

Pasteurizing Non-Saleable Milk and Colostrum

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■ Take Home Message

- ▶ Potential advantages of feeding pasteurized milk include:
 - reduced pathogen transmission (vs. feeding raw milk).
 - improved rate of gain (vs. conventional milk replacer programs).
 - improved calf health.
 - improved economic efficiency.
 - disposal of a waste product.
- ▶ Potential disadvantages of feeding pasteurized milk include:
 - need for more intensive management of feeding program.
 - risk of pasteurization failure if procedures for milk handling, pasteurization, equipment sanitation or monitoring are inadequate.
 - need strategy to feed calves if supply of non-saleable milk is inadequate.
- ▶ Producers should weigh the potential advantages and disadvantages to decide if a pasteurized milk feeding program is suited for their operation.
- ▶ Heat-treating colostrum
 - must be done in a batch pasteurizer using a lower temperature and longer time (60°C for 60 minutes) in order to preserve colostral antibodies.
 - can reduce pathogen exposure from colostrum.
 - can result in improved absorption (passive transfer) of colostral antibodies.
 - long term health and economic implications have not yet been determined.

■ Introduction

Professional heifer growers and dairy producers must raise 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 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 milk feeding program. This paper will discuss some of the benefits and limitations of feeding pasteurized milk, describe commercially available on-farm pasteurization systems, describe the results of studies feeding pasteurized milk, and outline the important considerations needed to successfully adopt and implement a pasteurized 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 daily 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 kg calf fed 4.5 L/day of whole milk (10% of body weight) would consume approximately 2.97 Mcal of metabolizable energy (ME) per day and be expected to gain 446 g/day. In contrast, if that same calf was fed 0.45 kg DM per day of a conventional 20:20 milk replacer, then it would consume only 2.47 Mcal/day and be expected to gain only 289 g/day (Davis and Drackley, 1998). This advantage in gain is explainable entirely on the basis of improved energy intake. This improved energy intake may also be valuable to the calf during periods of cold stress (ambient temperature less than 10°C), 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 (non-saleable 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 kg 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* (1983; Farber et al., 1988; McEwen et al., 1988; Clark et al., 1989; 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 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 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 in milk increased (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; Berge et al., 2005). 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 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 bacteria. 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 has a very high concentration of bacteria, then some viable pathogenic bacteria may survive the pasteurization process. The pasteurized milk ordinance (PMO) defines two different methods for pasteurization: batch pasteurization or continuous flow (flash) pasteurization.

Commercial Batch Pasteurizers

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 which is submerged in the liquid. Commercial units offer thermostatically controlled automation, which simplifies operation. Milk is heated to the target temperature (63°C), held there for 30 minutes, and then automatically and rapidly cooled to 38 to 43°C 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 3.8 L to over 570 L 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 (and later to cool) very large volumes of milk up to the target temperature (e.g. >285 L 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 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 \$3800 or greater, depending on capacity.

Commercial Continuous Flow Pasteurizers

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 (72°C) and held there for 15 seconds, then rapidly cooled to 43°C prior to discharge and feeding. It is recommended that equipment possess a valve that will divert milk back through the pasteurizer if milk 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 between \$9,500 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*, *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 is 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 the milk. 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 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: 3.8 L/d, 4.8 L/d, and 5.7 L/d if ambient temperature was $>-4^{\circ}\text{C}$, -15 to -4°C , or $<-15^{\circ}\text{C}$, respectively. Average daily gain was significantly greater in calves on the pasteurized non-saleable milk program (0.47 kg/day) versus calves fed the conventional milk replacer program (0.35 kg/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, 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.

Installation Requirements:

- ▶ **Cost.** Purchase and installation costs, plus estimated variable costs.
- ▶ **Installation support** from manufacturer or distributor.
- ▶ **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?

- ▶ **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.
- ▶ **Water supply, drainage and electrical requirements.**

Considerations for Day-to-Day Use:

- ▶ **Maintenance and Service.** Is the equipment reliable? How quickly can service be provided? Is a regular maintenance program provided?
- ▶ **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.
- ▶ **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 dairies.
- ▶ **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 (i.e. relatively low bacteria concentrations), the same cannot be expected if highly contaminated raw milk is processed through the pasteurizer. If raw milk contains excessively high bacteria levels (>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 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 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 dairies, 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 et al., 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 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 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 et al., 2006).

- ▶ **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. 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 (38 to 41°C) 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 (e.g. buckets, bottles, nipples) between every use.

- ▶ **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 levels in the finished product, even though the pasteurizer was functioning as it should. The point to be made here is that without 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. 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. 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. In

addition to bacterial cultures, an alternate test that may be performed on pasteurized milk is the Alkaline Phosphatase Test (goal: <500 mU/ml). Alkaline Phosphatase is an enzyme naturally found in milk that 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, for that remaining 12%, if they never did any monitoring, then they would never know that the system wasn't working.

- ▶ **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, lab pasteurized count).

■ Heat-Treating Colostrum

First milking colostrum is an important source of nutrients and of passively absorbed maternal antibodies (immunoglobulins or Ig), 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. Also, it is thought that bacteria in colostrum may interfere with passive absorption of colostrum 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 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; 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 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 60°C for 60 minutes, was fed to calves, the calves experienced significantly improved efficiency of absorption of colostrum 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 heat-treated colostrum (using a low-temperature, long-time approach: 60 min x 60°C) to reduce pathogen exposure while maintaining, or even improving, passive transfer of colostrum 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:

- ▶ Routinely monitor times and temperatures for heat-treatment of colostrum in a batch pasteurizer (e.g. heating to temperatures above 61°C will result in denaturation of IgG).
- ▶ Periodic culture of raw and heat-treated colostrum samples to monitor efficacy of the heat-treatment process (Goal: TPC in heat-treated colostrum < 20,000 cfu/ml).
- ▶ Proper cleaning and sanitation of the pasteurizer, colostrum storage and colostrum feeding equipment.
- ▶ 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.
- ▶ 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 TP value ≥ 5.0 g/dl).

■ Summary

Feeding non-saleable milk represents one way to gain important economic and nutritional efficiencies for calf growers, but 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-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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