

Pasteurized Milk and Colostrum Feeding Systems: Capturing the Benefits and Avoiding the Pitfalls

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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 (e.g. 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 this can introduce the risk of infectious diseases to dairy calves. The 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, describe the results of studies with 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.

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 90 lb (41 kg) calf fed 1 gallon/day of whole milk (approx. 10% of body weight) would consume approximately 2.97 Mcal of metabolizable energy (ME) per day and be expected to gain about 1 lb/day. In contrast, if that same calf was fed 1 lb DM per day of a conventional 20:20 milk replacer, then it would consume only 2.47 Mcal ME/day and be expected to gain only 0.64 lb/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 (ambient temperature less than 50°F) and may also support improved immune function and health of the calf.

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Feeding non-saleable (discard or waste) milk is particularly attractive to some producers. Non-saleable milk typically includes transition milk (non-saleable milk from the first 6 milkings after calving), as well as discard milk harvested from cows after antibiotic treatment for mastitis or other infectious diseases. Blosser (1979) estimated that 48 to 136 lb per cow of milk 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; Clarke 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 (e.g., with manure) or proliferation in milk that is not stored/chilled properly.

In addition to possible pathogen transmission, one other concern with feeding non-saleable milk considers 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 that fed calves milk artificially spiked with varying concentrations of penicillin showed a dose response, with increased shedding of penicillin-resistant bacteria as concentrations of penicillin increased 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 the 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 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 is pasteurized that already has a very high concentration of bacteria, then some viable pathogenic bacteria may survive the pasteurization process. The pasteurized milk ordinance (**PMO**) defines 2 different methods for pasteurization: batch pasteurization or continuous flow (flash) pasteurization.

Batch pasteurizers are typically the simplest and least expensive. They are comprised of a balance tank, an agitator and, depending on

the design, a heated water jacket surrounding the container or a heating element and stirring device which is submerged in the liquid. Commercial units offer thermostatically controlled automation, which simplifies operation, and temperature recording charts. Milk is heated to the target temperature (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 gallon to over 150 gallons of milk or greater. One concern with batch pasteurization is that it may take several hours to heat (and later to cool) very large volumes of milk up to the target temperature (e.g., > 150 gallons per batch). In such circumstances, as may be the case with large farms feeding a large number of calves, it may be more time efficient to use multiple batch pasteurizers or move to a larger capacity continuous flow pasteurizer. While small capacity, non-automated batch systems can be purchased or built for as little as a few hundred dollars, most automated systems currently cost \$5,000 to \$10,000, depending on capacity.

Continuous flow pasteurizers, also called flash pasteurizers or high temperature – short time (HTST) pasteurizers, are utilized primarily on very large dairies or large calf ranches due mainly to ability to process very large volumes of milk quickly. 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 (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 milk has not reached an adequate temperature. Most HTST systems will also have the option of an automated clean in place (CIP) wash system. Automated commercial HTST systems can currently be purchased from between

\$20,000 to greater 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. (Butler et al., 2000; Green et al., 2002; Green 2003; 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 (Stabel et al., 1996; Keswani and Frank, 1998; Grant et al., 1999; Stabel, 2001; Stabel et al., 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 very high concentrations of the organism (Chiodini and Hermon-Taylor, 1993; Grant et al., 1996b; Sung and Collins, 1998; Gao et al., 2002). It is understood that Johne's-infected cows that may shed the 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 the milk. As such, producers should take steps to avoid fecal contamination of non-saleable milk during the harvest, storage, pasteurization, or feeding processes.

Using Ultraviolet Radiation to Treat Milk on Farms. While this non-thermal approach to pasteurizing milk is not recognized by the PMO, commercial on-farm systems have recently been introduced to the marketplace that operate on the principle of disinfecting milk or colostrum by use of radiation from the ultraviolet (UV) region of the electromagnetic spectrum, typically using

wavelengths from 100 to 400 nm (GEA Farm Technologies, WesfaliaSurge, Inc., Personal Communication, 09/2010). Commercially available systems have a 50, 100, or 150 gallon balance tank and work by pumping/recirculating milk through the UV line. According to a MN distributor of this technology, pasteurization times may run from 1.5 to 2 hours per batch, depending on batch size, and systems cost between \$18,000 to \$20,000 (Stearns County Veterinary Outlet Store, Personal Communication, 09/2010). Food scientists have expressed concern that this approach may not be effective for disinfecting turbid liquids, such as milk or colostrum, since particles in the liquid will attenuate and scatter UV radiation, resulting in less microbial inactivation (David Smith, University of Minnesota, St. Paul, MN, Personal Communication, 2010). Two peer-reviewed published laboratory studies have reported that UV pasteurization was poorly effective in reducing the concentration of viable Map in milk (Altic et al., 2007; Donaghy et al., 2009). Apart from these 2 laboratory-based studies, to date there are no independently conducted peer-reviewed published studies to describe the effectiveness of on-farm UV treatment of milk or colostrum.

Calf Performance and Economics When Feeding Pasteurized Non-Saleable Milk

To date, only 2 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 10-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 qt/day, 5 qt/day, and 6 qt/day if ambient temperature was > 24 °F, 5 to 24 °F, or < 24 °F, respectively. Average daily gain was significantly greater in calves on the pasteurized non-saleable milk program (1.03 lb/day) versus calves fed the conventional milk replacer program (0.77 lb/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. Readers are invited to examine the spreadsheet model, as well as to perform their own calculations (http://www.ahc.umn.edu/ahc_content/colleges/vetmed/Depts_and_Centers?CVM_Dairy_Center/index.cfm).

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, they 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.

I. Installation requirements

- a. **Cost.** Purchase and installation costs, plus estimated variable costs.
- b. Installation support from manufacturer or distributor.
- c. **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 pasteurizer, wash milking system, etc.) or is a separate designated hot water heater required?
- d. **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.
- e. Water supply, drainage, and electrical requirements.

II. Considerations for Day-to-Day Use

- a. **Maintenance and Service.** Is the equipment reliable? How quickly can service be provided? Is a regular maintenance program provided?
- b. **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.
- c. **Strategy for inconsistent supply of non-saleable milk.** Depending on the number of fresh and treated cows, the amount of non-saleable milk can fluctuate from day-to-day or week-to-week. As such, all farms

should have a plan or strategy for what to do in the event that an adequate volume of non-saleable 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 dairy farms.

- d. **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) concentrations if the raw milk is initially of high quality (i.e., relatively low bacteria concentrations), the same cannot be expected if highly contaminated raw milk is processed through the pasteurizer. That is, if raw milk contains excessively high bacteria concentrations (> 1 million cfu/ml), 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 (acidified) 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 pasteurization 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, and 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 it 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 even days, prior to pasteurization and feeding, then the raw milk must be kept chilled so as to prevent bacterial proliferation and spoiling. In situations where a professional heifer grower may be regularly picking up milk from several source dairy farms, then a system must be developed to chill stored raw milk at the source dairy, to transfer and haul the raw milk to the heifer site, and to chill the raw milk at the heifer site until such time that 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, 2006). This will help ensure that

the milk fat composition is uniform from feeding-to-feeding and day-to-day. This will be particularly important if only a portion of the raw milk is removed from the storage tank to pasteurize in any one batch.

Regular and thorough sanitation of all storage, transfer, and transport systems must be a priority so as 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, as this practice could seriously dilute the solids content of the milk, thus leading to malnutrition and suboptimal calf performance (James, 2006).

- e. **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 of hours before being fed. It is for this reason that 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 feeding temperature (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, 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 (e.g. buckets, bottles, and nipples) between every use.

f. **Monitoring pasteurizer function.**

Reasons for pasteurization failure (failure of the equipment to reach the target time and temperature) can include such things as improper equipment settings or calibration, equipment malfunction, lack of enough hot water, or human error (e.g., turning off the equipment early in order to finish chores early). Alternately, the bacteria counts in the raw milk may be excessively high, resulting in above-target bacteria concentrations in the finished product, even though the pasteurizer was functioning as it should. The point to be made here is that, without a routine monitoring in place, 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 each and 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. An alternate test that may be performed on pasteurized milk is the Alkaline Phosphatase Test (goal: less than 500 mU/ml). Alkaline phosphatase is an enzyme naturally found in milk which is inactivated at approximately the same times/durations as we are using to pasteurize milk (James, 2006). In one recent study of 31 Wisconsin dairy herds, all but 12% of the pasteurization systems tested successfully

deactivated the alkaline phosphatase enzyme (Jorgensen et al., 2005). Again, the take home message is that producers must monitor the pasteurization system in order to detect problems early.

g. **Monitoring Quality of Raw and Pasteurized Milk.**

i. ***Bacteria Counts.*** 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. It is recommended that the total bacteria count in raw and pasteurized waste milk be less than 1 million cfu/ml and less than 20,000 cfu/ml 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. It is also suggested that producers periodically collect a third milk sample, at the location of feeding the calf, to estimate if significant post-pasteurization recontamination of the milk is occurring.

ii. ***Total Solids Content of Milk.*** The total solids (TS) content of whole milk from Holstein cows is approximately 12.5%. Accidental dilution of milk with wash water or failure to properly agitate milk prior to transferring it into the pasteurizer and/or prior to feeding

calves, can result in significant variation in milk TS content. In addition to developing protocols and training farm staff to avoid these kinds of milk handling errors, producers may use a hand-held Brix refractometer to measure the TS content of milk on a daily basis. Moore et al., (2009) reported that a hand held Brix refractometer (Reichert Inc., Depew, NY) provided TS readings that were well correlated with TS readings from laboratory spectrophotometry, provided that the user adjust the Brix instrument readings up by 2 percentage points to predict the true TS value. In a study of nonsaleable milk samples collected over time from 12 CA dairy farms, the adjusted Brix TS measures ranged between 5.1 to 13.4%. Again, this points to the need for dairy farmers to monitor the quality of the milk or milk replacer being fed to calves. The obvious solution to the problem of low TS milk would be to find and fix the source of the problem (dilution? failure to agitate?). Another use for the Brix refractometer is to monitor TS content when augmenting or extending pasteurized nonsaleable milk with milk replacer powder.

- iii. ***Milk pH.*** The pH of milk is normally approximately 6.7. However, if raw milk is allowed to be stored for too long and/or under warm conditions, then natural fermentation and the production of lactic acid will occur, reducing the pH of milk. If producers try to pasteurize fermented milk (pH < 5.0), they can expect serious problems in that heating will result in creating a batch of cheese curd in the pasteurizer;... a real mess to clean up and not feedable to

calves. To avoid fermentation, producers should chill raw stored milk and use it up or turn it over on a relatively frequent basis (every 2 to 3 days maximum). If fermentation of milk is suspected, narrow range pH paper or an electronic pH meter may be used to measure milk pH.

- h. **Cleaning the Pasteurization System.** With poor cleaning procedures, it is likely that fat, protein, and inorganic films (minerals) 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 preceding and following pasteurization. Effective cleaning protocols should be provided by the equipment manufacturer or distributor. Evaluating cleaning can include visual assessment for build-up of residual films, plus performing bacterial cultures of pasteurized milk (e.g. standard plate count, total bacteria count, or lab pasteurized count).

Heat-Treating Colostrum

First milking colostrum is an important source of nutrients, hormones, non-specific immune factors, and of passively absorbed maternal antibodies (immunoglobulins or Ig) critical to protect the newborn calf against infectious disease and to promote growth and development 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.

Another concern, it has been proposed that bacteria in colostrum may interfere with the passive absorption of Ig across the small intestine (James et al., 1981). This hypothesis, and the exact mechanism of interference, should it exist, is yet to be fully proven or described. However, it is supported by an observational study of 101 calves, in which calves fed high bacteria count raw colostrum experienced lower levels of passive transfer as compared to calves fed low bacteria count raw colostrum (Poulson et al., 2002). However, not all studies agree. In a very recent trial, there was no difference in serum total protein and serum IgG concentrations for 10 calves fed high bacteria load raw colostrum (mean standard plate count = 5.61, \log_{10} cfu/ml) as compared to 10 calves fed low bacterial load raw colostrum (mean standard plate count = 3.97 \log_{10} cfu/ml) (Elizondo-Salazar and Heinrichs, 2009b). However, the latter study may have failed to detect a relationship possibly due to a small sample size (10 calves per group) and a relatively narrow difference in colostrum bacteria counts for the two treatment groups (3.97 vs 5.61, \log_{10} cfu/ml standard plate count). Clearly, the nature (and mechanism, if present) of the relationship between colostrum bacteria counts and Ig absorption requires further study.

Because of the aforementioned concerns, producers have expressed an interest in heat-treating colostrum to reduce bacteria levels in colostrum. Early research pasteurizing colostrum using the conventional methods and temperatures as are typically used 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; Godden et al., 2003; Green 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-treatment of 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).

This heat-treatment protocol has since been validated in 3 separate clinical trials; 2 trials conducted in individual university dairy herds, and one larger field study conducted on 6 commercial dairy farms and involving over 1000 dairy calves (Johnson et al., 2007; Donahue et al., 2008; Elizondo-Salazar and Heinrichs, 2009a). These studies consistently report that on-farm heat-treatment of colostrum significantly reduces colostrum bacteria concentrations without causing significant loss of IgG or changes in feeding characteristics. Furthermore, calves which were fed heat-treated colostrum experienced significantly improved efficiency of IgG absorption and higher serum IgG levels, as compared to calves fed the untreated, fresh colostrum (Johnson et al., 2007; Donahue et al., 2008; Elizondo-Salazar and Heinrichs, 2009a).

The combination of reducing microbial exposure while improving passive transfer of IgG in calves should, theoretically, result in improved calf health and performance. However, in a large field study involving over 1000 calves fed either heat-treated or raw maternal colostrum, there was no effect of treatment on morbidity, mortality, or growth

rates in preweaned dairy calves (Donahue et al., 2009). Long-term follow-up of these animals is currently in progress to describe if feeding heat-treated colostrum results in reduced transmission of Map. Such long-term studies are needed to identify and describe if there are potential economic or health benefits resulting from adopting this practice on farms.

Producers wishing to feed heat-treated colostrum must pay close attention to following factors in order to be successful:

- i) Routinely monitor times and temperatures for heat-treatment of colostrum in a batch pasteurizer (e.g. heating to temperatures above 141°F will result in denaturation of IgG).
- ii) Constant agitation during the heat-up, holding, and cool-down phases of the heat-treatment cycle.
- iii) Active, rapid cooling (do not ‘turn off’ while still hot and allow to cool down slowly on its own).
- iv) Periodic culture of raw and heat-treated colostrum samples to monitor efficacy of the heat-treatment process (Goal: total plate count in heat-treated colostrum < 20,000 cfu/ml).
- v) Proper cleaning and sanitation of the pasteurizer, colostrum storage, and colostrum feeding equipment.
- vi) Proper handling, storage, and refrigeration or freezing of colostrum to prevent bacterial contamination and growth in the raw product and to prevent re-contamination in heat-treated colostrum.
- vii) 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 (Goal: > 90% of calves tested between 24 hours and 7 days of age should have a serum total protein value ≥ 5.0 g/dl).

Summary

Feeding non-saleable milk represents one way to gain important economic and nutritional efficiencies for calf growers, but this can represent a large risk factor for introducing infectious diseases to calves. The recent introduction of on-farm commercial pasteurizers represents a method for reducing this risk. This technology has been adopted and used successfully on many farms, and 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, including 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-treatment of colostrum can be successful in eliminating important pathogens, while preserving important colostrum 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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