Practical Aspects of Accelerated Feeding of Dairy Calves

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Abstract

Classic accelerated feeding refers to enhanced nutrition compared to conventional (restricted) feeding; for example, milk replacer with 26% protein rather than 20%, a mixing ratio of 170 grams per litre rather than 125, and feeding volumes of five litres per day rather than four litres. Greater protein, mixing ratio, and volume results in greater weight and stature at weaning compared to conventional feeding. Recently, accelerated feeding has taken on new meaning thanks to some old and some new milk delivery systems. These systems enhance a calf's feeding experience by allowing individual calves to achieve their biological growth in addition to meeting their physiological and behavioral needs. Ad libitum feeding may be the new paradigm for accelerated feeding because ad libitum systems mimic more closely nature's way and compliment group housing. This presentation looks at a few practical aspects of accelerated feeding in its various forms.

Résumé

L'alimentation accélérée classique fait référence à une nutrition améliorée qu'on contraste à l'alimentation conventionnelle (restreinte). Par exemple, ceci correspondrait à un lait de remplacement contenant 26% de protéines plutôt que 20%, un rapport de mélange de 170 g/l plutôt que 125 et à un volume d'alimentation de 5 l par jour plutôt que 4 l. Des valeurs plus élevées de protéines, du rapport de mélange et du volume produisent un plus grand poids et une plus haute stature au sevrage qu'avec l'alimentation conventionnelle. Récemment, l'alimentation accélérée a pris un nouvel essor en raison d'anciens et de nouveaux systèmes d'apport de lait. Ces systèmes rehaussent l'expérience d'alimentation des veaux en leur permettant d'atteindre leur croissance biologique tout en rencontrant leurs besoins physiologiques et comportementaux. L'alimentation *ad libitum* peut devenir le nouveau paradigme pour l'alimentation accélérée car les systèmes d'apport à volonté se rapprochent plus de l'alimentation naturelle et complémentent la stabulation en groupe. Cette présentation se penche sur certains aspects pratiques de l'alimentation accélérée dans ses multiples formes.

Why This Topic at this Time?

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[8] 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, we devote great effort to assuring passive transfer, cleanliness, biosecurity, or identification-control-treatment of diarrhea-causing pathogens while 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 interest in welfare, calf health, and economics, or responses to public advocacy or milk processor and retailer interests.

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 ruminal acidosis and the rumenitis-omasitis-abomasitis complex associated with bucket, tube, or gorge-fed calves.

Health, Growth, and Economics

Calf health may be another impetus for accelerated adoption of ad libitum 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.[36] Prevention of hunger may reduce the risk of diarrhea. With accelerated feeding, calves may be weaned at heavier weights and at an earlier age. Accelerated or ad libitum feeding permits normal growth and development and reduced age at breeding and calving.

Figure 1. A group of Holstein calves fed free-access acidified whole milk.

Because of quicker throughput, overhead costs related to buildings and infrastructure may be reduced on a per calf basis. In the United States, producers may be adopting 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 automated feeding compliment an accelerated feeding scheme. The package contributes to decreases in labor[13,22] and facilitates adoption of precision farming technology available through automation. Although hutch rearing has advantages for calf health, labor, 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 behavior, including suckling, and may be the reason for greater milk intakes and gain compared to calves reared in single pens.[14] 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, ad libitum or automated feeders 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. The unwanted behavior is being prevented by meeting the calf's needs for milk and nipple feeding. At weaning, intersuckling may be alleviated by gradual reductions in milk over a 14-day-interval and provision of grains with higher protein content.

Accelerated Colostrum Feeding

The defining characteristics of accelerated colostrum feeding may be a single feeding of four litres by esophageal feeder within four hours of birth. Features are speed of ingestion, quantity of nutrients, volume delivered or labor devoted to the task. The common advice is to feed four litres of colostrum as soon as possible after birth to provide 150-200 grams of IgG that is needed to diminish the risk of failure of passive transfer (FPT).[33,37] Since average colostrum contains about 50 grams of IgG per litre, simple math was used to arrive at the four litres. As a result, producers are force feeding four litres of colostrum in one meal, a practice based on science, assumptions, mathematical extrapolation, convenience, or misinterpretation.

Questioning Four Litres in One Meal

Accelerated colostrum feeding may be rooted so deeply in calf management that what may be traumatic to the calf has become normal to us. Certainly, immunoglobulins benefit a calf. But does the volume of colostrum or method of delivery[3] do harm? Producers who follow the advice complain about calves not suckling at their next meal. This makes calf feeding frustrating and time consuming for producers and, perhaps stressful for calves. Some abandon the technique whereas others carry on while questioning the practice. During the first three days of life and with suckling their dams, daily colostrum intake for Holstein calves may vary from 9 to 21% of their birth weight[23] and they consume their colostrum in several meals. Since each meal is generally small, abomasal capacity is about two litres, and suckling two litres satisfies a calf's feelings of hunger, should we force feed more than two litres in a meal? Why do advisors recommend gorge feeding colostrum yet tell producers that overfeeding is a hazard for milk-fed calves? It's difficult to find information about pain, discomfort, reflux or aspiration, or a long intermeal interval following force feeding with four litres of colostrum. Yet, information in postmortem reports for neonatal calves should make us wary about overfeeding colostrum, especially by esophageal feeder.

Refusal to Suckle after Colostrum Feeding

Refusal to suckle the first meal after colostrum feeding may be common on some farms. Observational data for 244 calves from one farm showed that 47% did not suckle their first meal of milk replacer after having received their colostrum. About half of the non-drinkers did not drink at the next meal. Within the non-drinkers, some were fed by nipple bottles and some by esophageal feeders, and volumes varied with a target of three to four litres. Analyses showed that refusals were similar for calves fed ≤3L vs >3L of colostrum. However, calves fed colostrum by esophageal feeder were less likely to suckle their first meal of milk replacer. Overall, refusals at the next meal by calves fed by esophageal feeder were 57% for calves fed ≤3L colostrum and 64% for calves fed >3L (Figure 2). The association of esophageal feeding and failure to suckle at the next meal does not imply causation; it merely gives us a hint to look deeper into the matter.

Ruminal Acidosis and Anaerobic Conditions

Esophageal feeders facilitate prompt and rapid administration of fluids to calves. Physical damage to the pharynx or esophagus, aspiration into the lungs, ruminal acidosis, or establishment of anaerobic conditions in the forestomachs may be unwanted side effects. Abnormal fermentation of milk in the forestomachs produces an accumulation of acid that leads to ruminal and systemic acidosis. Significant volumes of milk entering the forestomachs may change conditions from aerobic to anaerobic. Whereas suckling stimulates closure of the groove under natural conditions, use of esophageal feeders, feeding large volumes at a calf's first meal, or bucket feeding can lead to failure of the reflex and failure of groove closure. Distension of the abomasum with large volumes of milk at one time can allow milk to overflow or reflux into the rumen. Similarly, the pressure from overfilling can force the groove to open partially and allow milk to leak into the rumen. Ruminal acidosis in itself may cause diarrhea.[11,12]

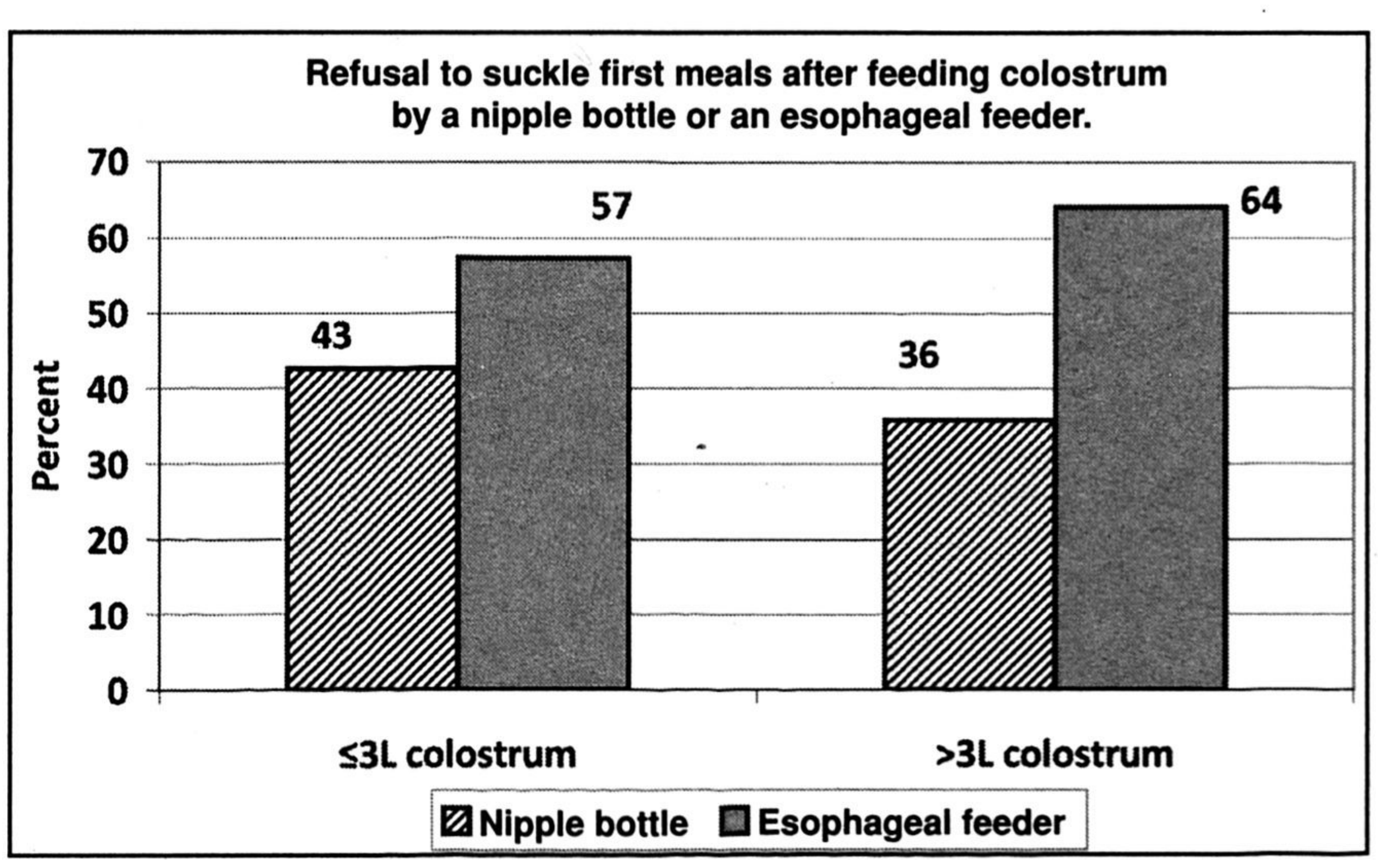

Figure 2. The proportion of calves that refused their first milk-replacer meal was associated (χ^2_{MH}=26, P=0.0000) with feeding colostrum by esophageal feeder.

A Tsunami of Colostrum and a Clostridial Meltdown

Ruminal acidosis with subsequent rumenitis, omasitis, and abomasitis may be underestimated and under-diagnosed in milk-fed calves.[11] A scan of about 300 postmortem reports for calves less than six weeks of age showed that one-third included rumenitis/reticulitis/omasitis/abomasitis in the diagnoses. Here's an example for consideration.

The case involved a 100 lb (45 kg) Holstein calf that received four litres of colostrum by esophageal feeder at three hours of age and an additional two litres at 13 hours of age, an inter-meal interval of 10 hours. The next morning it could not stand, was dehydrated severely, and had abdominal distension and loose manure. The calf died at less than 30 hours of age. The rumen contained watery fluid with clots and had areas of acute hemorrhage, especially around the esophageal groove. The abomasum was severely distended with watery fluid and large amounts of clotted milk. It had severe acute mucosal congestion with emphysema and areas of mucosal necrosis. After culturing *Clostridium perfringens* from the abomasum and small intestine, the pathologist gave a final diagnosis of severe acute clostridial abomasitis. In effect, the final diagnosis focuses on germ theory that often leads us to prescribe oral antibiotics or vaccinations to prevent new cases of the disease.

Consideration of the sequence of events leading to clostridial abomasitis may change our recommendations. At three hours of age, the farmer rapidly overfilled the calf's forestomachs with high-solids-content colostrum (i.e., faster and a greater volume than a suckled meal). The flood of colostrum destroyed tissues and overpowered metabolic processes. Imagine a stretched abomasal wall, ruptured capillaries, hemorrhage, blood clots, and hypoxia to local tissue; colostrum spilling into the rumen, fermentation, acid production, rumenitis, systemic acidosis, and compromised metabolic and circulatory systems; and an abomasum overfilled with thick colostrum, slow emptying, overwhelmed abomasal acid-defense mechanisms, abomasal pH in the clostridial-friendly range greater than 4.5, anaerobic conditions, proliferation of *Clostridium*, and toxin production with local and systemic damage. The second feeding of colostrum was an aftershock, the final blow. Clearly, the fundamental cause of death was rapid overfilling of the forestomachs – a colostral tsunami and clostridial meltdown triggered by an expert's advice to feed four litres of colostrum. Neither the calf's suffering nor the owner's distress appear in any reports.

This case and others with a similar root cause but longer duration raise a prickly question about the logic of slug-feeding four litres of colostrum into newborn calves. Slug feeding four litres of colostrum is a treatment for failure of passive transfer, according to a laboratory report. How can we weigh a decrease in the prevalence of FPT in a herd (i.e., benefit) against the potential suffering of individual calves (i.e., cost) from over-filling with colostrum? Generally, experiences with FPT and morbidity or mortality have involved calves fed restricted volumes of milk.[35] FPT may be unimportant to well-fed calves raised in a clean environment.

Decelerating Colostrum Feeding

Amongst the 244 study calves mentioned in our case study, there were nine deaths - four following complications of umbilical infections and five with abomasitis and/or rumenitis as part of the necropsy findings. Because of the findings of abomasitis, milk refusals, and slow starts, the owners chose to shift colostrum feeding closer to Nature's way - suckling and smaller volumes. There are practical alternatives to force feeding four litres of colostrum. For example, recommending suckling as the primary route of ingestion, three litres of colostrum within the first four hours of age, practical volumes (e.g., two litres) of colostrum per meal, use of decision points for interventions when necessary, and volumes of about two litres when intubating assure high probability of successful passive transfer.[6]

Ruminal acidosis should be placed near the top of the list of differential diagnoses for acutely ill neonatal calves, poor-doers or slow drinkers. As advisors, we should modify our recommendations for accelerated colostrum feeding towards smaller volumes per meal and more meals to achieve a four-litre target. Enhanced early nutrition may lessen the importance of accelerated colostrum feeding and hasten a return to practical and safe volumes for colostrum feeding. Cleanliness, pathogen load or virulence, or nutrition may play key roles in baseline mortality on a farm regardless of FPT.

Liquid Feeds

Producers may feed unpasteurized or pasteurized whole milk or non-saleable whole milk or milk replacer to calves. Non-saleable milk may include colostrum, milk harvested from recently calved cows, or milk from cows undergoing therapeutic treatments. Often the various non-saleable milks are pooled. Milk or milk replacer may be fed sweet or sour (preserved with acid).

Delivering Milk or Milk Replacer

Conventional Feeding

Conventional milk feeding systems may restrict 1) volume (e.g., 8-10% of body weight per day), 2) nutrient density compared to whole milk, 3) milk intake per meal (e.g., 2 litres), or 4) meals per day (e.g., two per day). Conventional feeding systems may encourage rapid intakes or gorging because of hunger, use of buckets, or use of nipples with large openings. Use of buckets deprives calves of normal suckling behavior.

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. Restricted feeding systems primarily allow for maintenance and limited, if any, growth.[9] For practical reasons, conventional feeding systems often deliver identical volumes of milk to all calves on a farm despite variations in body weight. With equal allocation of milk, the lightest calves may do well while the heaviest calves suffer. The origins of limit-feeding of milk may have been from research showing this practice stimulates greater intakes of grain at a younger age and from economists advising producers to limit costs (e.g., milk vs grain) in calf rearing. Historically, early milk replacers contained plant proteins that caused diarrhea because they were either poorly digested or irritated the intestinal tract. To decrease the unwanted effects, smaller quantities of powder were recommended and the view that "too much powder causes scours" persists to this day.

High quality all-milk-source powders are being used successfully for enhanced conventional feeding by many producers. They are mixing milk replacer at 15% solids, feeding eight to 10 litres per day to Holstein calves during the first month, providing three meals per day, and using nipples rather than buckets.

Accelerated Feeding

Accelerated feeding has been described as biologically normal growth, optimum growth, enhanced feeding, or enhanced early nutrition.[9]

Milk replacers formulated specifically for accelerated feeding programs may contain 26 to 30% crude protein and 15 to 20% fat. The mixing ratio is often 17% solids. Typical feeding guidelines for large-breed heifers include: two to 2.5 litres per feeding (twice a day) for week one, three to 3.5 litres per feeding (twice a day) from week two to weaning, maintaining the volume as the calf grows, and feeding three to 3.5 litres once a day for the week of weaning to stimulate starter intake. The system specifies availability of water at all times starting at day two. This advice may be due to the concentration of the mixing ratio and the restricted volumes.

Accelerated feeding systems may meet the nutritional needs for biological growth for the majority of calves on a farm. However, the system may not meet requirements for optimum growth for the heaviest calves. As presented above, accelerated feeding may not meet a calf's needs for inter-meal intervals, suckling minutes, meals per day, or volume per meal.

Mob Feeding

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) or classic accelerated 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.

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 ad libitum 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 fed in ways that mimic nature. No doubt they also are looking for methods to decrease labor.

Free-access feeding includes the principles of enhanced biological growth and normal suckling activity. Producers use whole milk, conventional milk replacer or accelerated milk replacer for ad libitum feeding. Nipples may be attached directly to the reservoirs or remotely from the containers of milk. Free access feeding with automated feeders provides the technology to monitor daily intakes by individual calves. Seasonal adjustments to mixing ratios for cold weather are not needed with ad libitum feeding. With continuous availability of milk, producers provide one or more nipples per group. Since feeding clusters around early morning and evening hours, nipple bars provide access to more calves at one time than a single nipple. The capacity of the milk reservoir varies with the number of calves and the setup of the system. Volumes vary from 20 to 1000 litres on Canadian farms. Some systems have a milk line to transport milk from the reservoir to groups in several pens within a barn. A peristaltic pump has been successful at circulating the milk with minimal foaming.

Unpreserved milk may be a hazard in ad libitum feeding because of rapid proliferation of bacteria. In Finland, other Nordic and European countries, and Canada, producers feed milk preserved with formic acid to groups of calves.[2,34] With preservation, milk may be kept at ambient temperatures. In cold housing during winter months, producers adopt innovative ways to keep the chill off the milk. Milk-line systems often have a reverse flow heat exchanger. On smaller farms, producers may enclose their reservoir (e.g., a 200-litre barrel) in a warm box or room.

Automated Feeders

An automated feeder will mix and dispense milk replacer to individual calves housed in groups. It may be programmed to feed calves for restricted, accelerated, or ad libitum feeding.[4] Milk may be delivered according to pre-programmed feeding curves or adjusted manually. Some allow feeding both milk replacer and whole milk. 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. Water measuring, temperature recording, cleaning, and calibration of powder, milk and water may be automatic features. Some feeders have options to dispense medications or weigh calves at the feeding station. 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. Mixing ratio for the powder, volume per meal, and meals per day can be programmed into the memory.

Daily Allowance, Meal Size, and Flow Rate Affect Feeding Behavior

Unwanted behaviors at a feeding station may be due to the number of calves per nipple, daily milk allowance, meal size, or flow rate.[16,17,18,20,25,26] Calves may loiter in the station, suckling but not receiving milk, and blocking the entrance to calves eligible to suckle. Unrewarded visits happen when hungry calves return but find they are not eligible for a feeding. Unrewarded visits may be reduced by reprogramming the computer to offer more milk per day or per meal. Prolonged time in the feeder also may be due to low flow rate of the milk. When calves are offered a high milk allowance without restrictions on automated feeders, their suckling patterns are similar to natural suckling. With ad libitum feeding, calves suckle a greater volume per meal and fewer meals per day as they get older. Producers often program automated feeders to deliver 1.4 to 2.5 litres per feeding. In general, newborn Holstein calves feel satiated after suckling two litres of milk. Therefore, an automated feeder should be programmed to deliver two litres per meal to assure that calves feel satisfied and to avoid lineups at feeding stations.

Training Calves to Automated Feeders or Ad Libitum Feeding

Strong suckling ability should be the decisive factor for introduction of a calf to an automated or ad libitum feeder. 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 10-14 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.[19] Contrastingly, with free-access acidified milk feeding systems, Ontario producers often introduce their calves at two to four days of age, and some during their first day for acidified colostrum. These producers want their calves to bond to the nipple barrel or teat bar and not to someone hand feeding with nipple bottles. A similar practice has been adopted by farmers with automated feeders.

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, the calves are released into the main pen.

Tutor calves assist with training of new entries to automated or free access feeders. A tutor calf is already trained to the system and new entries follow it to the nipples. A nipple bar may facilitate tutoring compared to feeding stations with access for a single calf. An automated feeder may have a pump to assure milk is at the nipple when calves are being trained to the machine. Some caregivers feed two litres by nipple bottle prior to introducing a calf to the feeder. Others find that training is easier and quicker when a calf is hungry upon entry.

Data about colostrum, bottle and automated feeding 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 farm calves were becoming very unthrifty shortly after introduction to an automated feeder. Bottle feeding was a generous eight litres per day divided into three meals prior to moving calves at 21 days of age to an automated feeder programmed for five litres per day. The calves experienced two stressors at the transition – commingling in groups and a substantial abrupt decrease of three litres per day in daily milk allowance.

Contrarians disagree with existing recommendations for age at introduction to automated feeders. At an Ontario farm, the owners invested in an automated feeder and took full advantage of its labor 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 (Figure 3).

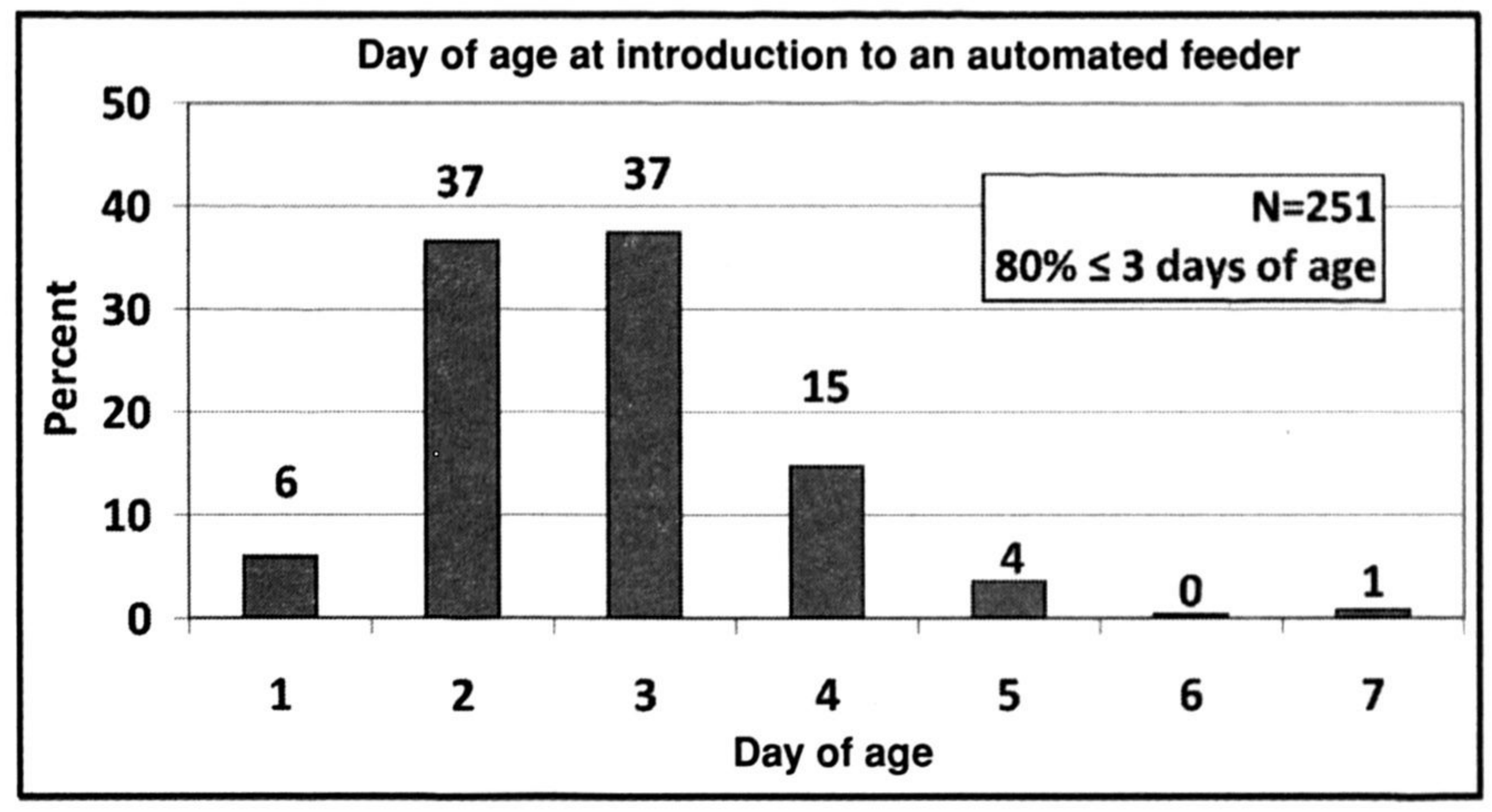

Figure 3. The distribution of day of age at introduction to an automatic feeder for calves on a commercial dairy.

Stockmanship and Management Alerts

There's such an element of uncertainty associated with mob or ad libitum feeding that producers may be reluctant to abandon the comfort of knowing that a calf drank the contents of a bottle or bucket. Stockmanship is an important attribute for those using automated feeding systems. With many ad libitum systems, we need to observe calves to know that they have suckled. A slightly pendulous abdomen indicates that a calf has consumed milk whereas a tucked-up abdomen shows that it has no fill and may not have suckled. A bawling calf may be telling us that an automated feeder isn't functioning or that it has not gone for meals. For sure, the contented behavior of well-fed calves differs from that of hungry calves and the calf barn should be much quieter.

An automated feeder may assist with identification of sick calves[5,31] and provide greater comfort than mob feeding because of records and alert lists. Volume consumed per day, drinking speed or partial meals are records that operators use to alert them to examine a calf. Drinking speed is a unique characteristic for an individual calf and it may give an early alert to sickness. Similarly, a calf may not suckle the entire volume that it was offered at a meal. Calves appear on an alert list when their intake or drinking speed varies from a predetermined tolerance.

Biosecurity and Cleanliness

Suckling is a messy, slobbery activity because of the production of lots of saliva. Surfaces around and below the nipple may become covered in saliva and spilled milk. Floor drains and water hoses at feeding stations make cleaning and disinfection of feeding stations an easy and timely chore. Slobber cups, pig slats, and sloped floors are useful design features. It's common for good caretakers to clean and disinfect these areas daily. Slobbered milk is very attractive to cats, rodents, and flies.

Milk lines and mixing bowls may be contaminated with bacteria and there have been anecdotal reports of extremely high bacteria counts in these parts of the machine. Cleaning involves the use of detergents, acid and alkaline cleaners, and sanitizers. The milk line to a nipple may complete a loop or form a dead-end depending upon the manufacturer of the machine. The loop sys-

Figure 4. Cleaning a feeding station is easier with a water hose, sloped floors, floor drains, pig slats, and slobber cups. Plastic milk lines and nipples need routine cleaning and replacement.

tem may have some advantages for automatic cleaning. With milk hoses dead-ending to a nipple, hoses need to be removed and cleaned daily. Since plastic hose is readily available and inexpensive, some producers replace the milk line after each group of calves. Mixing bowls and floats need equal attention for cleaning and sanitation. Automated feeders have cleaning cycles as standard features. The operator needs to keep detergents and sanitizers in the dispensers and for some machines, hand clean a few parts. Free-access acidified milk systems require regular cleaning. Proper acidification prevents the formation of slimes in the lines. However, reservoirs need a good cleaning on a regular schedule.

Disease may spread between calves by means of contaminated nipples. The hazard may be greater with whole milk than with milk replacer. There is scant information to quantify the risk.

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

Checking the Mixing Ratio for Automated Calf Feeders

When investigating sickness or poor performance of calves fed by automated feeders, a check of the mixing ratio of milk replacer powder (weight) to water (weight) should be part of the examination. A check of the mixing ratio should not be confused with calibration of the machine as described in an owner's manual. Extremes of 90 grams per litre (10% w/w) (too little powder) to 215 grams per litre (21.5% w/w) (too much powder) have been found when checking mixing ratios. It's more common to find that automated feeders prepare mixes close to those of the programming.

The equipment list for the job includes paper plates, plastic measuring cups, a gram scale, a pocket thermometer (23° to 122°F; -5° to 50°C), pen, paper, and calculator.

With the owner's help, I follow these steps.

1. Look at the most recent date and calibrations for water (L), powder (g) and temperature (°C) on the operating panel display. Record the data. (i.e., show me what the machine is programmed to do.)
2. Empty the mixing bowl.
3. Prepare four mixes. Each time, catch the powder onto a paper plate before it dumps into the mixing bowl and empty the water into your measuring cup. Weigh the powder in grams, weigh the water in grams and note the temperature. Record your findings (i.e., show me what the machine is doing).
4. Calculate the ratio of grams of powder to grams of water. Compare your findings to the programming and the targets for milk replacer preparation. For example, if the average of your four mixes was 120 grams of powder and 800 grams of water, the mixing ratio would be 120/800 x 100 = 15% on a weight-per-weight basis.

When ratios are outside the mixing goals, you may need to re-program the computer or look for problems using the troubleshooting section in the owner's manual as a guide. For most automated feeders, water and powder may be dispensed by time. Moisture could combine with powder to form a gummy obstruction that prevents powder from flowing from the outlet. The float rod or float also may be gummed-up with sticky powder, or the float may have been installed upside down. These faults could alter the filling level of water in the mixing bowl. Dirty in-line water filters or low water pressure could alter the volume of water delivered to the bowl in the time programmed into the computer. If so, clean the powder discharge orifice, float rods, floats, or replace the filters and re-check the mixing ratio. Since milk replacers vary in flowability, the mixing ratio should be checked when switching to a different milk powder. Simple maintenance items should be checked before reprogramming the computer or calling the service technician. For veterinarians, the mixing ratio may be an important item on a checklist during an investigation of sick or poor-performing calves fed by automated feeders.

Water, Grain, and Forage

Guidelines for classic accelerated feeding specify free-choice water starting at two days of age. Acting on this advice is difficult with hutch rearing in winter because the water freezes. Heated water bowls make implementation easy in cold housing with various milk delivery systems. Calves using a free-access acidified milk system drink scant amounts of water until weaning, when water intake increases rapidly upon withdrawal of milk.[15]

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.[29] 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.[21]

Ad Libitum Feeding with an Automated Feeder

An automatic feeder allows calves to show us how much milk they want or need when it is programmed for ad libitum feeding. They tell us clearly that their wants and needs vary among calves and that they want more than offered conventionally.

From summer 2009 to spring 2011, we recorded daily milk replacer intake for Holstein heifer calves for 16 days after introduction to an Urban® automatic calf feeder that was programmed to mimic 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 powder into 1000 grams water). From entry to the start of weaning, the machine provided each calf a maximum of 12 litres per day and a maximum volume of two litres per meal. As described earlier in this paper, 80% of the calves were three days of age or younger upon admission to the feeder. 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 more than 240 calves to date.

Figure 5 shows a linear increase in average daily milk replacer consumption from 4.9 litres per day at three days of age to 9.4 litres per day at 17 days of age. In this 14-day period, the calves increased their intakes by 4.5 litres or about 320 mL per day. Consumption increased an average of 1.2 litres 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 6.8 to 8.7 litres.

Although not shown, the medians at each age were similar to the averages. The median is the midpoint, and indicates that half the calves drank more than and half drank less than the data show. Our study calves stepped up their intakes quicker to greater volumes than historical recommendations for programming automated feeders (Figure 6).

Ad Libitum Intakes Compared to Automated Feeder Programming

As shown in Figure 6, automated feeders have been programmed to provide calves a fixed volume (e.g., 4.4 litres per day) during the first 10 days on the feeder, then a gradual increase (e.g., 250 mL per day) over about a week to a standard quantity (e.g., six litres per day) for a 30-35 day feeding interval, and then a gradual decrease (e.g., 0.4 litres per day) for a 14-day weaning period. The programming differs from the average ad libitum intakes shown in Figure 5. For example, the computer programming provides less volume at each age, smaller daily increases, and less volume per day during the feeding period than the averages for our calves on ad libitum feeding.

Ad Libitum Intakes Compared to Milk Replacer Labels

Milk replacer labels provide mixing ratios, volume per feeding, and feedings per day for calves in age ranges. Label recommendations vary amongst companies and formulations. In the past, calves were fed about 112 grams of powder per litre of water for a total of four litres per day. This was approximately 1% of their body weight as milk powder. New mixing and feeding guidelines are appearing on labels of many milk replacers. The new standard recommends that calves be fed 2.0% of their body weight as milk replacer powder, that mixing ratios be 15% solids for moderate and high protein milk replacers, and that calves be fed greater

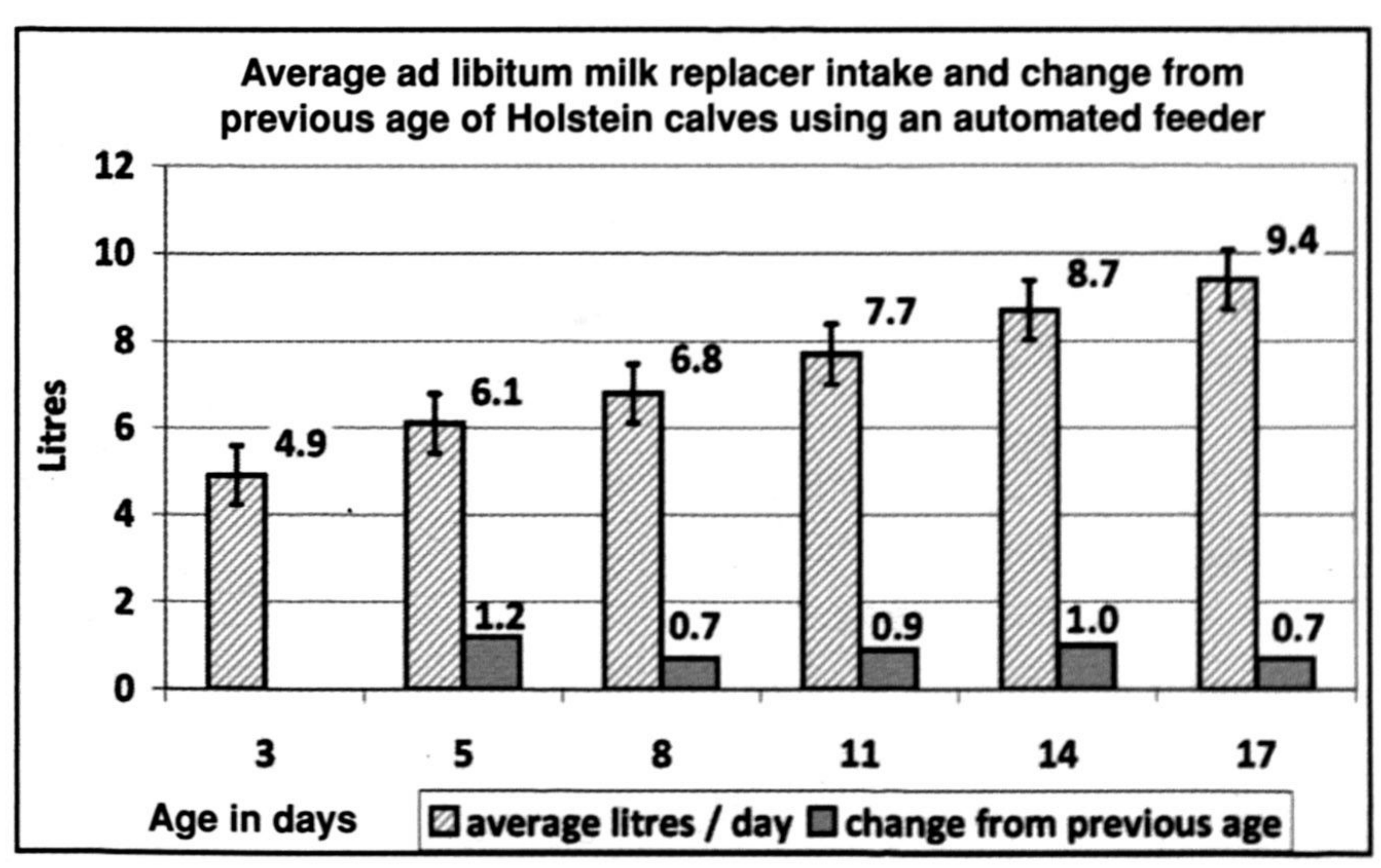

Figure 5. Average ad libitum daily milk replacer intake (L) and change from the previous age.

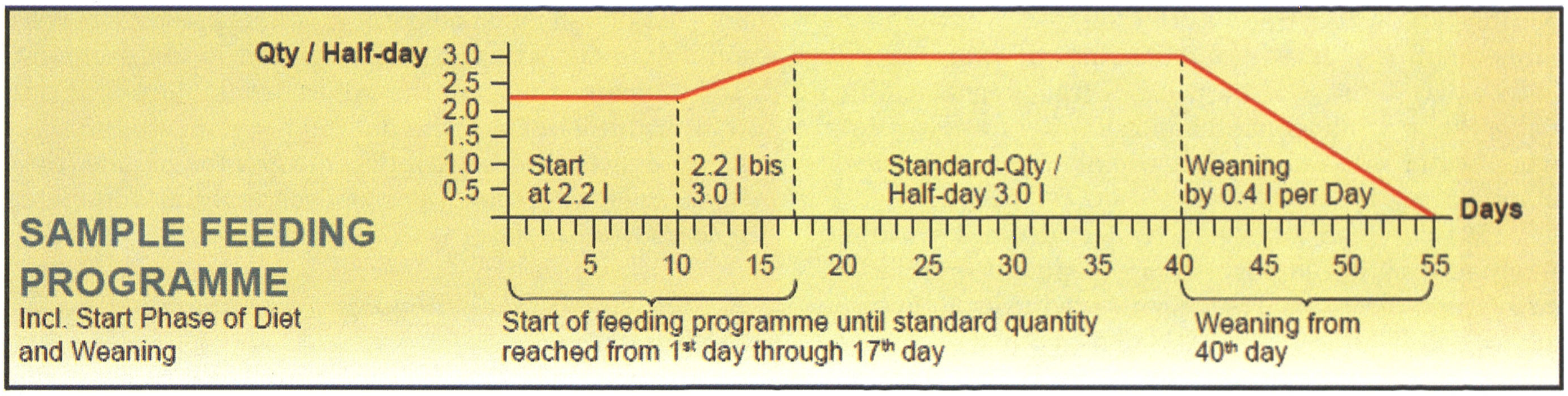

Figure 6. Sample feeding program for an automated feeder. (http://www.holm-laue.de)

volumes per day. Examples of the new mixing and feeding guidelines appear in Table 1 along with ad libitum intakes for calves using an automated feeder with the 20% P:15% F milk replacer (MR).

Generally, calves fed at 15% solids gain faster, grow taller, and use their nutrients more efficiently than calves fed at less or greater solids concentrations. In addition to distension of the forestomachs with milk (volume), a desire for a certain caloric intake may regulate nutrient intake. At the same mixing ratio of solids to water, calves may suckle more or less volume depending upon the concentration of protein or calories in the powder.[27] Although Table 1 requires a bit of study, comparisons of volume, grams of dry matter or grams of protein may be of interest.

Ad Libitum Automated Feeding – Variation in Daily Intakes

Although nutrient requirements vary by body weight or ambient temperature, it's established practice with conventional feeding to give all calves the same volume of milk. Some interpret the new feeding guidelines as two percent of birth weight and feed calves 8-10 litres per day from three days of age until the start of weaning. Ad libitum feeders allow calves to suckle to their needs and allow calves to use their inborn computer to adjust their daily intake.

Six graphs (Figure 7) show the variations in milk replacer intake for calves at three, five, eight, 11, 14, and 17 days of age. Each of the 12 columns represents an intake volume per day in one-litre increments from one to 12 litres. The column height indicates the percentage of calves in the age group that consumed that amount of milk replacer.

Scan the graphs starting at the top for three-day-olds to the bottom graph for 17-day-olds. You see a shift of the tallest columns in each graph from less milk on the left to more milk intake on the right with increasing age.

The variation for three-day-olds may be attributed to time spent by more than half the calves learning to use the feeder. For eight-day-old calves, the graph has a bell curve distribution with an average of 6.8 litres per day, and a median, or mid-point, of 6.7 litres.

For 11-, 14- and 17-day-old calves, there is a noticeable shift to the right, or more volume, for a greater percentage of calves. At 17 days old, >50% of our calves suckled 10 litres or more per day.

The Urban feeder[a] let us mimic free-choice feeding. Overall, calves in our study drank milk replacer to

Table 1. Comparison of feeding guides for an accelerated milk replacer (MR) and a 20:15 milk replacer to ad libitum 20:15 milk replacer intakes (average and 75th percentile).

	Accelerated MR 26%P, 18%F, 150 g/L feeding guide			Milk replacer - 20%P, 15%F, 150 g/L — Ad libitum – automated feeder: Average intake			75th percentile			Feeding guide		
Age (days)	L/d	g MR	g Prot	L/d	g MR	g Prot	L/d	g MR	g Prot	L/d	g MR	g Prot
3	6	900	234	4.9	750	150	6.1	915	183	4.5	563	113
5	6	900	234	6.1	900	180	7.8	1125	225	6	900	180
8	7	1050	273	6.8	1050	210	8.6	1290	254	6-8	9-1200	180-240
11	7	1050	273	7.7	1200	240	9	1350	270	6-8	9-1200	180-240
14	7	1050	273	8.8	1350	270	10.5	1575	315	6-8	9-1200	180-240
17	7	1050	273	9.4	1425	285	11.7	1755	351	6-8	9-1200	180-240

meet their individual needs within our imposed 12-litre-per-day limit. Their intakes were considerably greater than volumes that would have been available had they been fed according to biological feeding guidelines accompanying the automated feeder. Over our observation time, average intake was about 8.4 litres per day or 2.8 lb (1260 g) of powder per day.

Intuitively, the smallest calves probably drank less than the heaviest calves. Clearly, the variation of intakes shows that fixed-volume feeding may not satisfy a majority of calves. On this ad libitum automated feeding system, our study calves consumed greater volumes of milk than the six litres per day fed previously in the hutch system. In addition, they suckled greater volumes of milk than suggested by the feeding guidelines on the milk replacer tag of 4 to 6 litres per day for milk replacer mixed at 13% on a weight-to-weight basis.

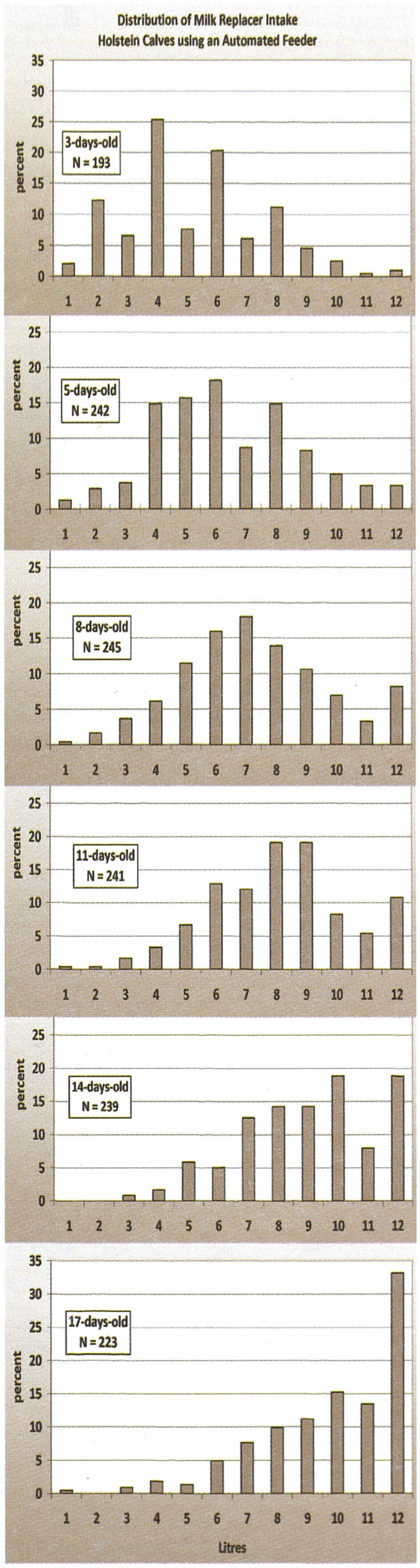

Figure 7. The distribution of daily milk replacer intake (L) by Holstein calves at six ages when fed ad libitum by an automated feeder.

Group Size and Pens

Small groups of six to 12 calves are being recommended to minimize disease, to achieve good weight gains, and to assure satisfactory social behavior.[30] 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. To maintain stable groups, Ontario producers choose group sizes in proportion to their herd size. Producers using free-access acidified milk systems report a preference for six to eight calves in a group.

Advice from researchers is at odds with the recommendations from manufacturers of automated feeders that 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.

Four pens seem to be practical for managing calves in groups. 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.

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 are used to wean calves from 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 milk 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 is often 14 days.

With ad libitum and accelerated 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.

Producers rearing calves with free-access acidified milk use one of the three weaning strategies. 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.

Automated feeders are marvellous machines for precision implementation of 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.[32]

Accelerated Feeding Nipples

Nipples may provide gratification, frustration or a hazard to milk-fed calves. Therefore, nipples merit careful inspection during our investigations.

Peach Teats®[b] 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 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.

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 accelerates calf feeding by reducing suckling time. 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. On the contrary, queues may happen when calves are hungry. 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.

Conclusions

Accelerated milk-feeding includes greater daily intakes (e.g., dry matter, nutrients, and volumes) compared to conventional restricted feeding. Accelerated colostrum-feeding (rapid overfilling of the forestomachs)

Figure 8. 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.

may be so common that we have become desensitized to the physical or metabolic harm that it does to calves. Enhanced early nutrition may lessen the importance of FPT and hasten a return to practical and safe volumes for colostrum feeding. New mixing and feeding guidelines for milk replacers recommend that calves be fed 2.0% of their body weight as milk replacer powder, that mixing ratios be 15% solids for moderate- and high-protein milk replacers, and that calves be fed greater volumes per day. In addition to nutrients, feed delivery systems that mimic Nature's way of suckling enhance a calf's feeding experience. Feeding systems for preserved milk allow calves free access to simulate normal suckling patterns and to attain normal biological growth. For preserved milk, the systems may be simple barrels with nipples or milk lines with gravity flow or pump assist. Automated feeders may be programmed for restrictive, accelerated or ad libitum feeding. In general, automated feeders require enhanced management skills compared to conventional feeding systems. Automated feeders provide easy access to useful records and may be programmed for gradual weaning.

Endnotes

[a]Urban GmbH & Co. Wüsting, Germany

[b]Peach Teats. Skellerup Industries Limited, Christchurch, NZ

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