CHOOSING THE BEST TEAT DIP FOR MASTITIS CONTROL AND MILK QUALITY

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Introduction

The prevention of bovine mastitis is the most important component of a mastitis control program, and both pre- and postmilking teat antisepses are the most effective procedures for preventing new intramammary infections (IMI) in dairy cows. These procedures involve dipping teats of dairy cows before and after milking with an appropriate germicidal preparation to reduce teat skin colonization and contamination with mastitis-causing bacteria and minimize penetration into the teat canal.

Protocols for determining efficacy of teat dips have been developed and used to evaluate more than 300 experimental and commercial formulations. The protocols have been accepted by scientists, commercial companies, and regulatory agencies throughout the nation and world. Because of the attention given to efficacy of teat dip products and the availability of acceptable testing methods, manufacturers have developed highly efficacious germicidal products that reduce the incidence of mastitis by 50 to 95%. The accompanying reduction in level of mastitis in U.S. dairy herds alone represents a savings of millions of dollars annually.

In the last 25 years, teat dipping or spraying with a germicidal solution immediately after every milking has been an effective management tool to reduce the rate of new IMI in dairy cows, especially those caused by the contagious pathogens such as *Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma bovis*, and *Corynebacterium bovis*. Postmilking teat antisepsis is regarded as the single most effective practice for the prevention of mastitis. More recently, premilking teat sanitization has been introduced and has been widely adopted to minimize the number of potential intramammary pathogens on teat ends prior to attachment of milking machines; these pathogens include the environmental bacteria such as *Streptococcus uberis*, *Escherichia coli*, and *Klebsiella pneumoniae*.

Establishment of IMI requires penetration of mastitis-causing organisms through the teat canal, and researchers agree that the number and types of bacteria on teat skin have a direct relationship to the incidence and type of mastitis that develops. Teat dipping is a simple, effective, and economical means to reduce bacterial populations on teat skin both before and after milking, and an abundance of published evidence shows that this practice will reduce the rate of infection among dairy cows. However, the duration of existing infections is not affected, and it may take several months before the herd level of infection is reduced after teat dipping is initiated.

A variety of germicides are incorporated into teat dip products and include iodine, chlorhexidine, quaternary ammonium, sodium hypochlorite, dodecyl benzene sulfonic acid, chlorine, nisin, hydrogen peroxide, glycerol monolaurate, and fatty acids. These germicides destroy bacteria through chemical or biological action such as oxidation-reduction mechanisms, denaturation/precipitation of cytoplasmic proteins, inhibition of enzyme activity, and disruption of cell membranes. Teat sanitization procedures, germicide classes used, and efficacy testing are described below.

Predipping

The primary objective of premilking udder preparation and teat sanitization is to achieve an acceptable level of decontamination of teat skin. This aids in reducing the spread of microorganisms and incidence of new IMI, and in minimizing the number of bacteria that find their way into the raw milk supply. In addition, the process of preparing teats for milking has several other advantages, which include promoting milk letdown, speeding up the milking process, and helping to ensure that the maximum amount of available milk is harvested without causing damage to the sensitive teat tissues.

With the decrease in mastitis caused by contagious mastitis organisms such as *Staph. aureus* and *Strep. agalactiae*, concern has increased regarding mastitis caused by environmental microorganisms, especially coliforms and environmental streptococci that contaminate teats and udders primarily between milkings. This has led to widespread use of a premilking sanitation procedure known as predipping.

This control method originated at the University of California, Davis, where researchers were attempting to prevent new cases of clinical coliform mastitis. It was theorized that predipping instead of udder washing before milking might help to minimize the amount of water on teat ends remaining from wash pens or prep stalls, and effectively reduce the number of bacteria on the teat surface, which serve as potential mastitis pathogens. To accomplish this, teats were dipped before milking in an iodine product instead of using an udder wash to reduce the coliform bacterial load on the teat skin, followed by drying with paper towels. This procedure was more effective than the udder wash in killing bacteria, and resulted in lowering the somatic cell count (SCC), but it was irritating to the teat skin. In addition, iodine residues were found in milk. However, switching to a lower iodine concentration for the predip prevented skin irritation, reduced residues in milk, and resulted in up to a 80% reduction in the new rate of infection.

The effectiveness of this premilking udder preparation procedure was confirmed in subsequent efficacy studies at Cornell University, the University of Vermont, and the University of Tennessee. Iodine concentrations in the products evaluated in these investigations ranged from 0.1 to 0.5%, and researchers stressed the need to thoroughly dry teats prior to machine attachment to avoid iodine residues in milk. In general, predipping was found to reduce the incidence of new IMI with environmental pathogens by greater than 50% compared with udder washing and drying with individual paper towels. In one study, predipping was also found to

reduce the new infection rate against *Staph. aureus*; however, this practice was not effective against the coagulase-negative staphylococci.

The effectiveness of predipping is dependent upon the organic load to which teats are exposed during the intermilking period. Bacterial challenge studies as well as natural exposure trials suggest that exposure to a heavy load of environmental pathogens shortly after milking reduces the effectiveness of predipping. However, minimizing the bacterial load by keeping cows clean for 1 to 2 hours after milking maximizes the benefits of this practice.

The predip procedure involves 1) precleaning of teats as necessary, 2) forestripping, 3) dipping or spraying teats with a proven germicidal predip product, 4) allowing the recommended contact time (15 to 30 seconds), 5) drying each teat thoroughly with a single service paper towel or laundered cloth towel to remove surplus germicidal product, microorganisms, and organic material, and 6) attaching teat cups to the dry udder. In some instances, the preferred method is to apply the predip, wait the recommended contact time, and forestrip followed by wiping; the additional benefit of massaging the teat during forestripping may massage the dip into the teat skin and aid in the removal of surface microorganisms. Predipping is sometimes done without prior washing of teats, and germicide is often placed on top of manure and dirt present on teat skin. This practice is not likely to reduce the incidence of mastitis or lower the SCC, and will probably reduce milk quality. Manure and dirt must be removed to realize the full benefits of predipping.

Herds experiencing a problem with environmental mastitis should consider adopting this simple procedure. Only products proven effective should be used as predips, and they should be used in strict accordance with manufacturer recommendations. It should be stressed that predipping does not replace good udder preparation, and after milking units are detached, postmilking teat dipping should also be continued. When used in conjunction with all other procedures, predipping is an asset to the total mastitis control program.

Postmilking Teat Dipping

The transfer of some organisms is inevitable at milking time, even under the best of hygienic conditions. To destroy mastitis organisms on teats at the end of milking, it is necessary to dip teats in a suitable disinfectant soon after milking machines are removed. Postmilking teat dipping is the most effective milking hygiene practice for preventing new infections caused by the two most common contagious mastitis organisms, *Staph. aureus* and *Strep. agalactiae*.

The concept of teat disinfection after milking dates back to 1916, when dilute pine oil was used in an effort to reduce the spread of *Strep. agalactiae*. However, the practice was not adopted widely for several decades because supporting research data were not available on existing teat dip products. The practice of postmilking teat antisepsis was revived in Canada, where researchers at the University of Ontario, Guelf, showed that the practice of dipping teats in a disinfectant after milking led to reductions in mastitis-causing bacterial populations on teat cup liners. Subsequent studies at the National Institute for Research in Dairying in England confirmed Canadian observations in large field trials, and led to extensive investigations at

Cornell University, where postmilking was included as a component of a comprehensive mastitis control program.

It is now widely accepted that the vast majority of postmilking teat dip products will reduce the new infection rate by at least 50%, and some products as high as 95%. Only products shown by research to be safe and effective should be used. This involves using a product registered with the Food and Drug Administration (FDA). The label for such products will provide information on each active ingredient, instructions for use, the manufacturer, a production lot number, and an expiration date. Responsibility for generating conclusive evidence of effectiveness belongs to the manufacturer. Dairy farmers should require evidence that a product meets FDA regulations and is effective in preventing new udder infections.

What Is the Best Teat Dip?

This question is often asked of researchers, extension specialists, veterinarians, and fieldmen by producers. It must be emphasized that producers should use teat dip products that have been registered and proven effective. Otherwise, they may be using a product that either provides no benefits or that is actually harmful to teat skin and promotes new infections. At present, there is no U. S. regulatory agency that the requires efficacy testing prior to marketing a teat dip product. Thus, many teat disinfectants have not been tested for their effectiveness in reducing new cases of mastitis in dairy cows.

Until recently, unless a producer dealt with a salesman who was knowledgeable about teat dip efficacy testing, he was unable to easily obtain information about product performance. However, in August of 1995, the National Mastitis Council (NMC) produced a document that is updated biannually, which summarizes the peer-reviewed scientific publications on the efficacies of tested pre- and postmilking teat dip products. In effect, the document is a list of teat dips, most of which are currently on the market, as a means of providing factual information to members of the dairy community.

Determining the Germicidal Activity and Efficacy of Teat Dip Products

In vitro testing: Three model test systems can be used to evaluate teat dip products. The excised teat model measures the ability of a germicide to kill bacteria on teat skin surfaces. It is only intended as an in vitro screening test to determine if an experimental product has potential to be further evaluated as a teat dip in cows. This model is less expensive and less time consuming than the models described below. A trial consists of applying mastitis-causing bacteria to teats (excised from cows at slaughter) followed by dipping in the test germicide preparation. The teats are then rinsed, and the fluid that is collected is cultured to determine the number of bacteria recovered from dipped teats. The number of bacteria is compared with that recovered from control teats that were dipped in the bacterial suspension but not with the germicide. If the test product is effective, it will significantly reduce the number of bacteria recovered from germicide-dipped teats compared with undipped controls. Products performing satisfactorily in this screening procedure can be considered for further evaluation to determine

effectiveness in the prevention of new intramammary infections using live cows as described below.

Experimental challenge model: A second testing method, known as the experimental challenge model, is conducted in a research dairy herd. This model evaluates the effectiveness of a product to reduce the incidence of new intramammary infections compared with undipped controls when teats are challenged experimentally with mastitis-causing bacteria to increase the infection rate. Basically, after the milking machine is removed from the udder, all teats of all cows in the herd are challenged by experimental exposure to bacteria by dipping into a suspension of *Staph. aureus* and *Strep. agalactiae* in milk. Immediately following challenge, two diagonally opposed teats (i.e., right front and left rear) are dipped in the product to be tested, and the remaining two teats serve as undipped controls. This procedure is performed during the afternoon milking, Monday through Friday. Milk samples are then taken weekly for several weeks from each quarter and cultured to determine the number of new *Staph. aureus* and *Strep. agalactiae* infections present. At the end of the trial, the number of new infections in dipped and control quarters are compared, and efficacy is expressed as the percentage reduction in new infections in dipped quarters.

Natural exposure model: Trials to evaluate teat dips using this method are usually performed by cooperator producers in commercial herds. As with the experimental exposure model, this method evaluates the effectiveness of a product in reducing the incidence of new infections compared with undipped controls; however, teats are not challenged with mastitis-causing bacteria, rather, the new infection rate is dependent upon natural exposure to mastitis-causing bacteria on the farm. After milking, half the teats of the cows are dipped in the test product and half are left as undipped controls. Quarter milk samples are collected every month for approximately 1 year (to cover all seasons), and at the end of the trial, the numbers of new infections in dipped and control quarters are compared and efficacy is determined. A variation of this model is to compare the test product with a positive control of proven efficacy.

How Should Teat Dips Be Applied?

The conventional method for applying teat dips is to immerse teats using some type of cup that contains the teat dip. Recirculating teat dip cups allow product that has contacted the teat skin to mix with the remainder of the dip cup contents. If this type of applicator is not kept clean and becomes heavily contaminated with organic material, spread of mastitis-causing organisms from cow to cow is possible. Noncirculating dip cups maintain the teat disinfectant that has contacted the teat skin separate from the rest of the dip cup contents, which is stored in a separate reservoir; the latter is preferred.

In more and more milking parlors, particularly in large herds, the germicidal product is applied by sprayers and electric pump/reservoir via hose drops at strategic locations in the milking parlor, or by using atomizers, aerosol cans, and spray bottles. This procedure is satisfactory if care is taken to ensure that the teat skin is completely covered with the product. Unfortunately, many operators only spray at teats, and significant portions of teat surfaces are

not covered. Although spraying often is faster, teat coverage is seldom as thorough as dipping, the potential exists for human inhalation and exposure, and approximately twice as much product is used by spraying compared with dipping.

Some producers have chosen teat spraying to reduce the possibility of spreading bacteria from cow to cow with a dip cup; however, contamination of teat dips with mastitis pathogens during the course of a milking is highly unlikely if the product is an effective germicide and the dip cup is not grossly contaminated. The only mastitis pathogens likely to grow in teat dips are *Pseudomonas* species and *Serratia* species, both of which rarely cause bovine mastitis. Thus, the suggestion that teat dipping causes mastitis is clearly wrong.

Both research and practical field experience have shown that teat spraying is as effective as teat dipping if it is done properly. To be as effective as teat dipping, the entire barrel of the teat contacted by the teat cup liner (inflation) must be covered with teat dip, but, unfortunately, this is rarely accomplished because producers and their employees usually apply spray to only one side of the teats rather than to the entire surface of the teats. Moreover, to do an excellent job of teat spraying will require more time and more teat disinfectant than teat dipping. For these reasons, it is often recommended to dip rather than spray. In many cases, teat spraying has been used more frequently than teat dipping in mastitis problem herds, which suggests that dipping is the preferred method. It is recommended that the entire teat surface be covered, regardless of whether the product is applied by dipping or spraying.

Weather Effects

During extremely cold weather (below 10° F), and particularly when windy conditions exist, extreme care should be exercised to avoid chapped or frozen teats. In very cold weather, it may be advisable not to dip or spray teats after milking, but if teats are sanitized, only the teat end should be exposed to germicide, and any excess blotted off with a single service paper towel. Teats should be dry before turning cows out of the parlor, and warming the product reduces drying time. Wind breaks placed in outside holding areas provide some protection against the freezing of teats that are still moist with product and predisposed to freezing.

Potential for Irritation and Contaminated Teat Germicides

Some teat dip products can be irritating to teat skin, causing chapping, lesions, drying, or a caustic reaction. Sources of irritants include the chemical composition of the germicide itself, too low or too high pH values, breakdown products that result from a product being improperly stored and exposed to temperature extremes, manufacturing problems, and not diluting a product according to directions or diluting with an incompatible water source.

There have been a very small number of instances in which a teat dip product became contaminated and caused herd outbreaks of mastitis. This problem can be avoided by handling products with care and following label recommendations. For example, the original container should be kept tightly closed and teat dip cups should be emptied and washed regularly. More importantly, the contents of a teat dip cup should never be poured back into

the original container. Additionally, teat dips should not be permitted to freeze because this may cause separation of ingredients and lead to ineffective germicidal activity. A teat dip should never be diluted unless indicated on the label.

Germicide Classes Used in Teat Dips

Iodophor

Iodine is a broad spectrum germicide, which is fast acting and effective against all mastitis-causing bacteria as well as fungi, viruses, and bacterial spores. This element is microbicidal due to the oxidizing reaction between iodine and organic matter. Iodine is dissolved in water by complexing with water-soluble detergents or surfactants, and this resulting solution is referred to as an iodophor. Nearly all of the available iodine in the iodophor is present in the complexed but unbound form, and, as such, is not antimicrobial. The uncomplexed form is referred to as free iodine (usually 6 to 12 ppm) and provides the antimicrobial activity by oxidizing microorganisms.

The free and the complexed iodine components of the iodophor constitute the available iodine, and exist in a state of chemical equilibrium. Upon reacting with bacteria, milk, and organic matter, the free iodine is used up, but it is immediately replaced from the complexed iodine. Thus, free iodine is always available until the total amount of available iodine in the iodophor is depleted.

Because detergents are used as complexing agents in iodophor teat dips, natural protective oils are removed from the teat skin as consequence of their use. Thus, conditioners are often added to iodine teat dips. These include moisturizers such as glycerin and propylene, which are normally added at concentrations ranging from 2 to 10%, as well as lanolin, which serves as an emollient to replace natural oils lost from the skin. Iodophors are available as conventional and barrier type products.

Chlorine

Chlorine is one of the halogens, which destroy a wide range of microorganisms in a rapid fashion. To be effective, chlorine-based teat dips must be used within several hours of preparation because of short shelf life. Two commonly used types of chlorine products are described below.

Acidified Sodium Chlorite

This type of chlorine product is a result of combining sodium chlorite with a suitable acid, such as lactic acid or mandelic acid, forming the active microbicidal components, chlorous acid and chlorine dioxide. Both of these compounds have broad spectrum of action and are effective against Gram-positive and Gram-negative bacteria, as well as molds, yeasts, and viruses. Acidified sodium chlorite products include humectants and emollients as ingredients, and are generally two part systems composed of an activator and a base, which must be mixed

and prepared daily to provide optimal antimicrobial activity. The mixed product contains a sodium chlorite level of approximately 0.32%. After application the product dries on the surface of the teat skin, forming a barrier, in which the killing action of chlorous acid is maintained.

Sodium Hypochlorite

Sodium hypochlorite solutions are sold commercially as laundry bleach. Although such solutions are not marketed as teat dips and their use violates federal regulations, they continue to be used both as pre- and postmilking teat dips. To be effective without damaging teat skin, commercial products (that typically contain 6.25% hypochlorite) must be diluted 4 parts of bleach to 1 part of water to reduce the concentration to 4.0% hypochlorite. The final concentration of sodium hydroxide must be less than 0.5%. Emollients are not included because of associated problems. Hypochlorite is a strong oxidizing agent, and destroys both structural and enzymatic proteins in procaryotic cells. When sodium hypochlorite solutions are first used, irritation to the teat skin as well as to milkers' hands is usually mild, but the condition is transitory, and teat condition returns to normal with a few weeks. Use of such products is not recommended.

Chlorhexidine

Chlorhexidine is a rapidly acting, nonirritating germicide composed of biguanide compounds. This germicide is effective against most Gram-positive and Gram-negative bacteria as well as some viruses by precipitating cytoplasmic proteins and macromolecules. However, if heavily contaminated, *Serratia* species and *Pseudomonas* species can survive in chlorhexidine-based products and serve as potential mastitis pathogens.

Teat sanitizers utilizing this germicide contain between 0.35 to 0.55% chlorhexidine gluconate or acetate as well as humectants and emollients to minimize irritation. Chlorhexidine sanitizers adhere well to teat skin, provide antimicrobial activity over time, and do not have deleterious effects on teat skin. Both conventional and barrier formulations are available.

Dodecyl Benzene Sulfonic Acid (DDBSA)

Teat dip products containing DDBSA incorporate an anionic surfactant as the active ingredient along with an organic acid, glycerin, and other emollients. It is believed that DDBSA products function by denaturing the proteins of microbial cells, inactivating essential enzyme systems, and disrupting cell membranes. Teat sanitizers composed of DDBSA are effective against Gram-positive and Gram-negative bacteria as well as yeasts, and are available as conventional or barrier formulations.

Hydrogen Peroxide

This disinfectant provides a wide spectrum of control against most mastitis-causing bacteria through its oxidizing action. Hydrogen peroxide may be combined with lactic acid, which

results in the formation of alpha hydroxy acids. This combination aids in the desquamation of dead teat skin and improves teat skin condition, thereby minimizing bacterial colonization on the teat skin surface. Food-grade emollient systems are also often added to hydrogen peroxide-based products, promoting skin conditioning and moisturizing properties.

Fatty Acid-Based Products

Saturated fatty acids having carbon chain lengths of 6 to 14 typically exhibit the greatest antimicrobial activity, and salts of such fatty acids are used as disinfectants against Gram-positive and negative bacteria. Being lipophilic, fatty acids such as capric and caprylic acids are not readily soluble in water and must be emulsified; however, these fatty acids are readily soluble in alcohol, glycol, and ether. Thus, products are available that have been emulsified in water as well as those that have been solubilized in an organic solvent, both of which usually contain approximately 1% fatty acids. Fatty acids and their derivatives function by disrupting the integrity of the bacterial cell membrane and inhibiting microorganism growth. The water-based products are recommended as both pre- and postdips, whereas the organic solvent-based products are generally recommended for postdipping and provide good protection during cold winter conditions.

Nisin

Nisin is a naturally occurring antimicrobial protein known as a bacteriocin. This protein is synthesized by the bacterium, *Lactococcus lactis* subspecies *lactis,* and has long been used as a food-grade preservative in dairy products. Nisin, in its purified form (Ambicin N) has been incorporated into pre- and postmilking teat dips as well as barrier products and is very bacteriocidal against Gram-positive as well as Gram-negative organisms through its lytic action on the phospholipid components of the cytoplasmic membrane.

Glycerol Monolaurate

This food grade antimicrobial agent, also known as lauricidin, is a commonly used food emulsifying agent, which has been incorporated into teat sanitizers. When lauricidin is formulated with lactic acid, the combination becomes a very broad spectrum antimicrobial. This germicide is lipid soluble and easily penetrates the bacterial cell membrane, leading to rupture of the cytoplasm.

Quaternary Ammonium

Teat germicides containing quaternary ammonium compounds are microbicidal through denaturing cell proteins, inhibiting enzyme systems, and altering membrane permeability, leading to bacterial cell disruption. The concentration of active ingredients (akyl dimethyl benzyl ammonium chloride, akyl dimethyl ethyl ammonium bromide) ranges from 0.05 to 1.0%. Emollients and skin conditioners are usually added to promote good teat skin health, but must be formulated properly to ensure effectiveness without interfering with germicidal properties. It is imperative that dip cups be cleaned periodically during milking if they become

overloaded with organic material as *Serratia* species and *Pseudomonas* species have been known to survive in quaternary ammonium teat dips.

Powdered Teat Sanitizers

The majority of powdered teat dips are starch based and some contain germicides as well as skin conditioners. Use of these products is recommended during extremely cold and windy weather, when it is not advisable to dip teats with conventional products due to the potential for frost bite. Under freezing conditions, the drying property of powdered teat disinfectants is valuable in removing surface moisture after machine removal, when cows would normally exit the milking parlor with wet teats.

Proper Storage and Handling

Regardless of the type of the class of teat dip used, products should be stored and used appropriately to minimize contamination. Storage areas should avoid extremes in temperature as freezing may cause separation of product components leading to inactivation of germicidal agents and pH changes that may damage teat skin, and overheating that may volatilize ingredients and negatively affect product efficacy.

If during milking, a product becomes grossly contaminated or diluted with milk, manure, other organic matter, or water, teat dip dispensers should be emptied, washed, and refilled with fresh product. Unused product should never be returned to the storage vessel. In addition, dispensers should be washed after every milking or at least once a day.

Summary

To conclude, pre- and postmilking teat antisepsis is probably the most important management strategy to reduce the new intramammary infection rate in dairy cows and to maintain a low level of mastitis. This practice, along with use of proper milking technique, adequately functioning milking equipment, dry cow therapy, prompt antibiotic treatment of clinical cases, and culling of chronically infected cows will help keep somatic cell counts well below the 750,000/ml limit allowable; a realistic goal is to maintain a bulk tank cell count below 200,000/ml. It is recommended that dairy producers use products that have been proven to be efficacious in reducing new cases of mastitis without irritating teat skin as well as hands of milkers.

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