A Review of Issues Surrounding the Feeding of Pasteurized Non-Saleable 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 (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 on-farm commercial pasteurizers represents a method for reducing this risk, and could be a viable economic strategy for feeding dairy calves. However, producers must carefully evaluate certain considerations in deciding whether or not to adopt this technology on their dairy. Furthermore, to be successful, producers must be committed to properly managing and monitoring a pasteurized non-saleable milk feeding system for dairy calves. This paper will review some important considerations in adopting and implementing a commercial pasteurization system and discuss available research findings related to feeding pasteurizing non-saleable milk and colostrum.

Economic and Nutritional Considerations in Selecting A Liquid Feeding Program

The choice to feed milk replacer, instead of saleable whole milk, is often an economic decision, because the cost of using milk replacers was lower than the cost of whole milk. It has been estimated that, at $13/cwt for saleable whole milk, there is a $12 economic advantage to feeding milk replacer (BAMN, 2002). Currently, milk replacer is fed on about 59% of U.S. dairy farms (Heinrichs et al., 1994). Today’s high quality calf milk replacers provide several benefits to the calf raiser and dairy producer, including consistency of product from day to day, ease and flexibility of storage, disease control, good calf performance, and economics (Davis and Drackley, 1998; BAMN, 2002). Producers wishing to learn more about the selection and use of high quality milk replacers should refer to a very useful review called “a Guide to Modern Calf Milk Replacers” (BAMN, 2002).

Despite these advantages for feeding milk replacer, there may be performance advantages for feeding whole milk over a traditional milk replacer program. Davis and Drackley (1998) calculated that a 45 kg (approx. 99 lb) calf fed whole milk at 10% of body would consume approximately 2.97 Mcal of Metabolizable energy (ME) daily, if whole milk contains 12.5% solids. In contrast, if a calf consumed 562 g/day of milk replacer containing 4.4 Mcal ME/kg of DM, then its intake of ME is only 2.47 Mcal daily. These two calves would be expected to gain 446 and 289 g/day when consuming milk and milk replacer, respectively, assuming that protein was not limiting in either case (Davis and Drackley, 1998). This growth advantage is explainable entirely on the basis of energy intake.

Excess colostrum and transition milk (non-saleable milk from the first six milkings) are alternate liquid feed options for calf raisers. The solids content of mixed colostrum and transition milk range between 16% to 18%, and so produce good gains by calves (Foley and Otterby, 1978; Davis and Drackley, 1998). It has been reported that day-to-day variation in its composition did not affect the incidence or severity of scouring or overall rates of gain (Foley and Otterby, 1978). However availability, storage, and preservations have been drawbacks to its widespread use. Freezing is one acceptable option but becomes problematic for feeding large numbers of calves. An alternative is the use of nonrefrigerated transition milk that has been allowed to ferment naturally. Allowing colostrum and transition milk to ferment produces a high-quality feed that is acceptable to calves and which supports good weight gains. In cold weather the fermentation process produces primarily lactic acid, resulting in a final pH of about 4.5 (Foley and Otterby, 1978). In warm or hot weather, however, putrefactive fermentation can occur, producing a product that is less accepted by calves (Foley and Otterby, 1978; Davis and Drackley, 1998). This problem can be addressed through use of preservatives such as acetic, propionic and formic acids and formaldehyde. However this is not popular due to the need to mix and handle caustic and toxic chemicals (Davis and Drackely, 1998).

One final opportunity is the use of nonsaleable or discard milk. This is milk from cows after antibiotic treatment for mastitis or other infectious diseases, which cannot be sold because of antibiotic residue concerns. Blosser (1979) estimated that 22 to 62 kg per cow of milk are discarded each year, representing economic loss, disposal issues, and environmental concerns. Some concerns with feeding discard milk to calves include infectious disease control, possible harmful effects from endotoxins, and the possible development of antibiotic resistance of intestinal bacteria in calves. One 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 intestine to bacteria and the subsequent risk of infection. Early studies in the 1970's and 1980's reported no long-term effects on health, production, or incidence of *Staphylococcus aureus* infections in first lactation heifers previously fed non-saleable milk as calves (Keys et al., 1980; Kesler, 1981; Barto et al., 1982).

One recent study that fed calves milk artificially spiked with varying concentrations of penicillin showed a dose response, with increased shedding of resistant bacteria as concentrations of penicillin in milk (Langford et al., 2003). However one limitation to this study is that it was conducted under artificial conditions. Furthermore, it is suspected that resistant bacteria are already present in the gut (resistance was not created) and that they simply had an opportunity to multiply when susceptible bacteria succumbed to the short-term presence of penicillin during the feeding phase of the study. 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, this concern is likely to receive further attention in future. Larger herds may combine excess colostrum and transition milk with nonsaleable or discard milk and feed it fresh to calves, thereby eliminating the need for fermentation or freezing. For the purposes of the rest of this paper, non-saleable milk will be defined as both transition milk and non-saleable discard milk.

Infectious Disease Control Considerations when Feeding Non-saleable Milk

While the feeding of non-saleable milk would seem to offer tremendous economic efficiencies, there have been some concerns with this practice, the most important of which may be the risk for transmission of infectious pathogens. Pathogens that may be transmitted in colostrum and milk, either by direct shedding in the mammary gland or from post-harvest contamination, include *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; Steele et al., 1997; Walz et al., 1997). Selim and Cullor (1997) demonstrated that raw non-saleable milk from 12 California dairies contained significantly higher concentrations of bacteria than other types of milk (milk replacer, bulk-tank milk), including *Streptococcus* sp. (84/165 samples), Enterobacteriaceae (83/165 samples), and *Staphylococcus* sp. (68/165 samples). *Escherichia coli* was the gram-negative species most commonly identified (52/165 samples). Some of these pathogens may be shed directly from the mammary gland, while others may result from post-harvest contamination (e.g. with manure) or proliferation in milk that is not stored/chilled properly. The study by Selim and Cullor (1997) concluded that producers should be cautious of feeding raw non-saleable milk to calves as it may contain a high number of bacteria that may be pathogenic to both cattle and human beings.

Pasteurizing Non-saleable Milk

Historically calf raisers have either accepted the infectious disease risks associated with feeding raw non-saleable milk or have avoided these risks by feeding a milk replacer. However a new alternative that has recently become recently available is use of commercial on-farm pasteurization systems. Pasteurization is simply a process of heating milk to a target time and temperature for a target microbe. The pasteurized milk ordinance (PMO) defines two different methods for pasteurization: 1) batch pasteurization at 145 ^{o}F for 30 minutes (low-temperature, long-time or LTLT) or 2) high-temperature, short-time pasteurization (HTST) at 161 ^{o}F for 15 seconds (usually using a continuous flow method). Heating results in a log reduction in the concentration of viable bacteria. The rate of heat inactivation of bacteria increases exponentially with time. 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.

Commercial batch pasteurizers are generally slower to heat milk to the target temperature (145 ^{o} F), hold it there for 30 minutes, and then should automatically and rapidly cool the milk to feeding or storage temperature. They should be equipped with some kind of agitator to allow for even heating. One concern with batch pasteurization is the volume of milk to be heated and the time to do so. If very large batches are used (e.g. > 150 to 200 gallons) and heating may take several hours, there are concerns that some bacteria (e.g. some Salmonella species) may become heat resistant, surviving the pasteurization process. In such cases it may be more appropriate and faster to use an HTST continuous flow design. The cleaning process for these units is usually manual.

Commercial HTST - Continuous flow Pasteurizers. Milk is usually circulated through a network of heated coils, rapidly heating it to the target temperature (161 ^{o} F) and holding it there for 15 seconds. If milk does not reach the target temperature during the first pass through the coils it may be discharged back into the original tank and recirculated. These systems should also be equipped to automatically quickly cool the milk to feeding or storage temperature. Cleaning will require steps similar to washing a pipeline system, with cleaning recommendations provided by the manufacturer or distributor. Ideally the cleaning process should be automated.

'Home-made pasteurizers'. Many creative producers have built their own versions of batch pasteurizers (e.g. old bulk tanks that circulate hot water) or pasteurizers that re-circulate milk. While these can be made to work well, they are generally not automated and there are many more concerns with their ability to function and clean properly (i.e. it will be far easier for mistakes to occur using a home-made pasteurizer as compared to a commercial pasteurization system).

Considerations for Using Commercial On-Farm Pasteurization Systems

There are several important requirements and issues that producers should educate themselves about, and plan for, before purchasing and implementing this technology:

Installation Requirements

a) Hot water heater. Is a new one needed or is a heater self-contained in the unit? Does the existing hot water heater work? (i.e. is the water hot enough?)
b) Water supply
c) Are there special electrical requirements?
d) Space/location
e) Drainage requirements
f) Purchase and installation costs

Considerations for Day-to-Day Use

a) Training farm staff to properly use and clean the equipment
b) Time/labor to use and clean equipment
c) Cleaning requirements
d) Variable costs
e) Service. Is the equipment reliable? How quickly can service be provided?
f) Moving and storing non-saleable milk before and after pasteurization
g) Monitoring performance. Is it working?

Handling of Pre-Pasteurized Non-saleable Milk

Pasteurization is heating milk to a target temperature for a target period of time. The rate of heat inactivation of bacteria increases exponentially with time at a given temperature. Depending on the initial levels of bacteria in the raw product, this process will reduce or eliminate pathogens in the milk. However, pasteurization should not be confused with sterilization. If the raw milk is of poor quality and already has a very high concentration of bacteria, then inactivation of all pathogens may be incomplete. For example, while high quality saleable raw milk is considered to have less than 50,000 CFU/ml, unchilled non-saleable milk may reach over 1 billion CFU/ml in the summer (Reynolds, 2002). It may be unrealistic to try to achieve extremely low concentrations of bacteria in prepasteurized non-saleable milk on dairy farms. However it is recommended that these levels be less than 1,000,000 CFU/ml in order to achieve adequate pasteurization efficacy and a high quality end product (Dr. Jim Cullor, University of California – Davis. Personal communication. 2003).

It is for this reason that non-saleable milk should be collected and stored in closed, clean containers, to prevent pre-pasteurization contamination. Similarly, if the milk is not to be pasteurized within a few hours of collection, it should be chilled in order to prevent bacterial growth and fermentation prior to being pasteurized. This is more critical in warm or hot ambient temperatures. This may not be an issue on small dairies when non-saleable milk is pasteurized and fed to calves shortly after each milking. However it can be a serious issue on large heifer growing operations where milk is picked up from other dairies, sometimes on an alternate-day basis, and then stored in large quantities for one or more days before being pasteurized and fed. In this situation a small functional bulk tank may need to be placed at both the source dairy and the heifer-rearing site to keep the non-saleable milk cool before pasteurizing.

Fermentation of milk that is not chilled is another factor that may complicate the pasteurization process, particularly in milk stored at moderate to warm ambient temperatures. Fermentation, itself, is not a problem, as it yields a nutritious product that is readily accepted by calves. However the fermentation process results in acid production, dropping milk pH to around 4.5. This acidic milk produces changes to milk protein structure that can result in protein coagulation and curd formation when the milk is pasteurized. In our experience, trying to batch pasteurize fermented milk occasionally resulted in an end product that consisted of a whey-like liquid with a thick layer of cheese curd sitting on the bottom of the pasteurizer. Obviously this is a concern because calves are deprived of important nutrients for that particular feeding. While curd formation occurred only sporadically in a field trial in central Minnesota (Godden et al., 2003), its occasional occurrence during the warmer spring months was enough to warrant installing a chilling system to store pre-pasteurized non-saleable milk.

Handling of Post-Pasteurized Non-saleable 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 very long 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, and 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 container until it can later be reheated and fed. This approach would add some inconvenience and labor into the calf feeding program.

Post-pasteurization contamination of 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 cleaning and sanitizing buckets, bottles, nipples, etc. Producers wishing to periodically monitor pasteurizer function can collect samples of pasteurized milk into sterile mastitis sample tubes, freeze the samples, and then submit to a local udder health laboratory to determine the total bacteria count. The goal for bacteria counts in post-pasteurized milk should be the same as for pasteurized grade A milk used for human consumption: < 20,000 CFU/ml (Dr. Jim Cullor, University of California – Davis. Personal communication. 2003). An alternative could be to submit pasteurized milk samples to a laboratory for an Alkaline Phosphatase test, an enzyme in milk that should be inactivated if pasteurization was complete.

Cleaning and Sanitizing Pasteurizers

With poor cleaning procedures, it is likely that fat, protein, and inorganic films (minerals) can build up in these systems, interfering with temperature transfer to the milk and serving as a source to 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. *Producers should contact the manufacturers or distributers of commercial on-farm pasteurizers for cleaning instructions that best fit their equipment*. Evaluating cleaning can include visual assessment for build-up of residual films plus cultures of pasteurized milk (e.g. standard plate count, total bacteria count, lab pasteurized count).

Effectiveness of On-Farm Pasteurization in Destroying Infectious Pathogens

Laboratory studies have shown that pasteurization is effective in destroying viable bacteria for most of the pathogenic species threatening calves. In one study at the University of Minnesota, batches of saleable raw bulk tank milk and colostrum were inoculated with both low (10^2 to 10^3 CFU/ml) and high (10^5 and 10^6 CFU/ml) concentrations of *E. coli* 0157:H7, *Salmonella sp.*, *Listeria monocytogenes*, and *Staphylococcus aureus*, and then pasteurized using two commercial on-farm pasteurizers; a batch model (Dairytech Inc., Windsor, CO) and a HTST model (Bettermilk Inc., Winona, MN). Pasteurization with the batch unit destroyed *E. coli* 0157:H7, *Salmonella sp.*, *Listeria monocytogenes*, and *Staphylococcus aureus* in both milk and colostrum. Pasteurization with the HTST unit effectively destroyed or significantly reduced *E. coli* 0157:H7, *Salmonella sp.*, and *Listeria monocytogenes*, and *Staphylococcus aureus* in milk and colostrum (1-3 CFU/ml of *S. aureus* survived in milk) (Green et al., 2002; 2003). Butler et al., (2000) demonstrated that batch pasteurization effectively destroyed both *M. bovis* and *M. californicum* when held at 60 ^{o}C (140 ^{o}F) for 10 min of heat, or when held at 65 ^{o}C (149 ^{o}F) for 2 min of heat. *M. canadense* spp. was slightly more resistant, requiring 10 min at 65 ^{o}C (149 ^{o}F) to be completely inactivated. A more recent study reported that pasteurization of non-saleable milk using a commercial on-farm HTST pasteurizer unit resulted in complete destruction of 3 strains of *Salmonella* (derby, dublin, typhimurium) and 4 strains of *Mycoplasma* (bovis, californicum, canadense, serogroup 7) using two different levels of experimental inoculation (Stabel et al., 2003).

The efficacy of pasteurization in destroying *Mycobacterium avium* subsp. *Paratuberculosis (Map)*, the organism causing Johne's disease, remains controversial. While a number of researchers have reported that laboratory studies simulating batch or HTST pasteurization was completely effective in destroying this pathogen (Keswani and Frank, 1998; Grant et al., 1999; Stabel et al. 1996), others have reported that small numbers of the organism may remain viable if inoculated into milk samples at high concentrations (Chiodini and Hermon-Taylor, 1993; Gao et al., 2002; Grant et al., 1996b; Sung and Collins, 1998). Limitations to most of these studies are that they were simulations only, frequently using very small volumes of milk, and inoculated at moderate or high concentrations of the pathogen which may not reflect actual concentrations of bacteria naturally shed in milk. Only two studies to date have used commercial on-farm pasteurization units. One of these studies reported that a commercial batch pasteurization unit effectively destroyed the Johne's organism (Stabel, 2001). The second of these studies reported that a commercial HTST pasteurization unit effectively destroyed the Johne's organism (Stabel et al., 2003). More of this type of work is required to verify if the commercial pasteurizers currently being marketed to dairy producers for on-farm use are, indeed, effective in destroying the Johne's organism. Furthermore, it is still necessary to determine what the infective dose is (and so relative risk) for Johne's infection through feeding colostrum or non-saleable milk from infected cows. It will be very important for producers to avoid fecal contamination of milk during the harvest, storage, pasteurization, or feeding processes, as the potential exists for large concentrations of infective *Map* bacteria to be shed in feces from infected cows.

Problems Encountered with On-Farm Pasteurization Systems

Tightly controlled laboratory studies may have demonstrated the efficacy of pasteurization to destroy various pathogens. However producers should be aware that problems can and do arise in the real-life and often uncontrolled environment of the farm. Problems that could interfere with pasteurizer performance include:

- Start with poor quality milk with a high degree of bacterial contamination:
  - Should chill stored raw non-saleable milk to reduce incubation
- Milk not heated to the correct target temperature (HTST-161 ^{o}F; Batch-145 ^{o}F):
  - Water heater doesn't get water hot enough or not enough hot water available
  - Inadequate plate cooler function
  - Pasteurizer malfunctioning or not calibrated properly
  - Cleaning failure => build-up of fat, protein or inorganic films will interfere with heat transfer
- Milk is not maintained at the target temperature for a long enough duration:
  - HTST: Milk not circulated for full 15 seconds
  - Batch: Milk not kept at target temperature for a full 30 minutes
  - Operator error – people rushing to complete chores may stop the pasteurization process before either target time or temperature is met.
- Curdling of milk if fermented (acidic pH):
  - Chill raw pre-pasteurized milk to prevent fermentation.
- Post-pasteurized milk should be cooled rapidly (should be automatic in commercial machines, more difficult to achieve in 'home-made' machines) to prevent incubation
- Post-pasteurization contamination of the milk:
  - Store in closed, clean container. Chill if delay before feeding.

Monitoring Pasteurizer Equipment Function

Ideally all pasteurizers should be equipped with a time-temperature control chart to document that the target temperatures are being reached for an appropriate duration. At the very minimum they must be equipped with a thermometer by which producers can periodically check and monitor times and temperatures. Adequacy of cleaning also needs to be monitored (previously discussed). Periodic testing (e.g. culture or Alkaline Phosphatase test) of pasteurized milk may also be used to monitor adequacy of pasteurizer function (previously discussed). Culture of pre-pasteurized milk may be done to investigate if inadequate pasteurizer function (should it occur) is due to excessive bacteria counts in the raw product.

Field Studies Feeding Pasteurized Non-Saleable Milk

Raw vs. pasteurized non-saleable milk – health, performance, and economics for California dairy calves. (Jamaluddin et al. 1996).

In a study of 300 calves on a large California dairy, calves fed pasteurized colostrum and milk had fewer sick days, lower mortality rates, lower costs for health expenditures, higher weights at weaning, and a higher gross margin ($8.41/calf) per calf, as compared to calves fed nonpasteurized non-saleable milk

Milk replacer vs. pasteurized non-saleable milk – health, performance, and economics for Minnesota dairy calves. *(Accepted for publication: J.A.V.M.A. 2004)*

A recent 10-month field study of 438 dairy calves raised by a professional heifer grower in Minnesota systematically assigned calves, on arrival, to one of two feeding programs: 1) treatment group = pasteurized non-saleable milk (n = 215) or 2) control group = traditional 20:20 milk replacer (n = 223). Non-saleable milk from just fresh (transition milk) and antibiotic-treated cows was pasteurized before each feeding using a commercial batch pasteurizer (Dairytech Inc., Windsor, Colorado). Calves in both treatment groups were fed equal volumes of liquid feed per day, but volume was adjusted according to ambient temperature: 4 qt/d, 5 qt/d, and 6 qt/d if ambient temperature was > 24 ^{o}F, 5 to 24 ^{o}F, or < 24 ^{o}F, respectively. Calves fed pasteurized non-saleable milk gained significantly more weight and were heavier at weaning (26.7 kg gain; 66.8 kg at weaning) than calves fed milk replacer (20.1 kg gain; 60.8 kg at weaning) ($P < 0.05$). Average daily gain (ADG) was significantly greater in calves fed pasteurized non-saleable milk (0.47 kg/day) vs. calves fed milk replacer (0.35 kg/day). Preweaning treatment rates were generally higher in both feeding groups in winter months as compared to summer months. However, for both seasons, significantly fewer calves were treated on the pasteurized milk diet (overall treatment rate = 12.1%) compared to calves fed the milk replacer diet (overall treatment rate = 32.1%) ($P < 0.05$). Preweaning mortality rates were also significantly lower for calves fed pasteurized non-saleable milk (overall mortality rate = 2.3%) than for calves fed milk replacer (overall mortality rate =

11.6%). However this difference was limited to calves born in the winter months (mortality $_{\text{pasteurized milk}}$ = 2.8%; mortality$_{\text{milk replacer}}$ = 21.0%) ($P < 0.05$). There was no significant difference in mortality rates between the two feeding groups for calves born during the summer months (mortality$_{\text{pasteurized milk}}$ = 1.7%; mortality$_{\text{milk replacer}}$ = 2.7%) ($P > 0.05$).

An obvious explanation for why calves on the whole milk diet had better preweaning growth rates (+ 6.6 kg gain) than calves on the milk replacer diet is the higher level of nutrient intake in the whole milk diet. On a dry matter basis, the crude protein and fat content of this diet would be expected to average 26.6% and 29.6%, respectively (and perhaps higher if non-saleable milk included significant amounts of transition milk). Using the 2001 NRC equations, feeding 3.8 L/d of whole milk to a 45 kg calf would be predicted to result in 0.32 kg/d energy allowable ADG and 0.36 ADP allowable gain. By comparison, feeding 0.45 kg of 20:20 milk replacer powder/day would be predicted to result in approximately 0.22kg/d energy allowable ADG and 0.25 kg/d ADP allowable gain (assumes 20^{o}C ambient temperature). Thus, the pasteurized milk fed calves might have been expected to gin approximately 0.1 kg/day x 45 days to weaning = 4.5 kg more weight than milk replacer fed calves, based on differences in energy intake.

It is less clear why calves fed the whole milk diet were healthier than calves fed the milk replacer diet (reduced treatment rate for all months, reduced mortality rate for winter months). One possible explanation for improved health in calves on the whole milk diet is that the pasteurized non-saleable milk will most likely contain significantly higher concentrations of protective immunoglobulins (e.g. IgG) and other non-specific immune factors than would powdered milk replacer (Reiter, 1977; Le Jan, 1996). A second possible explanation is that the calves managed on a higher plane of nutrition may have had improved immune function. Considerable evidence has shown a very important influence of neonatal nutrition on immune function in humans and several animal species. For example, in one study of calves fed two amounts of milk replacer solids with either ad libitum or restricted access to calf starter, calves fed the higher amount of milk replacer with ad libitum access to starter had the greatest ADG and least mortality (Williams et al., 1981). Pollock et al., (1993, 1994) reported that feeding milk-fed calves a higher level of nutrition resulted in improved humoral immune responses. Nonnecke et al., (2003) has also reported that increased dietary energy and protein can modulate specific aspects of the neonatal immune system. This extra protein and energy intake may have been particularly important in supporting the immune system during the winter months, when increased energy is required for thermoregulation.

A partial budget model of the economics of pasteurizing non-saleable milk was developed to account for major areas of difference between a feeding system depending on pasteurized non-saleable milk and one using milk replacer (EXCEL spreadsheet model; Microsoft Office, 2000). The model assumed a fixed number of calves would be fed each day and considered fixed and variable costs. Fixed costs considered the purchase and installation of the pasteurization equipment, as well as the purchase of trailers and refrigerated holding equipment for storing and transporting non-saleable milk. Equipment costs were prorated over a 3 year term. Variable costs included ongoing maintenance and utilities associated with using the pasteurization system and any additional labor required for managing the handling and pasteurization of non-saleable milk. Differences in growth rates, treatment rates, and mortality rates (as observed in our study) were also modeled. This model estimated that feeding pasteurized milk resulted in a $34 per calf advantage over the calf's life up to weaning, and that a minimum of 23 calves would be necessary to make feeding pasteurized non-saleable milk economically feasible (or 41 calves if only feeding costs and labor were considered, but growth and health benefits were not considered). Note: this model is available at the web site for the University of Minnesota's College of Veterinary Medicine, Center for Dairy Health, Management, and Food Quality. Users are free to examine the model and to alter the assumptions to best fit their own farm's situation (http://www.ahc.umn.edu/ahc_content/colleges/vetmed/Depts_and_Centers?CVM_Dairy_Center/index.cfm.

Pasteurizing Colostrum

In contrast to milk, the question pasteurizing colostrum presents some special challenges. Problems with congealing or loss of important immunoglobulins (e.g. IgG) and other immune factors could render this practice unacceptable. The few studies investigating pasteurization of colostrum have reported varying results with respect to effect of pasteurization on both colostral immunoglobulin molecules and on rates of failure of passive transfer in calves.

Meylan et al. (1995) heated five ml volumes of a total of 18 colostrum samples to 63 ° C (145 ° F) for 30 minutes to simulate pasteurization of colostrum under laboratory conditions. Mean IgG (+/- S.D; range) values for fresh and pasteurized samples were 44.4 g/L (+/- 30.3; 3.3 to 87.7) and 37.2 g/L (+/- 23.8; 2.9 to 70.3), respectively. This study reported a mean loss of immunoglobulins after pasteurization of 12.3% (+/- 8.7%; -3.19 to 24.94). These authors concluded that this 12.3% loss was manageable, assuming that the quality of colostrum is determined by a colostrometer prior to heat treatment and the amount fed is adjusted to ensure successful passive transfer of immunity. Unfortunately, this study was performed using very small volumes of colostrum and under laboratory conditions simulating pasteurization.

Green et al., (2003) used two commercial pasteurizers, one HTST design (BetterMilk Inc., Winona, MN), and one batch design (Dairytech, Inc., Windsor, CO), to pasteurize five one-gallon (HTST) and ten eight-gallon (batch) batches of colostrum. The mean IgG loss for both units ranged between 25 and 30%. Similar results (mean 25% IgG loss) were attained when pasteurizing almost 40 separate 1-gallon batches of colostrum using a lab-scale batch pasteurizer.

One field study, using a HTST pasteurization method (72 ° C (or 161 ° F) for 15 seconds), reported that total colostral IgG mass (g) received by 150 calves fed pasteurized colostrum (mean (SE) = 151.4 (3.27)) was significantly lower than for 150 calves fed unpasteurized colostrum (mean (SE) = 203.12 (4.54) ($P < 0.01$) (Jamaluddin, 1995).

However there was no difference in the number of calves experiencing failure of passive transfer (FPT) (based on less than 10 mg/ml of total serum IgG measured at 48 to 96 hrs after colostrum intake) between treatment (16.2%) and control (19.5%) groups ($P > 0.05$). Similarly there was no difference in mean (SE) serum IgG concentrations between treatment (1476 mg/dl (39.2) and control (1435 mg/dl (42.4)) groups ($P > 0.05$). While the results of this field trial were promising, there are practical concerns with adopting HTST pasteurization of colostrum: In one study HTST pasteurization of colostrum consistently produced an end product that congealed into a thick pudding as it cooled, or worse, while still in the heating coils, making feeding and cleaning difficult (Green et al., 2003).

In a more recent field study of newborn calves on a large dairy in Colorado, 123 newborn calves were systematically allocated to be fed either fresh or pasteurized colostrum at both the first and second colostrum feedings (Godden et al., 2003). Colostrum was pasteurized using a commercial batch method (Dairytech Inc., Windsor, Colorado). Pasteurization caused a significant reduction in colostrum IgG concentration, with the percent reduction averaging 58.5 % and 23.6% for large (95 L) and moderately sized (57 L) batches, respectively. Pasteurizing high quality colostrum in moderate-sized (vs. large) batches resulted in higher IgG concentrations in the end product. Pasteurization of moderate-sized batches produced colostrum of normal or only mildly thickened consistency that could be fed to calves. Serum IgG concentrations were significantly higher for calves fed fresh colostrum and for calves with a shorter time interval (≤ 6hrs) between first and second colostrum feedings. After controlling for the time interval between feedings, serum IgG concentrations were significantly higher for 40 calves fed unpasteurized (LSmean = 19.1 mg/ml) vs. 55 calves fed pasteurized colostrum (LSmean = 9.7 mg/ml) for calves fed 2 L at first feeding. By contrast, there was no statistically significant and a numerically smaller difference in serum IgG concentrations between eight calves fed unpasteurized (LSmean = 16.1 mg/ml) vs. 20 calves fed pasteurized colostrum (LSmean = 13.5 mg/ml) for calves fed 4 L at first feeding. While this study suggests that pasteurizing colostrum may be made to work for producers with excellent colostrum management, these results are preliminary and should be interpreted with caution, given the fewer number of calves and batches of colostrum involved with this second comparison. Further research is to describe the effect of batch size, time, and temperature on percent reduction in IgG concentrations.

It is recommended to producers considering pasteurizing colostrum only attempt to do so after ensuring that they can successfully implement the following steps and then carefully monitor the outcome on an ongoing basis.

1. Use only high quality colostrum (goal > 60 mg/ml with a colostrometer).
2. Collect and store colostrum under sanitary conditions and keep pre- and post-pasteurized colostrum chilled if is any delay in pasteurization and/or feeding.
3. Pasteurize only small-to-moderately sized batches (maximum 57 L or 15 gallons)
4. Monitor pasteurizer function by routinely culturing samples of pasteurized colostrum.
5. Pay attention to equipment maintenance and day-to-day cleaning.
6. Feed a full four L of colostrum as soon as possible after birth.
7. Provide a second feeding of two L of colostrum within 6 hours of the first feeding.

8. Monitor serum IgG concentrations as well as morbidity and mortality rates in calves.
9. Pay strict attention to sanitation and hygiene in the maternity pen, feeding procedures, and the environment, so as to minimize calf challenge with infectious pathogens.
10. Use a batch pasteurization method. Avoid HTST continuous flow methods.

Ongoing research pasteurizing colostrum: We are currently in the process of investigating a lower-temperature/longer-time approach to heat-treat colostrum that would protect the important colostral antibodies, and yet still yield satisfactory results with respect to pathogen destruction. Preliminary results have shown promise in preserving colostral antibodies if the holding temperature in a batch pasteurizer does not exceed 140^{o}F. However, work is still ongoing to determine how much longer the heat-treatment process may need to be extended, at this lower temperature, in order to achieve acceptable pathogen kill. Results (to date) will be presented at the meeting.

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 health, performance, and economic advantages to feeding pasteurized non-saleable milk. However, in order to be successful, producers must pay careful attention to quality control including careful handling of non-saleable milk, both pre- and post-pasteurization, pasteurizer performance (monitoring times/temperatures), and pasteurizer cleaning.

Some commercial pasteurizer equipment distributors are provided below.
Disclaimer: *This is not a comprehensive list, nor is it to be considered a recommendation for any company or design over others that may be in the marketplace.*

Batch Pasteurizers:

DairyTech Inc. , Windsor, CO 80550
Tel: 866-DTI-COWS
www.dairytech.org

Continuous Flow Pasteurizers

Calf-Star, LLC. New Franken, WI 54229
Tel: 920-866-2485
www.calfstar.com

Goodnature Products Inc.
http://goodnature.com/pasteurizers.html

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