

# Smart approach to post-milking teat disinfection

**John Williamson<sup>1</sup>, Dave Malcolm<sup>2</sup>**

<sup>1</sup>DairyNZ, Private Bag 3221, Hamilton

<sup>2</sup>423 Tauwhare Rd, RD 3, Hamilton

## Post milking teat disinfection in NZ

The control of mastitis in dairy cattle is a multi-factorial process, with post-milking teat disinfection a well-established, internationally recognised and effective cornerstone of mastitis prevention programmes (Neave *et al.* 1969).

In most countries the disinfectant is applied by dipping, but in New Zealand it is sprayed onto the teats in the interest of saving time and labour. Controlled studies have shown spraying to be as effective as dipping in controlling the contagious pathogens *Staphylococcus aureus* and *Streptococcus agalactiae* (Pankey and Watts 1983, Meaney 1974).

A telephone survey of 383 NZ dairy farmers, conducted by LIC on behalf of DairyNZ (Cuthbert 2008) found that the use of post-milking teat spraying was widespread, with 92% of farmers acknowledging that they use it, and 78% saying that they teat sprayed for the complete lactation. Most used manual spraying methods with only 13% of those surveyed using an automated system. Iodine-based disinfectants were the most widely used (64%) with chlorhexidine the next most popular active ingredient (34%).

Dairy farmers have been teat spraying cows in NZ since the mid-1970s but few studies of its effectiveness in preventing mastitis have been conducted in New Zealand. A study was undertaken during 2001-2 season by DairyNZ (formally Dexcel) to examine the effect of teat spraying compared with no teat spraying on the incidence of new intramammary infections, milk cell count and teat condition.

## Effect of post-milking teat disinfection on mastitis, SCC and teat condition

A total of 511 mixed-breed dairy cows on five dairy farms were allocated between two groups, one receiving teat spray after each milking for a whole lactation (n=257) and the other not being sprayed, from the first milking after calving onwards (n=254). A commercially available iodine sanitiser (23g/l available iodine) was used for the sprayed group. The study (Williamson and Lacy-Hulbert 2010) ran for a complete lactation, with the difference in new intramammary infections (sub-clinical mastitis) and clinical mastitis between sprayed and non-sprayed established through regular collection of milk samples for bacteriological analysis. Herd test results were used to measure differences in individual cow and group cell count (SCC), and teat skin condition was determined by visual assessment of teats on four occasions during lactation.

Cows that were teat sprayed had 60% less sub-clinical mastitis due to *Staph. aureus* (P<0.05) and *Streptococcus uberis* (P<0.01) and nearly 50% less clinical mastitis. The significant reduction observed for new infections by *Strep. uberis* was somewhat unexpected, but reassuring, since post-milking teat disinfection was designed to be effective against contagious mastitis rather than environmental bacteria (Galton 2004).

Reductions in subclinical mastitis measured in this study were also reflected in lower SCC across a complete lactation with teat sprayed cows having cow SCC that were typically 50% lower than non-sprayed cows. Average lactational SCC for sprayed and non-sprayed cows were 181,000 and 306,000 cells/ml respectively. Teat sprayed cows also had a lower prevalence of skin lesions and cracks, particularly in early lactation.

These results emphasise that teat disinfection is effective under NZ conditions with significant reductions in new infections, clinical mastitis cases, somatic cell counts and teat skin abnormalities.

For the disinfectant to work it must be applied correctly. A sub-committee of the National Mastitis Advisory Committee (NMAC) has recently reviewed the Countdown Downunder technical material as part of the SmartSAMM development process and has issued Technote 7 “Use post-milking teat disinfection on every teat after every milking” (see Appendix).

This presentation summarises some of the key points from this document and provides some practical recommendations.

### Correct preparation and application of the teat disinfectant

Using a standard format Joe *et al.* (2010) identified problems including the milking machine, cow factors and milking procedures during milking time assessments across 200 farms. These farms had high BMSCC and/or severe clinical mastitis and it was noted that poorly diluted teat sprays and poor coverage were the most common faults. Only 12% of herds were achieving good teat spraying practices, in the opinion of the authors.

Reasons for incorrect dilution included:

- Inability to interpret the label directions
- Lack of clear instructions
- Not measuring quantities
- Saving money

Reasons for poor coverage included:

- Inadequate training
- Rushed job
- Poor coverage by some automatic systems

SmartSAMM recommends that advisors emphasise the importance of using the correct mix of teat disinfectant and achieve adequate coverage on teats. Advisors could help farmers to create farm-specific mixing instructions or standard procedures with the appropriate seasonal teat disinfectant dilutions.

### Sensitivity of teat disinfectants to water quality

Guideline 7.3 (SmartSAMM Technote) emphasises the water quality that is suitable for preparing the different types of disinfectants (Table 1). In practice, very few farm waters in NZ will exceed the 500ppm hardness and alkalinity specified. However, there are situations when precipitation of chlorhexidine teat disinfectant can block spray nozzles and equipment. Several issues have been identified.

Some products precipitate out in seemingly good water supplies such as those from the Hamilton reticulated supply and from farm waters tested to meet the alkalinity and hardness requirements of Guideline 7.3 (Table 2).

Products B, C, and D were more susceptible to water quality than Products A and E. Teat disinfectant containers and filters should be cleaned regularly. If there is evidence of instability with the water supply, consideration should be given to changing the disinfectant formulation.

	Iodine	Chlorhexidine	Acid anionics	Chlorine
Alkalinity	Should not exceed 500 ppm CaCO <sub>3</sub>	No specific recommendations available	Should not exceed 900 ppm CaCO <sub>3</sub>	No specific recommendations available
Hardness	No specific recommendations available	Should not exceed 500 ppm CaCO <sub>3</sub>	Should not exceed 900 ppm CaCO <sub>3</sub>	No specific recommendations available

Table 1. Assessing the requirements of water used to mix teat disinfectant solutions on farms (CaCO<sub>3</sub> = calcium carbonate), reproduced from SmartSAMM Technote 7

Product	Hamilton City Water	Tatuanui Farm Water	Te Aroha Farm Water
A	None	None	None
B	Slight	Slight	Slight
C	Slight	Slight	Slight
D	Slight	Slight	Slight
E	None	None	None

Table 2. Degree of precipitation of chlorhexidine teat disinfectants in various waters at 1:4 dilution after 24 hours

### Sensitivity of teat disinfectants to alkaline and chlorinated detergents

Several reports of severe precipitation of chlorhexidine disinfectants have also been investigated and it was found that both iodine and chlorhexidine disinfectants are very sensitive to contamination with alkaline and chlorinated detergents.

The amount needed to cause severe precipitation can be readily achieved through the use of unrinsed shared measuring utensils. Up to 40% of both iodine and chlorhexidine active ingredients have been precipitated out of solution through this contamination. SmartSAMM recommendations include:

- Use a clean, rinsed container for storage.
- Use a clean, rinsed, dedicated measuring container.

### Measuring teat disinfectant efficacy – Protocol A versus EN 1656

Since the early 1990, the bactericidal activity of teat disinfectants in New Zealand has been measured *in vitro* using the Protocol A assay. In this test, excised teats are treated in the laboratory with bacteria, and the killing power of disinfectants on those teats is tested. This test is no longer recommended by NMC (National Mastitis Council) and is now a uniquely NZ test but is still required by ACVM for registration purposes.

In May 2010 NMAC considered changing to the European EN 1656 standard suspension test to align NZ testing methods with other countries. EN 1656 measures the disinfectant effect on bacteria in suspension rather than on teat skin. Some initial work comparing these methods has been undertaken.

Early indications include:

- The EN 1656 assay is less sensitive on disinfectants than the Protocol A assay. Iodine and chlorhexidine disinfectants at use dilutions that fail Protocol A show higher bactericidal activity when tested with the EN 1656 assay. There is a danger that inferior products may be allowed into the marketplace if EN 1656 is used as a screening test.
- The Protocol A assay has always shown that iodine has some advantages over chlorhexidine, in that it kills more bacteria than chlorhexidine, and is especially more effective against *Escherichia coli* than chlorhexidine. But testing with the EN 1656 assay indicates that chlorhexidine kills the same proportion of total bacteria as iodine and that it is just as active against *E. coli* as it is against *Staph. aureus*.

### Conclusion

Farmers should be encouraged to use post milking teat disinfection and not see it as ‘just another job to do’; NZ studies have shown it to be effective if applied properly. A number of factors which can affect its performance have been identified and farmers need to be aware of ‘what can go wrong’ and how to go about preparing and applying an effective product.

### References

- Cuthbert S. DairyNZ Mastitis Management Perceptions Survey. April 2008
- Galton DM. Effects of automatic postmilking teat dipping system on new intramammary infections and iodine in milk. *Journal of Dairy Science* 87, 225-31, 2004
- Joe AK, Cranfield SW, Hodge IC, Clarke TG. Summary of problems identified in 200 milking assessments from mastitis problem herds during 2008 and 2009 in two regions of New Zealand (Waipa and South Canterbury). Mastitis Research into Practice: *Proceedings of the 5th IDF Mastitis Conference*. Pp 363-368, 2010

**Meaney WJ.** Post-milking teat disinfection- a comparison of dipping and spraying. *Irish Journal of Agricultural Research* 13, 157-61, 1974

**Neave FK, Dodd FH, Kingwell RG, Westgarth DR.** Control of mastitis in the dairy herd by hygiene and management. *Journal of Dairy Science* 52, 696-706, 1969

**Pankey JR, Watt JL.** Evaluation of spray application of post-milking teat sanitiser. *Journal of Dairy Science* 66, 355-358, 1983

**Williamson JH, Lacy-Hulbert SJ.** Effect of post milking teat spraying on mastitis, SCC and teat skin abnormalities in five Waikato dairy herds. *Proceedings of the 5<sup>th</sup> IDF Mastitis Conference* Pp. 665, 2010

## **Appendix – Reproduction of SmartSAMM Technote 7**

# TECHNOTE

# 7

## *Use post-milking teat disinfection on every teat after every milking*

Milk from infected quarters contains bacteria that may contaminate the teat skin of other cows during milking. Bacteria in milk from an infected cow may be found on the teat cup liners and transferred to the teat skin of the next 5-6 cows that are milked with that unit (Phillips, 1982). Once on the teat skin, they can increase the risk of entry into the teat canal and infect the udder.

Post-milking teat disinfection aims to:

- reduce the bacterial population at the teat orifice and on the areas of teat skin that have come into contact with the teat cup liner during milking and
- maintain healthy skin.

Routine post-milking teat disinfection has been, and still is, the single most effective component of hygienic milking programs. The additional benefit, of keeping teat skin healthy and healing skin lesions, is almost as important, for effective mastitis control (Hillerton 1997).

Many field experiments have shown that effective post-milking teat disinfection lowers new infection rates of the cow-associated mastitis bacteria (*Staph. aureus* and *Strep. agalactiae*) by 50% or more (Bramley 1992). Recent field observations in NZ have demonstrated a similar reduction in new infection rates for cow-associated mastitis bacteria as well as for the environmental pathogen, *Strep. uberis* (Williamson *et al* 2010).

The majority of NZ dairy farmers rely on post-milking teat disinfection, applied by a spray technique, as an integral part of their mastitis control programs (Woolford 1995). Spraying is preferred because it is considered to be quicker and easier. Most European and American research on teat disinfection has used teat dipping as the method of application.

An experimental challenge trial comparing dipping and spraying found similar effectiveness for spraying, at least against *Strep. agalactiae* and using a 0.5% quaternary ammonium disinfectant (Pankey and Watts 1983). The authors stressed the importance of teat coverage with the spray to

The NMC (National Mastitis Council) in the US periodically reviews and summarises publications on teat disinfection in their Annual Proceedings, available to members from:  
[www.nmconline.org](http://www.nmconline.org)

ensure effective prevention of new infections.

There is no benefit from disinfecting any part of the udder surface apart from the teat skin. It is, however, important that the entire teat barrel (everywhere the liner has touched) is disinfected and not just the teat end.

Efficient application of teat disinfectant is essential. All the benefits of correct product selection, preparation and handling are lost if the teat disinfectant does not reach clean teat skin.

Investigation of mastitis problems usually requires an assessment of the whole teat disinfection process, including the product used, its preparation, storage and handling on the farm, and the method and efficiency of its application to teats (Ryan 1991). Common problems in Australia were reported as:

- failure to mix to label recommendations;
- failure to measure components accurately;
- addition of inappropriate emollients, and other additives;
- use of poor quality water;
- incorrect or prolonged storage of teat disinfectants; and
- inadequate coverage of the teat skin.

In NZ, Joe *et al* (2010) examined faults found during milking time assessments across 200 poorly performing farms and noted that poorly diluted teat sprays and poor coverage were the most common faults. Only 12% of these herds were achieving good teat spraying practices, in the opinion of the authors.

The presence of *Corynebacterium bovis* in a herd is one warning sign of inadequate teat disinfection (Bramley *et al* 1976). A high prevalence of infection by this minor pathogen increases the bulk milk SCC (Hillerton *et al* 1995) and also increases, by 5 fold, the risk of *Strep. uberis* infections in quarters that do not receive dry cow antibiotics at dry off (Woolford *et al* 2001).

The spread of *C. bovis* can be controlled in herds by effective post-milking teat disinfection (Pankey *et al* 1993; Hillerton *et al* 1999). But once *C. bovis* has colonised a quarter it usually remains present until an antibiotic is administered (for example, as antibiotic Dry Cow Treatment).

**Technote 13 and the SmartSAMM Mastitis Investigation Kit provide an approach to assess teat spraying effectiveness on-farm. See Sheets G and L.**

**Technote 5 provides more information on control of *Corynebacterium bovis***

# 7.1

## *Use a registered teat disinfectant.*

Teat disinfectants are designated as a veterinary medicine under the ACVM Act 1997.

The Agricultural Compounds & Veterinary Medicines Group (ACVM), operated by the New Zealand Food Safety Authority (NZFSA), is the regulatory body that controls the importation, manufacture and supply of agricultural and veterinary chemicals in NZ. Chemicals used in agriculture in NZ must be registered with the ACVM (unless used in special circumstances, such as under veterinary prescription or on a research permit).

Registered products are issued with a unique ACVM Registration Number and this number must be displayed on product labels and all product advertising materials. The wording required by ACVM is in the form: "Registered pursuant to the ACVM Act 1997, No. A####."

### **Product Registration**

The product registration process intends to provide an assurance of efficacy and safety with respect to human and animal health, environmental impact and its likely impact on trade relating to the use of the product within the NZ dairy industry. The ACVM standards and guidelines for evaluation of product efficacy and animal welfare can be obtained from the NZFSA website.

The assessment process is both comprehensive and rigorous in scope, covering:

- Chemistry, toxicology and manufacture of the product and its components
- Efficacy of the product in reducing mastitis risk specific to causal organisms and environmental conditions in NZ
- Animal welfare with particular focus on irritancy of teat skin under 'normal' and adverse climatic conditions

All claims regarding product efficacy require validation according to the ACVM Standards and Guidelines.

Companies invest considerable resource in registering products and their compliance with ACVM Good Manufacturing Practice standards is regularly assessed through Manufacturing plant audit and registration.

### **Off-label use of Registered Products**

Use of registered products in a way that is contrary to label can put farmers at risk of fines covering consequential risk or loss by dairy processors.

Examples of such practices include:

- Use of a pre-milking teat disinfectant in a non-compliant fashion e.g. by not wiping off before applying the teat-cups.
- Use of a post-milking teat disinfectant product for pre-milking teat disinfectant, which has not been registered for this use.

#### **Confidence – High**

Before any product can enter the NZ market, it must go through the ACVM's assessment process to ensure that it meets high standards of safety and effectiveness. Any proposed changes in formulation or use of a product that is already on the market must also be referred to the ACVM regarding requirements for further evaluation of intended use.

#### **Research priority – Moderate**

There is a continual need to review assessment and registration process to maintain a balance between prudent testing of new chemical and products, and preserve the commercial viability for companies to bring new products to the marketplace.

- NZFSA maintains a list of registered veterinary medicines, agricultural chemicals and vertebrate toxic agents on its website.
- Consumers may also contact the ACVM industry liaison group to obtain information on the registration details of specific products, by:  
Phone: (04) 899 2699,  
E-mail: [acvm@nzfsa.govt.nz](mailto:acvm@nzfsa.govt.nz)

Use of unregistered products on farm, or use of registered product in an off-label manner has the potential to make milk or its products unsaleable, and can put



farmers at risk of being fined by the dairy processor.

### **Unregistered Products**

Unregistered products can be identified by the fact that they have no ACVM Registration Number on the label and are not on the ACVM database. Farmers using unregistered products risk applying ineffective treatments, having chemical residues in milk or meat, and causing harm to the environment, human health or animal health. Supply of un-registered product for sale is an offence under the ACVM act. NZFSA does not undertake routine inspection to detect unregistered products, but relies on reports from industry and the public.

The only exception regarding use of unregistered product is where it is approved by ACVM under veterinary supervision. This covers the requirements for management of: human medicines; specially compounded veterinary medicines; trade-name product veterinary medicines not registered in NZ and over-the-counter veterinary medicines used in a discretionary manner.

Off-label use of products under veterinary supervision is described in Technote 4.9.

### **Reporting adverse experiences with products**

The ACVM act makes provision for surveillance of and enforcement of the regulatory requirements relating to product registration. It is the responsibility of the public, industry stakeholders and other regulatory agencies to notify NZFSA ACVM Group whenever a breach of registration is suspected or identified. The conditions regarding enforcement and response are detailed on the NZFSA food safety website.

### **Active ingredients in teat disinfectants**

More than 10 different active disinfectant ingredients have been used in teat disinfectants throughout the world over the past 20 years. The National Mastitis Council in the United States reviews and summarises all the scientific literature on teat disinfectants published since 1980 on an annual basis (National Mastitis Council, 2012).

Active ingredients currently registered in NZ are:

- iodine;
- chlorhexidine;
- acid anionic compounds (dodecyl benzene sulphonic acid);
- chlorine and Chloramine T

Companies with registered products are listed on the SmartSAMM website.

### **Iodine**

There are many formulations of iodine-based teat disinfectants on the NZ market. They incorporate an organic iodine complex (the active ingredient) and different combinations of complexing agents, surfactants, detergents and emollients. The iodine-based teat disinfectants used to be called (incorrectly) iodophors because in the past many contained phosphoric acid.

The antimicrobial spectrum of iodine-based teat disinfectants includes bacteria, viruses and fungi. They destroy microorganisms by chemical action through oxidation/reduction mechanisms that interrupt protein synthesis or nucleotide and lipid membrane structure. Free iodine also reacts with organic material so the bactericidal activity of iodine-based teat



disinfectants is reduced when the products are exposed to high levels of organic matter i.e. dirt.

Iodine chemistry is complex. Iodine forms complexes with certain polymers, e.g. surfactants or polyvinyl pyrrolidone, which hold the iodine in solution. The iodine complexes release a very small fraction of the complexed iodine as 'free iodine'. The combined iodine species are known as the 'total available iodine' and the concentration of free iodine is very small, typically (1-4ppm) out of 10,000ppm. The complexed iodine provides an on-going source of free iodine by equilibrium reaction as it is consumed. Typically iodine-based teat disinfectants will have >2% total available iodine (20g/L) in their concentrated form.

Free iodine is recognized as the bactericidal component of iodine-based teat disinfectants. High levels of free iodine are very irritating to the teat skin and products are typically formulated to provide a balance of bactericidal performance and skin health with free iodine levels of 2-3ppm. The type of complexing agent affects the dynamics of the free iodine equilibrium, so measurements of the total available do not in themselves provide a true measure of performance. Unlike available iodine, free iodine levels are difficult to measure, but it is possible to do so, for example by potentiometric techniques.

Iodine-based teat disinfectants have no residual bactericidal activity after the solution has dried on the teat surfaces. Bactericidal action requires up to 10 minutes exposure to be fully effective but the action starts from the time of application. The rate of bactericidal action of the free iodine may vary depending on the presence of organic matter such as residual milk. Surfactants are added to improve the wetting of the teat skin and penetration of disinfectants into organic matter and bacterial cells.

Iodine-based teat disinfectants should be acidic (pH <6.5) to provide for iodine stability. Exposure to acidic solutions has the potential to irritate teat skin. Many products on the market contain emollients and/or humectants to reduce the potential for irritation and maintain teat health.

### **Chlorhexidine**

Chlorhexidine gluconate is a colourless, odourless organic compound which is readily soluble in water. The active compound is typically present at 0.2 - 0.5% in the final solution and a colouring agent is commonly added to commercial products to allow the solution to be seen on teat skin.

The antimicrobial activity of chlorhexidine is primarily against bacteria, with limited effect against viruses and fungi. Some Gram negative environmental bacteria, e.g. *Pseudomonas aeruginosa* and *Serratia marcescens*, which occasionally cause severe mastitis, show less sensitivity to chlorhexidine.

Chlorhexidine has an affinity for lipid materials and is adsorbed onto the teat skin where it can accumulate and provide residual protection. It kills by binding to bacterial membranes leading to cell death.

Chlorhexidine is a positively charged (cationic) molecule that readily complexes with organic anions or other negatively charged molecules, such as carbonate, sulphate, phosphate and chloride. When chlorhexidine is mixed with water that is 'hard', high in organic matter, or has been treated with chlorine, insoluble salts are formed leading to a breakdown of the

Measurement of total iodine concentrations is possible in the field using simple test kits available from teat disinfectant suppliers.

Technote 7.5 summarises information on addition of extra emollient to teat disinfectants.

product.

This reaction necessitates higher use rates in hard water to account for removal of the active ingredient from solution. The optimum pH range for chlorhexidine is 5.0-8.0 (Denton 2001). Emollients are often used in conjunction with chlorhexidine to enhance teat health.

#### **Acid anionic compounds (dodecyl benzene sulphonic acid, DBSA)**

The active chemical ingredients in acid anionic disinfectants are anionic surface-active agents. These compounds display rapid (30 seconds) bactericidal action on a number of bacteria, and have moderate efficacy against some viruses and fungi. It is known that at least one active ingredient (dodecyl benzene sulphonic acid) in this class of teat disinfectants does not control *Corynebacterium bovis* or coagulase negative staphylococci (Pankey *et al* 1984; Pankey *et al* 1985)

The bactericidal action of acid anionic disinfectants is not fully understood but is thought to be due to their ability to disrupt cell membranes, causing leakage and cell death. A pH range of 2.0 - 3.0 offers the optimal acidity for effective antimicrobial action of these products. As the pH increases beyond 4, the bactericidal activity decreases rapidly, reaching a minimum at neutral or slightly alkaline pH.

Alkalinity up to 900 parts per million can be tolerated (Dychdala *et al* 1991). Water hardness typically does not affect performance except in extremely hard waters (>400ppm). Emollients are added to products to reduce the adverse effects of low pH on teat skin.

#### **Chlorine and Chloramine T**

Chlorine is one of the halogens that destroy a wide range of microorganisms in a rapid fashion. To be effective, chlorine-based teat disinfectants must be used within several hours of preparation because of short shelf life. Chloramine T (toluenesulfonylamide sodium or Tosylchloramide sodium) is the active ingredient in the only chlorine-based disinfectant registered in NZ. Chloramine-T is slightly basic (pH typically 8.5) and in water, it breaks down to the disinfectant hypochlorite. This rapidly oxidises organic materials such as bacteria and viruses on contact, and kills them.

#### **Sensitivity to disinfectants**

Bacterial resistance to teat disinfectants is not recognised as a problem at present. While there is experimental evidence that certain bacteria, particularly Gram negative organisms, do have the capacity to develop resistance to some disinfectants, this scenario is unlikely to apply to teat disinfection.

For information on active ingredients and efficacy in preventing mastitis, see latest review by NMC (NMC 2012).

### **Selection of a teat disinfectant on farm**

Farmers should regularly review their satisfaction with the teat disinfectant they are using and avoid making snap decisions about product selection at the time of purchase. Factors to consider are:

#### **Effectiveness:**

In general the industry relies on the ACVM's registration process to establish that all products available on the market are effective in NZ dairying conditions. Published information on product efficacy is usually available from the product manufacturer.

Particular recommendations may be made by advisers in special circumstances. For example, a herd experiencing a mastitis outbreak with a pathogen such as *Pseudomonas aeruginosa* may be advised to avoid using a chlorhexidine product.

#### **Suitability for a given farm water quality:**

Some active ingredients in teat disinfectants have reduced biocidal activity and form precipitates when mixed with water that does not have compatible characteristics. These precipitates can block spray equipment.

Technote 7.3 gives a guide for selection of the most appropriate product type when water quality is known.

#### **Occupational health issues:**

Adverse reactions in milking staff such as skin reactions (on the hands and exposed skin), respiratory and eye sensitivity problems may be the result of an allergic response to an ingredient in a product, or may result from heavy exposure due to faulty settings or siting of spray equipment or poor operator technique.

The method in use should be assessed and the type of disinfectant may need to be changed if any staff members have adverse reactions. A review is appropriate whenever new staff begin milking.

#### **Teat skin reactions:**

Teats should be regularly checked to ensure the skin is supple and in good condition. Corrective changes may involve altering the concentration of emollient or changing the product. It is important to monitor changes closely whenever a new product is used.

#### **Visibility:**

Teat disinfectants which are visible on the teat skin enable operators to more easily assess their success in achieving good teat coverage. Technote 7.6 outlines the issues to be addressed regarding application.

#### **Price:**

There is considerable variation in the shelf price of teat disinfectant products. To compare the prices it is helpful to calculate the cost per cow per milking (given that, for spray application, SmartSMMM recommends using 20 mL of solution per cow per milking).

For example: Product X is an iodine concentrate (iodine 20 g/L) in a 200-litre drum which costs \$1400. Stock solution is diluted 1 part to 3 parts water (1:3) to make up 80 litres of final solution.

Cost of stock solution = \$1400

Cost/litre of stock solution = \$1400/200 litres = \$7

Cost/mL of stock solution = \$7/1000 = 0.7 cents

Vol. of stock solution used per cow per milking =

20 mls x 1 part in 4 = 20 x (1/4) = 5 mls

Cost of 5 mls of stock = 5 x 0.7 cents = 3.5 cents

For different concentrations:

At **1:3** concentration, cost/cow/milking = **3.5 cents**

At **1:4** concentration, cost/cow/milking = **2.8 cents**

At **1:9** concentration, cost/cow/milking = **1.4 cents**

#### **Shelf life:**

When purchasing teat disinfectant products (either in concentrate or a ready-to-use (RTU) form), farmers should ensure that the quantity purchased will be finished prior to the expiry date specified on the label.

#### **Milk residues:**

In general, the industry relies on the ACVM's registration process to establish that no product available on the market leaves unacceptable milk residues when used according to the label directions.

There have been no problems identified in NZ of iodine residues in milk associated with normal post-milking use of iodine-based teat disinfectant.

Problems have been identified when iodine-based disinfectants have been used in an off-label fashion, by being applied before milking with insufficient wiping.

## 7.2

### *Mix a fresh batch regularly.*

Dairy farmers in NZ prepare the majority of teat disinfectant solution from products purchased as concentrates. A small number of ready-to-use (RTU) products are registered in the market.

Whether the concentration of the active ingredient in a teat disinfectant's final mix is maintained for hours, or days, depends on a complex interaction of factors – including the amount of water in the mix, the quality of the water used, the original concentration of the active ingredient and the ambient temperature.

Some solutions remain stable for long periods under excellent storage conditions. In the case of iodine, the rate of loss of iodine is doubled when the mixed solution is stored at 40 °C compared with 30 °C or less. The level of available iodine is also reduced if: containers are not well sealed preventing ingress of contaminants, water quality is poor, inappropriate emollients are added, or if the solution is contaminated with milk, dirt or other organic matter.

It is strongly recommended that teat disinfectants are made up with water used for food contact surfaces in the farm dairy. Farm dairy water standards are defined in the NZFSA DPC2: Animal Products (Dairy) Approved Criteria for Farm Dairies (NZFSA, 2009). The standard defines limits for acceptable microbiological quality and nominal physical contaminants, as measured by turbidity.

Water quality does vary considerably due to the presence of various compounds, particularly minerals and soluble organic matter. A number of areas in NZ have water with very high iron and manganese content which will affect the stability of prepared teat disinfectant solutions.

For these reasons, it is difficult to predict the stability of teat disinfectants mixed on farms. SmartSAMM provides a 'safety net' by making a blanket recommendation: when using concentrate products, either:

- Mix the product in-line so that fresh product is constantly available
- Make up fresh teat disinfection solutions to use within 3 days of make-up, or
- Use an RTU product.

General requirements for making up teat disinfectant solutions for storage (maximum recommended period – 3 days) include:

- Use a clean, rinsed container for storage,
- Use a clean, rinsed, dedicated measuring container,
- Only use water sources approved for milk contact surfaces,
- Don't make up more solution than can be used in 3 days,
- Cover securely to prevent accidental or environmental contamination,

#### Confidence – Moderate

The recommendation to mix a fresh batch of disinfectant regularly (i.e. every 2-3 days) provides a safeguard to ensure stability and efficacy of the teat disinfectant solution.

#### Research priority – Low

See Technote 7.3 for methods of testing teat disinfectant mixes.

- Store inside, out of direct sunlight and in a cool area; do not store at temperatures >40°C.

## 7.3

### *Use water of very high quality.*

Because teat disinfection is such a significant part of preventative action in mastitis control, it is important to be confident that the final mix being applied to teats is effective.

#### *Water quality characteristics that alter effectiveness of teat disinfectants*

Alkalinity, water hardness, organic matter, and chlorine concentration can all affect the bacterial killing power of teat disinfectants:

- Alkalinity is a measure of the buffering capacity of water and is expressed in parts per million of calcium carbonate (CaCO<sub>3</sub>). Field tests kits and laboratory confirmatory tests for alkalinity use acid-base titration techniques. Water with alkalinity greater than 500 parts per million greatly reduces the concentration of available iodine for iodine-based teat disinfectants, and can affect the final pH of acid anionic teat disinfectants.
- Hard waters should be avoided for preparation of teat disinfectants. Hard water has high levels of cations such as calcium, magnesium and sometimes manganese. Hardness is expressed in parts per million of calcium carbonate. Field tests are based on titration, and laboratory tests are performed with electrical conductivity meters or by a technique called Inductively Coupled Plasma. It is important to check numeric values; different thresholds are used internationally for the terms 'very soft', 'soft', 'hard' and 'very hard'.
- There should be no colour, sediment, suspended solids or smell to water being used to make up any teat disinfectant. Particulate organic matter can be assessed visually but should not be present in farm water supplies as per NZFSA DPC2. Soluble organic matter, including tannins, can be an issue and may support moderate numbers of environmental bacteria, which are typically detected by odour. Organic load can be measured by laboratory tests based on combustion techniques that measure total organic carbon or chemical oxygen demand. Organic matter and moderate bacterial loads consume free iodine. Chlorhexidine forms insoluble salts with organic acids and tannins.
- Chlorine in water can be assessed by calorimetric field tests. Chlorinated water forms an insoluble salt with chlorhexidine at high concentrations. It is not known to cause a problem with iodine-based disinfectants or acid anionics.
- Iron and manganese compounds, which are common in bore water, can cause problems in dairy plant cleaning by forming deposits in milking equipment. They will also have a significant deleterious effect on chlorine-based teat disinfectants.

#### Confidence – High

The active ingredients of teat disinfectants are adversely affected by poor water quality.

#### Research priority – Moderate

Farmers and their advisers need ready access to appropriate tests. Practical methods of providing high quality water for many tasks in dairies (making up teat disinfectants, preparing udders and washing equipment) should be evaluated.

When assessing water quality reports, check the parameter being described as both alkalinity and hardness are measured using the same units (parts per million CaCO<sub>3</sub>). The buffering capacity of a solution is expressed as carbonate content (CO<sub>3</sub>) and its hardness is expressed as the concentration of calcium cations (Ca<sup>++</sup>).

Potable water standards are set out in NZFSA DPC2: Animal Products (Dairy) Approved Criteria for Farm Dairies (NZFSA, 2009) This recommends:

- E. coli – absent in 100mL
- Turbidity – maximum of 5NTU; or
- Clarity as specified in the Drinking Water Standards for NZ (2005)

If the quality of water available at the dairy is suspect, farmers are advised to use an alternative water supply, e.g. rain water tank, or potable water from the farm house, to make up teat disinfectant, or use an RTU product.

Note that all teat disinfectants are susceptible to inactivation by water with high levels of hardness, alkalinity, or chlorine. These high levels are unlikely to occur naturally in NZ, but can easily occur when common measuring vessels are used to measure alkaline or chlorinated detergents as well as teat disinfectants.

Great care should be taken to ensure that measuring containers used for teat disinfectants are not contaminated by detergent or chlorine residues. The use of a measuring jug dedicated solely to the teat disinfectant is strongly recommended.

**Testing the final mix of teat disinfectant solutions and water on-farm**

For teat disinfectants that are mixed on farm, it is important to be able to regularly test the level of active ingredient in the final mix (if possible), and the water used. Advisers can access field testing kits through teat disinfectant manufacturers, or laboratories that can perform such tests.

Contact details for the main teat disinfectant suppliers in NZ are listed on the SmartSMMM website.

Confirmatory tests are advised when field tests are not available and a real problem is suspected based on farm history, or if repeat field testing gives widely variable results or results that are difficult to interpret in the light of other observations.

More sophisticated water testing can be obtained from independent laboratories. Some manufacturers of registered teat disinfectants can offer or recommend a water and active ingredient testing service. The experience and expertise of technical staff in these companies is a valuable resource in troubleshooting problems with teat disinfection.

If any problem is suspected with the purchased concentrate, it should be referred to the manufacturer immediately, with the remaining product.

**Assessing the level of active ingredients in teat disinfectant solutions applied to teats (in the final mix or RTU solution)**

	Iodine	Chlorhexidine	Acid anionics	Chlorine
<b>What concentration of active ingredient is required?</b>	Not less than 0.2% total iodine	Not less than 0.3% chlorhexidine	Not less than 2% anionic	Not less than 0.2% chlorine
<b>How can it be tested in NZ?</b>	Field test kits use sodium thiosulphate titration. Laboratories confirm levels by potentiometric titration	No field tests available. Laboratories confirm levels by High Pressure Liquid Chromatography (HPLC)	No field tests available. Laboratories confirm levels by High Pressure Liquid Chromatography (HPLC)	Field test kits are available. Laboratories confirm levels by potentiometric titration

**Assessing the suitability of water used to mix teat disinfectant solutions on farms**

	Iodine	Chlorhexidine	Acid anionics	Chlorine
<b>Alkalinity</b>	Should not exceed 500 ppm CaCO <sub>3</sub>	No specific recommendations available	Should not exceed 900 ppm CaCO <sub>3</sub>	No specific recommendations available

<b>Hardness</b>	No specific recommendations available	Should not exceed 500 ppm CaCO <sub>3</sub>	Should not exceed 900 ppm CaCO <sub>3</sub>	No specific recommendations available
-----------------	---------------------------------------	---	---	---------------------------------------

## 7.4

### *Mix products according to the label directions.*

Mix teat disinfectants according to label directions. Products have been designed to provide the correct level of active ingredient at the recommended use concentrations. The ACVM registration process for teat disinfectants places a high weighting on performance, and testing is done at the manufacturer's recommended use concentrations.

Often label statements refer to different application rates relative to weather conditions. These variations in recommended use concentrations relate to the greater emolliency required for teat condition in adverse weather conditions. More concentrated solutions provide more emollient and greater antimicrobial protection.

It is important that on each farm the steps for mixing teat disinfectant are clearly established and the task of mixing is allocated to staff that understand how to do it. Field examination of 200 problem farms (Joe *et al* 2010) found that only 33% of 200 farms were able to make up their teat disinfectants correctly.

The availability of RTU products now provides an option for farms that experience difficulties in sourcing water of adequate quality or mixing solutions consistently.

If testing shows the concentration of the active ingredient in the final mix is incorrect, check that:

- the mixing rate used on farm is correct;
- components are measured accurately;
- the type and amount of emollient used is appropriate;
- the water used is visibly free of organic matter and colloid;
- the water used is not alkaline or hard;
- the stock product is within expiry date;
- the stock product is sealed and stored appropriately;
- the mix is made up freshly; and
- the containers used to mix the teat disinfectant are clean.

#### Confidence – High

This guideline is a safety net given the absence of efficacy data to support the use of lower concentrations of iodine-based products, the lack of clear directions about the effect of water quality on each product, and the variation in water quality on farms.

#### Research priority – Low

**SmartSAMM Healthy Udder provides tips and reminders on the correct way to mix up teat disinfectants.**



## 7.5

### **Maintain teat condition, by adding additional emollient if required.**

An emollient is a compound used to soften or condition teat skin. The addition of emollients to teat disinfectant can improve teat skin health and so reduce the likely reservoir of mastitis pathogens in teat sores and cracks. They have an important role in mastitis control for these reasons.

Many teat disinfectants contain emollients when they are sold, especially those formulated with relatively low pH where skin irritation would be expected without some additional protectant.

Emollients registered for addition to specific teat disinfectants on farms can be found on the ACVM list of registered products, available from the NZFSA website: [www.nzfsa.co.nz](http://www.nzfsa.co.nz).

Some emollients that are well regarded in the field, such as food-grade glycerine and sorbitol, are generically permitted for use in teat care applications by ACVM and are readily available in the marketplace. They need not be specifically registered and labelled for addition to teat disinfectants.

Other unapproved materials should not be used as emollients. Examples include: bloat oil, canola oil, tea tree oil or emulsified paraffin.

Addition of up to 9% glycerine led to improvement in teat skin condition when an iodine-based teat disinfectant dip was used in 30 dairy herds in the United Kingdom, but there was no further benefit at concentrations of up to 24% (Bramley 1981). The addition of 10% glycerine in the formulation of an iodine-based teat dip helped reduce *Staph. aureus* colonisation and was associated with faster healing of teat chapping lesions (Fox *et al* 1991, Fox 1992). Skin condition in a Danish research herd milked robotically was significantly better when the teat spray contained 8% glycerol compared with 2% glycerol (Rasmussen *et al* 2002).

The addition of emollients has been reported to reduce the bactericidal activity of the disinfectant, but the evidence to support this is not consistent or convincing. Using emollient at a concentration higher than 15% is more likely to affect the viscosity, and have a detrimental effect on the delivery of product through the spray system.

The overall effect of the teat disinfectant preparation used is a balance between the bactericidal activity of the disinfectant component, the skin conditioning properties of the emollient, and effective delivery through the teat spray system.

For these reasons, SmartSAMM recommends that the concentration of total emollient in the final solution should be no more than 15% (see Table below).

#### **Confidence – High**

Maintenance of healthy skin condition is an extremely effective way to reduce bacterial populations on teat skin.

#### **Research priority – Low**

It is possible that bactericidal efficacy of different disinfectants is affected by the type and concentration of different emollients.

Glycerol is the name of the compound. Glycerine is the name of the product.

**Technote 9 describes the evaluation of teats and teat lesions.**

### Adding additional emollient

Many registered teat disinfectants are marketed with some emollient incorporated. More emollient may be added to bring the concentration in the final mix up to a maximum of 15%.

This should occur in situations of high challenge i.e. when teats are exposed to adverse weather and muddy conditions, and the risk of new infections is high.

### SmartSMM recommendations for adding extra emollient

	High Challenge	Low Challenge
<b>Examples of different conditions</b>	<ul style="list-style-type: none"> <li>Wet &amp; cold weather</li> <li>Muddy pastures</li> <li>High degree of teat dryness</li> <li>High level of teat end damage</li> <li>Bulk milk SCC above herd target</li> <li>Clinical case rate above target</li> </ul>	<ul style="list-style-type: none"> <li>Dry &amp; warm weather</li> <li>Dry pastures</li> <li>Little teat dryness</li> <li>Little teat end damage</li> <li>Bulk milk SCC below herd target</li> <li>Clinical case rate below target</li> </ul>
<b>Emollient concentration</b>	Add extra emollient (5-10%) to provide a total maximum emollient concentration of <b>15%</b> in the final mix.	Check if extra emollient is required, to provide an emollient concentration of <b>5%</b> in the final mix.

- As a rule of thumb, "no teat spray currently on the market can cope with a NZ spring without extra emollient".
- Calculating the amount of emollient to add requires knowledge of:
  - Total volume of made-up teat spray required
  - Concentration of emollient in the teat spray concentrate
  - Final total concentration in the final mix
- Additional emollient should displace some of the water, not teat spray concentrate.

**Contact your teat disinfectant supplier to determine emollient concentration in the teat spray concentrate.**

#### Example calculation:

Total volume required = 20 litres of made-up product. This is sufficient to spray 250 cows x 2 milkings x 2 days at 20 mL per cow per milking.

Concentrate Product Y contains 20 g/litre iodine and 200 g/litre glycerol, labelled to mix in the ratio of 1 litre concentrate to 3 litres of water (1:3).

When mixed according to label, the solution contains 0.5% of iodine and 5% of glycerol (200 g/L x 1/4 of glycerol = 50 g/L). In 20 L of mix, the total amount of glycerol will be 1000 g (50 g/L x 20 L).

To bring the emollient concentration up to 15% in the final mix (equivalent to 3000 g in 20 L), add a further 2000 g (approximately 2 L) of glycerol.

Reduce the water by the volume of glycerol added i.e. less 2 L. Volumes in the final mix to achieve 20 litres with 15% emollient and 0.5% iodine are:

5 litres Product Y  
 2 litres glycerol  
13 litres water  
 20 litres total

**SmartSMM Healthy Udder provides tips and reminders on the correct way to mix up teat disinfectants.**

## 7.6

### *Spray or dip the whole surface of all teats after every milking throughout lactation.*

One of the biggest variables in successful use of teat disinfection is the quality and consistency of application. Failure to cover the whole teat of every cow at every milking is the most common error in teat disinfection.

Farmers acknowledge that achieving good coverage of every teat at every milking is a major challenge. Performance is affected by factors involving operators and equipment. The 'people factors' include training for all operators on why and how to apply teat disinfectant, providing safe facilities to ensure operators can spray adequately, and arranging work routines to avoid boredom. The 'equipment factors' include choosing the approach (dip or spray) and the best appliance. Regular checking, cleaning and maintenance of equipment is also essential to getting consistently good coverage.

Disinfectant is applied by dipping each teat separately in a cup or by spraying disinfectant on to the teats from below. Dipping has the advantage that complete coverage of the teat barrel is fairly easy to achieve. Spraying disinfectant often coats one side of each teat only, and might use twice as much disinfectant in creating the aerosol and covering the base of udder (which is not the target area). Dipping avoids the potential of operators being exposed to aerosols, especially in windy conditions.

However, spraying is generally considered to be quicker and easier to incorporate into milking routines than dipping, although correct spray application may take as long as dipping. So, in most NZ herds, spraying is the preferred method to apply teat disinfectants.

There is a vast array of products on the market that are designed to deliver disinfectant onto teats. Some delivery systems are discussed below.

#### **Spraying**

Sprays can be applied using a gun-type hand piece with a spray nozzle or a fully automated spray system.

Teats should be sprayed from below using a circular motion to cover all sides of all teats. The coverage obtained from the different types of spray units and nozzles varies substantially. Spray nozzles that direct the spray vertically achieve far better teat coverage than horizontally directed jets (which are not satisfactory). Spray nozzles that deliver a solid cone pattern provide better coverage than nozzles that deliver hollow cone patterns.

Spray nozzles must allow the free passage of disinfectant and be checked regularly to ensure they are not blocked or partially blocked and achieve the spray pattern required. Spray nozzles should achieve an even cover of fine droplets that spread to about 10 centimetres diameter when spraying vertically upwards onto paper over a distance of 10 centimetres. Droplets should not be so fine (<10 micrometres in diameter) that there is drift away

#### **Confidence – High**

Extensive field experience and experimental observations show that consistent application of post-milking teat disinfection is an essential element of mastitis control.

#### **Research priority – High**

More efficient methods of dispensing teat disinfectants (e.g. better spray nozzles and automatic spray units) are required to improve teat skin coverage and minimize labour.

Despite the common saying that 'it is the drip at the end of the teat that's important', coverage is not considered adequate unless there is disinfectant on the whole surface of the teat.

**SmartSAMM Healthy Udder provides examples of unsatisfactory spray patterns.**

Nozzle openings can become blocked or corroded. Nozzles that don't produce the desired pattern or delivery rate should be serviced or changed.

from the target area.

Delivery of solution to hand-held spray units may be from:

- Manually operated pressurised sprayers with reservoirs which last for a hundred or so cows without the need to refill (2 L); or
- Semi-automatic application systems where disinfectant solution is delivered via a pressurised line into the milking area from a reservoir normally outside in the machine or vat room. With these installations there is normally one wand applicator for a number of milking units, suspended from the ceiling.

See [www.milksmart.co.nz](http://www.milksmart.co.nz) for a summary of different ways to apply teat disinfectant, and issues to consider when setting up a farm system.

Fully automated teat disinfectant delivery systems are also available. These can be installed:

- At or near the exit of rotary milking platforms.
- Just after the exit in a dedicated teat spray lane.

Sensors detect the presence or movement of a cow, and activate spray nozzles. Spray patterns are adjusted to deliver sufficient spray at the height of the average cow's udder. These systems can give very variable results and should be checked regularly to ensure that teat disinfectant is reaching cows' teats. They also require more disinfectant solution than hand spray units or dipping.

### *Dipping*

Teat dip cups are hand-held and usually 200-400 mL in size. There have been many designs developed and sold in overseas markets. They usually come with a small bottle below the cup from which disinfectant is squeezed through a one-way valve. The act of immersing each teat in a reservoir of disinfectant usually ensures that the entire teat barrel (any area in contact with the teat liner) will be covered, as long as the cup is deep enough and filled with the appropriate amount of effective solution.

Cups should be emptied before refilling, rather than 'topped up' when the solution becomes low. This application method requires slightly more time than most spraying applications when taking preparation, refilling and actual application into account.

### *Volume required*

As a general rule, the volume required to achieve good coverage per cow varies as follows:

- Hand dipping – requires **10 mL** of solution per cow per milking
- Hand spraying – requires **20 mL** of solution per cow per milking
- Auto spraying – requires **30 mL** of solution per cow per milking

## 7.7

### **Check coverage.**

Careful operators or well-adjusted automated systems can achieve very good results with teat spraying. However, both systems can achieve poor coverage. Encouraging milking staff to regularly assess their own and each other's teat coverage is important.

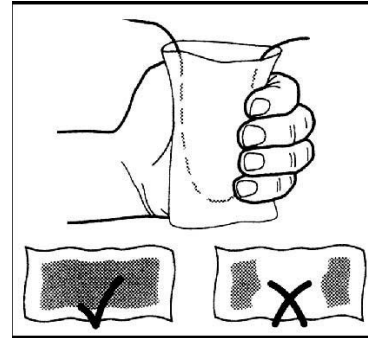
Simple checks include:

- Visual examination of teat condition.
- Visual examination of coverage on individual teats of several cows to determine if all sides of the teat barrel are being covered.
- Manual check of coverage by wrapping a paper towel around the barrel, then carefully removing and examining the wet or stained area.
- Assess volume used per cow to check that at least 20 mL of prepared teat disinfectant is being used per cow per milking if spraying (10 mL if dipping). This involves measuring the total amount of teat disinfectant used over two milkings, and dividing this number by the total number of cows milked at both milkings.
- Checking the time in seconds that is needed to apply the correct amount of disinfectant solution. This can be done, for example, by counting the number of seconds required to fill an empty 20 mL syringe barrel with the spray. This can then be compared with the actual time that operators take to spray each cow.
- Check automated systems/walk over systems by holding a piece of white card (or filter sock or inflated white rubber glove) horizontally over the sprayer, at the level of the udder.

Regular review of teat disinfection efficiency with an adviser can add to staff training and awareness about the importance of this routine activity in mastitis control.

### **Checking coverage with a paper towel.**

(Used with permission from Countdown)



### **Acknowledgements**

DairyNZ and NMAC (NZ National Mastitis Advisory Committee) acknowledge the huge contribution of Dairy Australia's Countdown Downunder as the original source material from which SmartSAMM Technotes are derived, being updated and adapted for NZ dairy farming in 2011.

These SmartSAMM adapted resources are made available to NZ dairy farmers and advisors through a Memorandum of Understanding between Dairy Australia and DairyNZ.

The SmartSAMM programme is funded by DairyNZ, and supported by the MPI Sustainable Farming Fund.

## Key papers

- Bramley AJ. The role of hygiene in preventing intramammary infection. In: *Mastitis Control and Herd Management, Technical Bulletin 4*. National Institute for Research in Dairying, Reading, England, 1981; 53-65.
- Bramley AJ. Mastitis and machine milking. In: Bramley AJ, Dodd FH, Mein GA, Bramley JA editors. *Machine milking and lactation*, Chapter 10. Insight Books, Vermont, United States, 1992; 343-372.
- Bramley AJ, Kingwell RG, Griffin TK, Simpkin L. Prevalence of *Corynebacterium bovis* in bovine milk samples. *Vet Rec* 1976; 99: 275.
- Denton GW. Chlorhexidine. In: Block SS editor *Disinfection, sterilization, and preservation* 5<sup>th</sup> edition, Chapter 15. Lippincott, Williams and Wilkins, Philadelphia (US). 2001; 321-336.
- Dychdala GR, Lopes JA. Surface-active agents: acid-anionic compounds. In: Block SS editor *Disinfection, sterilization, and preservation* 4th edition, Chapter 14. Lea & Febiger, Philadelphia (US). 1991; 256-262.
- Fox LK, Nagy JA, Hillers JK, Cronrath JD, Ratkowsky DA. Effects of postmilking teat treatment on the colonization of *Staphylococcus aureus* on chapped teat skin. *Am J Vet Res* 1991; 52: 799-802.
- Fox LK. Colonization by *Staphylococcus aureus* on chapped teat skin: effect of iodine and chlorhexidine postmilking disinfectants. *J Dairy Sci* 1992; 75: 66-71.
- Hillerton JE. Control of mastitis. In: Phillips CJC, editor. *Progress in Dairy Science, CAB International*. 1997; 171-191.
- Hillerton JE, Staker RT, Shearn MF. Failure of exit-race teat spraying to control *Corynebacterium bovis* colonisation. *Vet Rec* 1995; 137: 633-635.
- Joe AK, Cranefield SW, Hodge IC, Clarke TG. Summary of problems identified in 200 milking assessments from mastitis problem herds during 2008 and 2009 in two regions of New Zealand (Waipa and South Canterbury). *Mastitis Research into Practice: Proceedings of the 5<sup>th</sup> IDF Mastitis Conference 2010*. 2010; 363-368.
- Lee PW. Teat disinfection usage by north eastern Victorian dairy farmers. *Dissertation for the Master of Veterinary Studies*, University of Melbourne, 1994.
- National Mastitis Council *Laboratory Handbook on Bovine Mastitis* Madison, Wisconsin (US) Revised Edition, 1999, p135.
- National Mastitis Council. Summary of peer-reviewed publications on efficacy of premilking and postmilking teat disinfectants published since 1980 (last revised 2009). *Proceedings of the NMC 51<sup>st</sup> Annual Meeting 2012*; 235-249.
- NZFS. *DPC2: Animal Products (Dairy) Approved Criteria for Farm Dairies* 2008. Accessed at: [http://foodsafety.govt.nz/elibrary/industry/Dpc2\\_Animal-Sets\\_Additional.pdf](http://foodsafety.govt.nz/elibrary/industry/Dpc2_Animal-Sets_Additional.pdf)
- Pankey, JW, RL Boddie, WN Philpot. Evaluation of linear dodecyl benzene sulfonic acid as a teat dip in a commercial herd. *J. Dairy Sci*. 1984; 67:1354-1358.
- Pankey, J. W., Pankey, P. B., Barker, R. M., Williamson, J. H. and Woolford, M. W. The prevalence of mastitis in primiparous heifers in eleven Waikato dairy herds. *NZ Vet. Journal* 1996; 44: 41-44.
- Pankey JW, Watts JL 1983 Evaluation of spray application of postmilking teat sanitizer. *J. Dairy Sci* 1983; 66: 355-358.
- Pankey JW, Watts JL, Nickerson SC. Field studies on linear dodecyl benzene sulfonic acid teat dip *J Dairy Sci* 1985; 68: 1523-1530.
- Phillips DSM. Reduction of pathogen transfer within the milking cluster. In: *Proceedings of the Conference on Dairy Production from Pasture, New Zealand and Australian Societies on Animal Production*, Ruakura, New Zealand, 1982: 81-82.
- Rasmussen MD, Hemling TC. The influence of automatic teat spraying on teat condition. In: *Proceedings 41st Annual Meeting, National Mastitis Council*, Orlando, Florida. 2002; 166-167.
- Ryan D. Investigation of mastitis problem farms. In: *Post Graduate Foundation in Veterinary Science Proceedings 161, Dairy medicine and production*, University of Sydney, 1991; 43-58.
- Tattawasart U, Maillard JY, Furr JR, Russell AD. Development of resistance to chlorhexadine diacetate and cetylpyridinium chloride in *Pseudomonas stutzeri* and changes in antibiotic susceptibility. *Journal of Hospital Infection* 1999; 42: 219-229.
- Williamson J, Lacy-Hulbert J. Effect of post-milking teat spraying on mastitis, somatic cell count and teat skin abnormalities in five Waikato dairy herds. *Mastitis Research into Practice: Proceedings of the 5<sup>th</sup> IDF Mastitis Conference 2010*. 2010; 665.
- Woolford M, Hook I, Eden M, Joe A. The "SAMM plan": Seasonal approach to managing mastitis. *The Third IDF International Mastitis Seminar*. Tel-Aviv, Israel. 1995; s-4: 59-63.
- Woolford MW, Williamson JH, Day TM, Lacy-Hulbert SJ, Henderson HV. Effect of localised

antibiotic infusions applied to the teat-canal and teat sinus at drying-off on mastitis in the dry-period and at calving. *J Dairy Res.* 2001; 68: 551-558.