Pasteurizing Milk and Colostrum

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Introduction

Professional heifer growers and dairy producers are faced with the challenge of raising healthy calves while still paying close attention to rearing costs and profit. Factors that may be considered in selecting a liquid feeding program may include the number of calves fed, economics and cash flow, nutritional characteristics, calf performance targets, resource availability -- for example, consistent supply of non-saleable milk -- infectious disease control concerns, and personal preferences. Feeding raw non-saleable milk represents one way to gain important economic and nutritional efficiencies but can introduce the risk of infectious diseases to dairy calves. The recent introduction of commercial on-farm pasteurization systems offers producers a method for reducing the risk of pathogen transmission and can be a viable economic strategy for feeding dairy calves. However, to be successful, producers must be committed to properly managing and monitoring a pasteurized, non-saleable milk feeding program. This paper will discuss some of the benefits and limitations of feeding pasteurized non-saleable milk; describe commercially available on-farm pasteurization systems and the results of studies feeding pasteurized non-saleable milk; and outline the important considerations needed to successfully adopt and implement a pasteurized, non-saleable milk feeding program. The paper will also discuss special considerations and early research findings surrounding the heat-treatment of colostrum.
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Choosing a liquid feeding program: whole milk or commercial milk replacer?

The choice to feed milk replacer, instead of saleable whole milk, is often an **economic decision**, because the cost associated with feeding a commercial milk replacer is usually lower than that of feeding saleable whole milk. In addition to these economic considerations, today's high quality commercial milk replacer products offer several benefits, including day-to-day consistency, ease and flexibility of storage, mixing and feeding, disease control and good calf performance (Davis and Drackley, 1998; BAMN, 2002).

Despite these advantages, there may be performance benefits for feeding whole milk. It is estimated that a 45-kilogram calf fed 1 gallon per day of whole milk (10% of body weight) would consume approximately 2.97 megacalories of metabolizable energy (ME) per day and be expected to gain 446 grams per day. In contrast, if that same calf were fed 1 pound DM per day of a conventional 20:20 milk replacer, then it would consume only 2.47 megacalories per day and be expected to gain only 289 grams per day (Davis and Drackley, 1998). This advantage in gain is explainable entirely on the basis of improved energy intake. In addition to supporting improved rates of gain, this improved energy intake may also be particularly valuable to the calf during periods of cold stress, when the ambient temperature is less than 50°F, and may also support improved immune function and health of the calf.

Feeding non-saleable, or discard or waste milk is particularly attractive to some producers. Non-saleable milk typically includes transition milk from the first six milkings after calving, as well as discard milk harvested from cows after antibiotic treatment for mastitis or other infectious diseases. Blosser (1979) estimated that 22 to 62 kilograms of milk per cow is discarded each year, representing economic loss, disposal issues and environmental concerns. While the feeding of non-saleable milk would seem to offer tremendous economic efficiencies, producers should be cautious of feeding raw non-saleable milk as it may contain bacterial pathogens such as *Mycobacterium avium* subsp. *paratuberculosis* (the agent causing Johne's disease), *Salmonella* spp., *Mycoplasma* spp., *Listeria monocytogenes*, *Campylobacter* spp., *Mycobacterium bovis*, and *Escherichia coli* (Lovett et al., 1983; Farber et al., 1988; McEwen et al., 1988; Clark et al., 1989; Giles et al., 1989; Streeter et al., 1995; Grant et al., 1996a; Selim and Cullor, 1997; Steele et al., 1997; Walz et al., 1997). Some of these pathogens may be shed directly from an infected mammary gland, while others may result from post-harvest contamination -- for example with manure -- or proliferation in milk that is not stored or chilled properly.

In addition to possible pathogen transmission, another concern with feeding non-saleable milk is the possible harmful effects from endotoxins that may be found in mastitic milk. One early study by Kesler (1981) concluded that it is generally safe to feed mastitic milk or colostrum to calves except for newborn calves, due to concerns about greater permeability of the newborn's intestine to bacteria or toxins.

One additional concern relates to exposure of calves to antibiotic residues that may be found in low concentrations in non-saleable milk, leading to meat residues and, possibly, shedding of antimicrobial-resistant bacteria. Producers feeding calves non-saleable milk that may contain antimicrobial residues will need to assign an appropriate meat-withhold time after weaning, prior to marketing of calves for slaughter. One recent study in which calves were fed milk artificially spiked with varying concentrations of penicillin showed a dose response, with increased shedding of penicillin-resistant bacteria as concentrations of penicillin in milk (Langford et al., 2003). However other studies have shown no obvious increase in antibiotic resistance of intestinal bacteria in calves fed non-saleable milk (Wray et al., 1990). Given growing public concern about antibiotic use in food animals, the practice of feeding non-saleable milk or medicated milk replacers is likely to receive further attention and study in future.

Pasteurizing non-saleable milk to reduce risk of pathogen transmission

Historically, calf raisers have either accepted the infectious disease risks associated with feeding raw, non-saleable milk or have avoided these risks by feeding milk replacer. However the recent introduction of commercial on-farm pasteurization systems now offers producers a solution to allow feeding of non-saleable milk while reducing the risk of disease transmission. Pasteurization is simply a process of heating milk at a target temperature for a given duration of time, resulting in a reduction in the concentration of viable bacterial. However, pasteurization should not be confused with sterilization. Some heat-tolerant -- usually non-pathogenic -- bacteria will survive the process. Additionally, if a poor quality milk that already has a very high concentration of bacteria is pasteurized, then some viable pathogenic bacteria may survive the pasteurization process. The pasteurized milk ordinance (PMO) defines two different methods for pasteurization: batch pasteurization and continuous flow, or flash pasteurization.

Commercial batch pasteurizers are typically the simplest and least expensive. They are comprised of a container, an agitator and, depending on the design, a heated water jacket surrounding the container or a heating element and stirring device submerged in the liquid. Commercial units offer thermostatically controlled automation, which simplifies operation. Milk is heated to the target temperature of 145°F, held there for 30 minutes, and then automatically and rapidly cooled to 100 to 110°F prior to feeding. These systems must be constantly agitated to allow for even heating of the milk. Cleaning of batch systems is usually manual. Batch systems can range in capacity from 1 to over 150 gallons of milk and can also be used for heat-treatment of colostrum. One concern with batch pasteurization is that it may take several hours to heat very large volumes of milk up to the target temperature, for example, more than 75 gallons per batch. In such circumstances, as may be the case with large farms feeding a large number of calves, it may be more efficient to use a larger capacity, continuous flow pasteurizer. While non-automated batch systems can be purchased or built for as little as a few hundred dollars, most automated systems currently cost $5,000 or more, depending on capacity.

Commercial continuous flow pasteurizers have captured a large portion of the market on very large dairies due mainly to speed and automation of processing and cleaning. This equipment is comprised of a plate or tube heat exchanger in which hot water is used to heat milk on the opposite side of a metal plate or tube. Circulating milk is rapidly heated to the target temperature of 161°F and held there for 15 seconds, then rapidly cooled to 110°F prior to discharge and feeding. It is recommended that equipment possess a valve which will divert milk back through the pasteurizer if it has not reached an adequate temperature. These systems are also often called flash pasteurizers or high temperature, short-time (HTST) pasteurizers. Newer HTST systems will have the option of an automated clean-in-place (CIP) wash system. Automated commercial HTST systems can currently be purchased from $9,500 to more than $50,000, depending on capacity.

Studies have reported that both batch and HTST pasteurization is effective in destroying viable bacteria for most of the pathogenic species threatening calves, including *E. coli* 0157:H7, *Salmonella* sp., *Listeria monocytogenes*, and *Staphylococcus aureus*, and *Mycoplasma* sp.(Green et al., 2002; 2003; Butler et al. 2000; Stabel et al., 2003). The ability of pasteurization in destroying *Mycobacterium avium* subsp. *Paratuberculosis* (Map), the organism causing Johne's disease, remains controversial. While a large number of laboratory and on-farm studies have reported that either batch or HTST pasteurization was completely effective in destroying Map (Keswani and Frank, 1998; Grant et al., 1999; Stabel et al. 1996; Stabel 2001; Stabel, 2003), a few researchers using in-lab simulations of HTST pasteurization have reported that small numbers of the organism may survive if the milk is inoculated with high concentrations of the organism (Chiodini and Hermon-Taylor, 1993; Gao et al., 2002; Grant et al., 1996b; Sung and Collins, 1998). It is understood that Johne's-infected cows that may shed the Map organism in the milk typically shed it at very low concentrations. However, if the milk was accidentally contaminated with infective feces during improper harvest or storage procedures, then it could be possible for high concentrations of Map to be found in it. As such, producers should take steps to avoid fecal contamination of non-saleable milk during the harvest, storage, pasteurization or feeding processes.

Calf performance and economics when feeding pasteurized non-saleable milk

To date, only two controlled field studies have been published describing health, performance and economics when feeding pasteurized waste milk to dairy calves. One early study of 300 calves on a large California dairy compared preweaning health, growth and economics of feeding raw colostrum and non-saleable milk versus pasteurized colostrum and non-saleable milk (Jamaluddin et al., 1996). In this study, calves fed the pasteurized feeding non-saleable milk experienced fewer sick days, lower mortality rates, lower costs for health expenditures, higher weaning weights and a higher gross margin ($8.13) per calf at weaning, as compared to calves fed raw, non-saleable milk.

A more recent ten-month study of 438 dairy calves on a Minnesota heifer growing operation compared preweaning health, growth and economics of feeding a conventional 20:20 milk replacer program versus batch pasteurized non-saleable milk (Godden et al., 2005). Calves in both treatment groups were fed equal volumes of liquid feed per day, but volume was adjusted equally in both groups according to ambient temperature: 4 quarts a day, 5 quarts a day and 6 quarts a day if ambient temperature was greater than 24°F, 5 to 24°F, or less than 24°F, respectively. Average daily gain was significantly greater in calves on the pasteurized non-saleable milk program (0.47 kilograms a day) versus calves fed the conventional milk replacer program (0.35 kilograms a day). Also, significantly fewer calves were treated or died on the pasteurized milk program (treatment rate = 12.1%; mortality rate = 2.3%) as compared to calves fed the milk replacer program (treatment rate = 32.1%; mortality rate = 21.0%). The authors reported that improved nutrient intake is one probable explanation for the improved rates of gain and improved health observed in the group of calves fed the pasteurized milk program. A partial budget model estimated a $34-per-calf advantage at weaning -- or breakeven at 23 calves on milk -- for calves fed the pasteurized milk program.

Considerations for successful use of on-farm pasteurization systems

Feeding pasteurized non-saleable milk may offer producers several advantages, including improved rates of gain, improved calf health and economic efficiencies. However, as with any technology, pasteurization systems must be properly managed and maintained or problems can arise. There are several important management requirements that producers should educate themselves about, and plan for, prior to implementing this technology.

1. **Installation requirements**
    1. ***Cost.*** Purchase and installation costs, plus estimated variable costs.
    2. ***Installation support*** from manufacturer or distributor.
    3. ***Hot water.*** Is a water heater self-contained within the unit, or is a separate hot water heater required? If the latter, is there enough hot water with the existing tank to run the pasteurizer, wash the milking system and meet other demands, or is a separate designated hot water heater required?
    4. ***Location*** to house equipment. Note: the PMO will not allow non-saleable milk in the milk house. As such, pasteurization equipment must be housed in a separate location.
    5. ***Water supply, drainage and electrical requirements.***
2. **Considerations for Day-to-Day Use**
    1. ***Maintenance and Service***. Is the equipment reliable? How quickly can service be provided? Is a regular maintenance program provided?
    2. ***Pasteurization procedures***. The manufacturer or distributor should provide effective protocols for pasteurizing milk. Farm staff using the equipment need to be trained to use these protocols and should adhere to them.

3. ***Strategy for inconsistent supply of non-saleable milk***. Depending on the number of fresh and treated cows, the amount of non-salable milk can fluctuate from day-to-day or week-to-week. As such, all farms should have a plan or strategy in the event that an adequate volume of non-salable milk is not available. One option may be to add saleable bulk tank milk or to milk a high- somatic cell count cow into a bucket milker and then add her milk to the non-saleable milk. A second option may be to extend the non-saleable milk, after pasteurization, with a high quality commercial milk replacer. Producers doing this generally suggest adding some milk replacer to the waste milk, even in times when an adequate supply of waste milk is available, so that calves are used to the taste and smell. Yet another option may be to feed pasteurized non-saleable milk to the younger calves, who presumably would benefit most from improved nutrient intake, and then feed older calves a commercial milk replacer feeding program until they are weaned. While there are no published studies to indicate which of these strategies is best, any one of these strategies can be made to work on dairies.

4. ***Handling and storage of raw milk***. Producers need to be aware that pasteurization does not equal sterilization. While a properly functioning pasteurizer can be expected to reduce bacteria counts to very low, or negligible, levels, if the raw milk is initially of high quality, the same cannot be expected if highly contaminated raw milk is processed through the pasteurizer. That is, if raw milk contains excessively high bacteria levels -- more than 1 million colony forming units per milliliter -- then the pasteurizer may not be able to adequately reduce these bacteria counts to acceptable low target levels in the finished product. Garbage in – garbage out! Similarly, if soured or spoiled milk is run through a pasteurizer, the heating process may precipitate cheese-curd formation, resulting in a plugged machine, in the case of an HTST system, and an end product that is unacceptable to feed to calves. Thus, raw milk must be handled in such a way, prior to pasteurization, as to minimize bacterial contamination, proliferation and spoilage during the harvest, transport or storage processes.

   To achieve this goal, producers must first determine where the milk will be coming from and what the likely time interval will be from when the milk is first harvested to when it will be pasteurized and fed. If the milk is to be harvested on the same farm as the calves are located and is to be pasteurized and fed within a couple hours of harvest, then an elaborate transport and chilling system is probably not necessary. However, the raw milk must still be collected and stored in closed, clean containers to prevent bacterial contamination.

   In situations where the milk is to be stored for several hours or days prior to pasteurization and feeding, then the raw milk must be kept chilled to prevent bacterial proliferation and spoiling. In situations where a **professional heifer grower** may be regularly picking up milk from several source dairies, then a system must be developed to chill stored raw milk at the source dairy, transfer and haul it to the heifer site and chill until it is pasteurized and fed.

   If the raw milk has been allowed to sit for any length of time prior to pasteurization and the milk fat has risen to the top, then the last step, prior to pumping the stored milk into the pasteurizer, must be to agitate it well (James et al., 2006). This step will help ensure that the milk fat composition is uniform from feeding-to-feeding and day-to-day. It will be particularly important if only a portion of the raw milk is removed from the raw milk storage tank to pasteurize in any one batch.

   Regular and thorough sanitation of all storage, transfer and transport systems must be a priority to prevent contaminating milk as it is moved through the system. However, producers should avoid flushing the system with water in such a way that the flush water is captured with the raw waste milk. This practice could seriously dilute the solids content of the milk, thus leading to malnutrition and suboptimal calf performance (James et al., 2006).

5. ***Handling of pasteurized milk***. Any bacteria surviving the pasteurization process will begin to replicate again 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 more than a couple hours before being fed. For this reason, all pasteurizers should be equipped to rapidly cool the milk to feeding temperature immediately after pasteurization is completed. Also, producers should try to feed the product soon after pasteurization is complete. If there is to be a significant delay between pasteurization and feeding, then the milk should be chilled in a clean, covered container until it is later reheated to a feeding temperature of 100 to 105 °F and then fed to calves. Again, milk should always be thoroughly mixed prior to feeding to ensure a consistent solids content in what is delivered to the calves (James et al., 2006).

   Recontamination of pasteurized milk is another important concern. Pasteurized milk should be stored in clean, closed receptacles and distributed to calves in clean buckets or bottles. Careful attention must be paid to regularly and thoroughly sanitize all milk holding, transfer and feeding equipment such as buckets, bottles and nipples between every use.

6. ***Monitoring pasteurizer function***. Reasons for the failure of pasteurization equipment to reach the target time and temperature can include improper equipment settings or calibration, equipment malfunction, lack of enough hot water, or human error, for example,turning off the equipment early in order to finish chores. Alternatively, the bacteria counts in the raw milk may be excessively high, resulting in above-target bacteria levels in the finished product, even though the pasteurizer was functioning as it should. Without routine monitoring, the producer will never know if the pasteurization program is working or not.

   Ideally, all pasteurizers should be equipped with a time-temperature control chart to document that the target temperatures and duration are being reached in every batch that is run. At the very minimum, the equipment must be equipped with a temperature sensor and display by which producers can periodically check and monitor times and temperatures on a daily basis. Times and temperatures should be monitored daily.

   On a weekly basis, or at least monthly, producers are also encouraged to submit frozen paired pre- and post-pasteurized milk samples to a local udder health or microbiology laboratory for bacterial culture. The recommended total bacteria count in raw and pasteurized waste milk is less than 1 million colony forming units per milliliter and less than 20,000 colony forming units per milliliter of milk collected directly from the pasteurizer, respectively. If bacteria counts are excessively high in the raw milk, then the sanitation and handling procedures for the raw milk must be investigated. If the bacteria counts in the raw milk are acceptable, but bacteria counts are excessively high in the pasteurized milk, then the producer must investigate the pasteurization process and the possibility of post-pasteurization contamination. Producers should also periodically collect a third milk sample at the location of feeding the calf to determine if significant post-pasteurization recontamination of the milk is occurring. In addition to bacterial cultures, an alternate test that may be performed on pasteurized milk is the Alkaline Phosphatase Test, with a goal of less than 500 mU/ml. Alkaline phosphatase is an enzyme naturally found in milk that is inactivated at approximately the same times and durations used to pasteurize milk (James, 2006). In one recent study of 31 Wisconsin dairy herds, all but 12 percent of the pasteurization systems tested successfully deactivated the alkaline phosphatase enzyme (Jorgensen et al., 2005). Without monitoring, there would have been no way of knowing the 12 percent weren't working.

7. ***Cleaning the Pasteurization System***. With poor cleaning procedures, it is likely that fat, protein and inorganic films can build up in pasteurization systems, interfering with transfer of heat to the milk and serving as a source to further 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. This includes sanitation not only of the pasteurization equipment itself, but also of all collection, storage, transfer or feeding equipment that the milk comes into contact with, both before and after pasteurization. Effective cleaning protocols should be provided by the equipment manufacturer or distributor. Evaluating cleaning can include visual assessment for buildup of residual films, plus performing bacterial cultures of pasteurized milk, for example, standard plate count, total bacteria count and lab pasteurized count.

Heat-treating colostrum

First-milking colostrum is an important source of nutrients and of passively absorbed maternal antibodies, critical to protect the newborn calf against infectious disease in the first weeks and months of life. However, colostrum can also represent one of the earliest potential exposures of dairy calves to infectious agents, including *Mycoplasma* spp., *Mycobacterium paratuberculosis*, fecal coliforms and *Salmonella* spp. (Streeter et al., 1995; Steele et al., 1997; Walz et al., 1997). Bacterial contamination of colostrum is a concern because pathogenic bacteria can act directly to cause diseases such as scours or septicemia. Bacteria in colostrum may also interfere with passive absorption of colostral antibodies into the circulation, reducing passive transfer of immunity in the calf (James et al., 1981: Poulsen et al., 2002).

There has recently been increasing interest in feeding pasteurized colostrum to reduce transmission of infectious pathogens to calves; however, early research on pasteurizing colostrum,using the conventional methods and temperatures to pasteurize milk, yielded less than acceptable results. Pasteurization resulted in mild to severe thickening or congealing of the colostrum, a reduction of up to 32% of immunoglobulin G (IgG) concentration in the colostrum, and lower serum IgG concentrations in calves that were fed pasteurized colostrum (Meylan et al., 1995; Green et al., 2003; Godden et al., 2003; Stabel et al., 2004). It has recently been determined, however, that this problem can be solved by using a lower-temperature, longer-time approach to heat-treat colostrum. In most situations, heat-treating colostrum at 140°F (60°C) for 60 minutes in a commercial batch pasteurizer should be sufficient to maintain IgG concentrations while eliminating important pathogens including *Listeria monocytogenes*, *E. coli*, *Salmonella enteritidis*, and *Map* (McMartin et al, 2006; Godden et al., 2006). A recent field trial showed that when colostrum, heat-treated at 140 F for 60 minutes, was fed to calves, these calves experienced significantly improved efficiency of absorption of colostral antibodies and had significantly higher serum IgG concentrations at 24 hours after birth, as compared to calves fed raw colostrum (Hagman et al., 2006). This benefit is thought to be due to the fact that there were significantly fewer bacteria present in the heat-treated colostrum to interfere with antibody absorption across the gut.

The preliminary results from this study suggest that commercial farms can feed calves colostrum that has been heat-treated using a low-temperature, long-time approach of 140°F for 60 minutes to reduce pathogen exposure while maintaining, or even improving, passive transfer of colostral antibodies. However, producers should understand that a great deal more research needs to be completed before this practice can be widely recommended to the industry. For example, the potential economic and health benefits from adopting this practice on farms have not yet been described. Farms wishing to feed heat-treated colostrum must pay close attention to following factors in order to be successful:

1. Routinely monitor times and temperatures for heat-treatment of colostrum in a batch pasteurizer. Heating to temperatures above 141°F will result in denaturation of IgG.
2. Periodic culture of raw and heat-treated colostrum samples to monitor efficacy of the heat-treatment process, with a goal of less than 20,000 colony forming units per milliliter.
3. Proper cleaning and sanitation of the pasteurizer, colostrum storage and colostrum feeding equipment.
4. Proper handling, storage and refrigeration or freezing of colostrum to prevent bacterial contamination and growth in the raw product and re-contamination in heat-treated colostrum.
5. Routinely monitor health records and passive transfer rates in calves. Using a refractometer method to monitor serum total proteins is an excellent way to do this. More than 90% of calves tested between 24 hours and 7 days of age should have a serum total protein value of 5.0 grams per deciliter or greater.

Summary

Feeding non-saleable milk represents one way to gain important economic and nutritional efficiencies for calf growers but can be a major risk factor for introducing infectious diseases to calves. The recent introduction of on-farm commercial pasteurizers is one method for reducing this risk. This technology has been adopted and used successfully on many farms. Early studies have shown significant health, performance and economic advantages to feeding pasteurized, non-saleable milk as compared to raw, non-saleable milk or a conventional milk replacer feeding program. However, in order to be successful, producers must pay careful attention to the pasteurized milk feeding program. This includes careful handling of pre- and post-pasteurized milk to prevent bacterial contamination or proliferation, monitoring of pasteurizer function, and routine cleaning and sanitation of pasteurization equipment, as well as milk collection, storage, transfer, and feeding equipment. Preliminary research suggests that using a low-temperature,long-time approach to heat-treat colostrum can be successful in eliminating important pathogens while preserving important colostral antibodies and improving passive transfer of antibodies in dairy calves. Further studies will be necessary to determine if this low-temperature long-time approach to heat-treatment of colostrum will result in significant health, performance or economic benefits.

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