ON FARM PASTEURIZER MANAGEMENT FOR WASTE MILK QUALITY CONTROL

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Increased value of proteins for calf diets has caused many to consider the utilization of waste milk as a source of nutrition for the growing calf. Waste milk is comprised of transition milk from cows during the first three days after calving and that collected from cows treated with antibiotics or removed from the milking string due to other illness. Surveys from Wisconsin and results from field studies conducted in North Carolina and California show it contains in excess of 29% fat and 27% protein. This compares very favorably to the nutrient content of 20% fat: 20% protein of most traditional milk replacers. It's also a reason why calves usually gain more weight when fed milk as compared to traditional milk replacers. However, it must be remembered that waste milk also represents a significant biosecurity risk to the calf. A Virginia Tech study found that waste milk on 3 North Carolina farms averaged 5,000,000 cfu/ml aerobic plate count (APC) and over 1,600,000 in 10 California farms. A study of 31 operations in Wisconsin (Jorgensen, et al, 2005) found an average of 8,822,000 cfu/ml and a range of 6,000 to 72,000,000 cfu/ml. Bulk tank samples collected over a 6 year period in California (Kirk, et al, 1997) from 267 herd yielding 3210 samples found *Mycoplasma bovis* in 55% of samples. *Mycobacterium paratuberculosis* has also been isolated from waste milk. Major concerns for the treatment of waste milk, sanitation of equipment and the management of calf feeding systems utilizing waste milk will be discussed in this paper.

Pasteurization

Fortunately several manufacturers are producing equipment which successfully treat waste milk to remove most pathogens. In addition, dairy producers and equipment manufacturers have developed custom designed equipment utilizing plate coolers which if properly maintained and operated achieve successful pasteurization conditions. Pasteurization is defined as the "partial sterilization of a substance and especially a liquid (as milk) at a temperature and for a period of exposure that destroys objectionable organisms without major chemical alteration of the substance" (Webster's 2004). Pasteurization does not sterilize milk and does not alter activity of antibiotics which might be present in waste milk. The goal of any pasteurizer is to produce milk with a **standard plate count of <20,000 cfu/ml** and an **alkaline phosphatase activity of less than 500 mU/ml.** Alkaline phosphatase is an enzyme present in milk which is deactivated at a temperature slightly above that required for successful pasteurization. It's a relatively easy and inexpensive test. Successful pasteurization is achieved at several different combinations of temperature and time as shown in Table 1.

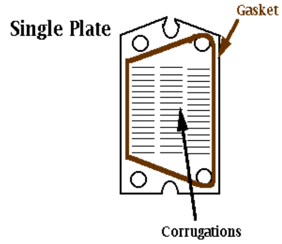
Table 1 Pasteurization time and temperature combination

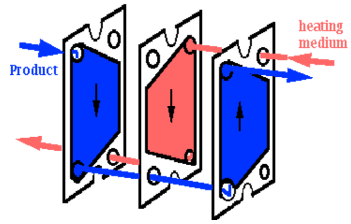
type	time	Temp. C°	Temp. F
Batch	30 minutes	63	145
HTST*	15 seconds	72	161
HHST**	1 second	88	190
HHST**	0.5 second	90	194
HHST**	0.1 second	94	201
HHST**	0.05 second	96	205
HHST**	0.01 second	100	212
UP***	2 seconds	138	280
UHT****	4 seconds	138	280

High temperature short time*
Higher temperature shorter time**
Ultra-pasteurized***
Ultra High Temperature****
Adapted from Chanan (1997)

Types of pasteurizers.

1. 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 145°F for 30 minutes and then cooled to 100 to 110°F prior to feeding. It can be used for treatment of colostrum. However, it's more suitable for treatment of smaller volumes of liquids and may be more suitable for operations with fewer calves. "Dead" spots where milk is not thoroughly heated can occur if milk is not agitated properly. In addition, it's important that the head space above the liquid reach a temperature high enough to assure that residual bacteria on the surface of the lid are killed. Sanitation is not as easily automated.
2. HTST pasteurizers have captured a large portion of the market mainly due to speed and ease of automation in 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. Hot milk is then rapidly cooled to 110 F prior to feeding. It is recommended that equipment possess a valve which will divert milk back through the pasteurizer if milk has not reached an adequate temperature. This equipment enables processing of large volumes in a short time and it's conducive to use of automated cleaning. Typically the initial purchase price of this equipment is higher due to greater complexity, electronics and the requirement of a substantial source of supplemental hot water. If equipment is not properly maintained plates can become clogged with burned milk solids requiring disassembly and laborious cleaning. The basic concepts of the HTST pasteurizer are shown in the figure below





Professor Douglas Goff, Dairy Science and Technology Education, University of Guelph, Canada, www.foodsci.uoguelph.ca/dairyedu/home.html.

3. Turbulent batch pasteurization is a hybrid of the previous two. Milk resides in a closed container but is recirculated through a plate or tube heat exchanger similar to HTST equipment. Commercial equipment is available, although dairy producers and calf ranchers have constructed devices utilizing plate coolers, milk pumps and auxiliary hot water sources. Milk is typically heated to 161 F for over 15 seconds. This equipment can be low cost and simple as it can utilize second hand equipment. It also involves violent movement of milk which may aid in exposure of bacteria to killing temperatures. However, it is slow, requires more hot water and careful monitoring to assure that critical temperatures have been achieved. Non commercial units offer little to no automation and require close supervision.

Critical control areas for pasteurization management. Many of the observations noted in this presentation are the result of a study of 3 dairies in North Carolina from February to August 2005 and a similar study of 10 facilities in Tulare and King county, California in June, 2005 and January, 2006. In North Carolina, herds were visited every two weeks. Samples of milk were obtained prior to and immediately following pasteurization and at 20 minute intervals until the last calf was fed. Temperature, standard plate count, SCC, fat%, and protein% were determined on all samples. Alkaline phosphatase was measured on post pasteurization samples. In California, herds were visited once in June and once in January to obtain similar information. Daily waste milk volume and number of calves fed was recorded. The cooperation of the herd owners, and their

employees, Sierra Dairy Laboratory and United DHI Laboratory is gratefully acknowledged.

Regardless of the type of pasteurizer used, **quality of incoming milk** is important. The range in quality of incoming milk for North Carolina and California and Wisconsin farms (Jorgensen, et al., 2005) is shown in Table 2.

Table 2. Quality of raw milk on farms in North Carolina, California and Wisconsin.

Location	Aerobic plate count		Fat		Protein	
N.C.	300,000	$1x10^{8}$	1.5%	4.5%	2.7%	3.8%
CA	26,000	$5.9x10^{6}$	1.2%	12.1%	2.7%	4.7%
WI	6,000	$7.2X10^{7}$	2.8%	4.7%	2.9%	5.1%

Note the high level of bacteria in milk sampled prior to pasteurization. Waste milk averaged 5,000,000 cfu/ml aerobic plate count on 3 North Carolina farms and 1,600,000 cfu/ml standard plate count on 10 California farms. It's important to note that pasteurizers do not sterilize milk they only reduce levels of bacteria. In our study pasteurizers in North Carolina lowered the bacteria to 105,000 cfu/ml, while the units we sampled in California lowered it to 19,400 cfu/ml. It is unfair to say that the pasteurizers we sampled California were superior to those in North Carolina because the systems in California were starting out with cleaner milk as shown in Table 2. Both groups of pasteurizers, although starting with very different levels of bacteria, averaged between 98-99% reduction in bacteria. The biggest difference in these two groups of farms was the way milk was stored prior to pasteurization. California farms tended to keep their milk cooler, agitated and, for the most part, treated it as if it was marketable milk. In contrast, the NC farms rarely refrigerated waste milk nor did they clean the tanks used to collect milk prior to pasteurization as aggressively as the California herds. One farm that refrigerated waste milk, kept it at 48-50ºF, to reduce energy needed to heat the milk during pasteurization. This practice along with infrequent cleaning resulted in very high pre pasteurization bacteria levels averaging 56 million cfu/ml. One California herd with the highest APC (5.9 million cfu/ml) had a receiving tank located outside in the sun.

Somatic cell count of milk ranged from a low of 41,000 to 4,500,000 in our study and 110,000to 3,800,000 in the Wisconsin study. Incoming milk should be filtered prior to pasteurization. Clumps of organic material can enable the more heat resistant Mycobacterium species to resist pasteurization.

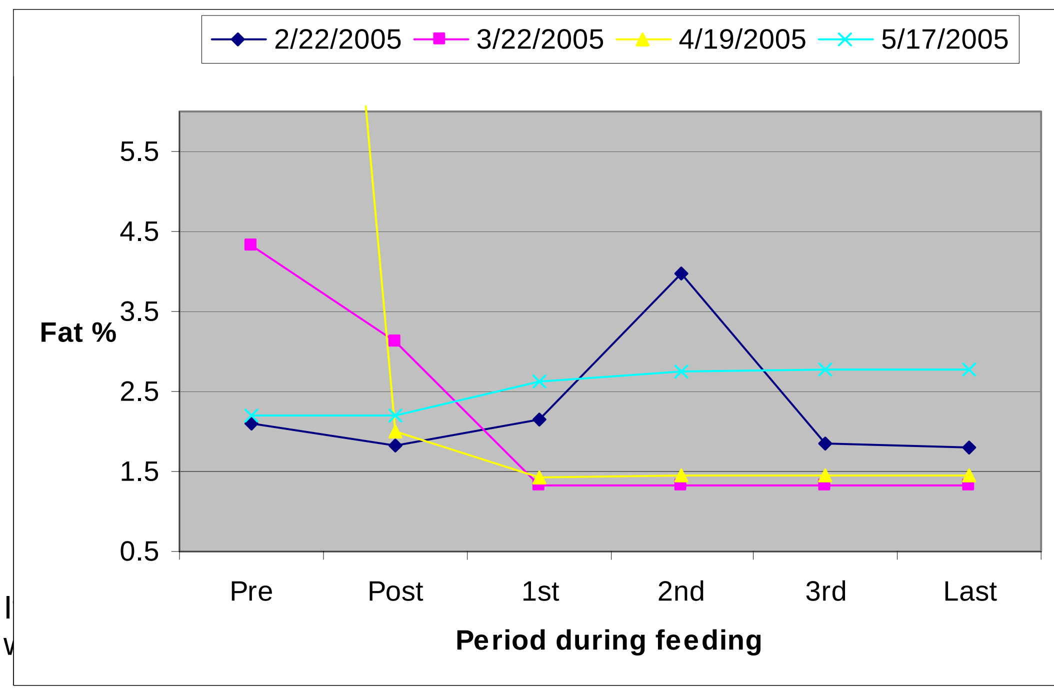
Factors influencing the microbial waste milk are a function of:

- microbial content of milk from the cow
- exposure of milk to microbial sources such as flies, manure from the environment
- cleanliness of equipment used to store waste milk and length of time waste milk is held prior to pasteurization

- temperature of milk during storage
- cleanliness of pasteurization equipment, bottles and tanks used to transport pasteurized milk.

Nutrient composition of waste milk varied tremendously. In most cases the level of fat and protein would exceed levels found in a 20:20 milk replacer with 12.5% solids. However some herds had waste milk with fat% less than 2.0%. There are several reasons for low fat and protein tests. Waste milk can be diluted when excessive water enters the receiving tank when milk lines are flushed after each milking. When receiving tanks lack an agitator, fat will separate in a relatively short time causing inconsistencies in milk fat content if bottles are filled immediately following pasteurization. One dairy collected milk in a stainless steel vat and pasteurized milk with an HTST unit several hours after the milk was collected. Milk was collected from an outlet at the bottom of the receiving tank and not all milk was pasteurized each day. The results of milk sampling are shown in the figure 1 below which shows fat content of milk collected from the top of the receiving tank before pasteurization, after pasteurization and at intervals during feeding.

Figure 1. Fat content of milk collected prior to and after pasteurization and at 20 minute intervals during feeding.



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Our study and one by Jorgensen and Hoffman (2005) found that commercially available pasteurizers when properly installed, maintained and operated successfully reduced APC to less than 20,000 cfu/ml and alkaline phosphatase scores to less than 500. However, like any equipment there is an opportunity for failure. Workers in Wisconsin evaluated 31 pasteurizers and found a 13% occurrence of AP activity, which implies that pasteurization temperature was not achieved. In the North Carolina, samples were positive for AP 18%, 15% and

0% for each of the study herds. Samples were only obtained twice on each farm in California and 4 of herds tested positive for AP. There are multiple reasons for failure of pasteurization. In some instances, herds in an effort to reduce installation costs installed hot water sources which were marginal at best. On one farm the herd bypassed the diversion value that was operating too often because the hot water supply was inadequate. In another instance a batch pasteurizer did not hold milk for an adequate time. It appeared that the automated temperature control was improperly programmed. There is greater concern for equipment failure in custom designed systems which require the operator to observe a thermometer and manually regulate milk and hot or cold water flow.

Cleaning pasteurizer and feeding equipment. Cleaning pasteurization equipment is not unlike cleaning milking equipment in importance. Each manufacturer has a recommended cleaning procedure which should be followed. HTST units are rinsed followed by a caustic alkaline detergent. Most systems need to be cleaned for at least 30 minutes at a temperature 10^{o}F hotter than pasteurization temperature. After the cleaning cycle is completed the system should be drained and rinsed. An acid cleaner is used to sanitize for at least 10 minutes followed by water flush. Batch systems require similar cleaning with caustic detergent followed by acid sanitizing. In general, cleaners containing nitric acid or iodine should not be used as they will cause damage to pumps and gaskets. Similarly chlorine sanitizers are very detrimental to gaskets. Milk preservatives are not recommended for HTST systems. Spoiled milk should not be pasteurized as it can coagulate and plug the heat exchanger plates requiring time consuming dismantling. Feeding equipment such as bottles, nipples, tanks and hoses must be subject to similar stringent sanitization procedures. In California 5 out of 7 herds experienced APC exceeding 20,000 cfu/ml within one hour of pasteurization. Two herds had APC exceeding the pre pasteurization levels indicating that the vessels receiving pasteurized milk were unclean. Feeding method (buckets or bottles) did not appear to influence results although most operations opted to use bottles. In North Carolina, milk samples were obtained more frequently from the exit of the pasteurizer and from the hose used to deliver milk to the calf buckets. In one herd 8 of 14 post pasteurization samples exceeded 100,000 cfu/ml. All samples obtained just prior to feeding the calf exceeded this level. Culture of one post pasteurization sample revealed 120,000 Staph/ml and 200,000 coliforms/ml. In another herd 4 of 14 samples exceeded 200,000 cfu/ml. Over a 4 month period all feeding samples exceeded 200,000 cfu/ml. Again Staph (20,000 cfu/ml) and coliforms (1,000 cfu/ml) were isolated from the end of the hose delivering the pasteurized milk into the bucket. In all cases, receiving tanks and hoses or bottles were hand cleaned providing an opportunity for considerable variation in cleaning. A modified gasoline nozzle used in North Carolina herds was difficult to clean and may have contributed to the problem. The herd feeding calves by buckets in California used a food grade valve and nozzle and bacteria counts were substantially lower.

The Wisconsin study found APC ranging from 0 to 420,000 cfu/ml after pasteurization. Coliforms averaged 340 cfu/ml with a range of <10 to 3400 cfu/ml. It appeared that pasteurization destroyed most of other species of bacteria of concern with the exception of Streptococcus spp. and Enterococcus spp. which averaged 5,117 and 723 cfu/ml.

Supply of waste milk. It's commonly assumed that the supply of waste milk will coincide with nutritional needs of the calf enterprise. Various factors influence this relationship including the following: number of bull calves raised, ratio of heifer: bull calves, herd health status (mastitis, other treated cows), age at weaning and feeding rate. If the herd practices intensive calf rearing the feeding rate can double from the typical gallon of milk fed per calf per day. Herds in North Carolina yielded an average of 6.2, 22.7 and 9.7 lb. of waste milk per calf per day for 7 months of our study. Two herds compared supply of waste milk with nutrition needs of the calf enterprise. Results are shown in Figure 2 and 3.

Figure 2. Comparison of milk required and supply of waste milk on Farm 1.

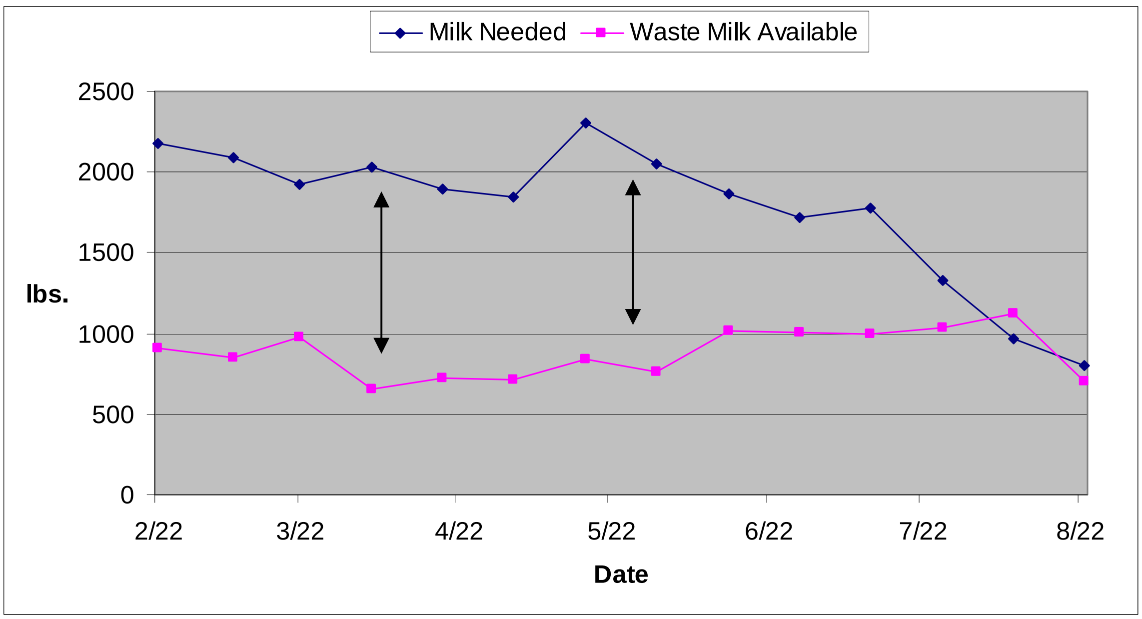
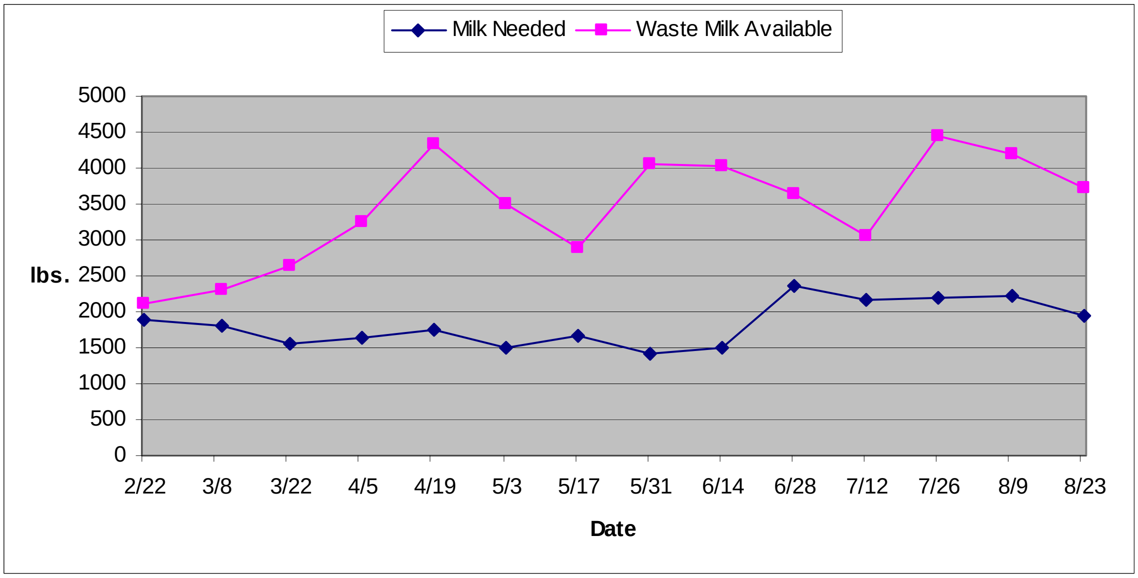
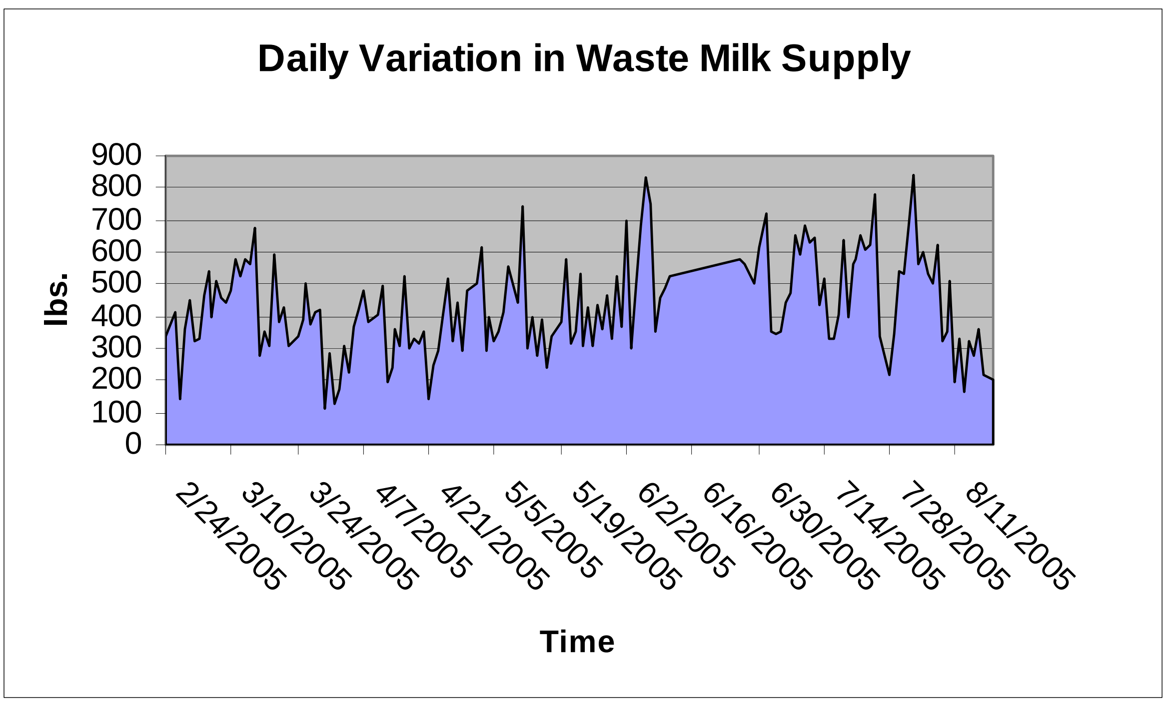


Figure 3. Comparison of milk required and supply of waste milk on Farm 2



Of greater interest was the evaluation of milk supply on a daily basis on Farm 1 which is shown in Figure 4.

Figure 4. Daily variation in supply of waste milk on a North Carolina dairy



It's frequently assumed that the supply of waste milk is relatively constant. However, this figure demonstrates the large variation in supply of milk. This producer opted to utilize a constant amount of waste milk daily which was fed to older calves. Younger calves, which one would assume would benefit from a more consistent feeding program, received milk replacer while pasteurized waste milk was fed to older calves (>4 weeks). In California it appeared that most operations had an ample supply of waste milk to feed heifer calves. If a deficiency was encountered, additional milk solids were provided by milk replacers ranging in composition from 20:20 to 28:20. A concern exists in estimating nutrient content of waste milk and knowing how much milk replacer powder and water to add to achieve the desired nutrient composition. Recall the variation observed in fat and protein content of waste milk observed between different farms and during different times after pasteurization.

On farm pasteurizers can be a valuable tool for management of the feeding program. However, significant risks are taken if managers do not address critical control points involved.

1. Treat waste milk with as much care as is given to marketable milk.
    a. Guard against addition of **too much water** when flushing lines at the end of each milking.
    b. **Refrigerate waste milk immediately** or pasteurize milk within two hours of the end of each milking.
    c. Clean tanks used for storage or transfer with the same procedures as used for herd milk.
2. Follow manufacturer's recommendations for operation and cleaning of pasteurizing equipment.
    a. Assure that there is an **adequate source of hot water** for operation of the pasteurizer and immediate cleaning when pasteurization is completed.
    b. Flush equipment with clean water followed by a caustic detergent and sanitizer. Avoid excessive use of chlorinated sanitizers as they are detrimental to the life of gaskets.
    c. Cleaning temperature should be 10^oF hotter than pasteurization temperature.
3. **Monitor operation of the pasteurizer** at least monthly and preferably weekly by measuring aerobic plate counts and/or alkaline phosphatase activity. Assure that all temperature gauges are accurate by checking temperature of the milk with an accurate hand held thermometer.
4. **Develop a strategy** to use when the supply of waste milk is inadequate. If additional powder and water are added to the tank, provide clear mixing instructions to enable feeders to achieve levels of protein, fat and total solids desired. Consider using pasteurized waste milk for one group of calves and feeding others milk replacer in accordance with mixing instructions provided by the replacer manufacturer.

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