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Pasteurization of Non-Saleable Milk

J. A. Elizondo-Salazar, A. J. Heinrichs, and S. L. Gelsinger

Department of Animal Science

TOPICS

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REVIEWERS

Virginia Ishler, Penn State
Sandy Costello, Penn State

PENNSTATE

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Cooperative Extension
College of Agricultural Sciences

INTRODUCTION

All dairy operations have a supply of milk that is not saleable, commonly called waste or discard milk. For the purpose of this paper, non-saleable milk or waste milk is composed of excess colostrum, transition milk, mastitic milk or non-saleable milk containing antibiotics. According to Blosser (1979), discard milk ranges from 48 to 137 lb (22 to 62 kg) per cow per year, representing a huge economic loss, disposal problems, and environmental issues. For many years waste milk has been fed to calves, but concerns with microbial contamination, such as *E. coli*, bovine viral diarrhea virus, *Listeria monocytogenes*, and various species of *Streptococcus*, *Salmonella*, *Mycoplasma*, *Campylobacter*, and *Staphylococcus* (Selim and Cullor, 1997; Stewart et al., 2005), as well as possible transmission of diseases such as Johne's, through feeding waste milk have discouraged many producers from feeding calves this milk. However, pasteurization of waste milk is one option to reduce management risk while utilizing a valuable, low-cost liquid feed source for calves. Equipment companies now produce a variety of small and large, self-contained, on-farm pasteurizers specifically for the utilization of waste milk for calf feeding. These pasteurizers are being marketed at affordable prices for an individual dairy operation. The objective of this paper is to review some important considerations of implementing an on-farm pasteurization system and discuss available research findings related to feeding pasteurized non-saleable milk to calves.

QUALITY OF MILK WASTE

Dairy producers feed a variety of liquid feeds to calves after the initial colostrum, including whole milk, surplus colostrum, transition milk, mastitic milk or non-saleable, antibiotic-containing milk, and milk replacer. Waste or discard milk cannot be sold for human consumption, thus it is often used as an economical alternative to milk replacer on many dairy farms. The nutrient profile of colostrum, transition milk, and whole milk is listed in Table 1.

Feeding this milk to calves offers a series of advantages besides economics. The solids content of mixed colostrum and transition milk ranges between 16% and 18% and produces good gains by calves (Foley and Otterby, 1978; Davis and Drackley, 1998; Kehoe et al., 2007). Despite its tremendous economic advantages, many dairy producers avoid feeding waste milk to calves for fear of increasing the incidence of heifers calving with mastitis or blind quarters, which was commonly seen in early studies where calves generally were housed in pens that enabled them to suckle teats of other calves. This led to an increase in the incidence of mastitis in developing heifers. There are also other concerns with feeding discard milk to calves. One is related to the possible development of antibiotic resistance of intestinal bacteria in calves. However, Kesler (1981) concluded that milk from cows treated with antibiotics for mastitis and other disorders can be fed safely to calves. Calf growth will be at least equal to that obtained by feeding fermented colostrum or other liquid feed. The most important concern has to do with the risk for transmission of infectious pathogens. Pathogens that may be transmitted in colostrum and milk include: *Mycobacterium avium* subsp. *paratuberculosis*, *Salmonella* species, *Mycoplasma*

Table 1. Characteristics and composition of Holstein colostrum, transition milk, and milk.

Variable	Colostrum (milking post-partum) 1st	2nd	3rd	Milk
Specific gravity[1]	1.056	1.045	1.035	1.032
pH	6.32	6.32	6.33	6.5
Total solids, %	23.9	17.9	14.1	12.5
Fat, %	6.7	5.4	3.9	3.6
Solids non-fat, %	16.7	12.2	9.8	8.6
Total protein, %	14.0	8.4	5.1	3.2
Casein, %	4.8	4.3	3.8	2.5
Albumin, %	0.9	1.1	0.9	0.5
Immunoglobulins, %	6.0	4.2	2.4	0.09
IgG, g/dL	3.2	2.5	1.5	0.06
Non-protein N, %	8.0	7.0	8.3	4.9
Lactose, %	2.7	3.9	4.4	4.9
Calcium, %	0.26	0.15	0.15	0.13
Potassium, %	0.14	0.13	0.14	0.15
Sodium, %	0.14	0.13	0.14	0.15
Vit A, μg/dL[2]	295	190	113	34
Vit E, μg/g of fat[2]	84	76	56	15
Riboflavin, μg/mL[2]	4.83	2.71	1.85	1.47
Choline, mg/mL	0.70	0.34	0.23	0.13

Source: Davis and Drackley, 1998.
[1]Specific gravity is a relative measure of the density of a substance compared to water. The density of water is 1. Substances with specific gravity greater than 1 are denser than water; those with specific gravity less than 1 are less dense than water.
[2]μg = microgram; 1,000 μg = 1 milligram.

species, *Listeria monocytogenes*, *Campylobacter* species, *Mycobacterium bovis*, *Enterobacter* species, *Staphylococcus* species, and *E. coli*, among others (Lovett et al., 1983; Streeter et al., 1995; Selim and Cullor, 1997; Stewart et al., 2005). When studying 12 dairies in California, Selim and Cullor (1997) demonstrated that raw, non-saleable milk contained significantly higher concentrations of bacteria than other types of milk or milk-based products (Figure 1). *Streptococcus* species and *Enterobacter* were the predominant bacteria identified, followed by *Staphylococcus. E. coli* was the most common gram-negative bacteria. For this reason, the former authors concluded that producers should be cautious of feeding raw waste milk to calves as it may contain a high number of bacteria that may be pathogenic to both cattle and humans.

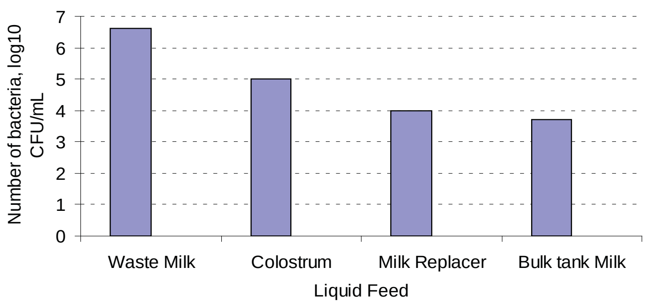

Figure 1. Bacterial count (colony forming units (CFU) per milliliter expressed as the logarithm of actual counts) in some common liquid calf feeds (Selim and Cullor, 1997).

Microbial load in waste milk is a function of several factors, including:

- microbial content of milk produced by the cow
- cleanliness of equipment used to collect milk
- cleanliness of equipment used to store milk prior to feeding
- storage time (time from collection to feeding)
- temperature of milk during storage
- exposure to microbial sources (feces, flies, etc.) from the environment
- pasteurization or other processing to reduce microbial load

The microbial content of waste milk will increase dramatically if the milk is left at room temperature or above. Unfortunately, some milk collected during the morning milking may not be fed until the afternoon. Consequently, the microbial load may increase dramatically. Even though this may not cause problems in some cases, the microbial load may become a source of disease in others.

PRECAUTIONS FOR FEEDING RAW WASTE MILK

- Determine the health status of the cows in your herd. Do not feed raw waste milk if the cows are shedding organisms that cause disease, such as Johne's and bovine viral diarrhea. If you are aware of the disease status of your herd and you and your veterinarian agree, it may be acceptable to feed raw milk and limit risk by feeding only milk from test-negative cows. However, the risk remains that you may spread diseases that exist in the herd but are not identified.
- Do not feed waste milk to newborn calves on the first day of life. The intestinal wall is permeable to bacteria that could cause illness.
- House calves fed waste milk individually to prevent them from suckling one another. This should reduce the transmission of infectious microorganisms that cause mastitis. Maintain individual pens for a few weeks after weaning to reduce cross sucking at that time as well.
- Do not feed milk that is excessively bloody or has an unusual appearance since it can contain active pathogens and white blood cells, which are difficult for a calf to digest.
- Feed waste milk to herd replacements or to calves being kept at least eight to twelve weeks after the last feeding of waste milk.
- Use caution when feeding waste milk from antibiotic-treated cows to calves intended for meat production. Antibiotic residues from the milk could be deposited in the calves' tissues.

PASTEURIZATION

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

Types of pasteurization

There are two common methods of pasteurizing milk: batch pasteurization and continuous flow high-temperature, short-time (HTST) pasteurization.

Standard batch pasteurization is accomplished when a batch (usually a vat or tank) of milk is heated to 145°F (63°C) for 30 minutes. Thereafter, the milk is cooled and can be fed to the calves. Batch pasteurizers should be equipped with an agitator to allow for even heating. There are concerns about the volume of milk to be heated and the time to do it. Very large batches take several hours to reach the desired temperature and there are concerns that some bacteria may become heat resistant, surviving the pasteurization process. The cleaning process of these units is most often done manually.

The process of HTST is different. Milk is circulated through a network of heated coils, rapidly heated to 161°F (72°C) and held there for 15 seconds. This type of system is also equipped to automatically cool the milk quickly to feeding or storage temperature. Continuous flow pasteurization is much more rapid than batch pasteurization and offers more opportunities for energy conservation. Continuous flow systems are generally more difficult to clean, requiring a cleaning procedure similar to that used in milking systems, but in many cases the cleaning process can be automated.

Effectiveness of pasteurization in destroying infectious pathogens

Pasteurization safely decreases pathogens in all types of milk fed to calves. Stabel (2001) showed that holding milk at 175.5°F (65.5°C) for 30 minutes is more than adequate to achieve total destruction of *Mycobacterium avium* subsp. *paratuberculosis*, the bacteria responsible for Johne's disease. Butler et al. (2000) demonstrated that on-farm pasteurization of waste milk held at 149°F (65°C) for 10 minutes also destroyed common mastitic mycoplasma such as *Mycoplasma bovis*, *M. californicum*, and *M. canadense*. In another study, Stabel et al. (2004) demonstrated that HTST pasteurization is effective in the destruction of *M. avium* subsp. *paratuberculosis* (Table 2), *Salmonella* species (Table 3), and *Mycoplasma* species (Table 4) in waste milk.

In another study, Butler et al. (2000) reported that at 140°F (60°C), *M. bovis* and *M. californicum* did not grow after 5 and 10 minutes of heat, respectively, while *M. canadense* remained viable even after 30 minutes of heat. *M. bovis* and *M. californicum* were both negative by culture after 2 minutes at 149°F (65°C), but *M. canadense* produced colonies when processed for up to 10 minutes. When the temperature increased to 153.5°F (67.5°C), 1 minute inactivated *M. bovis*, 2 minutes inactivated *M. californicum*, and 5 minutes inactivated *M. canadense*. *M. bovis* and *M. californicum* failed to produce viable cultures after 1 minute at 158°F (70°C), but *M. canadense* remained viable after up to 3 minutes of exposure.

Table 2. Destruction of *Mycobacterium avium* subsp. *paratuberculosis* after HTST heat treatment at 161°F (71.7°C) for 15 seconds.

	High level of inoculum		Low level of inoculum	
Strain	Prepasteurization	Postpasteurization	Prepasteurization	Postpasteurization
19698 (lab)	8.2×10^4	ND[1]	6.0×10^1	ND
	7.8×10^4	ND	1.3×10^2	ND
	2.3×10^3	ND	2.3×10^2	ND
167 (wild)	1.9×10^5	ND	6.3×10^2	ND
	2.1×10^5	ND	4.2×10^2	ND
	2.2×10^4	ND	8.2×10^2	ND
6112 (wild)	1.9×10^6	ND	5.4×10^1	ND
	5.9×10^5	ND	4.3×10^2	ND
	6.8×10^5	ND	2.1×10^2	ND

[1]ND = Not detected. Source: Stabel et al. (2004).

Table 3. Destruction of *Salmonella* species during HTST heat treatment at 161°F (71.7°C) for 15 seconds.

		High level of inoculum		Low level of inoculum	
Species	Strain	Prepasteurization	Postpasteurization	Prepasteurization	Postpasteurization
S. derby	NVSL 2681b	2.0×10^6	ND[1]	2.5×10^3	ND
		2.0×10^6	ND	1.5×10^3	ND
		2.0×10^6	ND	9.0×10^2	ND
S. dublin	NVSL 3129	6.0×10^6	ND	NP[2]	ND
		9.0×10^6	ND	NP	ND
		3.3×10^7	ND	NP	ND
S. typhimurium	NVSL 5372	2.1×10^7	ND	NP	ND
		2.1×10^7	ND	NP	ND
		2.0×10^7	ND	NP	ND

[1]ND = Not detected. [2]NP = Not performed. Source: Stabel et al. (2004).

Table 4. Destruction of *Mycoplasma* species during HTST heat treatment at 161°F (71.7°C) for 15 seconds.

		High level of inoculum		Low level of inoculum	
Species	Strain	Prepasteurization	Postpasteurization	Prepasteurization	Postpasteurization
M. bovis	1135-6	1.0×10^6	ND[1]	1.0×10^2	ND
	UCD9	1.0×10^6	ND	1.0×10^2	ND
	Jasper	1.0×10^6	ND	1.0×10^2	ND
M. californicum	Cs657	1.0×10^6	ND	1.0×10^2	ND
	ST6	1.0×10^6	ND	1.0×10^2	ND
M. canadense	275C	1.0×10^6	ND	1.0×10^2	ND
M. serogroup 7	CS826	1.0×10^6	ND	1.0×10^2	ND
	PG50	2.0×10^4	ND	1.0×10^2	ND

[1]ND = Not detected. Source: Stabel et al. (2004).

The efficacy of on-farm pasteurizers was further confirmed in a field study conducted by Penn State (Elizondo-Salazar et al., 2010) which tested samples from commercially available batch and HTST pasteurizers in addition to "homemade" pasteurizers which used a large heating coil and agitator to process the milk. Bacterial counts in samples collected after pasteurization with all of the systems studied were consistently lower compared with samples collected before pasteurization. Pasteurization of milk was able to consistently reduce bacterial populations to levels acceptable for feeding calves. Any of these heat pasteurization systems can be effective and are recommended for use in reducing the bacterial load in milk fed to calves. The type of system to be used depends on farm size and individual producer preference.

Jamaluddin et al. (1996) reported that calves fed pasteurized milk had fewer days with diarrhea and pneumonia than calves fed non-pasteurized milk. Also, calves fed pasteurized milk had greater average weight gain than calves fed non-pasteurized milk. Calves fed pasteurized milk grossed an extra $8.13 per head, attributed to reduced health complications and treatment costs, when compared with calves fed non-pasteurized milk. They also indicated that calves fed pasteurized waste milk continued to perform better after weaning than those fed raw waste milk.

Godden et al. (2005) indicated that calves fed conventional 20% protein, 20% fat milk replacer had significantly lower rates of gain, lower weaning weights; higher risk for treatment during the summer and winter months, and higher risk of death during the winter months than did calves fed pasteurized, non-saleable milk. These differences were primarily due to the higher nutrient content of the non-saleable milk compared to the conventional milk replacer. The estimated savings of feeding pasteurized non-saleable milk compared with milk replacer was $0.69 per calf per day, and the estimated number of calves needed to economically justify the non-saleable milk pasteurization system was 23 calves per day.

The results of these and other studies suggest that on-farm pasteurization of waste milk is effective in generating a safer product to feed to young calves. In addition, using pasteurized milk is a nutritionally sound system for raising healthy and well-grown calves.

UV LIGHT TREATMENT

UV light treatment, though commonly referred to as pasteurization, does not use heat to kill microorganisms and cannot be technically classified as pasteurization. Rather, UV "pasteurizers" function by emitting ultraviolet radiation into the milk, and the high energy released in the UV radiation breaks molecular bonds and causes mutations in the DNA of the bacteria. These mutations inhibit DNA replication so the bacteria cannot reproduce and will eventually die. However, radiation is nonspecific and can break other bonds found within the fat and protein molecules of milk as well as those found in bacterial DNA, and once the radiation energy has been used to break a bond in protein or fat it is no longer available to attack bacteria. Thus, there are some concerns as to the ability of UV light to penetrate the milk and affect bacteria.

Despite this concern, UV light "pasteurizers" are now commercially available for treatment of milk for calves. Potential advantages to these systems are that they are highly automated and convenient to use and require much less energy compared to either batch or HTST pasteurization and thus are lower cost to maintain. The system includes a single milk storage tank, UV reaction chamber, and control panel. The system functions by cycling milk through the UV reaction chamber where the milk is exposed to a series of UV lights before returning to the storage tank. Milk cycles through the UV reaction chamber multiple times to increase the cumulative dose of UV radiation. After the final cycle, the full volume of milk is returned to the storage tank and warmed up to feeding temperature (~100°F). These systems do not have a cooling mechanism and should therefore be programmed to end milk treatment precisely at feeding time to avoid any regrowth of bacteria in the warm milk after treatment. Cleaning is fully automated, though the effectiveness should be monitored regularly. Results from studies conducted with UV light treatment of milk have been much less consistent compared to heat pasteurization. Table 5 shows the maximum reductions in bacteria populations reported from using UV light to treat milk.

Table 5. Bacterial reduction results observed in studies of UV light treatment.

Bacteria Types	Max Reduction (Log_{10} cfu/mL)	Publication(s)
Staphylococcus aureus	7.2	Krishnamurthy et al., 2007
Mycobacterium avium subsp. *paratuberculosis*	2.6 1.1	Altic et al., 2007 Donaghy et al., 2009
Escherichia coli	1.6 3.4 (skim milk) 2.9	Palgan et al., 2011 Miller et al., 2012 Engin and Yuceer, 2012
Listeria innocua	0.8	Palgan et al., 2011
Listeria monocytogenes	5.6 (goat milk)	Matak et al., 2005

In addition to these results, a recent field study conducted by Penn State (Gelsinger et al., 2013) counted bacterial colonies in milk pre and post UV treatment and found that less than 50% of milk samples collected after UV treatment could be considered acceptable for feeding calves. In addition, UV light treatment was not able to achieve a full log reduction in 3 of 8 bacteria types. In contrast, a similar study measuring the same bacteria types with heat pasteurizers showed that pasteurization of milk decreased bacterial populations by 1.4 to 2.4 logs (Elizondo-Salazar et al., 2010). Based on these data, we currently do not recommend UV light systems for on-farm pasteurization of milk for calves.

CONSIDERATIONS FOR USING COMMERCIAL ON-FARM SYSTEMS

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

suggest the following installation requirements and considerations for day-to-day use.

Installation requirements

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

Considerations for day-to-day use

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

Handling of pre-pasteurized milk and equipment requirements

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

Handling of post-pasteurized milk

Any bacteria surviving the pasteurization process will begin to replicate in the warm medium if the cooling process is delayed. This can occur if the milk is allowed to cool slowly for several hours at ambient temperature or if milk is left to sit at warm ambient temperatures for long periods before being fed. For this reason, pasteurizers should be equipped to rapidly cool the milk to feeding temperature immediately after pasteurization is completed, and producers should try to feed the product soon after pasteurization is complete. If there is to be a delay between pasteurization and feeding, then the milk should be chilled.

Post-pasteurization contamination of milk is another important concern. Pasteurized milk should be stored in clean, closed containers and distributed to calves in clean buckets or bottles. Careful attention must be paid to cleaning and sanitizing buckets, bottles, nipples, etc. A field study conducted by Penn State (Elizondo-Salazar et al., 2010) measured bacterial growth in milk pre and post pasteurization and in individual calf buckets before calves were allowed to drink. Although bacterial populations were significantly reduced by pasteurization, these counts were very much increased in samples collected from individual calf buckets. In some cases, the milk calves actually consumed contained more bacteria than raw milk prior to pasteurization. No matter how well a pasteurizer may work, there is ultimately no effect if the calves' buckets are not adequately cleaned and sanitized prior to use.

Cleaning and sanitizing pasteurizers

With poor cleaning, fat, protein, and inorganic films (minerals) can build up in these systems, interfering with temperature transfer to the milk and serving as a source to inoculate milk with bacteria. Additionally, if residue builds up on the surface of the light source in a UV treatment system, it can severely affect the ability of UV radiation to penetrate the milk and affect bacterial cells. Producers should clean this equipment as diligently as they would the milking system, using procedures similar to common milking system sanitization procedures. One recommended cleaning process (Reynolds, 2002) is as follows:

1. Pre-rinse with cold water
2. Circulate alkaline detergent rinse to remove fat (1% wt/vol NaOH; 167°F, 30 minutes)
3. Rinse with hot water (167°F, 15 minutes)
4. Circulate nitric acid rinse to remove protein (0.7% wt/vol; 158°F, 15 minutes)
5. Post-rinse with hot water (167°F, 15 minutes)

Producers should contact the manufacturers or distributors of commercial on-farm pasteurizers for cleaning instructions that best fit their equipment. Evaluating cleaning can include visual assessment for build-up of residual films plus cultures of pasteurized milk (e.g. standard plate count, total bacteria count, lab pasteurized count).

Potential problems

Dairy operations have to consider their supply of waste milk. To be practically effective a dairy operation must have a stable supply of waste milk. A stable supply of waste milk is critically important because the liquid feed fed to calves should not be changed frequently. For smaller herds this is sometimes difficult because days can go by where there is little or no waste milk. In these situations an alternative feed must be available, such as marketable milk from the bulk tank, milk from high somatic cell cows, milk replacer, or a milk extender.

Quality control is also an issue that demands constant attention. Milk pasteurizers need to be operated, evaluated, and maintained so a quality product is produced. Milk pasteurizers are also an investment requiring a return on investment.

Calves fed pasteurized waste milk may be contaminated with antibiotic residue and as result should not be sold until after the appropriate withholding period.

The cost of equipment can be substantial, and the capital cost as well as the cost of managing the process should be carefully evaluated. If your operation does not have the management skill to properly purchase, install and utilize a pasteurizer, then it is important to make this determination prior to making the capital investment.

Maybe the greatest challenge with on-farm pasteurization is maintaining the equipment in proper repair and calibration so that the proper time and temperature is achieved consistently.

Tips for success

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

THE BOTTOM LINE

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

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