Appendix H
Management of Whole Milk, Waste Milk, Pasteurized Milk, Acidified Milk and Combinations

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I. Feeding Pasteurized Milk to Dairy Calves – BAMN
IV. Calf Note #148 – Supplementing waste milk – CalfNotes.com
V. Keys to Successful Free-Access feeding of Milk Acidified with Formic Acid – Calving Ease

I. A BAMN Publication – Feeding Pasteurized Milk to Dairy Calves
This guide is published by the Bovine Alliance on Management and Nutrition (BAMN), which is comprised of representatives from the American Association of Bovine Practitioners (AABP), American Dairy Science Association (ADSA), American Feed Industry Association (AFIA), and United States Department of Agriculture (USDA). The BAMN group is charged with developing timely information for cattle producers regarding management and nutritional practices.

Common liquid feeding programs include commercial milk replacer, saleable whole milk and non-saleable (waste) milk. Non-saleable milk typically includes transition milk from the first six milkings, abnormal milk and milk from treated cows. Factors to consider when selecting a liquid feeding program include 1) targets for nutrient intake in relation to goals, 2) ease of managing the program, 3) economics and 4) potential disease risks. An important risk associated with feeding raw milk is the potential exposure to pathogenic bacteria such as *Mycobacterium paratuberculosis*–the bacterium causing Johne’s disease, *Salmonella* spp., *Mycoplasma* spp., and *Escherichia coli*. Some pathogens may be introduced directly from an infected udder, while others are introduced through manure contamination or bacterial growth in milk improperly collected, stored or handled. Because of these concerns, it is often recommended that producers avoid feeding raw (saleable or non-saleable) milk to calves. Two alternatives include feeding commercial milk replacer or pasteurized milk. The objective of this paper is to discuss some of the potential benefits and disadvantages of feeding pasteurized milk, as compared to traditional milk replacer. A companion BAMN paper “Managing a pasteurizer system for feeding milk to calves” discusses the management of a pasteurizer feeding system.

**Milk Replacer Feeding Programs**
In 2007, milk replacer was fed on approximately 70% of U.S. dairy farms (USDA, 2007). When properly mixed, handled and delivered, high quality milk replacers provide several benefits including consistency of product, ease and flexibility of storage and management, infectious disease control and good calf performance. However, milk replacers are not sterile and can become contaminated and support bacterial growth. Also, the quality and price of milk replacer programs can vary significantly due to factors such as ingredient quality, manufacturing techniques and nutritional composition. More information on milk replacers can be found in other BAMN publications at http://nahms.aphis.usda.gov.

**Pasteurized Milk Feeding Programs**
Pasteurized milk is an economical and highly nutritious liquid feed for calves. Pasteurization reduces or eliminates disease-causing bacteria by achieving a selected temperature for a defined period of time. In 2007, pasteurized milk was fed on 2.8% of U.S. dairy farms: 28.7% of large operations (500 or more cows), 3.0% of medium operations (100-499 cows) and 1.0% of small operations (fewer than 100 cows) (USDA, 2007).

**Benefits of Feeding Pasteurized Milk**
*Reduced bacterial transmission in pasteurized vs. raw milk.* Bacterial counts in raw milk are variable
and can be extremely high. Studies from 51 farms in 4 states had total bacteria counts in raw non-saleable from 0 to 1 billion bacteria per ml of milk (Table 1). Laboratory and on-farm studies have reported that both batch and continuous-flow pasteurization techniques are effective in significantly reducing or eliminating disease-causing bacteria. In on-farm studies, pasteurization reduced or eliminated bacteria counts in non-saleable milk by 98 to 99% (Table 1). One field study of 300 calves reported lower rates of illness and death loss as well as improved rates of weight gain in preweaned calves fed pasteurized colostrum and pasteurized non-saleable milk, as compared to calves fed raw colostrum and raw non-saleable milk (Jamaluddin et al., 1996). These benefits were attributed to reduced bacterial exposure.

**Improved rate of weight gain for calves fed pasteurized milk vs. traditional milk replacers.** On a dry matter basis, whole milk has higher concentrations of protein and fat (25.4 and 30.8%, respectively) compared to traditional milk protein-based milk replacers in which protein concentrations range from 18 to 20% and fat concentrations range from 15 to 20% (NRC, 2001). Thus, when fed on an equal volume basis (traditionally 2 quarts a day), a milk-fed calf is expected to have a higher rate of gain than a calf fed milk replacer (Table 2). The impact on calf growth of this nutrient intake difference was demonstrated in a 10-month study of 438 Minnesota dairy calves in which calves were fed on an equal volume basis either pasteurized non-saleable milk or a commercial 20:20 milk-protein based milk replacer (Godden et al., 2005). Calves in the study fed pasteurized non-saleable milk gained 1.0 pounds a day and calves fed 20:20 milk replacer gained 0.77 pound per day (Table 3). However, daily gains should be equal if the level of nutrient intake in the milk replacer diet were increased to match that of a milk diet (Scott et al., 2006). Since 2000, commercial milk replacers containing higher levels of nutrients more similar to milk have become available.

**Improved health for calves fed pasteurized milk vs. traditional milk replacers.** Meeting nutritional requirements is essential for adequate immune system function and calf health (Pollock et al., 1994). The impact of nutrient intake differences on health was demonstrated in Minnesota dairy calves fed either pasteurized non-saleable milk or a commercial 20:20 milk replacer (Godden et al., 2005) (Table 3). Improved health in milk-fed calves was primarily attributed to higher levels of nutrient intake. Additionally, immunoglobulins and non-specific immune factors found in milk (e.g. interferons, cytokines, growth factors, hormones, lactoferrin and lysozyme) also promote calf health (Nonnecke et al., 2003).

**Economic efficiency and disposal of a waste product.** Between 5 and 22 pounds of non-saleable milk per calf per day is produced on dairy operations (Scott, 2006). Using this milk as feed for calves allows producers to avoid potential economic loss, disposal challenges and environmental concerns. When considering fixed and variable feeding costs, improved rates of gain, reduced treatment costs, and reduced preweaning death loss, a partial budget model estimated a $34 per calf advantage at weaning for calves fed pasteurized non-saleable milk as compared to calves fed a 20:20 milk replacer (Godden et al., 2005). Economic results will vary from farm-to-farm depending on fixed and variable costs of the feeding program, calf health, and other factors.

**Toxin concerns in mastitic milk.** One concern of feeding mastitic milk mixed with non-saleable milk is whether bacterial toxins are harmful to calves. Most bacterial toxins produced by mastitis pathogens will not survive pasteurization. In addition, many of these toxins are digested in the stomach before reaching the small intestine. Of the common mastitis pathogens, only *Staphylococcus aureus* toxin is known to survive pasteurization. However, even if this toxin is present it should be greatly diluted by milk from other cows. A comprehensive review by Kesler (1981) recommended that mastitic milk not be fed to newborn (day old) calves because their intestines are very permeable to bacteria and toxins. However, the gut barrier is intact in the older calves, preventing the absorption of toxins. This has been verified in studies in other species including mice and pigs. Feeding pasteurized mastitic milk to older calves is probably not a health concern, although grossly abnormal milk should not be fed.

**Disadvantages of Feeding Pasteurized Milk**

**Intensive management.** A pasteurized-milk feeding program requires more intensive management than a milk-replacer feeding program. Producers must research the type of pasteurization system most suited to the farm prior to its purchase and installation. Producers must also create the infrastructure needed to correctly harvest, store and transport both pre- and post-pasteurized milk to avoid contamination and bacterial growth. Finally, requirements for daily use include adhering to protocols of pasteurization, sanitizing equipment, routine equipment maintenance and monitoring of the system.

**Pasteurization failure.** Pasteurization failure can be caused by human error, unclean or malfunctioning equipment, inadequate hot water supply, excessively high bacteria counts in pre-pasteurized milk and recontamination of pasteurized milk. Producers should not pasteurize soured milk because this can result in coagulation (curd formation) and soured milk typically has excessively high bacteria counts. Routine monitoring is necessary so that if pasteurization failure occurs it can be quickly detected and corrected.
Variable supply of non-saleable milk. The supply of non-saleable milk on a farm may not always be adequate to feed all calves. The volume needed will depend on the number of calves raised, volume of milk fed, weaning age, and number of fresh and treated cows in the herd. In addition, large fluctuations occur in the supply of non-saleable milk on some dairies (Figure 1). In a 7 month study of 3 herds, the average volume of non-saleable milk ranged from 6.2 and 22.7 pounds per calf per day (James and Scott, 2006). Producers must have a strategy for periods when non-saleable milk supplies are inadequate. Options include using saleable milk, using milk from high-somatic-cell-count cows, or adding high quality milk replacer to pasteurized milk. Producers often add some milk replacer to pasteurized milk—even when adequate supplies of milk are available—to acclimate calves to the different taste and smell. A final option is to feed pasteurized milk to some calves and high quality milk replacer to other calves. Avoid switching calves from replacer to non-saleable milk or vice versa more than once. Older calves are more tolerant of diet changes than younger calves.

Maintaining consistent nutrient composition. On an as-fed basis, saleable whole bulk-tank milk typically contains 3.17% crude protein and 3.85% crude fat (NRC, 2001). However, because non-saleable milk consists of milk pooled from both fresh and treated cows, some variability in nutrient composition is inevitable. Minnesota studies (Foley and Otterby, 1978) showed that normal day-to-day variation in non-saleable milk composition did not affect the incidence or severity of scouring or overall rates of gain. Studies of Wisconsin and North Carolina dairies reported average protein in non-saleable milk to be 3.4 and 3.5%, respectively, and average fat to be 3.6 and 3.9%, respectively (Jorgenson et al., 2005; James and Scott, 2006).

Antibiotic residues. Pasteurization does not alter the activity of many antibiotics, causing concern that exposing calves to low concentrations of antibiotic residues in non-saleable milk may result in violative meat residues or increased shedding of antimicrobial-resistant bacteria. However, one study conducted under natural feeding conditions showed no increase in antibiotic resistance of intestinal bacteria in calves fed non-saleable milk (Wray et al., 1990).

Summary
When managed correctly, pasteurized milk is an economical and highly nutritious liquid feed for calves. The advantages and disadvantages are summarized below.

Advantages:
1. Reduced disease transmission
2. Improved rate of weight gain
3. Improved calf health
4. Improved economic efficiency
5. Utilization of non-saleable milk

Disadvantages:
1. Intensive management required
2. Failure of pasteurization
3. Inadequate non-saleable milk supply
4. Inconsistent nutrient composition
5. Potential antibiotic residue concerns
Table 1. Mean Bacteria Counts and Ranges in cfu/ml for Raw and Pasteurized Non-Saleable Milk on Commercial U.S. Dairy Farms.

<table>
<thead>
<tr>
<th>States (# farms)</th>
<th>Raw Non-Saleable Milk</th>
<th>Pasteurized Non-Saleable Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Range</td>
</tr>
<tr>
<td>Wisconsin (61)</td>
<td>8.829,000</td>
<td>(6,000 - 72,000,000)</td>
</tr>
<tr>
<td>North Carolina (3)</td>
<td>17,000,000</td>
<td>(300,000 - 1,000,000,000)</td>
</tr>
<tr>
<td>California (10)</td>
<td>1,600,000</td>
<td>(3,000 - 8,900,000)</td>
</tr>
<tr>
<td>New York (7)</td>
<td>82,512</td>
<td>(0 - 1,220,000)</td>
</tr>
</tbody>
</table>

(Jorgensen et al., 2005; Capel et al., 2006; James and Scott, 2006)

Table 2. Estimated Daily Gain for a 100 lb Calf Fed Whole Milk or a Milk Protein-based 20:20 Milk Replacer (Assumes Ambient Temperature of 68.0 °F)

<table>
<thead>
<tr>
<th>Energy Allowable Gain</th>
<th>Protein Allowable Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Replacer – 1 lb/day</td>
<td>0.69 lb/day⁴</td>
</tr>
<tr>
<td>Milk Replacer – 1.0 lb/day</td>
<td>1.10 lb/day⁴</td>
</tr>
<tr>
<td>Whole milk – 1 gallon/day</td>
<td>0.76 lb/day⁴</td>
</tr>
<tr>
<td>Whole milk – 1.5 gallon/day</td>
<td>1.09 lb/day⁴</td>
</tr>
</tbody>
</table>

¹ Gain predicted. Energy is the growth-rate limiting nutrient in this diet.
² Gain predicted. Protein is the growth-rate limiting nutrient in this diet.
(NRC, 2001)

Table 3. Preweeding Growth and Health of Commercial Minnesota Dairy Calves Fed Equal Volumes of Pasteurized Non-Saleable Milk or a Milk Protein-based 20:20 Milk Replacer Diet

<table>
<thead>
<tr>
<th>Pasteurized Non-Saleable Milk Diet</th>
<th>20:20 Milk Replacer Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Gain</td>
<td>1.0 lb/day</td>
</tr>
<tr>
<td>Proportion Treated</td>
<td>11.6 %</td>
</tr>
<tr>
<td>Proportion Died</td>
<td>2.2 %</td>
</tr>
</tbody>
</table>

(Godden et al., 2003)

Figure 1. Daily variation in non-saleable milk supply on one North Carolina dairy

References
II. PRECAUTIONS FOR FEEDING RAW WASTE MILK

Determine the health status of the cows in your herd. Do not feed raw waste milk if the cows are shedding organisms that cause disease, such as Johne’s and bovine viral diarrhea. If you are aware of the disease status of your herd and you and your veterinarian agree, it may be...
acceptable to feed raw milk and limit risk by feeding only milk from test-negative cows. However, the risk remains that you may spread diseases that exist in the herd but are not identified.

- Do not feed waste milk to newborn calves on the first day of life. The intestinal wall is permeable to bacteria that could cause illness.
- House calves fed waste milk individually to prevent them from suckling one another. This should reduce the transmission of infectious microorganisms that cause mastitis. Maintain individual pens for a few weeks after weaning to reduce cross sucking at that time as well.
- Do not feed milk that is excessively bloody or has an unusual appearance since it can contain active pathogens and white blood cells, which are difficult for a calf to digest.
- Feed waste milk to herd replacements or to calves being kept at least eight to twelve weeks after the last feeding of waste milk.
- Use caution when feeding waste milk from antibiotic-treated cows to calves intended for meat production. Antibiotic residues from the milk could be deposited in the calves' tissues.

**PASTEURIZATION**

One strategy to decrease pathogen load and still utilize waste milk is to pasteurize the milk. Pasteurization is a method of exposing milk to elevated temperatures for a period of time as a means of reducing the bacterial contamination. This process kills bacteria that can cause diseases in humans and animals. It is important to note that *pasteurization is not sterilization*. Pasteurized milk still may contain measurable amounts of bacteria. Pasteurizing poor quality milk with a very high concentration of bacteria may allow some viable pathogenic bacteria to survive the pasteurization process. DAS 07-121 Pasteurization of Non-saleable Milk

**Types of pasteurization**

There are two common methods of pasteurizing milk: batch pasteurization and high-temperature, short-time (HTST), continuous flow pasteurization. Standard batch pasteurization is accomplished when a batch (usually a vat or tank) of milk is heated to 145°F (63°C) for 30 minutes. Thereafter, the milk is cooled and can be fed to the calves. Batch pasteurizers should be equipped with an agitator to allow for even heating. There are concerns about the volume of milk to be heated and the time to do it. Very large batches take several hours to reach the desired temperature and there are concerns that some bacteria may become heat resistant, surviving the pasteurization process. The cleaning process of these units is most often done manually. The process of HTST is different. Milk is circulated through a network of heated coils, rapidly heated to 161°F (72°C) and held there for 15 seconds. This type of system is also equipped to automatically cool the milk quickly to feeding or storage temperature. Continuous flow pasteurization is much more rapid than batch pasteurization and offers more opportunities for energy conservation. Continuous flow systems are generally more difficult to clean, requiring a cleaning procedure similar to that used in milking systems, but in many cases the cleaning process can be automated.

**Effectiveness of pasteurization in destroying infectious pathogens**

Pasteurization safely decreases pathogens in all types of milk fed to calves. Stabel (2001) showed that holding milk at 175.5°F (65.5°C) for 30 min is more than adequate to achieve total destruction of *Mycobacterium paratuberculosis*, the bacteria responsible for Johne's disease. Butler et al. (2000) demonstrated that onfarm pasteurization of waste milk held at 149°F (65°C) for 10 min also destroyed common mastitic mycoplasma such as *Mycoplasma bovis*, *M. californicum*, and *M. canadense*. In another study, Stabel et al. (2004) demonstrated that HTST pasteurization is effective in the destruction of *M. paratuberculosis*, *Salmonella* species, and *Mycoplasma* species in waste milk.
III. CONSIDERATIONS FOR USING COMMERCIAL ON-FARM PASTEURIZATION SYSTEMS
Department of Dairy and Animal Science, The Pennsylvania State University

A benefit to on-farm commercial waste milk pasteurizers is that they are becoming relatively easy for users to operate, clean, and maintain. Control systems are simple, easy to understand and installation is not complex. On-farm pasteurizers are relatively small, taking up the space of a small bulk tank. In spite of those advantages, there are several important requirements and issues that producers should evaluate before purchasing, installing and using this technology. Godden et al. (2004) suggests the following installation requirements and considerations for day-to-day use.

Installation requirements
- Hot water heater. Is a new one needed or is a heater self-contained in the unit? Does the existing hot water heater work? (i.e. is the water hot enough?)
- Water supply
- Are there special electrical requirements?
- Space/location; sanitation laws may require that waste milk be stored in a room separate from salable milk
- Drainage requirements
- Purchase and installation costs

Considerations for day-to-day use
- Training farm staff to properly use and clean the equipment
- Time/labor to use and clean equipment
- Cleaning requirements
- Variable costs
- Service. Is the equipment reliable? How quickly can service be provided?
- Moving and storing waste milk before and after pasteurization
- Monitoring performance. Is it working properly?

Handling of pre-pasteurized milk and equipment requirements
When handling large quantities of waste milk, dairy operators need to have the proper equipment. It is recommended to have an adequate container, preferably an used bulk tank to store the waste milk produced daily. This allows pooling of all waste milk sources (mastitis and/or transition milk, excess colostrum, etc.) and reduces the chance of feeding excessive amounts of antibiotic milk in one feeding (Davis and Drackley, 1998). Pooling waste milk in larger quantities also minimizes daily variation in nutrient content of the milk. The bulk tank or container has to be clean and closed to prevent contamination of the prepasteurized milk. If the milk is not to be pasteurized within a few hours of collection, it should be chilled to 45°F or less to prevent fermentation and bacterial growth.
This is very important since a heavy bacterial load in waste milk will not be eliminated completely by pasteurization.

Handling of post-pasteurized milk
Any bacteria surviving the pasteurization process will begin to replicate in the warm medium if the cooling process is delayed. This can occur if the milk is allowed to cool slowly for several hours at ambient temperature or if milk is left to sit at warm ambient temperatures for long periods before being fed. For this reason, pasteurizers should be equipped to rapidly cool the milk to feeding temperature immediately after pasteurization is completed, and producers should try to feed the product soon after pasteurization is complete. If there is to be a delay between pasteurization and feeding, then the milk should be chilled. Post-pasteurization contamination of milk is another important concern. Pasteurized milk should be stored in clean,
closed containers and distributed to calves in clean buckets or bottles. Careful attention must be paid to cleaning and sanitizing buckets, bottles, nipples, etc.

**Cleaning and sanitizing pasteurizers**

With poor cleaning, fat, protein, and inorganic films (minerals) can build up in these systems, interfering with temperature transfer to the milk and serving as a source to inoculate milk with bacteria. Producers should clean this equipment as diligently as they would their own milking system, using procedures similar to common milking system sanitization procedures. One recommended cleaning process (Reynolds, 2002) is as follows: a) Pre-rinse with cold water b) Circulate alkaline detergent rinse to remove fat (1% wt/vol NaOH; 167°F, 30 minutes) c) Rinse with hot water (167°F, 15 minutes) d) Circulate nitric acid rinse to remove protein (0.7% wt/vol; 158°F, 15 minutes) e) Post-rinse with hot water (167°F, 15 minutes) Producers should contact the manufacturers or distributors of commercial on-farm pasteurizers for cleaning instructions that best fit their equipment. Evaluating cleaning can include visual assessment for build-up of residual films plus cultures of pasteurized milk (e.g. standard plate count, total bacteria count, lab pasteurized count).

**Potential problems**

Dairy operations have to consider their supply of waste milk. To be practically effective a dairy operation must have a stable supply of waste milk. A stable supply of waste milk is critically important because the liquid feed fed to calves should not be changed frequently. For smaller herds this is sometimes difficult because days can go by where there is little or no waste milk. In these situations an alternative feed must be available, such as marketable milk from the bulk tank, milk from high somatic cell cows, milk replacer, or a milk extender. Quality control is also an issue that demands constant attention. Milk pasteurizers need to be operated, evaluated, and maintained so a quality product is produced. Milk pasteurizers are also an investment requiring a return on investment. Calves fed pasteurized waste milk may be contaminated with antibiotic residue and as result should not be sold until after the appropriate withholding period. The cost of equipment can be substantial, and the capital cost as well as the cost of managing the process should be carefully evaluated. If your operation does not have the management skill to properly purchase, install and utilize a pasteurizer, then it is important to make this determination prior to making the capital investment. Maybe the greatest challenge with onfarm pasteurization is maintaining the equipment in proper repair and calibration so that the proper time and temperature is achieved consistently.

**Tips for success**

- Monitor pasteurizer function by routinely culturing samples of pasteurized milk.
- Train all employees that will be using the pasteurizer to be sure they understand how to operate the unit and what the concepts of pasteurization are.
- Conduct follow-up training and review for employees.
- Do not pasteurize extremely abnormal milk because nutritional characteristics may be altered.
- If calf death loss occurs, diagnose calf morbidities and mortalities.
- Know how to manually check the temperature of pasteurized milk to ensure proper temperatures are being met.
- Visit other operations successfully using on-farm waste milk pasteurization systems.

**THE BOTTOM LINE**

Pasteurizing waste milk can provide an opportunity to produce a low-cost, highvalue liquid feed for calves, which if managed properly has the potential to substantially reduce the cost of rearing calves. Quality control, routine maintenance, and proper utilization of the waste milk are essential to ensuring the safety of milk for calves. As commercial units come down in price, more dairy operations may find it economical to install a pasteurizer on-farm. The decision process should weigh all of the advantages and disadvantages of milk pasteurization.
IV. Calf Note #148 – Supplementing waste milk

Calf Notes.com

Introduction
Waste milk is a common source of nutrients for preweaned calves. It is cheaper than whole milk, generally available and has few other productive uses. Waste milk has been used to feed calves for many years. Researchers have evaluated the value and risks associated with using waste milk, especially regarding bacterial contamination (Selim and Cullor, 1997) and economics (Jamaluddin et al., 1996; Godden et al., 2005). Several Calf Notes are available that discuss various aspects of waste milk, including Calf Note #8 (Can I use waste milk for my calves?), Calf Note #35 (Risks of using waste milk), Calf Note #98 (What is the true cost of waste milk?), Calf note #110 (Pasteurizing waste milk – an objective study), Calf Note #144 (Milk pasteurization – more is not always better) and Calf Note #146 (Waste milk vs. milk replacer, revisited).

Variation in waste milk solids
Normal whole milk should have approximately the following composition: solids 12.5%; protein 3.2%; fat 3.7%; lactose 4.6%. Of course, content can vary somewhat depending on diet, season and many other factors.

Composition of waste milk can vary from that of normal milk. In a recent study, Moore and coworkers (2009) reported that calf raisers don't always get what they expect in terms of nutrients when they feed waste milk.

A little background
Waste milk used to feed calves on large ranches is collected at dairies and stored until it is collected by the ranch. This usually occurs daily when the ranch workers come to the farm to collect newborn calves. Milk from several farms can be collected, pooled and transported back to the ranch for processing.

Bacteria can grow rapidly in waste milk. Further, the milk may contain mastitis pathogens, fecal coliforms and other infectious agents. Finally, equipment and procedures for handling waste milk may not be cleaned as thoroughly as for saleable milk. Thus, it’s essential that waste milk be pasteurized prior to feeding. Most ranches use pasteurizers as a normal protocol to reduce bacterial counts and improve biosecurity.

Variation in nutrients in waste milk
Moore et al. (2009) found large variation in solids content in waste milk collected at dairies. The solids and somatic cell counts are in Table 1. Six of the samples were between 12.5 and 13%, indicative of normal composition. The other six samples had solids content less than normal milk, indicating that the milk had been diluted to some degree. In the case of samples 8 and 10, the dilution was great – solids of those samples were only 5.1 and 6.7%, respectively.

Why so dilute?
Why would some waste milk have so little solids? The short answer is water. It’s likely that these farms were adding water (probably wash water) to the milk prior to sending it to the calf ranch. Adding water increases volume that can be sold, but decreases the nutrients available to the calf. Note that one sample - #11, actually had solids content greater (though slightly) than that of normal milk. This could be due to inclusion of colostrum in the waste milk, which is thicker (more solids) than milk. First milking colostrum averages about 28% solids (Kehoe et al., 2007).

The bottom line regarding solids is that there is a lot of variation in waste milk. Indeed, waste milk can vary from farm to farm and from day to day. This makes the job of managing incoming waste milk more difficult and can lead to unacceptable variation in calf performance.
The solution to dilution
One approach taken to monitor variation in solids content of incoming waste milk is to use a BRIX refractometer. Refractometers are used to monitor concentration of solutes in a liquid sample; BRIX refractometers monitor solids content of liquids and are widely used in wine, sugar and other industries. In the case of waste milk, a BRIX refractometer can satisfactorily estimate solids in waste milk. Moore et al. (2009) estimated that a standard BRIX refractometer underestimated waste milk solids by about 2 percentage units – i.e., if the BRIX refractometer reported 10% solids, the actual solids in waste milk was about 12%.

Variation in total solids also implies variation in nutrients in waste milk. Table 2 estimates variation in waste milk protein, fat and lactose using the following assumptions (1) when solids content is <12.5%, the waste milk is diluted with water, which contains no nutrients; (2) when solids is >12.5%, waste milk contains colostrum, which contains 27.6% solids, 14.9% protein, 6.7% fat and 2.5% lactose (Kehoe et al., 2007).

We can also use the estimated nutrient content of waste milk using Table 2 to predict nutrient intake and compare that to an “optimal” intake using normal (12.5% solids) milk as a reference.

Comparison to whole milk
If we look at Table 2, we see that waste milk containing 11% solids will be about 2.8% protein, 3.3% fat and 4.0% lactose. Thus, if we feed 11% solids waste milk, we provide only 88% of the dry matter, protein, fat and lactose that calves would receive if fed an equivalent amount of normal milk. Thus, we should supplement the waste milk to increase nutrient content and reduce nutrient variation.

Supplementing waste milk
Many producers utilize calf milk replacer (CMR) to increase the nutrient content of their waste milk. Table 3 shows an example of the changes in nutrients fed when we add 41 lbs of a 20/20 CMR to 300 gallons of waste milk. In this example, milk + CMR provide 283 and 39 lbs of solids, respectively, which exactly matches the solids in 300 gallons of whole milk (322 lb). In addition, the mixture of waste milk + CMR provides 81 lbs of protein and 92 lbs of fat, which are both slightly below the nutrient content of whole milk (82 and 95 lb, respectively). Finally, the amount of lactose in the mix is greater than the lactose in whole milk.

Should we want to provide a more nutritionally complete feed for calves, we need to change the nutrient content of the feed used to supplement waste milk. Table 4 shows that a supplement containing 24% protein, 28% fat and 34.6% lactose will match exactly the nutrient profile of milk containing 12.5% solids. Producers who are interested in getting maximal performance from their calves should consider a formulation with more protein and fat and less lactose than a 20/20 CMR. A 24/28/35 formulation (as in Table 4) will exactly match nutrients needed by calf regardless of the solids content of the waste milk – assuming that the amount is increased to meet solids intake.

The vitamin question
Another consideration when using commercial CMR to supplement waste milk is the amount of vitamins provided. Commercial CMR are formulated to provide at least the NRC requirements for vitamins and minerals, but may not provide the right kind of vitamin and mineral supplementation to properly fortify waste milk. Table 5 shows the vitamin and mineral recommendations for commercial CMR obtained from the 2001 NRC Nutrient Requirements for Dairy Cattle as well as typical composition of vitamins and minerals in whole milk. These values are NOT corrected for dilution effects.

As can be seen from Table 5, the NRC requirements for the calf and vitamin / mineral content of whole differ. Therefore, a specific supplement containing the correct amounts of vitamins and minerals is needed to properly supplement waste milk. Simply using a commercial CMR will not
provide the correct proportions of important vitamins and minerals, particularly when a CMR is added at relatively small amounts per day. In the example Table 3, calves are fed 300 gallons of waste milk plus 41 lbs of CMR. If this milk is fed to 300 calves, the amount of CMR fed per calf is $41 / 300 = 0.14$ lbs/day, or about 10% of a normal feeding of CMR powder. Thus, calves would receive only about 10% of the vitamins normally provided in a CMR. Clearly, using a commercial CMR to supplement waste milk will provide incomplete nutrition to young milk-fed calves.

**What’s being used on the farm**

Producers have a number of options available to supplement waste milk to increase its nutrient content and improve calf growth. There are a few categories of products intended for different purposes.

*Commercial CMR.* As I’ve outlined, though commercial CMR is a common way to increase the solids content of waste milk, it is not optimal. A standard 20/20 CMR contains too little protein, fat, vitamins and minerals and too much lactose to optimally supplement waste milk. However, CMR is widely available, easy to use and is recommended by many dairy professionals.

*Vitamin supplements.* Some commercial products are available to increase the vitamin / mineral content of waste milk. These products are fed at a rate of a few grams per day and do not increase solids, fat or protein.

*Protein supplements.* Some producers add CMR plus additional protein to increase both the solids and protein content of waste milk. Proteins sources include whey protein concentrate and spray-dried animal plasma. Adding plasma to waste milk has the advantage of providing functional proteins such as IgG which can help maintain normal intestinal immune function and reduce the risk and severity of diarrhea in young calves.

*Complete supplements.* There are few supplements specifically formulated to supplement waste milk on the farm. A nutritionally complete product would be higher in protein, fat, vitamins and minerals and lower in lactose than a typical CMR. Using the assumptions in this Calf Note, a supplement containing 24% crude protein, 28% fat and 35% lactose plus proper vitamin and mineral supplementation would precisely meet the nutrient requirements of milk-fed calves.

**Summary**

We continue to improve our understanding of the feeds we provide to young calves. Variation in waste milk nutrient content is an important source of variation and can explain at least some of the variation we see in calf growth on the farm. Proper supplementation requires a more sophisticated nutritional approach than simply adding commercial CMR to waste milk. Formulation of products specifically designed for this task will improve our ability to raise calves using waste milk as a nutrient source.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Solids, %</th>
<th>SCC*</th>
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<tbody>
<tr>
<td>1</td>
<td>12.9</td>
<td>2.3</td>
</tr>
<tr>
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<td>3.5</td>
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<td>3</td>
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<td>3.7</td>
</tr>
<tr>
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<td>1.6</td>
</tr>
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<td>11</td>
<td>13.4</td>
<td>1.9</td>
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</tr>
<tr>
<td>AVG</td>
<td>11.2</td>
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Table 1. Waste milk solids and somatic cell (SCC) counts (*million/ml). From: Moore et al., 2009.

<table>
<thead>
<tr>
<th>Solids</th>
<th>Protein</th>
<th>Fat</th>
<th>Lactose</th>
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<tr>
<td></td>
<td>Liquid</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>DM</td>
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</tr>
<tr>
<td>15.0%</td>
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<td>28.7%</td>
<td>32.2%</td>
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<tr>
<td>14.0%</td>
<td>4.0%</td>
<td>4.1%</td>
<td>4.8%</td>
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<tr>
<td></td>
<td>28.4%</td>
<td>29.1%</td>
<td>34.0%</td>
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<td>13.0%</td>
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<td>3.8%</td>
<td>4.7%</td>
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<td></td>
<td>26.5%</td>
<td>29.4%</td>
<td>35.9%</td>
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<td><strong>3.7%</strong></td>
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<td><strong>36.8%</strong></td>
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<td>2.4%</td>
<td>2.9%</td>
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<tr>
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<td>29.6%</td>
<td>36.8%</td>
</tr>
</tbody>
</table>

Table 2. Composition of protein, fat and lactose in waste milk diluted with water (<12.5% solids) or containing colostrum (>12.5% solids).
V. Keys to Successful Free-Access feeding of Milk Acidified with Formic Acid

As a compound regulated by the Federal Food and Drug Administration (FDA) the use of formic acid to acidify milk fed to calves in the USA is not currently permitted or approved use. For alternative compounds see www.atticacows.com, click on Calf Facts, select “Alternative compounds for preserving milk” and “Preservatives and acidifying chemicals for milk.”

1. Start with a good product. Clean, fresh milk with low bacteria count.
2. Start with clean equipment.
3. Prepare it properly. Cooler milk (50°F) acidifies better than warmer milk (over 75°F) and requires less stirring when feeding.
4. Safety First! “Formic acid 85% is hazardous to skin, eyes and lungs. For safety, dilute acid 1 in 10 with water and work with weaker acid. Store acids safely and keep them out of reach of children.” (Anderson, 2006)
5. Always add dilute acid solution to milk. Never add milk to acid. Stirring while adding acid results in a product superior to that when acid is dumped in and then milk is stirred.
6. Remember to allow adequate contact time for the acid to work on bacteria. Depending on bacteria contamination level contact times may vary from 10 hours to 48 hours.
7. Feed cool acidified milk to minimize scours. Acidified milk over 75°F is not recommended. Do not expose milk to sunlight. Stirring 3 to 4 times a day will help maintain a uniform product.
8. A ratio of 1:1 teats-to-calves recommended although 1:3 will work. A high ratio of calves to nipples is likely to result in uneven growth rates among calves.
9. Volume of milk per calf – the first two weeks of life calves may be expected to consume around 10 percent of their live body weight. Calves five to six weeks old may consume in the range of 12 to 15 quarts daily.
10. Group size of 4 to 10 is recommended.
11. Expect well-fed calves to behave differently than calves fed only twice daily. Fewer vocal calves as well as less sucking behavior is normal.
12. If acidified milk pH is kept low (4.0 to 4.5) equipment should be cleaned every three days. However, in practice, longer intervals between cleaning may be satisfactory. If acidified milk pH is higher than 4.5 equipment may need to be cleaned daily.
13. Free access should be provided for both water and calf starter grain. Several detailed documents are available either from your veterinarian or on the Internet. One is a 17-page paper by Dr. Neil Anderson from the Ontario Ministry of Agriculture, Food and Rural Affairs.

<table>
<thead>
<tr>
<th>Solids</th>
<th>Protein</th>
<th>Fat</th>
<th>Lactose</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs</td>
<td>%</td>
<td>lbs</td>
<td>%</td>
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<tr>
<td>Waste milk</td>
<td>2,786</td>
<td>11.0%</td>
<td>283</td>
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<tr>
<td>CMR</td>
<td>41</td>
<td>95.0%</td>
<td>39</td>
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<tr>
<td>Whole milk</td>
<td>2,617</td>
<td>12.3%</td>
<td>322</td>
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<tr>
<td>% of milk</td>
<td>100%</td>
<td>98%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Table 5. Evaluation of nutrient intake when waste milk (11% solids) is supplemented with 41 lbs of a CMR containing 20% protein and 20% fat.
“Mimicking Nature’s Way for Milk- Fed Dairy Calves: Free Access Feeding with Acidified Milk.” In addition to practical guidelines for using acidified milk for feeding this guide also has an extensive reading list. The URL is:
http://www.omafra.gov.on.ca/english/livestock/dairy/facts/grouphousing.htm
Additional resources also by Dr.Anderson with practical advice on setting up to feed acidified product may be found at:
http://www.omafra.gov.on.ca/english/livestock/veal/facts/info_acidic.htm and
and this resource gives directions how to build a warm milk bar box for cold housing:
Sam Leadley, Calf & Heifer Management Specialist sleadley@frontiernet.net www.atticacows.com
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