restricted-access systems include housing intermittently with an accommodating nurse cow, an automatic computerized feeding system programmed in a conventional manner, or bottle, pail or mob feeders with feeding two or three times per day. The origins of limit-feeding (frequency and quantity of milk) may have been from research showing this practice stimulates greater intakes of grain at a younger age, and a desire by producers to limit costs (milk vs. grain) in calf rearing.

Free-access milk-feeding systems include housing with a nurse cow or unrestricted access to a container of milk. An automatic feeding system programmed for unrestricted access may still restrict access because of the calf-to-nipple ratio. The origins of free-access feeding (frequency and quantity of milk) may have been from producers or their advisors noticing improved health, greater feed conversion, rate of gain and growth in calves fed in ways that mimic nature. No doubt they also are looking for methods to decrease labor.

Choices and Benefits

Choices in feeding systems, housing and management affect health, growth and behaviour of calves and profit for a farm. Ontario producers commonly rear milk-fed dairy calves in individual pens and restrict milk feeding to two or three meals per day.

Finnish farmers have 11 years of practical experience with free-access feeding with formic acid-preserved milk. They claim less labor, inexpensive equipment and efficient use of surplus colostrum, transition cow milk or milk from cows under treatment. They also report calves stay healthy, have few bouts of diarrhea and rarely suck on navels or ears. For Finnish farmers, free-choice feeding is an easier feeding method for substitute workers because sufficient milk can be prepared for a weekend supply. It allows calves to eat to appetite and satisfies the calves' biological need to suckle. Of course, calves have very good growth with weight gains near 2.2 lb (1 kg)/day. Closer to home, a New York state study showed a reduction in labor per calf per day, from 10 minutes for calves in individual pens to one minute for calves reared and fed in group housing.[24] Early adopters began using the feeding system in June 2005 in Ontario. They have three years of experience and now have their first free-access, acidified-milk-fed heifers in production. Anecdotally, their experiences are similar to the Finlanders.

The basic components of a Finnish free-access feeding system include a reservoir to contain the milk

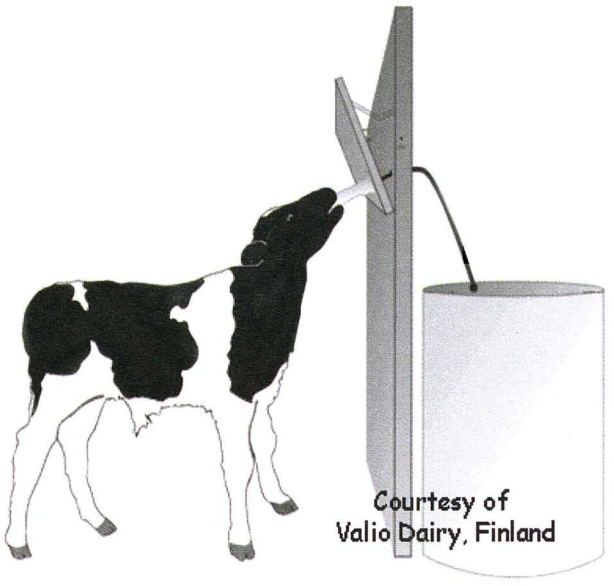

Figure 1. A simple free-access feeding system for formic acid-treated milk.[37]

or milk replacer and a plastic tube with a one-way valve to carry milk to a soft, rubber nipple. Acidification with formic acid preserves the milk for storage at room temperature and allows mixing of batches at 1- to 3-day intervals to save labor. The milk is fed cool (68-75°F) (20-24°C) in winter and at ambient temperature in summer.

Hunger – Quantity, Frequency, Quality

Hunger is a state of discomfort, queasiness or weakness caused by a lack of food. Hungry calves are in need of food. With current calf-feeding strategies, it is common for calves to receive the same volume of milk, regardless of the calf's body weight. In comparison, calves suckling their dams consume milk to their needs. Although feeding a fixed volume of four quarts (4 L) milk per day is common, the practice is associated with weight loss in the first seven days of life for many Holstein calves.[5]

Calves display hunger by their behavior,[14] searching for a teat or their vocalizations. Some behaviors may be indicators of feeding practices that cause hunger. Calves on restricted quantities of milk ingest their allotment quicker, are more active, more competitive and spend more time at the feeder.[15] Intersuckling on other calves may be a sign of hunger, but it is often perceived as unwanted behavior. Hunger may be the main stressor contributing to sickness in newborn calves (Figure 2).

Conventional feeding strategies and new computerized feeding systems often provide less milk than calves would consume with free access to a nurse cow. A comparison of conventional calf feeding to suckling or free-access systems shows that we fail to meet the standards of an average cow mother (Figure 3). Our conventional feeding practices usually fall short in quantity and frequency of feeding, and missed potential for weight gain. The comparison supports concern that hunger is a prime issue for calves 1-21 days of age.

In addition to quantity and frequency, we may fail to deliver milk of sufficient quality to our calves. With milk replacer, one error is in mixing an inadequate weight of powder per liter of water. With whole milk, some choose to dilute it with water.

Bacterial quality may be an important issue. On some farms, waste milk, colostrum and prepared milk replacer can be found stored in pails at room temperature. This milk incubates bacteria and quickly becomes a hazard for calf feeding. In Minnesota, researchers

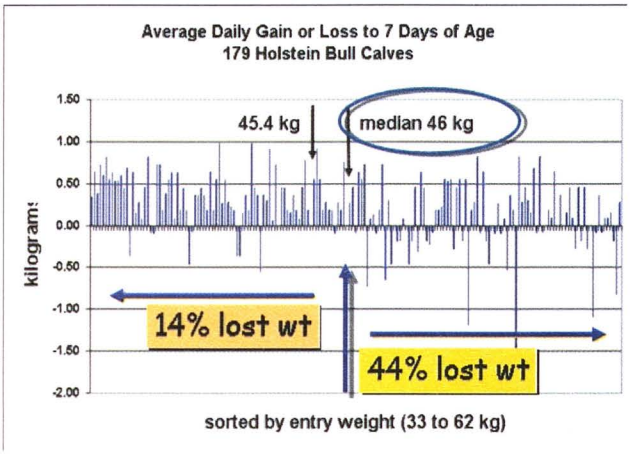

Figure 2. The graph shows the average daily gain or loss at seven days of age for 179 Holstein bull calves fed 4 liters (L) of milk per day. The calves are sorted by birth weight from left to right (73-137 lb; 33 to 62 kg). Fully 44% of calves greater than the median weight of 101 lb (46 kg) did not gain or lose weight in their first week of life on the restricted-milk feeding scheme.

	Nature's Way	Conventional Feeding
% body wt	20 – 25	8 – 15
liters	8 – 10	4 – 6
gain g/day	1000	200 – 500
meals	7x	2x – 3x
nursing minutes	48	6 – 8
interval hrs	4	10 - 14

Figure 3. A comparison of conventional feeding to suckling or free-access feeding.

found storing colostrum at warm ambient temperatures resulted in the most rapid increase in bacteria counts, followed by intermediate rates of growth in non-preserved refrigerated samples or preserved (potassium sorbate) samples stored at ambient temperature.[32] Studies using formic acid showed refrigeration was an advantage during summer months.[23] With convenient storage methods, surplus colostrum reduces feed costs for milk-fed calves.[35]

Myths and Contradictions

There is a contradiction in feeding practices on our dairy farms, one that should be a topic of discussion among producers and their advisors. For milking cows, 'feed available throughout the entire day' is common dogma and practice. For milk-fed calves, restricted volume of milk and twice-a-day-feeding are customary. For their health and welfare, free-access feeding of newborn calves is logical, defensible, and just common sense.

Several myths contribute to hunger of calves. The first is 'too much milk causes scours.' It's the reason milk is restricted or diluted with water. 'Too much milk powder causes scours' is on the same theme. This may have been true years ago when soy was a major component of milk replacers. However, most modern milk replacers are made with all milk products. The last myth has to do with willingly withholding milk from calves. The common advice is to feed 10% of body weight as whole milk. This feeding strategy is to stimulate calves to eat grain. For sure, they will eat grain when starved of milk, but no more in the first 14 days of their life than calves that have free access to milk. Further, the young calf uses milk as a food source and not grain in its early days. Ontario experiences have dispelled some of the myths.

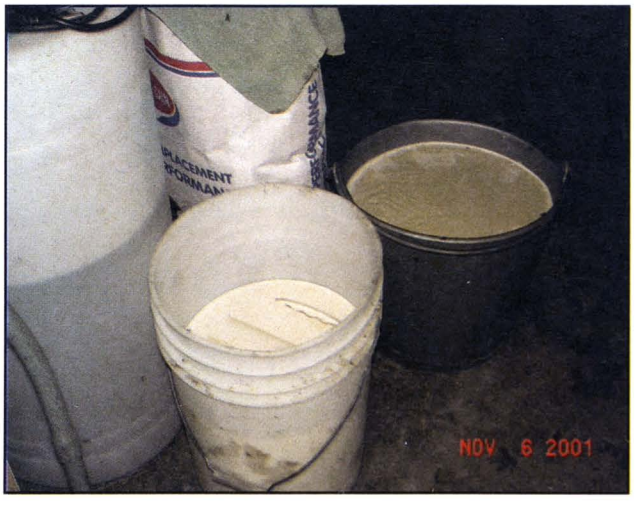

Figure 4. Preservation with formic acid could facilitate storage of milk or colostrum at room temperature. However, during warm seasons, refrigeration will assure more favourable preservation for up to 20 days.

Free-access Milk Feeding

With free-access feeding, milk is available (not restricted) throughout the day. Groups of calves on free-access feeding have enough nipples (e.g. 2-3 nipples per 6-9 calves) and space for more than one calf to suckle at a time. Free-access feeding systems require preservation of colostrum, milk or milk replacer by acidification or by souring with the use of specific bacteria. A few Ontario producers have programmed their computerized calf-feeders to be almost free-access by providing 2.6 gallons (10 L) per day for 1-day to 3-week-old calves.

Simple Equipment

Inexpensive equipment includes an electric drill and paint mixer attachment to mix the milk and formic acid, a container for milk and nipples on the container or attached to a milk-bar on a wall. The system may be gravity fed, with teats at the bottom of the container. A line-fed system has teats attached to a plastic line with a one-way valve on the end of the plastic line. One-way valves keep milk in the line and at the nipple for quick satisfaction by the calf. The size of container depends upon the number of calves given free access to the milk and the frequency of filling. It could be a 5-gallon (20-liter) pail for a single calf or 25-50 gallon barrel (100-200 L), or more for a few calves. With larger containers, producers have enough milk for a weekend supply.

The stirring system can be automated with agitators on timers. Some producers have milk lines with gravity feed or recirculation pumps that deliver milk from a reservoir to groups of calves or individual calves in several pens and back to the reservoir. Free-access feeding is also possible with some computerized feeding systems that have a milk reservoir. Free-access systems are suitable for individual or group-housed calves. Recently, in Finland, computers and electronic identification of individual calves have been adapted to the system. In general, acidified milk may be prepared at 1- to 3-day intervals and the equipment cleaned twice per week. The use of a preservative (acidification to pH 4-4.5) and feeding at a cool temperature (to limit intake per meal) are essential to success of these systems.

Purpose of Adding Formic Acid

Formic acid is mainly used as a preservative and antibacterial agent in livestock feed. Acidification to

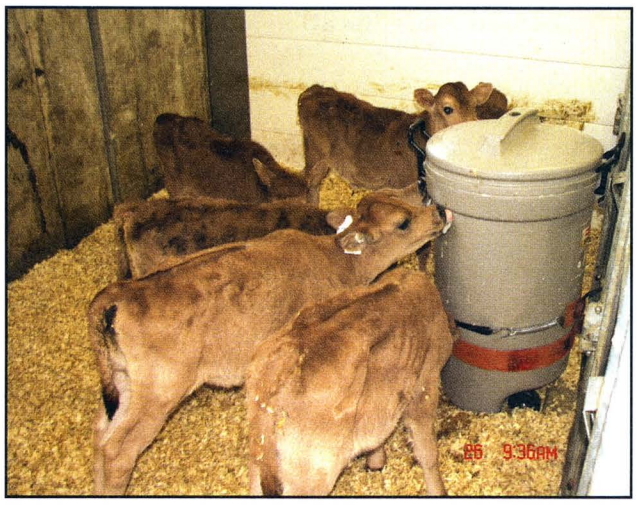

Figure 5. A line-fed system with nipples attached to the reservoir. A plastic milk line extends from the nipple to the bottom of the barrel. A one-way valve is on the end of the line.

pH 4-4.5 is to *preserve* milk by killing or inhibiting growth of bacteria, yeasts and fungi. Preserved milk can be stored at room temperature for several days. Preservation permits free-access feeding of milk to calves. Acidification decreases a calf's exposure to bacteria. It may be useful for storing surplus colostrum or waste milk when refrigeration is not available. There may be merit in acidifying surplus colostrum prior to storage in freezers.

Reasons for pH 4-4.5?

Standard textbooks of laboratory procedures show that many bacteria and fungi will either not grow or be inhibited at pH less than 4.5, but they survive and reproduce readily at pH levels greater than 4.5. To test the theory that acidification (pH 4-4.5) preserves milk, a summer student and I conducted standardized plate-loop-count bacterial cultures on a control and acidified bulk-tank milk sample stored at room temperature. Bacteria multiplied quickly in the control sample and colonies became too numerous to count, whereas the acidified sample showed no bacterial growth after several hours of contact with the formic acid and pH of 4.2.[2]

There is scarce information about contact time with formic acid needed to inactivate specific bacteria common in milk, waste milk or colostrum. In practical application, some producers acidify and feed immediately while others acidify and wait 6-12 hours before feeding. For example, milk acidified in the afternoon is fed the next morning.

	Optimum	Range	Inactivated/ lost activity
Bacillus cereus		4.3 – 9.3	< 4.3 and > 9.3
Clostridium perfringens	6.0 – 7.0	5.5 – 9.0	< 5 and > 8.3
Clostridium botulinum		4.6 – 9.0	< 4.6 and > 9
E coli (STEC)	6.0 – 7.0	4.4 – 9.0	< 4.4
E coli O157:H7	6.0 – 7.0	4.4 – 9.0	< 4.4
Lactobacillus acidophilus	5.8 – 6.6	4.0-4.6-6.8	< 4.4*
Listeria monocytogenes	7.0	4.4 – 9.4	< 4.4
Mycobacterium avium para TB (Johne's)	6.0 -7.0	5.0 – 7.0	< 5 no growth
Pseudomonas aeruginosa	6.6 – 7.0	5.6 – 8.0	< 5.6
Salmonella spp	7.0 – 7.5	3.8 – 9.5	< 4.4*
Staph aureus	7.0 – 7.5	4.2 – 9.3	< 4.2
Strep pneumoniae	7.8	6.5 – 8.3	< 4.5
Vibrio cholerae	7.6	5.0 – 9.6	< 4.5

Figure 6. The table lists several bacteria of interest on dairy farms, the optimum pH and range of pH for their growth, and the pH at which they are inactivated or lose their activity under laboratory conditions.

Acidified milk replacers usually have a pH of about 5.5-5.8. They contain bacterial contaminants, sour and curdle when left at ambient temperatures. A review of acidified milk replacers can be found in the textbook by Davis and Drackley.[12]

Choice of Acid, pH, Contact Time

Acids vary in their ability to inhibit or kill bacteria, yeasts or fungi. Formic acid is classified as a 'strong' acid. It is an organic acid authorized for use in feedstuffs in Canada and other countries. Acidification with formic acid does not kill all organisms.

Acetic acid, formic acid and potassium sorbate have been studied as preservatives for short term storage of bovine hides by monitoring total numbers of aerobic microorganisms, gram-negative bacteria, *Clostridium perfringens*, coagulase-positive staphylococci, and yeasts and molds during storage. Formic acid proved to be the better preservative in the study.[10]

Although in low numbers, coliforms often are found as contaminants in milk replacer. Formic acid quickly (1-2 hours) kills coliforms. Therefore, I recommend that producers acidify milk replacer and feed it immediately. In experiments with whole milk from a few cows, we found no growth of coliforms after a con-

tact time of one hour at pH 4.1 in whole milk acidified with formic acid. We found no growth of *Staphylococcus aureus* after a contact time of 4-6 hours at pH 4.1 in whole milk acidified with formic acid. There is a need for information about the effects of formic acid on other common bacteria and *Mycoplasma* spp in milk.

During a study of 24 farms feeding acidified milk during the summer of 2006, we found 81% of 46 milk samples were in the target pH range of 4.0-4.5. On bacterial culture, the majority of samples had no growth or less than 1000 colony-forming units per milliliter (cfu/mL) of milk. Thirty-one of 48 samples had no coliform growth. We found environmental staphylococcus and streptococcus in less than half the samples and at levels of 1-5,000 cfu/mL.[6] A total bacterial count of 100,000 cfu/mL and lower limits for specific bacteria have been established for bacterial quality of colostrum deemed suitable for feeding to calves.[27] The bacterial counts found in on-farm, formic acid-treated milk were low, and met or beat these guidelines.

In the presence of milk, formic acid kills about 90% of *Mycobacterium avium* subsp. *paratuberculosis* (MAP) (Johne's bacterium, field strain) with eight hours contact time at pH 4.0 and 100% at 48 hours.[28] Hydrochloric, formic and AgriAcid® (mixture of orthophosphoric, formic and lactic acids) vary in their affects on MAP as shown in Figure 7.

		Percent viable MAP (Madonna strain) after 8 h and 48 h in acidified raw milk	
Acidifier	pH	8 hours	48 hours
Hydrochloric Acid	5.0	100	100
	4.5	100	100
	4.0	100	64
	3.5	100	54
AgriAcid®	5.0	100	100
	4.5	100	100
	4.0	100	40
	3.5	100	10.1
Formic Acid	5.0	91	100
	4.5	89	11.6
	4.0	16	0
	3.5	3.4	1.25

Figure 7. Choice of acid, pH and contact time are important considerations when considering inactivation of a field strain of *Mycobacterium avium* subsp. *paratuberculosis* (MAP) in milk. Data courtesy L. Mutharia, University of Guelph.

Shelf Life and Alteration of Acidified Milk

Finnish farmers and advisors recommend preparation of batches every 1-3 days. At least one Ontario producer has acidified whole milk and used it to feed calves over a 7-day interval. The change of physical characteristics of colostrum over 30 days following preservation with 0.7% acetic, 1.0% propionic and 0.3% formic acids was the focus of a study by Korean researchers.[39] With storage at ambient temperatures, they found differences during summer and winter conditions. More recently, it has been shown that storing formic acid-treated colostrum in a refrigerator ensured a more effective preservation than storage at ambient temperature.[23]

The most obvious change to cool colostrum, milk or milk replacer (milk) is separation that happens within 10-30 minutes after acidification to pH 4-4.5. However, agitation puts the milk back into solution. In the 6-8 hours immediately following acidification, milk/milk replacer will separate again and require agitation. However, when agitated eight hours after acidification, I found milk stayed in a uniform mix for 12 to 18 hours, and even days. An agitator set on an automatic timer is a practical solution to separation. Acidification of warm or hot milk produces cottage cheese that cannot be put back into solution.

Figure 8. The photographs show the separation that occurs when milk replacer is acidified to pH 4.2. Similar separation occurs with colostrum, milk or waste milk. The separation is more rapid with warm milk. The milk replacer used in this test was an all-milk product, 22% protein and 17% fat and mixed at 150 g/L. All samples looked like the control sample after a vigorous stir. It is essential to agitate acidified milk two-to-four times per day to keep the constituents in solution.

Following acidification with formic acid (0.5% and 0.1%), there was no significant change in crude protein or total solids in colostrum from Sahiwal cows after 28 days at ambient temperatures.[26] At least two research projects (Canadian, USA) are underway to compare absorption of immunoglobulins from acidified and sweet colostrum. Acidified milk has a tart taste because of the acidic pH. Calves drink the acidified milk readily when they have been introduced to it at a day or two of age. Some calves fed sweet milk for 1-2 weeks will refuse acidified milk. A slight change in taste may be beneficial to limit intake in free-access feeding systems.

Effect on Abomasal pH

Acidified milk should have a moderating effect on abomasal pH. Recently, researchers showed abomasal pH decreased below 4.0 in two hours after feeding formic acid-treated milk replacer (pH 4.2-4.4) and five hours after feeding non-acidified milk replacer (pH 6.4-6.6). The authors commented that acidified milk replacer, together with secreted hydrochloric acid, result in optimum abomasal acidity that supports the activity of proteolytic enzymes.[36]

Frequency of Suckling

In the summer of 2005, we recorded on video tape the feeding activity for eight calves on free-access feeding.[4] The calves were in groups of four with three nipples per four calves. On average, with free-access feeding, dairy calves eat seven meals per day and a meal lasts seven minutes, for a total of 49 minutes suckling per day. Meals are generally at four-hour intervals and cluster in evening and morning hours. For sure, there is competition for nipples in group-housed calves.[38] In the first few days after birth, kids suckle frequently each hour. However, suckling frequency decreases to one or two times per hour for a single kid birth, while twins suckle more often.[30] The frequency of suckling may be 2-6 bouts per hour for lambs.[20] It would be unattainable to bottle-feed calves, kids or lambs to mimic natural suckling.

Frequent Suckling Benefits Abomasal pH

Prevention of abomasal ulcers or abomasitis in suckling calves presents challenges to veterinarians and their clients. The commonly proposed etiologies for abomasal ulcers include mechanical abrasion from coarse ingesta, infection with *Clostridium perfringens* Type A, trace mineral deficiencies and stress. Because of sudden deaths or unrewarding treatments, it is important to control or prevent ulcers. Feeding frequency could be a preventive measure.

Researchers at the University of Illinois set out to find practical treatments.[1] They speculated that long periods of low pH in the abomasum could increase the chance of injury to the abomasal mucosa. Further, they wondered if feeding frequency had an effect on abomasal luminal pH and the risk of ulceration. The researchers discovered changes in abomasal pH with different schedules for feeding milk replacer. From their findings, they advise increasing feeding frequency to prevent abomasal ulcers by attaining an abomasal pH>3.0 for the greatest percentage of hours each day.

Figure 9 shows that frequent suckling succeeded in reducing the number of hours per day that the abomasal lining was exposed to low pH. However, it also shows the abomasal pH was less than 5.5 for the entire day. A quick look back to the table in Figure 6 shows that *Clostridium perfringens* prefers a pH of 5.5–9.0 for optimum growth. Frequent suckling seemed to assure that the optimum pH for that growth was not achieved. Further to the argument, free-access feeding of acidified milk could be of benefit because the milk entering the abomasum is at a pH less than 4.5.

Reasons for Feeding Cool Milk

Formic acid-treated milk is fed cool to limit intake and avoid risks associated with gorge feeding. Researchers have compared health, feed conversion and rate of gain in calves fed cool and warm milk.[22,29,31] In general, calves fed cool milk had the best perfor-

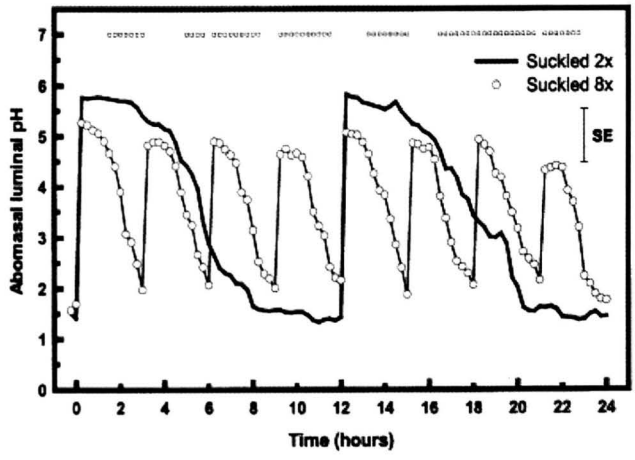

Figure 9. The graph shows the least squares mean abomasal luminal pH in dairy calves (n=6) that suckled milk replacer at 3-h intervals (8x; O_O) and 12-h intervals (2x;__). Open symbols at the top of the graph represent values that were significantly ($P < 0.05$) different at the same time. Bar represents the overall standard error (SE) for least squares means. (Ahmed AF, 2002)

mance in all three categories. Ontario producers report less problems with diarrhea in calves fed free-access, acidified milk. Some Ontario producers reported diarrhea in their calves and kids when feeding warm or hot acidified milk or milk replacer.

Ways to Keep the Chill Off Milk in Cold Barns

Calves will drink milk colder than 68°F (20°C). However, feed conversion, intake and calf performance decline with consumption of cold (<59°F; <15°C) milk. Producers have devised several unique ways to keep the chill off milk. Here are some examples:

- An aquarium heater to warm water within a 3-inch plastic pipe submersed in the milk
- A waterbed heater as a band heater around the milk barrel
- Chest freezers (insulated boxes) with heaters keep milk warm inside the freezer.
- A central warm room for milk preparation, storage and utilities keeps milk warm for nipples attached to walls of abutting pens.
- A piglet warmer under the milk barrel keeps milk warm in the barrel.
- A counter-flow heat exchanger warms milk to 68°F (20°C) as it returns to the storage tank. A temperature probe, located near the pump, senses milk temperature in the line going to the nipples. When the milk temperature drops below 68°F (20°C), a thermostat starts a pump that circulates hot water through the counter-flow heat exchanger. Heat exchangers vary in length and can be made locally using one-inch stainless steel pipe inside two-inch stainless pipe, with some baffling to direct water flow (Figure 10).
- Band heaters for steel barrels successfully melt plastic barrels.
- Stock-tank heaters prevent freezing but do not heat to 68°F (20°C).
- Pail heaters are too hot and cook milk on the element.
- Warm water, from a small water heater, circulating through the cooling coils of a bulk milk tank will keep the chill off milk.
- A heat lamp hung over the milk barrel provides adequate warmth in some barns.
- In Nova Scotia, family members designed and built a complete milk bar feeding system for cold housing. The milk bar includes three nipples mounted into 4-inch (102mm) PVC end caps that fit flush with the wall and recess inside the warm box (Figure 11). This technique bathes the end caps in warm air. Warm end caps radiate heat around the nipples. Although it has not been necessary, holes could be drilled in the end caps to allow warm air to escape around the nipples. A 300-watt baseboard heater with thermostat control keeps the interior of the box and the milk at about 68°F (20°C).
- Warm-air duct as a milk line conduit. Ideas from the Nova Scotia warm box feeder could be used for a milk line in a cold barn. The milk line could travel within an insulated warm box. At each pen, there could be a milk bar with nipples mounted to end caps recessed into the warm-air duct. A lid would provide access to the nipples. All other components would be in a warm room within the cold barn.

Ways to Avoid Making Cottage Cheese or a Cesspool of Bacteria

With inadequate acidification (pH>4.5), in a few hours at ambient temperature, milk will become a filthy cesspool containing billions of bacteria. A rank odor indicates bacterial growth.

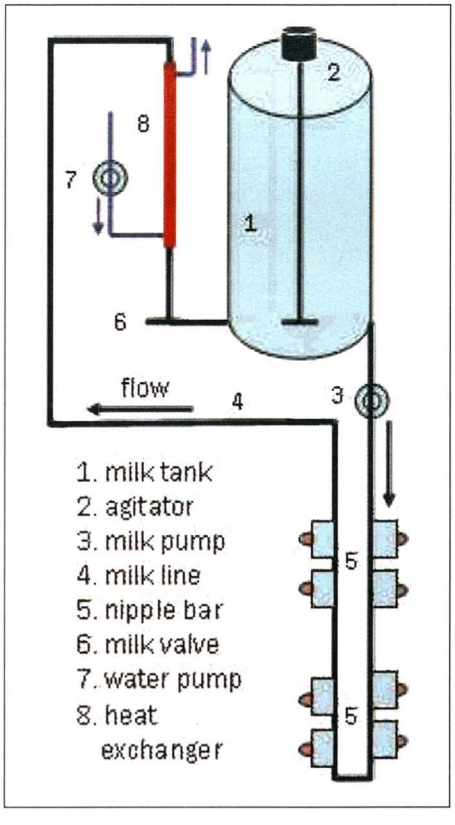

Figure 10. A counter-flow heat exchanger warms milk as it returns to the storage tank in this milk-line system.

You will make cottage cheese if you use hot (>75°F; >24°C) milk, add concentrated formic acid, add too much dilute acid, or do not stir the milk while adding acid. Here is a checklist to assure you do not make cottage cheese:

- Use cool (<75°F; <24°C) milk replacer and cooler (<68°F; <20°C) whole milk.
- Use dilute formic acid.
- Stir vigorously while adding acid to milk.
- Get to the target pH of 4.0 to 4.5.
- Agitate a few times daily after acidification.
- Mix 20% milk replacer with 80% whole milk to prevent cream (fat) separation in milk.

Number of Nipples for a Group of Calves

Since calves have the herd instinct to eat and rest as groups, it is advisable to provide ample teats for feeding, at least three nipples for nine calves. It is practical to provide two or more nipples per group to assure availability of milk when a single nipple becomes plugged or unserviceable. An abundance of nipples assures that smaller and timid calves will experience fewer displacements from nursing opportunities. Older calves teach young calves by example. The youngest calves explore what the older calves are doing and quickly learn from them. Free-access feeding implies a teat and milk are available when wanted and, in general, there should be no waiting for milk. With reduced access to teats (4 teats: 3 calves vs. 1 teat: 3 calves), calves will experience reduced time on teats, reduced daily milk intake and increased competitive displacements from teats.[38]

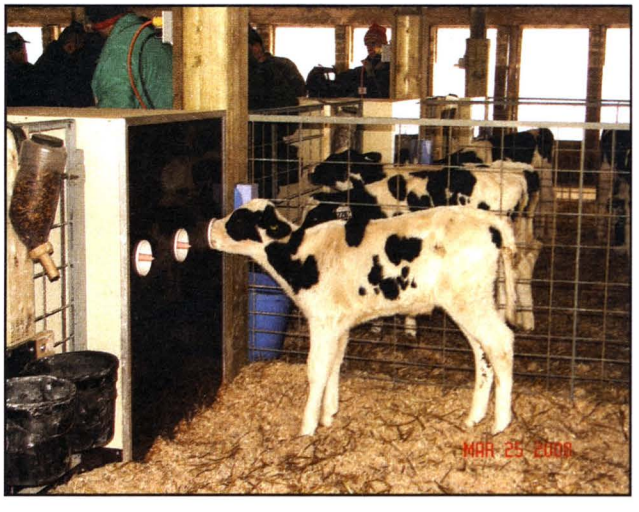

Figure 11. A calf nurses from a nipple that is recessed within a warm-box to protect it from freezing. This idea from Nova Scotia makes free-access feeding possible in cold, curtain-walled calf housing.

Nipple-mounting Height, Check Valves and Leaking

Mount nipples at shoulder level of a calf, kid or lamb. For calves, the height is about 28-32 inches (70-80cm) above floor level. In simple bucket or barrel systems, a check valve must be on the end of the line submersed in the milk. This valve keeps milk in the line and at the nipple so milk is immediately available when the calf or kid begins to suckle. In gravity-flow systems or milk-line systems, a loop in the plastic line, or a check valve at the nipple, should prevent leakage at the nipple.

Cleaning the Equipment

Wash nipples, hoses, valves and pails every three days. Use warm water and dish-washing detergent. A black, green or pink slime in clear plastic lines is an indication of inadequate acidification. In general, slimes and molds do not grow at pH 4.0-4.5.

How Do I Know That a Calf Has Suckled?

In restricted feeding systems, calves rise and start bawling to greet the arrival of the calf feeder. Although some associate the behavior with a healthy calf, it may be more correctly related to hunger. In free-access systems, calves bawl when deprived of milk because of plugged nipples or empty milk containers. Otherwise, the calves seldom vocalize when fed on free-access milk systems. The stockperson must become accustomed to the appearance of a normal calf. Calves may be resting and may not rise to greet the arrival of the caregiver. Caregivers may notice less activity and fewer hours standing. Calf abdomens will be slightly pendulous but not potbellied, as may be the case with calves after gorging on a meal of milk. Frequent butting and switching teats may indicate reduced flow of milk or plugged nipples.[14]

Rate of Gain

Holstein calves will gain 1.8-2.6 lb (800-1200g), or more, per day with free-access feeding.

Skim Milk Powder in Milk Replacer

Finlanders stressed the importance of skim milk powder in milk replacer used in their free-access feeding systems. Therefore, when setting up the system on pilot project farms, I recommended milk replacer that con-

tained skim milk powder. Most products sold in Ontario contained about 30% skim milk powder. Since clotting in the abomasum is nature's way, whole milk proteins may be better diets for calves less than four weeks of age. When in doubt about the skim milk content of a milk replacer, telephone the manufacturer. I have no experience with all-whey-source milk replacers used in free-access, formic acid-treated milk feeding systems.

Costs and Benefits

Ontario producers report greater intake of milk during the milk-fed period. However, they claim the investment in milk or milk replacer is offset by better health and fewer treatment costs related to diarrhea, thus giving the advantage to the free-choice fed calves compared to calves on restricted feeding. Body reserves gained by free-access feeding may be used to overcome or prevent sickness. In one study, the cost of body weight gain was higher for calves fed whole milk compared with those fed acidified whole milk, due mainly to the costs of veterinary treatment for scours.[22] Long-term effects of free-access milk-feeding in the first few weeks of life could be the greatest benefit of the system. Published articles show 880-2200 lb (400-1000 kg) more milk in the first lactation for calves fed about twice the milk or milk replacer compared to conventional feeding during the first few weeks of life.[9,17]

Cross-suckling

With Holstein calves, producers report cross-suckling as a very rare event in groups with free-access feeding. Similarly, Jersey calves rarely cross-suckle while on the free-access feeder. However, some producers report Jersey calves start cross-suckling behavior after weaning. Since the behavior may be related to hunger, hay should be offered prior to weaning. Several useful tips for managing calves in groups can be found in a recent review.[13]

Figure 12. Jersey calves housed in groups and fed free-choice grain did not cross-suckle while on the free-access, acidified milk replacer. However, some did when weaned.

Milk, Water and Grain Intake with Free-access Feeding

Calves can and will suckle 20-25% of their body weight daily. Producers report Holstein calves drink 1.6-2.4 gal (6–9 litres) of formic-acid-treated milk each day in the first week of life. Prior to weaning at 6-7 weeks, calves may drink 3.2-4 gal (12-15 L) of milk per day. Over the milk-fed period, average intake is equal to or greater than 3.2 gallons (12 L) per day.

As with conventional feeding systems, calves should have free access to clean water and a starter ration of grain or pellets at all times while on the acidified milk feeding program. Calves consume very little water when provided *ad libitum* access to acidified milk replacer. However, water consumption increases dramatically after abrupt weaning from milk.[19] With free-access milk, grain intake lags behind conventionally fed calves but increases rapidly after weaning.[21] Hay is beneficial to calves and should be available free-choice. It may be wise to provide a salt lick.

Rumen Development

Penn State calf rumen images show a lack of development of rumen mucosa in a calf fed *only* milk.[8] Free-access, acidified-milk feeding *is not* milk-only feeding. Calves on the system have free-access milk plus grain, hay or combinations. Recently, we examined (macroscopically) the rumens from four male, Jersey calves on free-access acidified milk. Study calves were housed in group pens with wood shavings for bedding. Their diet consisted of free-access, acidified (pH 4-4.5) milk replacer (20% protein:15% fat) mixed at 150g/L, free-choice water and free-choice supplement pellets (20% protein) with rolled corn. At the ages of 24, 31, 38 and 65 days, macroscopic examinations showed normal rumen mucosa in all calves. There were papillae in various stages of development and a linear arrangement as seen in a normal rumen. There were no control calves for comparison[7] (Figure 13).

Contrary to common advice to feed only grain to milk-fed calves, roughage is important to the calf. Roughage in pre-weaned calf diets decreased the incidence of plaque formation (rumen mucosa containing focal or multifocal patches with coalescing and adhering papillae covered by a sticky mass of feed, hair and

cell debris) and the incidence of calves with poorly developed rumen mucosa. In veal calves, the addition of roughage to concentrate diets did not affect growth performance and positively influenced the macroscopic appearance of the rumen wall[33]. Hay benefits rumen environment, intake and feed efficiency of milk-fed calves.[11]

Weaning Methods

Dairy calves on free-access feeding of acidified milk are weaned either gradually or abruptly at 6-7 weeks of age. With abrupt weaning, producers report separation anxiety and vocalization after removal from the nipple and milk. However, the calves appear to suffer no greater setback at weaning than calves weaned from conventional feeding systems. Gradual weaning is also an option on some farms. Some producers wean over a five-day period (Monday-Friday) by diluting the milk about 20% with water each day.

Health Challenges with Group Rearing

Respiratory disease and diarrhea are considered the greatest health issues associated with group rearing. Indeed, hutch-housing became popular as a way to separate calves and diminish the risk of diseases. Recent research from Sweden looked at the effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders.[34] The authors found a higher incidence of respiratory illness and less growth in calves housed in pens of 12-18 than calves housed in groups of 6-9 animals. They detected no differences between calves kept in the small-sized versus the large-sized groups in terms of risk of diarrhea.

Figure 13. Normal development of the ventral sac of the rumen from a 24-day old, male, Jersey calf reared with free-access, acidified milk replacer and free-choice grain and water.

A US national survey showed a high death level on farms with preweaned heifers placed in groups of seven or more.[25] My recommendation is 6-8 calves per group, but many producers tend to the lesser number. A few Ontario producers have been very successful at finding that acidified milk does not cure poor ventilation or overcrowding in calf barns. Ontario producers have a renewed interest in calf housing. Curtain-walled and plastic barns with individual and group pens are becoming popular. Some are adapted to milk feeding with computers and with free-access, acidified milk.

Acidified Milk and Diarrhea

In Finland, advisors recommend feeding acidified milk for farms experiencing diarrhea problems in their calves. They claim acidified milk prevents diarrhea. With free-choice milk intakes of 2.4-3.2 gallons (9-12 L) per day, the consistency of feces may be fluid but the situation is different from a serious diarrhea caused by bacteria. Producers report scours as a rare event with free-access feeding. In practice, producers use colostrum, milk or milk replacer and switch sources or feed mixtures with no apparent ill effects in their calves.

However, diarrhea was a problem on three pilot project farms where acidified milk was fed hot. Since acidified milk has fewer bacteria, the risk of scours from contaminated milk should be lower. A comparative study found the occurrence of diarrhea and death was lower among calves group-fed acidified milk replacer *ad libitum* compared with calves fed normal milk replacer under similar circumstances.[16] The frequency of scouring days and treatments for scours is lower for calves fed acidified (formic acid, pH 4.8) milk.[22]

In a previous section about frequent suckling, I argue that milk acidified to pH 4-4.5 should have a benefit for calves, especially when one considers *Clostridium perfringens* Type A. This bacterial agent is being diagnosed with increasing frequency in calves with abomasitis and sudden death. Since its optimum range for growth is pH 5.5-9.0, milk entering the abomasum at pH 4.0-4.5 should produce an inhospitable environment for clostridial growth and sporulation in the abomasum. For sure, some research would be helpful to prove or disprove this theory. Frequent feedings or feeding acidified milk merit consideration as prevention strategies.

Goat Kids and Lambs

My first experience with the feeding system was with goat kids at a dairy that milked about 1000 does.[3]

Death loss in the kids was 32% and most deaths were related to scours that started at 7-10 days of age. Challenges with colostrum quality (late harvest), under nourishment (thin body condition), engorgement stress (pot bellies after feeding) and diarrhea were identified and addressed with a feeding protocol designed to mimic the normal feeding behavior of *ad libitum* suckling. The intention also was to improve consumption of colostrum and transition milk in the first few days of life and to overcome the stress of hunger. Several buck kids were enrolled as the acidified milk treatment group. Within a few days, the owner switched all kids to the feeding system because of the obvious improvement in health and performance of kids in the treatment group. Free-access feeding of acidified goat's milk, cow's milk and milk replacer to goat kids has been very successful on several Ontario dairy goat farms. Adoption of this feeding scheme has been more rapid by Ontario dairy goat producers. In the past year, several sheep producers started using the system to rear their orphan lambs.

Training Calves to Free-access Feeding

Many advisors recommend feeding four quarts (4 L) of colostrum to calves either by suckle bottle or by stomach tube. Producers observe that some calves fed four quarts (4 L) will not drink for several hours or a day following this large meal. In effect, the practice is contrary to suckling small volumes frequently. Some producers give two quarts (2 L) whilst others give four quarts (4 L) before introduction to free-access feeding. With experience, many producers recommend switching to free-access feeding within the first day of birth because the calf will bond quickly to the nipple. With free-access feeding of acidified colostrum, the volume suckled can be monitored by housing the calf in an individual pen. In general, most producers move calves to groups when calves are suckling strongly, usually one or two days.

Figure 14. Newborn goat kids suckling acidified colostrum.

Need-to-Know Safety Information

Safety information is available from safety data sheets, for example, BASF Safety Data Sheet for 85% Formic Acid. Version 2.1 revised June 12, 2007. This is not intended as a substitute for reading the complete Manufacturers Safety Data Sheet document. Please read and follow all label instructions.

Formic acid is a combustible liquid. It is corrosive to eyes and skin and it is harmful if swallowed. The vapors cause respiratory tract irritation. General safety and hygiene measures include avoidance of contact with eyes and skin, inhalation of vapor, and eating, drinking or smoking while handling the product. There must be adequate exhaust ventilation to control work-place concentrations. Personal protective equipment and exposure controls include breathing respirator, eye goggles or face shield, hand gloves, body apron and boots.

Dilute (9.8%) formic acid is less hazardous for daily use. Therefore, mix one part formic acid 85% into nine parts water to prepare a dilute mixture. For example, prepare 53 gallons (200 L) of dilute acid by mixing 5.3 gallons (20 L) of formic acid 85% into 47.7 gallons (180 L) water. Use the dilute mixture for routine preparation of acidified milk.

Conclusions

Producers in Ontario and other provinces have been very successful at finding what does and does not work with free-access feeding of formic-acid-treated milk. Some started and quit because of cost (greater milk consumption), inability to keep the chill off milk in cold barns, pneumonia in group housing, unease about not knowing consumption by individual calves, or discomfort with handling acid. For many, the improvement in calf health, growth and welfare during the milk-feeding period has convinced them of the benefits. The greatest challenge has been setting up systems for calves reared in cold housing. This paper shows some very innovative ways to keep the chill off milk and to agitate acidified milk. Within a very short time, producers have devised ways to feed free-access using milk-line and warm box systems in barns below freezing. The feeding system shows that hunger is the prime stressor and health and welfare issue of calves aged 1-28 days, rather than a deficiency of antibiotics

or scour medications. Our early adopters acknowledge that freedom from hunger is in our contract with calves. They are preventing hunger by simple changes to their beliefs and feeding practices. Free-access feeding with formic-acid-treated milk benefits the calf and the calf rearer. It is an option worth considering.

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