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Practical Aspects of Free-Access Feeding with Acidified Milk

Neil G. Anderson
Ontario Ministry of Agriculture, Food and Rural Affairs, Elora, ON N0B 1S0

Introduction and concepts

Choices in feeding systems, housing and management affect health, growth and behaviour of calves and farm profit. Ontario producers traditionally rear milk-fed dairy calves in individual pens and feed milk in two or three meals per day. However, there has been significant adoption of a Finnish feeding system in a relatively short time. Finnish farmers have 18 years and Ontario farmers have seven years of practical experience with free-access feeding of milk acidified with formic acid. Producers claim less labour, inexpensive equipment and efficient use of surplus colostrum, transition cow milk or milk from cows under treatment. They also report calves achieve excellent health and diarrhea is a rare event for calves fed free-access acidified milk. For Finnish farmers, free-choice feeding is an easier feeding method for substitute workers. Free-access feeding systems enhance a calf's feeding experience by allowing individual calves to achieve their biological growth in addition to meeting their physiological and behavioural needs, for example suckling, eating to appetite and socialization. Free-access feeding may be the new standard for accelerated feeding because *ad libitum* feeding and group housing systems mimic more closely Nature's way.

The components of a basic free-access feeding system include a reservoir to contain the milk or milk replacer, a plastic tube, a check valve and a nipple. (Figure 1) Acidification with formic acid preserves the milk for storage at room temperature and allows producers to mix batches at one- to three-day intervals to save labour. Traditionally, the milk is fed cool (20-24°C in winter) to slow the speed of intake and reduce the chance of gorge feeding. Since they began using the system in June 2005, Ontario producers have been very successful at finding what does and what does not work. This presentation looks at a few practical aspects of free-access feeding of acidified milk in its various forms.

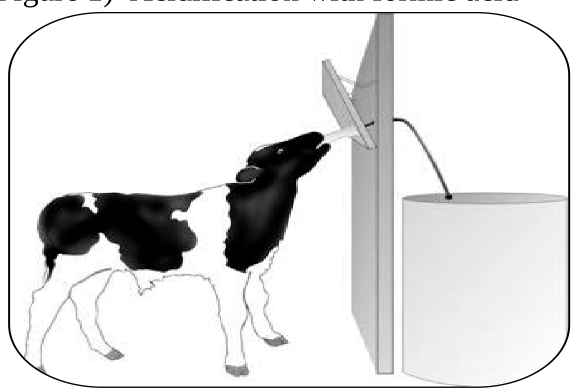

Figure 1. A simple free-access feeding system includes a nipple, plastic line, check valve, milk reservoir, and preserved milk. Image courtesy of Valio Dairy, Finland

Why this topic now?

Enhanced feeding and group rearing are important topics at this time because of calf health and welfare, economics, labor efficiency, and public advocacy. Recent innovations have made group feeding and rearing a practical alternative to traditional rearing in individual pens or hutches.

Welfare – producer and public interest

Hunger[9] and the biological need to suckle may have been under-recognized in conventional calf rearing. Traditionally, caregivers interpreted loud bawls from calves as signs of good health and appetite rather than protests about hunger. Additionally, caregivers strive to assure passive transfer, cleanliness, biosecurity, or identification-control-treatment of diarrhea-causing pathogens while perhaps being less sensitive to or ignoring physiological, behavioral or welfare challenges associated with conventional restricted-milk-feeding systems. Happily for calves and their caregivers, bawling is being recognized as a sign of hunger and the natural benefits of suckling are being adopted for milk delivery systems. Recent changes to milk feeding and rearing practices may be motivated by producer interests in calf well-being, dairy profitability, or responses to advocacy by consumers, milk processors and retailers.

Benefits of suckling

Our ancient contract with calves is a barter of food, shelter and welfare in exchange for future considerations, primarily milk for sale. In exchange for the loss of suckling its dam, we should provide an alternative milk delivery system that mimics Nature's way.[2] An imitation system should deliver milk on demand to satisfy a calf's inborn needs for suckling, small volumes per meal, several meals per day,[1] and increasing daily volumes to satisfy health, maintenance and growth. A system that mimics Nature's way should prevent the risk of ruminal acidosis and the rumenitis-omasitis-abomasitis complex associated with bucket, esophageal feeder, or gorge-feeding.[11]

Health, growth, and economics

Calf health may be another impetus for accelerated adoption of free-access feeding strategies. Diarrhea is the most common disease of milk-fed calves and accounts for the majority of pre-weaned heifer calf deaths. Pneumonia is the most common disease of recently weaned calves.[23] Prevention of hunger may reduce the risk of diarrhea. With enhanced feeding, calves may be weaned at heavier weights and at an earlier age. Enhanced or *ad libitum* feeding permits normal growth and development and reduced age at breeding and calving. Because of quicker throughput, overhead costs related to buildings and infrastructure may be reduced on a per calf basis. In recent times in the United States, producers may have adopted accelerated rearing of heifer calves because of a greater demand, limited supply, and favorable pricing for bred heifers. In addition, US researchers have shown greater first-lactation milk production by heifers on accelerated milk-feeding programs compared to heifers on restricted-milk diets.[7]

Group rearing – opportunities

Group housing and free-access or automated feeding compliment an accelerated feeding scheme. The package contributes to decreases in labor[12,17] and facilitates adoption of precision farming technology available through automation. Although hutch-rearing has advantages for calf health, labour and worker comfort may be reasons for leaving the hutch system and adopting group feeding and rearing. Loneliness has been under-recognized as a stressor in calves reared in hutches or individual pens with solid sides. Socialization in pairs or small groups benefits calves. Group housing allows calves to see and mimic behaviour, including suckling, and may be the reason for greater milk intakes and gain compared to calves reared in single pens.[13] In some European countries, legislation has forced the adoption of group rearing systems. In Canada, a recommended best practice calls for a *minimum total daily intake of 20% of body weight in whole milk (or equivalent nutrient delivery via milk replacer) until 28 days of age*. Since body weight increases with daily gain, free-access feeding or use of automated feeders with simulated free-access programming may be the easiest way to adopt the new feeding recommendations.

Producers using restricted feeding or buckets often avoid group housing because of cross-suckling. Intersuckling is a hunger-related behavior – hunger for milk and for suckling. Caregivers are preventing the unwanted behaviour by meeting the calf's needs for milk and nipple feeding. At weaning, intersuckling may be alleviated by gradual reductions in milk over a 15-day-interval and provision of grains with higher concentrations of protein.

Calf behaviour and choice of a feeding system

An understanding of behaviour of calves and their caregivers is useful to design or choose feeding and housing for milk-fed calves. It's reasonable to provide feeding and housing that promote positive interactions between calves and caregivers. To do so, we must be familiar with normal, sensitized to abnormal, and aware of the consequences of compromises and coping. Normal feeding behaviour meets physiological functions and social needs of the calf. Suckling, eating, resting and playing are group activities and they follow a pattern with a daily rhythm. Suckling events cluster near dawn and evening and may be related to hunger or changes in light. With free-access feeding of acidified milk, dairy calves may suckle an average of seven meals per day and meals may last for seven minutes for a total of 49 minutes suckling per day. The youngest calves may have inter-meal intervals of four hours while older calves suckle at less frequent intervals. Overall, young milk-fed calves seldom choose 14- or 16-hour intervals between meals, common intervals with twice daily feeding schedules. In addition, calves compete for what they perceive to be limited resources such as a nipple at a nipple bar or space at a grain feeder. Since suckling and eating grain follow a cyclic pattern within a day, a group of calves should have enough nipples and feed trough space for several calves to suckle or eat at the same time.

Free-access or ad libitum feeding

Nature's way of feeding calves includes free access, nursing until satiated, frequent meals per day and suckling. Free-access milk-feeding systems include housing with a nurse cow or unrestricted access to a container of milk. An automatic feeder programmed for a generous total daily volume or free-access feeding may still restrict access because of the calf-to-nipple ratio. The origins of free-access feeding of milk may have been from producers noticing improved health, greater feed conversion, rate of gain and growth in calves nursing cows or fed in ways that mimic nature. No doubt they also are looking for methods to decrease labour and to make feeding calves easier. Free-access feeding includes the principles of enhanced biological growth, normal suckling activity and social behaviour. This feeding strategy prevents hunger, weight loss or stress and allows for optimum growth and future milk potential. Frequent small meals moderate pH fluctuations in the abomasum.[1] Producers use whole milk, conventional milk replacer or accelerated milk replacer for free-access acidified milk feeding.

Unpreserved milk may be a hazard in free-access feeding because of rapid proliferation of bacteria. In Finland, other Nordic and European countries, Canada, and some States in the USA, producers feed milk preserved with formic acid to groups of calves.[2,22] Formic acid preserves milk by inhibiting the growth of or killing bacteria and allows milk to be stored at ambient temperatures for a few days without refrigeration. Acidification decreases a calf's exposure to bacteria in milk.

Loose stool may be associated with consumption of greater volumes of milk. The frequency of occurrence may be greater with free-access feeding. A stockperson needs to differentiate between sick calves and healthy calves with loose stool. Clinically ill calves may be removed from a group for nursing care.

Delivery systems for acidified milk

Acidified milk or milk replacer may be fed with a nipple bottle, a nipple bucket, a barrel with nipples, a milk line with nipple bars, or an automated feeder. A few Ontario producers successfully discovered that their calves refused to drink acidified milk from buckets and that this may be related to an odour. I am unaware of anyone feeding acidified milk in a trough. An ideal milk delivery system should meet a calf's needs for inter-meal intervals, suckling minutes, meals per day, volume per meal, and stress-free access to milk.

Nipple bottles or nipple buckets

Bottles or buckets are common containers for feeding calves housed in single pens. The nipple provides the benefits of normal suckling. A conventional feeding system may be enhanced by providing a greater volume per day and more meals per day. Acidified milk may be fed with nipple bottles or nipple buckets.

Mob feeders

The origins of the name *mob feeding* become obvious when you watch a gang of hungry calves swarm the nipples of a feeder filled with milk. Mob feeding systems are common in regions where cows calve in groups and produce many calves in a short time. In general, *mobs* of calves are grouped together and fed milk in containers with multiple nipples. In Europe and North America, mobs may consist of fewer calves than in New Zealand and be housed indoors in cool and cold months or outdoors in summer. The container may be filled with a fixed volume (e.g., four litres) per calf at each of two daily feedings. Mob feeders may be used for *conventional restricted*, *classic accelerated or acidified-milk feeding*. The volume consumed by a calf will vary with the suckling speed of the individual. The feeder usually has a nipple for each calf in the group.

Milk barrels and milk trolleys

Plastic or stainless steel reservoirs are common containers for holding acidified milk. Stainless steel has an advantage for ease of cleaning over plastic but recycled 200-litre barrels are inexpensive and easy to obtain. Some trolleys serve multiple purposes as mixers, transporters, agitators and reservoirs for nipple bars. The capacity of the milk reservoir varies with the number of calves in the group and how often it will be refilled. Nipples may be attached directly to the container or mounted on a nipple bar on a wall or gate. A plastic line attaches to the nipple and feeds off the bottom of the container. Milk will stay in the plastic line when an appropriate check valve is attached to the end of the line in the container.

Automated feeders

An automated feeder provides the technology to monitor daily milk intakes of individual calves. Forster, Urban and Holm & Laue are the most common machines in Canada. Some producers are storing cold acidified milk or milk replacer in functioning bulk milk tanks and connecting these tanks to their automated feeders. The automated feeder warms the acidified milk and dispenses it to the calf in the feeding station. The automated feeder may be programmed to feed calves for restricted, accelerated, or free-access feeding.[5] Milk may be delivered according to preprogrammed feeding curves or adjusted manually. The feeding station has a reader for an electronic identification tag carried by each calf. Base models will store individual calf data for two days and there are options to store and retrieve data for a calf's entire milk-feeding period. Action lists alert managers to examine calves that may not have consumed their daily milk allowance. Gradual weaning is possible by programming the machine to decrease the milk allowance over a short or long interval of days. Generous programming of three litres per meal and 10 to 12 litres per day move feeding closer to Nature's way. Calves may enter the group at three days of age and receive these allowances from the day of entry until the start of weaning.

A "Powder Maid Milk Maker" is a recent Finnish innovation built by Finnlacto. The machine prepares milk powder in four to seven litre batches and will automatically dose acid into the milk for acidification. Hoses connect the milk container to a nipple bar and the machine mixes a fresh batch when the container empties. The machine has modular components, for example, one collects data for monitoring daily milk intake of individual calves. This latter device may be attached to existing 'warm box' systems being sold in Ontario.

Milk lines

Several producers use milk lines to transfer milk from a central storage tank to nipple bars mounted at pens in a group housing barn. Initially, foaming of the milk or milk replacer, the formation of butterballs or cottage cheese, leaking or plugging of nipples, or cleaning were challenges to producers. However, these have been overcome and now there are calf barns with milk lines mounted beneath floors, on top of floors and at various convenient or practical heights. Milk may be distributed by gravity flow or by pump. For pump-assisted systems, an air-operated peristaltic pump has become the pump of choice for circulating the milk with minimal foaming. In the pump-assisted systems, a check valve is mounted at the nipple to prevent leaking. Early milk line systems were designed to keep the acidified milk at about 70ºF while in the storage tank. In these systems, reverse flow heat exchangers took the chill off the milk as it returned to the tank. In cold barns the milk may cool quickly while traveling in a loop back to the tank and calves may reduce their milk intakes. An alternative system is gaining favor for practical reasons. With these, acidified milk is kept cold and a plate warmer (an adapted plate cooler, heat exchanger) warms the milk leaving the tank and entering the milk line. Figure 4 shows a schematic of the system. Milk line systems may be washed with automated clean in place equipment.

Nipples

Nipples may provide gratification, frustration or a hazard to milk-fed calves. Therefore, nipples merit careful consideration when choosing a milk delivery system and routine inspection during our investigations of calf sickness.

Peach Teats® have become a popular choice with Ontario farmers for free-access feeding of acidified milk. They have a unique ergonomic shape, a built-in pinch valve, and two small slits placed on the sides rather than a hole at the end. The correct orientation places the slits at the top and bottom so milk squirts upon the palate and tongue. Other nipples have an opening on the end, either a round orifice or an X-shaped opening. These are common with automated feeders, nipple bottles or mob feeders.

Figure 2. A cluster of nipples. Top left, new red and white nipples. Top right, a white nipple that has had surgery and modest use. Bottom left, a surgically modified, well- used nipple from a nipple bottle used to feed colostrum. Bottom right, a new Peach Teat.

Producers complain about calves not wanting to suckle on some types of nipples. Calves may have trouble suckling because of hardness of the rubber, diameter and length, or restrictive orifice. Drinking speed may be a function of the calf's ability and / or the nipple. Nipple surgery with a pocket knife is a common practice by those feeding calves in hutches because a larger opening reduces suckling time, accelerates calf feeding and decreases the caregiver's exposure to harsh weather. Enlargement of the opening also is common with automated feeders because caregivers believe that line ups at the feeding station are due to small nipple openings that slow drinking speed. Alternatively, queues may happen because calves are hungry when offered small volumes per meal. Unwittingly, large orifices permit rapid ingestion of milk and may encourage calves to loiter to satisfy their need to suckle. Long suckling times also may be due to worn out or collapsed nipples, a common finding. Like milk liners, the rubber becomes tired after repeated use and does not return to its shape. Large openings permit rapid ingestion, reduce suckling time and saliva production and may be an under-recognized hazard for aspiration pneumonia or digestive upsets. Since feeding clusters around early morning and evening hours, nipple bars are practical because they provide access to more calves at one time than a single nipple.

Biosecurity and cleanliness

Free-access acidified milk systems require regular cleaning. Proper acidification prevents the formation of slimes in the lines. A black, green or pink slime in clear plastic lines is an indication of inadequate acidification. In general, slimes and moulds do not grow at pH 4.0 - 4.5.

However, reservoirs need cleaning on a regular schedule, and twice per week is common practice. Cleaning involves the use of detergents, acid and alkaline cleaners, and sanitizers. With milk hoses dead-ending to a nipple, hoses need to be removed and cleaned. Since plastic hose is readily available and inexpensive, some producers replace the hoses on a regular schedule.

Suckling is a messy, slobbery activity because of the production of lots of saliva. Surfaces around and below nipples become covered in saliva and spilled milk. Floor drains and water hoses at feeding stations and nipple bars make cleaning and disinfection an easy and timely chore. Floor drains and sloped floors are useful design features in new barns or renovations. It's common for good caretakers to clean and disinfect these areas daily. Slobbered milk is very attractive to cats, rodents, and flies. Disease may spread between calves by means of contaminated nipples. There is scant information to quantify the risk.

Group size and pens

For our average-sized dairies milking 75 cows and with three or four heifer calves born each month, four pens are common. At any time, the barn may have a clean, disinfected pen that is sitting idle, a pen that houses recently weaned calves, a pen with a full compliment of suckling calves, and a pen being filled with calves. A dairy milking 600 cows may be able to fill a pen with eight calves in ten days and require 12 or more pens for calves from birth to post-weaning. The size and weight of a calf at weaning should be used to determine the pen area allocated per calf in a group. Forty square feet per calf may be a reasonable minimum for Holstein calves weaned at 42 to 60 days or less of age. To maintain stable groups, producers may choose group sizes in proportion to their herd size.

Ontario producers using free-access acidified milk systems have been advised to house eight or less calves in a group based on findings about group housing and disease from Sweden.[20] Through personal communication, a US dairyman reported his observations after rearing calves in groups of six through 14 per pen. With about 600 calves on free-access acidified milk each day, he found that a group of eight calves was ideal for his housing and management.

For automated feeders, small groups of six to 12 calves are being recommended to minimize disease, to achieve good weight gains, and to assure satisfactory social behaviour.[20] Stable groups are preferable to moving calves in and out.[10] All-in all-out management may be practical for large herds but more difficult to achieve for small dairies. Advice from researchers is at odds with the recommendations from manufacturers of automated feeders. Manufacturers and their sales persons recommend 20 to 30 calves per nipple and advertise machines that can feed 40 to 120 calves. In Ontario, pens with 10 calves are common while at least one producer manages 30 calves in a group pen with two feeding stations.

Weaning strategies

The weaning process introduces calves to grain or forage while milk is being removed from their diet. Weaning is complete when the calf no longer receives milk. Briefly, weaning involves a change in diet over a period of time. Three methods may be used to wean calves from free-access acidified milk - abrupt, step and gradual.

Sudden removal of milk is the defining characteristic of abrupt weaning. When done at a young age or when calves are consuming large volumes of milk, there will be a rapid reduction in daily nutrient intake. Calves may experience a loss in weight during this time because their nutrient intake from solid feed may not compensate for the nutrients removed by weaning off milk. Abrupt weaning is stressful to the calf and their hunger may lead to intersuckling.

Reductions in the volume of milk by several stages over several days are characteristics of step weaning. Each stage may be over a few or several days. The process allows calves to increase their intake of grain or forage to replace nutrients withdrawn with the milk. This weaning process is less stressful than abrupt weaning but it also may lead to intersuckling amongst hungry calves.

Gradual weaning includes small daily reductions in milk over a prolonged period of time. A reduction in volume is often recommended as the preferred technique but producers claim excellent results by gradually diluting the milk with water. In practice, the time period may be 14 days.

With free-access milk feeding, calves often eat less grain or forage than calves on restricted milk diets. For calves on these systems, gradual weaning is the method of choice. Practical implementation of gradual weaning requires some ingenuity. In groups with wide ranges of age, calves may be removed to another pen for gradual weaning. With milk-line systems, producers may reduce milk intake by restricting access to the nipple for more hours each day until weaning is complete. In contrast, some choose a gentler weaning by shutting off the valves on the milk line, removing the nipples and providing milk at a nipple bar supplied from a container of milk.

Automated feeders are marvellous machines for implementing gradual weaning. In general, milk is reduced gradually over 15 days for a relatively stress-free weaning. During weaning, the daily intake of dry feed and water increases as milk is removed from the diet.[21]

Keeping the chill off the milk

In cold housing during winter months, producers adopt innovative ways to keep the chill off the milk. Some warming devices have been ineffective with the milk being too cold resulting in calves refusing to drink adequate volumes and suffering as a consequence. Other devices have been too hot resulting in milk baking on heating elements or making a container of cottage cheese.

Figure 3. A warm box milk bar may have nipples mounted on three sides. The other side has a door for access to the barrel of acidified milk.

Winding River Farms in Nova Scotia invented a practical solution, a warm box with devices to maintain the inside of the box at about 70ºF (21ºC). Warmth comes from a thermostatically controlled, electric base board heater. An agitator on a timer stirs the milk at predetermined intervals. The designers had the wisdom to recess the nipples inside the box to prevent them from freezing. The box is not intended to warm cold milk to feeding temperature. However, it does an excellent job of maintaining the temperature of a container of acidified milk. The plans and list of materials for building a warm box are available on the OMAFRA website. Use your internet browser and type in the following words to get the plans: *Stewiacke Warm-Box Milk Bars Free-Access Milk Feeding in Cold Calf Barns*. Advanced Dairy Systems in Wellesley, Ontario build a box based upon the Winding River plans. The company builds their warm box with plastic and stainless steel. (see Figure 3) Complete units or the components are sold in Ontario, across Canada and into the USA. The company also sells components for milk line systems.

A warm room has been adopted on many farms with the walls providing mounts for the nipple bars to feed calves in adjacent pens. A warm room provides space for the equipment needed for a free-access acidified milk system using milk lines or for barrel and nipple systems.

Milk-line systems may include a reverse-flow heat exchanger to take the chill off the milk. The heat exchanger may be purpose-built or adapted from a plate cooler. Figure 4 shows the basic configuration with a plate warmer on the outgoing side of the milk line. With this system, there is no remixing of milk back into the cold acidified milk in the main storage tank. 'Warmed' milk not suckled by the calves returns to a small sink where it mixes with cold milk from the bulk tank. This system has been in use for about two years on a farm where cold acidified milk is being warmed to about 100ºF (38ºC) without the formation of cottage cheese. An alternate setup warms milk on the return line just before entering a main bulk tank. In effect, it attempts to keep the chill off a large volume of milk. Placement of the warmer on the outgoing milk line has inherent advantages and some Ontario producers are changing to this design.

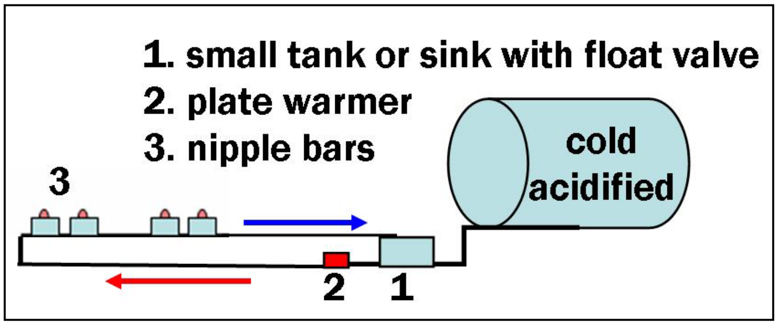

Figure 4. A plate 'warmer' takes the chill off cold acidified milk before the milk goes to the nipple bars. The return line empties into a small sink where the 'warmed' milk mixes with cold acidified milk flowing from the storage tank.

Setting up the system

OMAFRA's website has a document (revised in 2008) that describes setting up a free-access feeding system using formic acid. To access the document, type the following words into your web browser: *free-access feeding of acidified milk setting up the system*. The document was written for Canadian dairy producers and some information may not be applicable to the USA. For example, formic acid may not be an approved product in the USA. Comments about temperatures for mixing acid into milk replacer may not apply to American readers because your milk replacer may not contain skim milk powder. Another section describes the addition of milk replacer powder to whole milk to avoid formation of cottage cheese in milk line systems. When the document was written, we were challenged by foaming and curd formation caused by pumps in milk line systems or agitators in barrel systems. An astute producer minimized the problem by adding milk replacer to his whole milk. In the past year we've found that an air-operated peristaltic pump solves the problem and there is no need to add milk powder to whole milk. Nonetheless, it's now apparent that we can mix whole milk and milk replacer without doing harm to calves. In addition, there are descriptions about ways to keep the chill off milk that may or may not be useful or applicable in light of recent on-farm experience. At the time of writing this paper, the document prepared in 2008 is undergoing a revision with deletions and additions and corrections. The revised document may not be posted on the website until after the Minnesota Dairy Health Conference in May. Therefore, check the site for the update.

Cautions and safety

Formic Acid 85% is hazardous to skin, eyes and lungs. Appropriate safety equipment (goggles, gloves, and clothing) is essential for handling this acid. For safety, dilute one part Formic Acid 85% into nine parts water to make a 9.8% product and work with this weaker acid. Store acids safely and keep them out of reach of children. A commercially prepared, dilute (9.8%) formic acid is available to Ontario farmers and many choose to buy this even though it costs more. You will find more safety precautions listed in the information sheet posted on our website. Although infrequent, sometimes producers add concentrated acid to water and then do not stir the contents of the barrel. Next they pump from the bottom where the acid settled and encounter problems with pH when mixing it into milk. To avoid this problem, stir well once and you may not need to stir the dilute solution again.

Preparing and feeding acidified whole milk or colostrum or milk replacer

Mix dilute acid into cool (68 to 75°F, 20 to 24°C) milk replacer* or cold (e.g., plate cooler temperature) whole milk to avoid gelation, coagulation or clot formation. (*Note: this caution about temperature applies to milk replacers that contain skim milk as a protein source. It may not apply to American milk replacers.) Add 30 mL (cc) dilute acid (Formic Acid 9.8%) into each litre of milk or milk replacer. Stir vigorously while adding the acid into the milk, again within the first hour, and several times each day. Check for the target pH of 4.0 to 4.5. Use narrow range (3.0 to 5.5) litmus paper or a pH meter. Feed at ambient temperature in summer *and at* 20 to 24°C in winter. Please see the notes above about keeping the chill off milk and a plate 'warmer' used in milk line systems. Provide free-choice water and calf starter and hay. Mount the nipples at a calf's shoulder height or lower for ease of access.

About hot or warm colostrum or milk or milk replacer

It's easy to make cottage cheese by adding acid to freshly harvested warm milk or by adding acid to cold milk and heating the mixture and holding it at a warm or hot temperature. The same is true for milk replacer powders that contain skim milk powder. Since most milk replacers sold in Canada contain skim milk powder, we mix the powder with part hot water and then add the remaining water as cold to produce a mixture at about 68 to 75°F (22 to 24°C), and then we add acid to this mix. Because we can make cottage cheese by heating cool acidified milk replacer, we acidify and feed our milk replacers at 22 to 24°C.

Since most milk replacers sold in the USA do not contain skim milk powder, this caution about temperature and making cottage cheese may not apply. Briefly, the precautions about feeding cool (not cold, not body temperature) milk or milk replacer focus on the prevention of curd formation. You may be successful at warming cold acidified whole milk (or milk replacer containing skim milk powder) to 100°F (38°C) and feeding it immediately. Or, you may make lots of cottage cheese by keeping a volume of acidified milk at warm or hot temperatures for several hours. You may make cottage cheese by focusing a heat source on one area of a barrel of acidified milk. An American milk replacer based upon whey protein concentrate may be acidified and warmed successfully without forming cottage cheese. It's best to read the label on the milk replacer, mix a small volume as a test batch and do some experiments with the powder of your choice.

Do not feed cold milk or milk replacer. Do not make cottage cheese or yogurt.

In winter when I'm told about low intakes of acidified milk, thin calves or diarrhea, the temperature of the acidified milk is the first item on my checklist. Usually, it is too cold and calves decrease their intakes. A thermometer is a handy tool. Use it to check the feeding temperature of the milk. In temperate climates during summer, we feed acidified milk at ambient temperatures. Sometimes, producers ruin batches of milk by exposing the containers to direct sunlight where the milk can quickly get too hot. Therefore, keep acidified milk in the shade.

pH and contact time for killing bacteria

pH paper is of little use to folks who are red-green color blind and pH meters lose their calibration. Meters should be checked and calibrated often. False readings can lead to adding too much acid and calves refuse to drink the acidified milk. (Yes, it has happened too many times.) Or, you may not add enough acid to preserve the milk. Acidification does not kill all bacteria. A pH of 4.0 to 4.5 with formic acid and contact time of eight to 12 hours should produce acidified whole milk that meets or exceeds quality targets. Because coliforms will be the most common contaminant in milk replacer, and since coliforms die quickly (e.g., one hour) upon acidification with formic acid, acidified milk replacer may be fed immediately. In experiments with whole fresh milk, acidified with formic acid, we found no growth of coliforms after a contact time of one hour at pH 4.1. We found no growth of Staphylococcus aureus after a contact time of 4 to 6 hours at pH 4.1 in whole milk acidified with formic acid. 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 to 4.5. On bacterial culture, the majority of samples had no growth or less than 10,000 colony-forming units per millilitre (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 less than 5,000 colony forming units per millilitre. One research report from the

University of Guelph claimed that formic acid killed *Mycobacterium avium subsp. Paratuberculosis* (MAP) (Johne's bacterium) but another study from Iowa State claimed that it did not.

Agitating acidified milk or milk replacer

Since acidified whole milk and milk replacers made with skim milk powder separate over time, agitation is essential. A vigorous stir for a short duration will achieve excellent mixing. Too much mixing will make butter. Therefore, choose slow, short-duration, and frequent agitation. In addition, whole milk separates naturally with fat rising to the top. Therefore, agitation is a practical consideration when drawing milk from storage tanks.

Training calves to free-access feeding or automated feeders

Ontario producers reported and researchers confirmed that newborn calves may not consume sufficient quantities of free-access acidified colostrum.[7] Refusals or slow drinking may be related to age (less than four hours old), an acidic taste or weak suckling ability.

Strong suckling ability should be the decisive factor for introduction of a calf to free-access feeding or an automated feeder. With free-access acidified milk feeding systems, caregivers may introduce their calves at two to four days of age. Producers want their calves to bond to the nipple-barrel or nipple bar and not to someone hand-feeding with nipple bottles or buckets. Contrastingly, the age of introduction to an automated feeder may vary from three to 21 days depending upon advice given by salespersons or choices made by producers. Bottle-feeding until 10 to 14 days of age seems to be a common recommendation because calves may fit into groups better when they are two weeks old compared to calves less than a week of age.[15] Contrarians disagree with existing recommendations for age at introduction to automated feeders. As an example, owners of an Ontario farm invested in an automated feeder and took full advantage of its labour-saving features by introducing a calf when it suckled strongly. They admit 80% of their calves to the feeder at three days or less of age.

Tutor calves may assist with training of new entrants to automated or free-access feeders. A tutor calf is already trained to the system and new entrants follow it to the nipples. A nipple bar may facilitate tutoring compared to feeding stations with access for a single calf. Some caregivers feed two litres by nipple bottle prior to introducing a calf. Others find that training is easier and quicker when a calf is hungry upon entry. An automated feeder may have a pump to assure milk is at the nipple when calves are being trained to the machine. With two feeding stations, a pen may be subdivided into a training pen for calves being trained to the nipples. This pen facilitates easy identification and handling of the youngest and newest additions to the automated feeder. When trained, calves are released into the main pen.

Data about daily intakes of colostrum, bottle milk and milk from automated feeders for each calf may be useful when investigating neonatal calf problems. Sometimes a nutritional deficiency, excess, or abrupt change may be identified as a predisposing cause of ill-thrift or disease. For example, at a study farm calves became very unthrifty shortly after introduction to an automated feeder. Bottle-feeding was eight litres per day divided into three meals prior to moving calves at 21 days of age to their automated feeder. However, a check of the feeder showed that it was programmed to provide five litres per day and at less total solids content. The calves experienced two stressors at the transition, commingling in groups and a substantial abrupt decrease of nutrient intake.

Avoiding practices that put calves off suckling

Accelerated colostrum feeding may put some calves off suckling and delay an easy or early transition to free-access feeding or automated feeders.[3] A defining characteristic of accelerated colostrum feeding may be a single feeding of four litres by esophageal feeder within a few hours of birth. Features are speed and method of delivery, quantity of nutrients, volume delivered or labour devoted to the task. Force-feeding differs from suckling in many ways. Does the volume of colostrum or method of delivery[4] do harm and should we consider the welfare aspects of the practice? For example, rapid administration of colostrum by esophageal feeder at a dose of 10 to 11% of birth weight differs from Holstein calves suckling nine to 21% of their birth weight[18] in several relatively smaller meals. Granted, there are challenges with bottle feeding but the hazards of rapid administration using an esophageal feeder that directs colostrum to the reticulo-rumen also merit our consideration.[11]

Some producers who followed the force-feeding advice complained about calves not suckling at their next meal or being slow drinkers afterwards. Non- or slow-drinkers make calf-feeding frustrating and time consuming for caregivers. Some abandon force-feeding except for exceptional cases whereas others carry on while accepting but questioning the practice. When looking for ways to get calves onto bottle or free-access feeding or automated feeders, the first step may be avoiding practices that put calves off suckling. The next steps may include feeding smaller volumes per meal and more meals to achieve four litres total volume. And lastly, some calves are not ready to suckle in the first hour of their life and delaying bottle feeding for two to four hours may be successful for them. There are practical alternatives to force-feeding four litres of colostrum to every newborn calf, alternatives that assure high probability of successful passive transfer.[6]

Milk intake

Producers often ask how much calves will drink when offered free access to milk. Unpublished data from research at the University of Guelph (Cindy Todd) compared calves suckling free-access acidified milk replacer to calves suckling free-access non-acidified milk replacer. Average intakes were 10 litres per day with acidified milk replacer compared to 11 litres per day with sweet milk replacer. There were no differences for weaning weight. In another trial, Emily Miller-Cushon found ad libitum intakes of milk averaged 12 litres per day with a peak of about 16 litres at week six prior to weaning.

The major manufacturers of milk replacers sold in Ontario enhanced the mixing and feeding schedules of their products in the past two years. For example, one popular brand recommends mixing 150 grams per litre and feeding six litres per day at five to seven days of age and six to eight litres per day for 45 kilogram calves at eight to 42 days of age. These may be considered conservative feeding levels compared to what calves want. Calves vary in birth weight and when given a chance they tell us clearly that their wants and needs vary and that they want more than offered conventionally.

Here are some data to illustrate the point above. From summer 2009 to spring 2012, we recorded daily milk replacer intake for Holstein heifer calves using an Urban® automatic calf feeder that was programmed to mimic some aspects of free-choice feeding. At our study farm, the milk replacer contained 20% protein and 15% fat and the mixing ratio was 15% on a weight to weight ratio (e.g., 150 grams of powder into 1000 grams of water), or about 13% total solids. From entry to the start of weaning, the machine provided each calf a maximum of 12 litres per day. Maximum volume per meal was initially set at two litres but this was soon increased to 2.5 during 2010 and then to three litres in 2011. Eighty percent of the calves were three days of age or younger upon admission to the feeder and data for three days of age may be considered training day intakes. Calves were penned in groups of 10 in naturally-ventilated cold housing with straw bedding in winter and sawdust in summer. Water and calf starter were available free-choice. Milk replacer consumption has been recorded for about 400 calves to date.

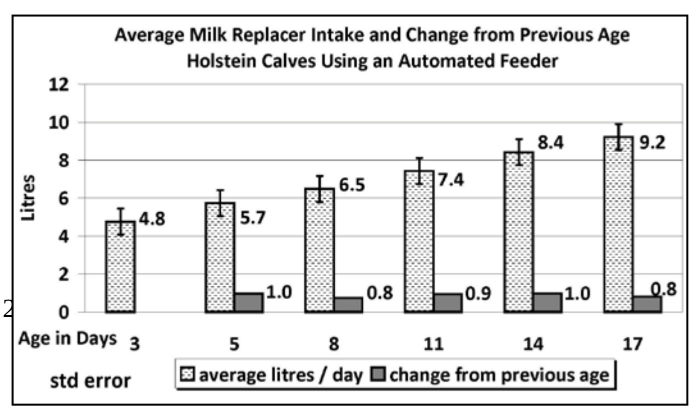

Figure 5. The chart shows the linear increase in average daily milk replacer intake from three to 17 days of age for calves using an automated feeder.

Figure 5 summarizes the data in chart form and includes standard error bars on the columns. The chart shows a linear increase in average daily milk replacer consumption from 4.8 litres per day at three days of age to 9.2 litres per day at 17 days of age. In this 14-day period, the calves increased their intakes by 4.4 litres or about 315 millilitres per day. Consumption increased an average of one litre from three days old to five days old. During the six day interval from eight to 14 days old, milk intakes increased an average of 1.9 litres, from a daily intake of 6.5 litres to 8.4 litres.

Although averages are interesting, the distributions of consumptions by calves of the same age may be more useful. As shown in Figure 6, at 11 days of age, the top 25% of calves were suckling more than nine litres each day and 50% were suckling more than 7.5 litres. Clearly, a fixed volume of six litres per day would not have met the needs of the majority of calves. These data may be useful for comparison to feeding guidelines on milk replacer labels or to recommendations for programming automated feeders. It's interesting to compare what calves want to milk allocations programmed into automated feeders. For example, it's common enough to find calves bottle-fed and then entered onto automated feeders at 10 to 14 days of age and offered six litres of milk replacer, far less than they want or require for their age. More generous feeding allowances during the first 28 days of life should help calves meet their potential.

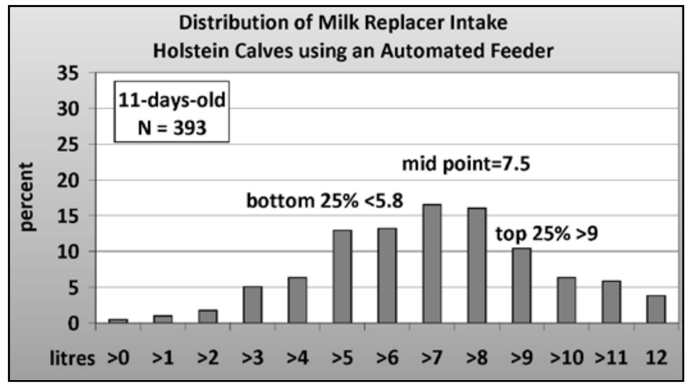

Figure 6. The chart shows the distribution of milk replacer intakes for 11-day old calves offered 12 litres of milk replacer per day. One half the calves suckled greater than 7.5 litres per day and 25% of them suckled nine litres or more.

Water, grain and forage

Calves using a free-access acidified milk system drink scant amounts of water until weaning when water intake increases rapidly upon withdrawal of milk.[14] Nonetheless, water should be available at all times to calves on the feeding system.

It's common advice to feed grain and withhold roughage to stimulate rumen development in milk-fed, dairy replacement calves. Some producers follow the advice while others ignore it and feed hay like grandpa did because he knew how to feed calves. What's old is new again because research has caught up to the old ways. Dry grass hay in the diet results in normal development of rumen mucosa in all calves whereas only grain, grain plus corn silage or grain plus free-access straw bedding results in normal development in 62-75% of calves.[19] Producers should question the dogma about feeding grain only to milk-fed calves. For sure, grain facilitates rumen development but some dry hay assures development of a healthy rumen.[16] Rumination and cud-chewing activities by 14-day old calves are common observations when calves are offered hay or even straw bedding.

Summary

Our ancient contract with calves is a barter of nourishment and welfare in exchange for future considerations, primarily milk for sale. Free-access feeding with acidified milk or novel programming of an automated feeder allows us to feed calves closer to Nature's way. Milk can be delivered on demand to satisfy a calf's inborn needs for suckling, small volumes per meal, several meals per day, and increasing daily volumes to satisfy health, maintenance and growth. Group housing compliments the feeding systems and allows calves to exhibit or develop normal social behaviours. Producer interest in calf well-being, dairy profitability, labour savings, caregiver comfort and protection of milk's good image has accelerated the successful implementation of group feeding and rearing.

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