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Efficacy of on-farm use of ultraviolet light for inactivation of bacteria in milk for calves[1]

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ABSTRACT

Ultraviolet light is being employed for bacterial inactivation in milk for calves; however, limited evidence is available to support the claim that UV light effectively inactivates bacteria found in milk. Thus, the objective of this observational study was to investigate the efficacy of on-farm UV light treatment in reducing bacteria populations in waste milk used for feeding calves. Samples of nonsaleable milk were collected from 9 Pennsylvania herds, twice daily for 15 d, both before and after UV light treatment (n = 60 samples per farm), and analyzed for standard plate count, coliforms, noncoliform, gram-negative bacteria, environmental and contagious streptococci, coagulase-negative staphylococci, *Streptococcus agalactiae*, *Staphylococcus aureus* count, and total solids percentage, and log reduction and percentage log reduction were calculated. Data were analyzed using the mixed procedure in SAS. In all bacteria types, samples collected after UV treatment contained significantly fewer bacteria compared with samples collected before UV treatment. Weighted least squares means for log reduction (percentage log reduction) were 1.34 (29%), 1.27 (58%), 1.48 (53%), 1.85 (55%), 1.37 (72%), 1.92 (63%), 1.07 (33%), and 1.67 (82%) for standard plate count, coliforms, noncoliform, gram-negative bacteria, environmental and contagious streptococci, *Strep. agalactiae*, coagulase-negative staphylococci, and *Staph. aureus*, respectively. A percentage log reduction greater than 50% was achieved in 6 of 8 bacteria types, and 43 and 94% of samples collected after UV treatment met recommended bacterial standards for milk for feeding calves. Based on these results, UV light treatment may be effective for some, but not all bacteria types found in nonsaleable waste milk. Thus, farmers should take into account the bacteria types that may need to be reduced when considering the purchase of a UV-treatment system.

Key words: ultraviolet light, waste milk, calf

INTRODUCTION

Pasteurized waste milk is considered a nutritious and low-cost liquid feed for dairy calves. Surveys show that it is gaining popularity in the United States (USDA, 2010), and studies show its value as a feed source for the neonate (Jamaluddin et al., 1996). It is most often recommended to pasteurize waste milk before feeding calves to reduce potential pathogen populations (McGuirk, 2008). Jamaluddin et al. (1996) reported that calves fed pasteurized milk were 3.7 kg heavier at 180 d of age compared with calves fed unpasteurized milk. This difference was attributed to fewer incidents and less severe cases of scours in the preweaning period in calves fed pasteurized milk. In addition, Godden et al. (2005) demonstrated a $0.69/calf per day reduction in costs when calves were fed pasteurized nonsaleable milk rather than milk replacer. High-temperature, short-time pasteurization (HTST; 72°C, 15 s) and batch pasteurization (63°C, 30 min) are 2 types of heat treatment that have been adopted on farms to reduce the bacterial populations in milk fed to calves (Elizondo-Salazar et al., 2010). However, heat pasteurization is a high-energy input process that can increase the cost associated with feeding milk to calves (Krishnamurthy et al., 2007; 2008).

Ultraviolet light treatment is an alternative method for bacterial inactivation that has been approved for use in fruit juice (FDA, 2000), and has been suggested as a possible alternative in milk processing as well (Matak et al., 2005). Ultraviolet light inactivates bacteria by creating covalent bonds between nucleic acids within bacterial DNA (Koutchma et al., 2009), thus rendering the bacteria unable to reproduce. Factors that influence the effectiveness with which UV light inactivates bacteria are the types and number of organisms present, dose of UV light, as well as solids concen-

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tration, volume, and transparency of the liquid medium (Guerrero and Barbosa-Canovas, 2004). Research trials conducted with juice have shown that, when properly applied, UV treatment is able to consistently attain the FDA-required 5-log decrease in microorganisms (FDA, 2011).

Results from experiments using UV light to inactivate bacteria in milk are more variable. Krishnamurthy et al. (2007, 2008) reported decreases in *Staphylococcus aureus* counts ranging from 1.05 to 6.61 $\log_{10}$ cfu/mL in milk foam, 0.14 to 8.55 $\log_{10}$ cfu/mL in stationary milk, and 0.55 to 7.26 $\log_{10}$ cfu/mL in flowing milk. Populations of *Listeria monocytogenes* were decreased by 5.62 $\log_{10}$ cfu/mL in goat's milk exposed to a cumulative dose of 28.4 mJ/mL of UV light (Matak et al., 2005). A more recent study found reductions >2 log in *Escherichia coli*, *Staphylococcus* spp., total coliforms, and mesophilic aerobic microorganisms after exposure to 13,870 mJ/mL (Engin and Yuceer, 2012). Miller et al. (2012), using a UV dose of 114,231 mJ/mL, were able to attain log reductions of 3.36, 2.89, and 2.94 in skim, 2%, and whole milk inoculated with *E. coli*. However, UV light treatment seems to be less effective for inactivation of *Mycobacterium avium* ssp. *paratuberculosis,* the causative agent of Johne's Disease in cattle (Stabel, 2001). Altic et al. (2007) reported a maximum 2.6 log reduction in whole milk exposed to 2,860 mJ/mL of UV light. In addition, Donaghy et al. (2009) reported a 1.1 log decrease using a UV dose of 1,836 mJ/mL. However, these reductions are considerably smaller than those reported from batch or HTST pasteurizers (Stabel, 2001; Stabel et al., 2004, respectively), where no *M. avium* ssp. *paratuberculosis* were isolated after heating. In both cases, milk was inoculated to levels in excess of 5 $\log_{10}$ cfu/mL.

A flow-through, pulsed UV treatment system commercially available for bacterial inactivation in waste milk for calves uses a series of UV lights, and milk flows through the system multiple times to increase the cumulative dose of UV light. Flow-through systems have been studied under a laboratory setting (Krishnamurthy et al., 2008). However, no data have been published concerning the efficacy of this technology applied on farms. Thus, the objective of our study was to describe the observed efficacy of UV light treatment systems in use on a sample of dairy farms in Pennsylvania. The total solids suspended within a liquid have previously been shown to affect the efficacy of UV light for bacterial inactivation (Miller et al., 2012). A secondary objective of our experiment was to assess the effect of total solids percentage on bacterial inactivation and describe the variation in total solids percentage between individual batches of milk.

MATERIALS AND METHODS

Description of Farms and UV Treatment System

Nine farms were chosen based on known use of UV light treatment of milk for feeding to calves and convenience of sample collection. Selected herds were located in the southeast, south-central, and north-central regions of Pennsylvania and represented various management strategies, including one farm utilizing robotic milking machines. All farms used the same UV treatment system (UV Pure, GEA Farm Technologies Inc., Naperville, IL), with the systems being in use on the farms from 2 to 48 mo at time of sampling. The UV Pure system is a completely automated system. Milk is pumped from a retention tank, through the UV reactor, and returned to the retention tank. Milk cycles through the system at least 16 times. The system will automatically increase the number of cycles to maintain a similar total dose of UV radiation as the UV light bulbs age. The UV reactor consists of 2 or 3 UV lights, depending on the size of the system. Larger systems include more lights to maintain efficiency while treating large volumes of milk. The lights are housed inside a quartz tube and milk is exposed to UV light by flowing over the outside of the quartz tube. After UV treatment, milk is heated to approximately 38°C for feeding. Each UV system was washed with an initial water rinse followed by detergent and acid wash cycles that were programmed to occur automatically after each use. Each system included a monitoring system for the UV lights to alert the operator when lights should be replaced. No UV lights had been replaced in any system at the beginning of sampling. Milk handling before entering the retention tank of the UV treatment system ranged from no human contact to employees moving milk into the retention tank via plastic buckets.

Sample Collection

Samples of nonsaleable whole milk were collected by farm personnel into sterile, plastic, 15-mL conical tubes (VWR International LLC, Radnor, PA) before and after UV treatment every morning and night for 15 d. Farm personnel were instructed to allow milk to agitate within the retention tank, then, using a gloved hand, collect samples, and freeze immediately after collection. Supplies and training for sample collection were provided by the authors before the sampling period. Samples were transported on ice from individual farms to the Pennsylvania State University on a weekly or biweekly basis throughout the sampling period, and stored at −20°C before bacterial analysis. At the time of transport, samples were examined