LACTATION

TECHNOTE 9

Manage teat sores and cracks

Maintenance of healthy teat skin is a key requirement for an effective mastitis control programme. The physical condition of the bovine teat is an indicator of the quality of the environment, the milking management and the milking system used on a dairy herd, and can also be used as an indicator for the risk of intramammary infections.

Mastitis risk is a numbers game – more bacteria near the teat end increase the risk of new infections occurring. Teat sores and cracks provide sites where bacteria can multiply. They can be painful to the cow, causing her to kick and defecate more frequently during milking, and have poor let-down.

Healthy, undamaged skin is easier to keep clean.

Defence mechanisms of the teat canal

Mastitis occurs when bacteria enter the mammary gland, usually via the teat canal. There are four physical components of the teat end and teat canal that protect against bacterial invasion. These are:

- tight closure and effective sealing of the teat canal between milkings;
- adherence of bacteria to the keratin lining of the teat canal;
- shearing of the keratin lining during milk flow; and
- drying and re-sealing of the canal lumen during the early post-milking period.

Disruptions to any of these increase the susceptibility of the udder to infection.

The teat canal is lined by a modified skin layer (epithelium) that is continuous with the outer teat skin. Typically, the canal is about 10-12 millimetres long. When opened, the circumference of the milk contact surface is about 6 millimetres. When closed in the inter-milking period, the canal is highly folded.

The teat canal provides the first and most important barrier to bacteria entering the udder. The new infection risk is increased if:

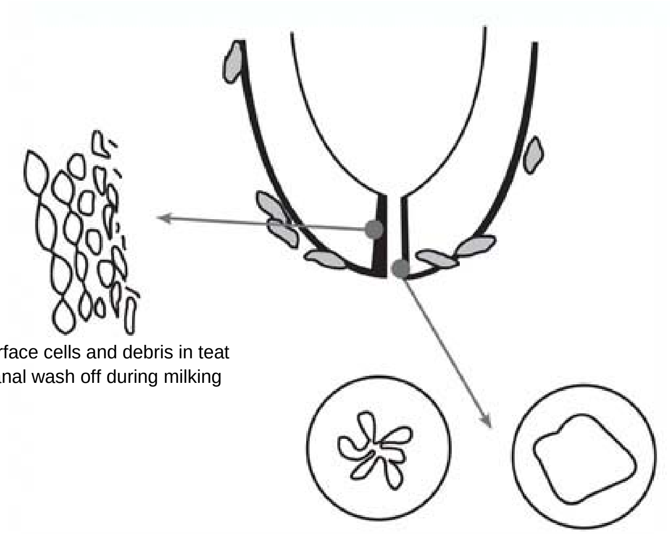
- The effective diameter of the teat canal is relatively wide (as indicated by a higher peak milk flow rate from the teat). For example, teats with high milk flow rates had higher infection rates in

Keratin is a wax-like substance produced by the cells lining the teat canal. It serves as a temporary seal between milkings and a more permanent plug throughout the dry period. Keratin is a protein complex that contains lipids, and is a major structural component in skin, hair, nails and hoof cells.

the dry period (Dodd and Neave 1951), and similarly, higher infection rates during lactation in experiments involving artificially high bacterial challenge (Grindal and Hillerton 1991).

- The teat canal is shorter than average (Grindal *et al* 1991; Lacy-Hulbert and Hillerton, 1995).
- The keratin that fills the lumen of the teat canal does not seal the canal effectively in the inter-milking period or during the dry period. For example, incomplete sealing of the keratin plug was linked with higher new infection rate in the dry period (Williamson *et al* 1995). During lactation, high bacterial challenges led to higher infection rates if keratin was removed from the teat canal by reaming (Capuco *et al* 1992).

Defence mechanisms of the teat end



The defence mechanisms that resist bacterial penetration through the teat canal are primarily physical (Williams 1984, Williams and Mein 1985, Lacy-Hulbert and Hillerton, 1995, Lacy-Hulbert 1998). At a microscopic level they involve:

Technote 14 describes the importance of the keratin plug in the teat canal at drying-off.

- formation of a lipid film in mature keratin layers that allows easy opening and cleaning of the teat canal during milking or suckling; and
- effective re-sealing of the canal when milking or suckling ceases.

Mature keratin cells are held loosely together in this film of lipid, and bacteria in the canal stick to these cells (see figure above). During milking, repeated compression by the pulsating liner and the flow of milk through the teat canal wash away a high proportion of the mature keratin cells and any adherent bacteria. This flushing action has the effect of cleaning the teat canal surface. The lipid film is continuously replenished by the keratin cells lining the canal.

It is thought that, for the teat canal to effectively seal at the end of milking this lipid film must reform and bind the keratin cells together. When the teatcups are removed, waves of muscle contraction occur in the teat. The film of milk on the teat canal surface is disrupted by the ‘wringing’ action of this muscle contraction (passing from the base of the teat to its apex) and squeezing between the folds of the teat canal lining. The absence of a continuous column of milk within the canal prevents movement of bacteria by capillary action along the canal and stops their migration from the teat orifice to the udder cistern. The external teat orifice is then dried by ambient air assisting this natural defence mechanism.

These physical mechanisms operating within the teat canal have many practical and interesting consequences. For example:

- The milk stream associated with normal milking vacuum levels (moving at about seven metres per second in the initial pulsation cycle of a correctly functioning machine) provides sufficient force to clean the lining of the teat canal by shearing the outermost layer of mature keratin cells, removing debris in the canal.
- Pulsation causes an action in the teat canal analogous to cleaning hands by rubbing them together under a tap. A cyclical pressure, applied by the liner collapsing around the teat apex at regular intervals, physically loosens debris that is flushed away during the next pulsation cycle. Capuco *et al* (1994) found nearly 40% of the mature keratin cells were removed at every milking by the combined effects of milk flow and pulsation compared with an average loss of about 25% in the absence of pulsation.
- The ability of the teat canal to trap bacteria is markedly reduced if a proportion of the teat lining is not flushed away by the end of milking. Milking without pulsation in post-milking challenge experiments leads to an accumulation of keratin in the teat canal (Lacy-Hulbert *et al 1996*), and very high new infection rates. A possible explanation for this is that keratin, potentially contaminated with pathogenic bacteria, is retained for longer in the teat canal, providing a greater opportunity for these bacteria to enter the gland.
- The highly convoluted surface of the keratin, covered by the lipid film, provides a high capacity to absorb and entrap bacteria, especially those with a high degree of cell surface hydrophobicity such as *Staph. aureus* and *Strep. dysgalactiae* (Mamo *et al* 1987; Calvinho *et al* 1996*.* This may support their ability to colonise the teat canal prior to gaining access into the gland.
- Bacteria cannot move towards the udder cistern if only small, isolated spots of milk remain on the teat canal lining after it has been 'wrung dry'. Most mastitis-causing pathogens are non-motile and require the random movement of milk through the teat canal to transport them through the teat canal. Resealing, and mild dehydration of the keratin material between milkings, helps prevent movement of this milk film through the teat canal. Certain bacteria, such as *Strep. agalactiae*, *Staph. aureus* and *Corynebacterium bovis*, may collect specifically in these isolated spots of milk, and make use of the teat canal lipid film and milk as energy and protein sources to grow and divide.

These natural defence mechanisms may explain why more frequent milking reduces the risk of new mastitis infections, by enabling more regular flushing and cleaning of the teat canal.
Conversely, the higher infection risk in the early dry period may be due to the absence of a mechanism to regularly remove pathogens adhering to the surface cells of teat canals.

9.1

Assess teat skin and teat ends systematically.

Changes to teat tissue, particularly the skin of the barrel, teat end and teat canal, will alter udder defence systems. Veterinarians, field extension personnel, and farmers require a simple and reliable method for evaluating teat health in dairy herds. For farmers and advisers investigating possible problems identified by general observation of teats, it is important to have a method to qualitatively or quantitatively record teat condition on a representative number of cows at milking time (Ohnstad 2010).

A protocol for systematic evaluation of teat condition in commercial herds, with guidelines for interpretation of observations, was developed by an informal discussion group of researchers and udder health advisers known as the 'Teat Club International' (Mein *et al* 2001; Hillerton *et al* 2001). Another, more recent paper (Ohnstad *et al* 2007) provided guidelines on:

- Effective treatments and changes in management or machine settings that appear to provide successful solutions for teat condition problems in commercial herds;
- The expected time scale - after the start of a successful treatment or management change - until improvements in teat condition should become evident;
- The estimated level of confidence for each recommendation or conclusion.

The series of guidelines in these three Teat Club papers form the basis of this Technote.

Various agents and mechanisms may affect the condition of the teats of the milking dairy cow. In general, these fall into one of three broad categories:

- milking-induced (machines and management);
- environmental; and
- infectious.

Table 1 lists the main conditions in the first two categories. For infectious conditions, see section C below (page 14).

Table 1. Teat conditions arising from milking-induced and environmental effects in Australia and New Zealand.

Milking-induced	Environmental
Discolouration	Skin dryness and chapping
Firmness or swelling	Teat orifice roughness and hyperkeratosis
Wedging of the teat end	Abrasions and cuts
Openness of the teat orifice	Photosensitisation, sunburn, frostbite
Petechial haemorrhages	Chemical damage
Hyperkeratosis (thickening of the skin at the teat orifice)	Allergic reactions
	Insect bites

Confidence – High

Maintenance of healthy teat skin is a key requirement for an effective mastitis programme.

Research priority – Moderate

International agreement on teat evaluation methods was achieved in September 2001. Further analyses are required to refine current guidelines for interpretation of results, including thresholds of concern for different conditions.

See Technote 13 for information about the SmartSAMM Mastitis Investigation Kit, which can be used for scoring teat condition.

A. Short-term, milking-induced changes in teat condition

Short-term changes are generally regarded as those seen in response to a single milking. Faults in milking management or milking machines are the primary cause of short-term effects such as:

- discolouration - that is, reddened, bluish, purplish or very white teats seen immediately after milking;
- firmness or swelling of the teat or "ringing" around the upper teat barrel;
- wedging of the teat end;
- degree of openness of the teat orifice.

Some specific causes, or exacerbating influences, on these teat conditions are summarised in Table 2.

Generally the teat takes some hours to recover its full integrity even from good milking conditions (Neijenhuis *et al* 2001b). However, improvements in teat condition should be evident immediately after the milking at which the specific fault or faults have been correctly identified and fixed. Full rectification may take one or more days.

Confidence – High

If improvements are not obvious or immediate, then it is likely that specific faults have not been identified correctly or not corrected adequately (Rasmussen *et al* 1998; Hillerton *et al* 2000).

Table 2. Primary causes (1) or exacerbating influences (2) on short-term_changes in teat condition induced by milking.

	Teat colour	Swelling at teat base	Firmness/hardness of teat end		Orifice
Observation	**Red/blue**	**'Ringing'**	**Hard**	**Wedged**	**Open**
Machine factors					
High milking vacuum	1	1	1		1
Faulty pulsation	1		1	1	
Short d-phase	1		1		
Long d-phase				1	
Liners*: - Wide bore liner with tapered barrel	2	2	2		
- Aged (i.e. stiff or very pliable walls)	2	2			
- High tension (i.e. stiff walled liner)	2			1	1
Mouthpiece: - Deep chamber	2	2			
- Small diameter	2	2			
- Stiff mouthpiece		2	2		
Mismatch of liner and teats	2	2			2
Milking management					
Long dribble times (flow below 1L/min per cow)	1	1	1		
Overmilking (flow below 200 ml/min per cow)	1	1	1		1
Teatcup crawling	2	2	2		

* For more information on liner characteristics, see the 'Liners' Advisors Note.

Evaluating machine-induced, short-term changes

1. Colour changes

Some teats are noticeably red, either at the teat end or over the entire teat, when the cluster is removed. Others may initially appear white, and feel cold, and then become reddened within 30-60 seconds of cluster removal. In extreme cases, teats become blue or already appear blue when the cluster is removed. Poor teat colour after milking may be worse for short or slender teats, or highly oedematous teats, because they are supported less effectively by the liner.

See Guideline 9 for images of teat conditions.

Reddish discolouration, indicating congestion, is exacerbated by over-milking, (especially with wide-bore liners or tapered liners with wide upper barrels); unusually heavy cluster weight; high milking vacuum; faulty pulsation; or mismatch between the type of liner used and mean teat size within a herd. Bluish discolouration, indicating cyanosis, may result from use of liners with a small mouthpiece diameter relative to the internal diameter of the barrel or liners mounted at unusually high tension.

See Technote 5 for more information on selecting the end point of milking.

See Technote 6 for more information on liner selection and matching liners to clusters.

Black teats and most pigmented teats must be excluded from colour-based evaluations because these changes cannot be seen.

Colour changes are classified according to the proportion of light-coloured teats which, when examined within one minute of cluster removal, are:

Use Sheet I of the SmartSAMM Mastitis Investigation Kit to record teat condition scores.

- **Normal** - pink.
- **Red** - part of, or the entire teat, may be reddened.
- **Blue** - part of, or the entire teat appears to be tinged with blue or purple.

Because the causes of reddened or bluish teats may differ, red and blue classes should be recorded separately. However, analysis is simplified by combining these two changes into a single category ‘Red or Blue’.

2. Swelling at or near the teat base

When examined after milking, the upper part of the teat may have a visible line or mark caused by contact with the liner mouthpiece lip, or visible swelling with a palpable, thickened ring. This occurs in the unsupported part of the teat that was inside the liner mouthpiece chamber near the end of milking. To avoid confusion with physiological swelling of teats and udders, cows with obvious signs of udder oedema or cows that calved within one week should not be evaluated.

Factors commonly responsible for swelling around the top of the teat as a direct result of milking include: high mouthpiece vacuum associated with wide-bore liners; over-milking, especially with wide-bore liners or tapered liners with wide upper barrels; liners with a large mouthpiece chamber; teatcup crawling; or liner mouthpiece lips that are unusually stiff or narrow in relation to teat size.

> Excessive teat cup crawling occurs when a teat cup moves so far up the teat that the passage of milk from the udder to the teat is obstructed.

Swelling at or near the teat base when examined within one minute of cluster removal is classed as:

- **Normal** – no ring, little or no swelling, and teats that have a visible mouthpiece lip mark or ‘garter mark’ (Hillerton *et al* 2000).
- **Swollen –** if there is marked swelling or a palpable thickened ring.

3. Firmness at or near the teat end

Teats should feel soft and pliant after milking and contract when touched. However, some teats feel swollen or firm or, in extreme cases, hard, cold and unresponsive to touch. Factors commonly responsible for swelling near the teat end include: over-milking; use of wide-bore liners; high vacuum; pulsation failure; or insufficient rest phase (d-phase) of pulsation.

Teats may look flat or wedge-shaped after milking. 'Wedging' describes the flattened shape of the teat end due to the compressive load applied by the opposing walls of a collapsed liner. Typically, this wedging will be slight. Severe wedging may result from: hard liners; liners mounted under high tension; a prolonged d-phase; or failure of the liners to open fully.

Teat ends are classified, by simple visual examination supported by manual palpation, as:

- **Normal** – soft and supple.
- **Firm** – firm, swollen or hard or noticeably wedged.

4. Openness of the teat orifice

When examined immediately after milking, the external teat orifice may appear to be closed, slightly open or, in extreme cases, has a funnel-shaped opening about the size of a match-head.

Factors linked with short-term, post-milking openness of the teat orifice include high milking vacuum, over-milking, unusually heavy cluster weight, or high liner mounting tension.

Teat orifices are classified by qualitative assessment within one minute of cluster removal as:

- **Closed**
- **Open** – more than 2 millimetres wide or deep.

When estimating the degree of openness, it may be helpful to *mentally* compare the width and depth of an open orifice with that of a common object such as a match-head (typically about 3 millimetres in diameter) or the shaft of the match (about 2 millimetres). Flicking the teat end, or use of a clean paper towel may be needed to remove milk residue from the teat end to facilitate assessment.

B. *Medium to long-term, milking induced or environmentally induced changes in teat condition*

Medium-term changes refer to teat tissue changes that take a few days or weeks to become noticeable. Some specific causes, or exacerbating influences, on medium-term teat conditions are summarised in Table 3.

Medium-term changes in teat condition take longer to resolve than short-term changes. Some improvements should occur within a few milkings but, for others, significant improvement may take up to 4 weeks after correct identification of the fault and elimination of the cause.

Confidence – Medium/High

Most problems occur with:

- poorly serviced and maintained equipment,
- over-milking,
- poorly set up installations.

Poor teat condition is more apparent after cluster removal.

Table 3. Primary causes (1) or exacerbating influences (2) on medium to long-term changes in teat condition induced by milking or environmental factors.

	Teat skin		Teat end
Observation	**Rough/scaly skin, cracks or lesions**	**Haemorrhages**	**Hyperkeratosis**
Duration	**Medium-term**	**Medium-term**	**Medium-long term**
Machine factors			
High milking vacuum		1	1
Faulty pulsation		1	
Liners*:			
- Wide bore liner with tapered barrel		1	
- Aged (i.e. stiff or very pliable walls)		1	1
- High tension (i.e. stiff walled liner)		1	1
Milking management			
Long dribble times (flow below 1L/min per cow)			1
Overmilking (flow below 200 ml/min per cow)		2	1
Chemicals (or insufficient emollient)	1		2
Environmental factors			
Cold, wet, windy weather	1		2
Mud/manure (e.g. from intensively grazed or stand-off areas)	1		
Sunburn or forage-related photosensitisation	1		
Infectious skin lesions	1		

* For more information on liner characteristics, see the ‘Liners’ Advisor Note.

Evaluating medium to long-term changes

1. Petechial haemorrhages

The proportion of teats with evidence of petechial haemorrhages (or more extensive haemorrhaging) on their teats gives an indication of the presence and extent of vascular damage. Machine-induced haemorrhages of the teat skin (petechial or larger haemorrhages) may take several days to become evident.

See Guideline 9 for images of teat conditions.

Vascular damage usually indicates some type of pulsation failure, or shortened d-phase, often associated with high vacuum and/or prolonged overmilking. If the damage is chronic it is more likely to result from prolonged over-milking (see Table 3). The incidence of vascular damage is lower in herds milked with narrow-bore liners, at low vacuum, and/or with automatic cluster removers.

Use Sheet I of the SmartSAMM Mastitis Investigation Kit to record teat condition scores.

This condition can be improved by correcting vacuum and/or pulsation settings to improve teat end massage during pulsation. Extreme care must be taken to ensure that vacuum and pulsation issues are considered in conjunction with cluster position and tube support. Where cluster position is poor, eliminating vacuum and/or pulsation faults may not provide a complete solution.

Some improvement should occur within a few milkings, but significant improvement may take up to 4 weeks after correct identification of the fault and elimination of the cause.

Petechial haemorrhages are classified by close examination of the teat end, according to their position and extent on light-coloured teats. Teats are scored as:

- **Normal** – no evidence of petechial haemorrhage
- **Mild** – Small pin-prick red spots in discrete areas or very diffuse across the teat end.
- **Moderate** – Dense red spots, affecting a discrete area.
- **Severe** – Spots or red marks coalescing into a bruise or sore with or without open lesions.

2. Teat skin condition - environmental changes

Healthy teat skin is coated with a protective mantle of fatty acids that slows the growth of bacterial pathogens. Teat damage causes this protective surface coating to be removed, allowing colonisation of pathogens such as *Staph. aureus*.

In cold, wet and windy conditions, the skin of machine-milked teats often becomes dry, rough or scaly. With time, the skin can become irritated and chapped (broken), which can lead to the formation of cracks. Weather changes can have an almost immediate effect on teat skin roughness, and teat skin and end cracking can occur within 1-2 days under severe winter weather changes (Timms, 2004). At moderate temperatures (-3 to 24^{o}C) teat skin condition could be improved significantly over a period of 4 weeks through the use of a teat spray containing 8% emollient, compared to a spray containing only 2% emollient (Rasmussen and Hemling, 2002) in an automatic teat spraying system.

Cold, wet or muddy conditions can also induce hardening or thickening of the teat skin, possibly by reducing circulatory blood flow through the tissues. Mud, as it dries, can also draw moisture from the skin with a consequent loss of elasticity of the teat skin. Hardening or thickening of the skin can lead to teat end hyperkeratosis (see below).

Poor teat skin condition is more apparent after cluster removal. Factors that exacerbate teat roughness and damage include:

- insufficient emollient in the teat disinfectant
- lack of teat spray coverage
- older style milking equipment
- poorly serviced and maintained milking equipment
- over-milking
- new installations lacking quality control of the machine set-up (Hillerton *et al* 2000; Hillerton *et al* 2002).

In the absence of cracks and sores, there is no distinguishable difference between dry and normal teat skin on new mastitis infection rates (Rasmussen and Larsen 1998).

Teat skin condition is classified as:

- **Normal** – smooth sheen, soft, healthy skin.
- **Dry** – scaly, flaky or rough skin but with no cracking.
- **Lesion** – if there is any infectious or open lesion on the barrel or teat end, including chapped or cracked skin, and blackspot.

The dryness of black teats tends to be over-estimated by observation alone. Evaluation is improved by lightly rubbing the teat skin with a finger, when wearing a latex glove.

3. Teat skin condition - chemical irritation

Chemical irritation associated with disinfectant type or concentration, or inappropriate type or concentration of emollients, may exacerbate the effects of harsh weather conditions and promote teat chapping. Skin conditioners or emollients either reduce evaporation from the skin or act as humectants (moisturisers) to maintain or improve the teat skin condition (Hemling 2002).

When teats were intentionally irritated with a harsh chemical (Fox 1992), the irritant effect was maximised after 1-3 days. Progressive healing from severe teat skin and teat end damage can take 3-5 weeks. More typical degrees of irritation resolve in 10-14 days (Rasmussen 2003).

Teat disinfectants more usually show an effect on teat barrel skin rather than on the teat ends. This is because the disinfectant and the environment are the major influences on the teat barrel, whereas the milking process has a more significant effect on the teat end. Skin thickness should not be affected by teat disinfectants although aggressive chemicals may induce a hyperplasia of the epidermis leading to thickened and scaly skin, which will resolve in 7-10 days with use of a milder disinfectant.

In a case study in the UK, teats were sprayed unintentionally with a concentrated, low pH, iodine-based, vat cleanser for three milkings (Ohnstad *et al* 2007). The burning of teats was severe and it took several weeks for the skin to return to visible normality. Further, many cows in the herd seemed to become sensitised to iodine products. Using a chlorhexidine formulation with a high concentration of glycerine successfully restored teat condition. However given the dominant use of iodine as the preferred teat disinfectant, sensitisation to iodine is not routinely observed.

The first generation of iodine-based teat disinfectants had a pH 1-2 and their irritant effect on teat skin was only partially ameliorated by emollients. More recent iodine-based disinfectant technologies have a pH of 3.5 or more, and produce little evidence of teat irritation with the appropriate use of emollient. Sensitivity is extremely rare. Chlorhexidine solutions are mild in most cases and unlikely to have an adverse effect on teat skin.

Classification of this condition is as described in section 2 above. Potential causes of chemical irritation can include:

- Use of an inappropriate chemical for teat disinfection e.g. use of milking plant sanitisers instead of teat disinfectant
- Use of an approved teat disinfectant product at too high a concentration

Improvements in teat skin roughness can be noticed almost immediately after elimination of the specific cause but reach an end point in improvement in 2-3 weeks (up to 5 weeks for more severe damage).

4. Teat skin conditions – photosensitisation

Skin damage or lesions due to photosensitisation are largely confined to non-pigmented hairless areas of skin exposed to sunlight and may, therefore, be evident on the outer surfaces of light-coloured teats of affected cows.

Primary photosensitisation usually occurs when photodynamic agents, mostly derived from plants, are retained in the bloodstream rather than being excreted at normal rates in the bile. Spring eczema is one example of this condition, which may be linked to the grazing of lush spring pasture.

Secondary or hepatogenous photosensitisation arises following damage to the liver, which limits its ability to clear chlorophyll break-down products, which are photodynamic, from the bloodstream. Common causes include ingestion of facial eczema spores, ingestion of blue-green algae, or grazing of certain plants (eg lantana, ragwort, lupins). For more information see “Diseases of Cattle in Australasia” by Parkinson *et al* (2010), pages 588-590.

Cows with early photosensitization of the teats may be restless and kick at their udders and abdomens, because the affected areas are very itchy. Affected skin becomes red and oedematous but changes may not be noticed until the top layers of skin die and become hard, dry and leathery, or sheets of dead skin flake off.

Treatment is by removal of the insults, shade from the sun and diet. Application of sun blocks, zinc oxide creams, or barrier creams can also help alleviate symptoms. If liver damage has occurred, this medical problem is the primary issue, with oral treatment with zinc oxide often recommended.

Light-coloured surfaces of teats can also be prone to sunburn, especially the front surfaces of widely-displaced front teats. This will show as redness of the skin and differs from the photosensitisation described above. Application of teat salves or sun blocks to the affected skin and improved coverage with teat spray will help prevent this condition from leading to mastitis. Classification of this condition is as described in section 2 above.

5. Teat end hyperkeratosis

Teat end hyperakeratosis is variously described as roughness, thickness, teat rings and fronds. It is a dynamic condition and is infrequent in heifers before calving, but common in machine milked animals (Sieber and Farnsworth 1981; Shearn and Hillerton 1995; Neijenhuis *et al* 2000). Once present it appears to vary little in response to milking management or other stimuli.

The amount of hyperkeratosis varies dynamically, increasing from calving to peak lactation and then decreasing towards the end of lactation. It also increases progressively with parity (Shearn and Hillerton 1996; Neijenhuis *et al* 2000). The extent of hyperkeratosis and the degree to which it can be improved is related to teat shape, being worse with long, slender or pointed teats. There may, therefore, be a genetic influence.

Teat end hyperkeratosis is often influenced by seasonal weather conditions (Table 4), with teats becoming more prone to developing hyperkeratosis when conditions are wet and cold, which may be mediated through reduced blood circulation.

Skin thickens in response to the forces applied to it. Just as the skin on a person's hands thickens in response to outdoor, manual work, so the skin of the teat-end thickens in response to milking and environmental effects. All teats experience low milk flow periods at the beginning and end of each milking and teat end condition deteriorates when flow is less than one litre per minute. More hyperkeratosis occurs with increased total time per day below this milk flow rate.

Noticeable improvements in teat ring roughness take about 4 weeks after elimination of the specific cause.

The major factors affecting teat end hyperkeratosis are seasonal weather conditions, and milking management and machine factors (Table 4). Machine factors affecting hyperkeratosis (Table 3) are principally:

- Inappropriate vacuum levels,
- High levels of teat compression during liner closure and
- Prolonged machine-on time.

Machine-on time is most influenced by the presence and threshold settings levels of automatic cluster detachers (Shearn and Hillerton 1996; Rasmussen, 1993). Faulty pulsation is not indicated by hyperkeratosis.

Teat end hyperkeratosis may be exacerbated by disinfectants that cause chemical irritation to teat skin but it is questionable whether it may be improved by the use of a disinfectant with a high concentration of an effective emollient (Britten *et al* 2004).

The Teat Club International notes that a small amount of teat end hyperkeratosis may be considered as a beneficial physiological response of the teat to machine milking, whereas a greater degree of roughness is associated with an increased probability of new intramammary infections (Neijenhuis *et al* 2001a).

Table 4. Major risk factors affecting teat end hyperkeratosis

Risk factor	Reason for increased likelihood of teat end hyperkeratosis
Pointed teats	The load applied by the closing liner is on a smaller area of teat surface
Increasing age	The 'wrinkle factor' in all species
Higher production	Cups are on for longer
Peak lactation	Cups are on for longer
Udder washing	Water and chemicals reduce skin moisture and elasticity
Cups on before let down	Longer period of milk flow below one litre per minute
Low thresholds for Automatic Cluster Removers (ACRs)	Longer period of milk flow below one litre per minute
Over milking	Longer period of milk flow below one litre per minute
High vacuum	Greater stress on teat tissues – more stretched in the open liner and squeezed in the closer liner
Stiff liner mouthpiece	The lip acts like a tourniquet which slows or restricts outflow of blood from the teat wall when the liner is collapsed
Liners mounted at high tension	The region of greatest local pressure is applied just above rather than at the teat end. This restricts outflow of blood from the teat tip (acts like squeezing a grape until the skin splits)

For routine field evaluation (in contrast to more detailed research observations), teat ends are often scored as shown in Table 5.

Use Sheet I of the SmartSAMM Mastitis Investigation Kit to record teat condition scores.

Table 5. A scoring system for teat end hyperkeratosis (from Mein et al 2001)

Score	Description	Illustration
N	No ring The teat end is smooth with a small, even orifice. This is a typical status for many teats soon after the start of lactation.	
S	Smooth or Slightly rough ring A raised ring encircles the orifice. The surface of the ring is smooth or it may feel slightly rough, but no fronds of old keratin are evident.	
R	Rough ring A raised, roughened ring with isolated fronds or mounds of old keratin extending 1-3 mm from the orifice.	
V	Very rough ring A raised ring with rough fronds or mounds of old keratin extending 4 mm or more from the orifice. The rim of the ring is rough and cracked, often giving the teat end a 'flowered' appearance.	

C. Teat conditions due to infectious agents

Infectious lesions of teat skin can indicate the standard of the general hygiene practices, as well as mastitis prevention and milk quality management, employed on the farm. Any deterioration of teat skin condition may adversely influence milk quality, milk safety, and udder health. Some may be hazardous to the health and safety of staff.

See Guideline 9 for images of teat conditions.

Viruses, pus-forming or necrotising bacteria, and fungi, are responsible for most infectious lesions of teat skin and can affect the skin of the teat end, teat barrel or udder.

Typical lesions associated with these conditions are summarised in Table 6 and the more commonly occurring conditions are described further in the text below. For more information on all conditions, see the relevant SmartSAMM Advisor Note.

Table 6. Summary of the typical features of infectious agents that can affect teat condition.

Organism type	Condition or agent	More information	Typical lesion
Virus	Pseudocowpox	'Pseudocowpox' Advisor Note	Local, red angry lesions in the early stages that develop over a couple of days into small, raised, circumscribed lesions with dark red centres. A characteristic ring or 'horseshoe' shaped scab may be seen when crusts fall away. People are occasionally infected with purple 'milkers' nodules on their fingers.
	Bovine herpes mamillitis	'Bovine herpes mamillitis' Advisor Note	Numerous, raised, oedematous plaques about 1-2 centimetres in size. Lesions can cover a large part of the teat surface. The skin sloughs off leaving raw ulcers that are subsequently covered with dark coloured scabs.
	Teat warts/papilloma	'Teat wart' Advisor Note	Appearance varies with strain of virus from 'rice grain' in appearance, to fronds.
	Foot and Mouth Disease (exotic)	'Other viral conditions' Advisor Note	Occasionally, the virus causes vesicular lesions and erosions on teats (exotic) before they appear in the mouth or hoof.
	Vesicular stomatitis (exotic)	'Other viral conditions' Advisor Note	Lesions similar to, and need to be differentiated from, Foot and Mouth Disease.
Bacteria	*Staph. aureus,* *Strep. dysgalactiae* *A. pyogenes*		Primary bacterial infections present as pustules. They may be necrotising, especially when *Staph. aureus* is involved. Secondary bacterial infections may cause significant changes in the appearance of other lesions, making diagnosis difficult.
	Blackspot or *Fusiformis necrophorum*	'Blackspot' Advisor Note	Lesions look like craters with raised edges and have a black spot of ulceration or scab in the centre. They often involve the teat end.
Fungi	Ringworm or *Trichophyton* spp.		A characteristic grey-white encrustation. The infection may spread to milking staff.

1. Viral infections of teat skin

Viral infections vary in their severity, infectivity and frequency of occurrence. Generally, they are rare in dairy industries where good udder hygiene is applied, because most are readily controlled by minimising transmission via manual handling and also by use of post-milking teat disinfection.

Early generation iodine disinfectants, with low pH, have a virucidal activity. Post-milking disinfectants and emollients reduce the incidence of the sores, rough skin, and cracks necessary for viral penetration and development. Some non-iodine teat disinfectants are less active against viruses.

See Technote 7.1 for the antimicrobial spectrum of active ingredients of teat disinfectants available in NZ.

Commonly, multi-use ointment containers are a significant source of new infections from poor hygiene. When treating any lesions with ointments, it is important to use only single-use containers and clean gloves and applicators where necessary.

Some exotic diseases can also cause lesions on teats (Hillerton *et al* 2001; Parkinson *et al* 2010). Some of the more common conditions are summarised below, but differential diagnosis for more unusual teat lesions should include:

- Foot and Mouth Disease (FMD),
- Vesicular stomatis (VS),
- Bovine herpes mamillitis (BHM),
- Ringworm.

Pseudocowpox

Pseudocowpox, a paravaccinia virus, causes acute infection in young cows after calving or cows introduced to a herd that has the virus infection. The spread of the infection can be relatively slow. Immunity is short-lived, lasting four to six months, and infections can be a chronic problem in some herds. As a consequence, cows in affected herds are likely to suffer repeat infections.

Early lesions are painful and affected animals resent being milked. The characteristic ring or 'horseshoe' shaped scab (Table 6) usually heals without scarring in 3-6 weeks. Milkers may develop localized lesions, usually on their hands, i.e. 'milkers' nodules'. No specific treatment exists.

Spread of infection can be minimised by milking infected cattle last, and by wearing gloves. Successful treatment depends on consistent complete coverage of teats with a licensed and effective disinfectant.

Teat warts or papilloma

Six separate papilloma viruses cause teat warts including: the 'rice grain' flat white warts (strain BVP-5); frond-like papillomas that protrude in a ragged fringe of up to one centimetre in length (strain BVP-6); and fibropapillomas that protrude from the teat surface (strain BVP-l).

Young animals are very susceptible to papilloma viruses, and usually develop immunity soon after they enter the milking herd. In older cattle, papilloma are usually confined to the udder and teat. Spread is between animals via teatcup liners and milkers' hands.

There is a wealth of anecdotal evidence that certain areas are more prone to warts, usually areas close to low lying river plains and forests.

Warts can interfere with the function of the liners and can, in some cases, block the teat canal. If they become damaged, they may be colonised by *Staph. aureus, Arcanobacterium pyogenes* or *Strep. dysgalactiae.*

Most warts are self-limiting and disappear within 5-6 months. The frond type can be physically removed. If there is a major problem in a herd, an autogenous vaccine can be made from wart tissue from cows in the herd. Type-specificity is high, so vaccines must include all serotypes and tissue types responsible for the outbreak. The response of the low, flat warts to vaccination is relatively poor. Teat dipping with a salicylic acid formulation is often used for heifers.

2. Bacterial infections of teat skin

Bacteria cause primary lesions or colonise existing lesions caused by machine-induced damage, environmental factors or viral infections.

Staph. aureus, *Strep. dysgalactiae* and *Arcanobacterium pyogenes* are ubiquitous on the skin of dairy cows. They are a major source of new intramammary infections and clinical mastitis, in lactating and non-lactating cows. It was shown clearly some 30 years ago that chapped teats were highly likely to be infected with *Staph. aureus* or *Strep. dysgalactiae*, and that such infections were closely associated with high new infection rates and frequent cases of clinical mastitis (Dodd and Neave 1970; Kingwill *et al* 1970). Even small teat lesions are significantly associated with sub-clinical mastitis and the risk of mastitis increases for lesions that are closer to the teat canal (Agger and Willeberg 1986).

Disinfectants developed for teat treatment are usually effective at eliminating bacteria from lesions and often contain emollients to promote skin healing. The requirement to disinfect all teats of all cows after every milking, as part of mastitis control, is directed at reducing the exposure of the mammary gland to these organisms and to expedite rapid healing of all lesions.

Technote 7 describes the characteristics of effective teat disinfectants and emollients.

Blackspot

Blackspot is the manifestation of a secondary infection of a teat end lesion by the anaerobe *Fusiformis necrophorum*. The primary lesion is colonised following poor hygiene. The resulting scab is pigmented black by the bacteria. The teat orifice may become blocked, leading to incomplete and very slow milking.

If more than 2–3% of teats are affected, hygiene should be improved and milking machine function should be thoroughly checked because blackspot is often associated with short teatcup liners, failure of pulsation, excessive vacuum or over milking.

Management of Blackspot in a herd involves:

- treating the lesions with iodine (or hydrogen peroxide);
- using teat disinfection to minimise bacterial infection of lesions; and
- checking the milking machine function.

3. Fungal infections of the teat skin

Infection of skin keratin by the fungus *Trichophyton* spp. occasionally spreads to the teat. The condition is very unlikely to be confined to the teats and udder and should be easily recognised from the characteristic grey-white and ash-like skin encrustations.

The infection is highly contagious and may spread to milking staff. Usually herd immunity develops but reoccurrence is typical when new susceptible animals are introduced or animals are immune-stressed, especially as spores survive in the environment for several years.

Few treatments are recognised for ringworm. Generally the disease is self-limiting after a few months. In some countries, vaccines are available for calves, which can reduce the number of animals affected in the herd.

D. Systematic evaluation of teat condition in commercial herds

1. Deciding how many teats to observe

Perhaps the most common weakness of teat evaluation procedures in commercial herds is that sample sizes are too small. In 2001, the Teat Club International recommended that teat condition be scored using a pass/fail criterion on all teats of all cows in the herd, if time and herd size allowed, or randomly selecting at least 80 cows, or 20% of the herd (whichever was the largest number of cows; Reinemann *et al* 2001).

In NZ, there are two approaches supported. Assessment of 50 cows, randomly selected throughout the herd, is recommended for farmers and milk quality advisors needing to quantify a potential problem, and know when to seek further advice.

Assessment of a larger sample of cows is recommended for vets and professional advisors when investigating system faults and potential causes of teat damage,.

SmartSAMM recommendations

- Assess all teats on at least 100 cows, selected randomly throughout the herd.
- Cows need to be selected randomly throughout a milking and across mobs to ensure a representative sample.
- Record results for all 4 teats of each cows, if practicable.

Use Sheet I of the SmartSAMM Mastitis Investigation Kit to record teat condition scores.

Evaluation Method A - Quarter-level recording

1. Examine all teats of the selected cows.
2. Score the exceptions (non-normal) at a cow and quarter level.
3. Record the cow and quarter details for each issue.

Benefits:

- Measures prevalence at quarter level.
- Provides a comprehensive list of cows and quarters that can be re-examined once an intervention has been applied.
- Use this technique for research purposes, for quantifying the specific impact of an intervention, or resolving teat end damage on specific cows.

Technote 13 provides more information on dfferent sections of the SmartSAMM Mastitis Investigation Kit.

Disadvantages:

- More time consuming.
- Often requires more labour units to perform, to minimise disruption.
- Quarters within cows are not truly independent. That is, where one quarter is abnormal, another quarter within that same cow is more likely to be abnormal than a quarter drawn at random from another cow in the population. This means that more quarters need to be recorded to provide confidence about the result.

Evaluation Method B - Cow-level recording

1. Examine all teats of selected cows; only score the worst teat for each animal.
2. Assign this score to the cow.
3. Record the score, but not necessarily the cow and quarter details.

4. Be aware of patterns of damage in certain locations of the udder to help diagnose the problem.

Benefits:

- Provides a simplified process where size, speed or cost is an issue.

Disadvantages:

- Less information available to help diagnose subtle problems associated with specific quarters in cows being affected.
- Unable to recheck the same cows later in time as cow details not recorded.
- Does not provide a true estimate of prevalence, but rather is the prevalence of cows with at least one quarter scored as positive for a particular characteristic.
- Will result in a higher estimate of prevalence than scoring at quarter level.

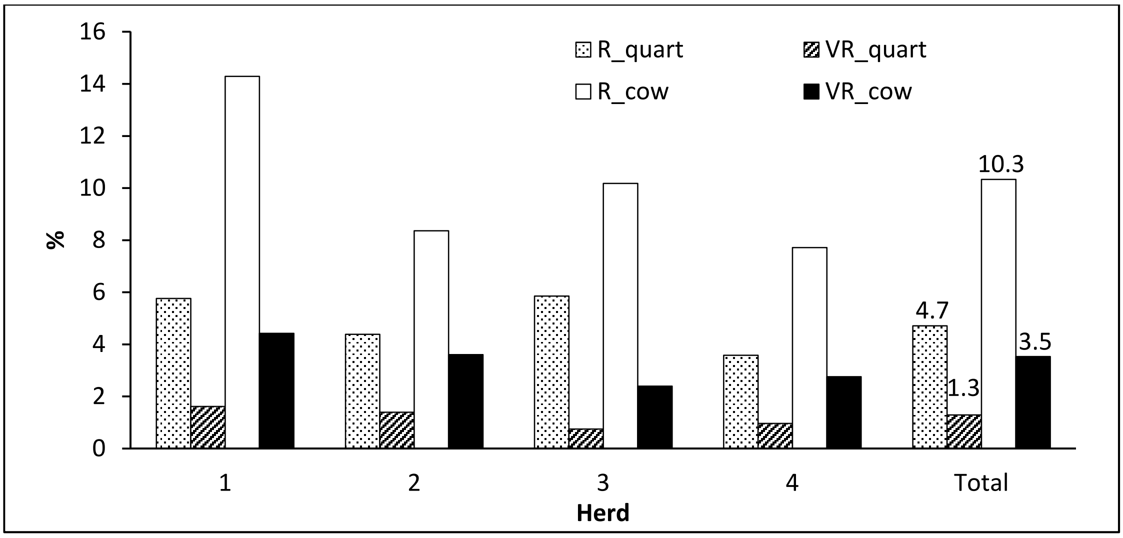
Note on interpreting prevalence for cow and quarter-level recording

When only the worst teat in the cow is scored, the prevalence will be higher than if each quarter was assessed (Figure 1). This is because cow-level assessments are a 'parallel' interpretation of the 4 teats. Higher thresholds are required at which the milking processes can be considered to contribute to a mastitis problem, if cow-level recording is used, compared to quarter-level recording.

Figure 1 compares prevalence of teat end scores determined using cow-level and quarter-level recording systems. The data relates to assessment of 9,169 quarters across 2,292 cows in 4 herds in early lactation (Adamson, McDougall and Roberts, unpublished results).

Prevalence of rough (R) or very rough (VR) teat ends, calculated at a quarter-level (i.e. number of teats scored as R (or VR)/total number of quarters assessed), was 4.7% and 1.3% of quarters, for R and VR teat ends, respectively. Prevalence calculated at a cow-level (i.e. number of cows with the worst gland within the cow being R (or VR)/total number of cows examined), was 10.3% and 3.5% of cows with one or more R or VR teat ends respectively.

Figure 1 Variation in prevalence of rough (R) and very rough (VR) teat end scores when calculated at quarter or cow level.



2. Making the observations

To simplify and streamline the procedure, teat condition should be evaluated immediately after the cluster is removed and before application of a teat disinfectant. However, if an observer wants, or needs, to assess skin changes in greater detail, it will be necessary to check skin condition before milking.

Practical tips to making teat observations are:

- Exercise great care when approaching cows and handling teats, especially in herds where cows are not used to having their teats touched.
- Observe and record teats in a regular pattern.
- View the teats, initially, without handling.
- Dry the teat end with a paper towel if milk residue or debris obscures the view of the orifice.
- View teats by gently grasping the teat above the teat end. Observe the teat from side on and then from end on. Good lighting is essential. If lighting is poor, use a headlamp rather than a flashlight for hands-free evaluation. This is important for work safety.
- To ensure confidence in the data, score a representative sample of cows from all age groups or management groups. Where multiple sub-herds are run, examination of cows should occur in all sub-herds. Additionally, sampling should occur across the milking, not just at the beginning or end. One way of achieving this is to calculate the number of cows that need to be sampled (see below) then divide this into the number of cows in the group, and the result of this calculation is the gap between cows to be sampled. For instance if it is a 400 cow herd and 50 cows are to sampled then every 8th cow (400/50) should be examined.
- An automatic recording method, such as a dictaphone with a ‘pause’ button, enables a single observer to evaluate and record teats. (Note a voice-activated recorder is difficult to use successfully in the noisy environment of the farm dairy.) If two people are present, one can observe teats while the other records data.
- A digital camera offers an excellent way to capture typical or interesting teat conditions for subsequent discussions with the farmer or other udder health specialists (or lawyers!). Before and after photos of specific cows can also be used for more in depth examination of certain conditions (Reinemann 2007).

3. Interpreting the results

Once a particular teat condition has been evaluated, the prevalence, at a cow or quarter-level can be calculated.

Thresholds for intervention (or “Triggers for Action”) have been developed by Teat Club International, based on field experience across a number of different countries and environments (Reinemann *et al* 2001). These thresholds vary, depending on:

- The criteria being evaluated.
- Whether the evaluation is at the cow or quarter-level. Generally the cow prevalence of teat conditions is 2.5 times that for quarters. So the trigger for action at a cow-level tends to be 2.5 times that for quarter-level data.
- Herd-specific circumstances e.g. season, that may necessitate changing thresholds.

Research Priority – High

Thresholds for intervention have not been fully validated against the probability that the milking machine or milking processes are suboptimal.

Triggers for Action

Further investigations of milking machine, management, environmental and infectious factors may be required if the triggers listed in Table 7 are exceeded.

It is important to use the proportion of abnormalities observed in a sample of teats from the herd as a guide rather than an inflexible threshold. Some herds that *do* have teat abnormalities may have values slightly below the threshold because:

- the sample of teats observed was not representative of the herd; or
- the estimate generated by the sample is within the lower limit of the 95% confidence interval for the threshold value (see Table 7).

If in doubt, it is worthwhile examining more teats before making a final assessment of the situation – especially if additional problems (with the milking machine, milking system or other teat abnormalities) have been identified in the herd.

The primary focus of observation is on teats (rather than cows), because this is the easiest way to make an initial assessment of whether or not a problem exists within a herd. Therefore, the first analysis is the proportion of teats affected with a particular condition.

Clearly this initial assessment may require some qualification. For example, a high proportion of cows may have the same teat affected. Alternatively, only a few cows may contribute most of the ‘problem’ teats if they each have 3-4 teats affected. These types of patterns can be very helpful indicators of a milking machine problem or a cow problem.

Table 7 Trigger levels for action for different teat abnormalities (from Reinemann et al 2001 and Reinemann 2007).

Criteria	Description	Trigger levels for: Quarter-level	Cow-level
Teat Colour	Red/Blue Light coloured teats are visibly reddened (congested) or tinged with blue (cyanotic).	8%	20%
Swelling	'Ringing' at teat base Marked swelling or palpable rings at or near the top of the teat.	8%	20%
Firmness	Hard or Wedged Teat ends are classified as firm, hard, swollen, or noticeably wedged.	8%	20%
Openess	Open Teat ends classed as open after milking.	8%	20%
Teat end	Hyperkeratosis Teats are scored R or V	8%	20%
	Teats are scored as V	4%	10%
Vascular damage	Haemorrhages Light-coloured teats have Moderate or Severe petechiation	4%	10%
Teat skin	Dryness, Roughness Teat skin scored as rough, dry and scaly.	4%	10%
Lesions	Chaps, cracks Teats have open lesions, cracks or chaps.	2%	5%

Colour, swelling near the top of the teat, firmness near the teat end, openness of teat orifice and vascular damage are **short to medium-term effects** primarily associated with milking machine faults or poor milking management resulting in long periods of low flow below 1 litre/minute and/or over milking.

Teat skin condition and teat end hyperkeratosis are **medium to longer-term effects** primarily associated with poor environment, management or chemical irritation, or cow factors such as teat shape, yield and genetics. They are exacerbated by machine milking, especially if poor milking management results in over milking or prolonged milking at a low milk flow rate. Faults in milking equipment are unlikely to be primary causal factors if one or more of the short-term changes are not obvious.

If the assessment has been conducted at a quarter level:

Table 8 lists the number of quarters with a teat abnormality at which it is likely that the prevalence of teat lesions is 8%, 4% or 2%. (Note: the number of quarters has been adjusted to account for the 'clustering' effect i.e. that quarters within a cow are not independent of each other. A variance inflation factor of 1.5 has been applied (S. McDougall *pers. comm.*).

So if 4 or more teat with abnormalities are found, following examination of 200 teats (all quarters of 50 cows), it is 95% likely that the prevalence is not different from 8%. But even if no abnormalities are found, after examining 200 quarters, the possibility that prevalence of teat abnormalities is 4% cannot be ruled out.

Table 8. The lower 95% confidence interval of number of quarters (or cows) that are significant (i.e. not different from the trigger level) when prevalence of the abnormality is 8%, 4% or 2% (quarters) or 20%, 10%, 5% (cows), based on a binomial distribution. If the number of abnormalities is greater than the number listed for that sample size, then the herd prevalence of that condition is not different from the trigger level, with 95% confidence.

	Number of abnormal quarters detected		
	Quarter prevalence		
No. quarters (cows) examined	8%	4%	2%
100 (25)	0	0	0
150 (38)	2	0	0
200 (50)	4	0	0
250 (63)	7	0	0
300 (75)	10	0	0
350 (88)	13	0	0
400 (100)	15	4	0
450 (113)	19	5	0
500 (125)	22	7	0
550 (138)	25	8	0
600 (150)	28	9	1
650 (163)	31	11	2

	Number of cows with at least 1 abnormal teat detected		
	Cow prevalence		
No. cows examined	20%	10%	5%
50	6	2	0
100	13	5	1
150	17	8	2
200	25	12	4
250	32	16	6
300	41	20	8
350	49	24	10
400	57	28	11
450	66	33	13
500	74	37	15
550	83	41	17
600	92	46	19

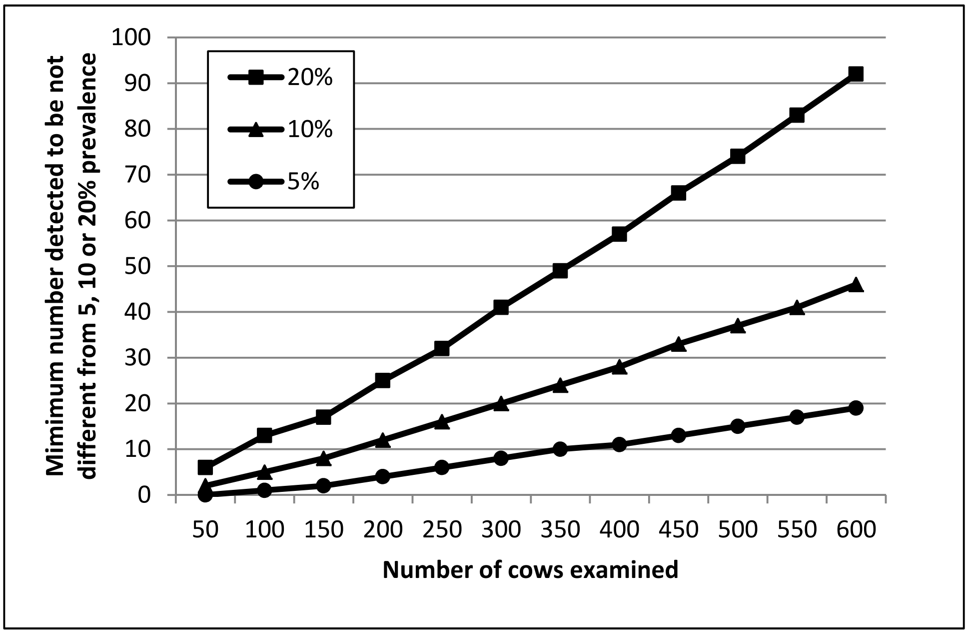
More quarters should be examined to rule out a prevalence of 4%. Conversely if 200 teats are examined and less than 4 teat abnormalities are found, it is 95% likely that the prevalence of teat abnormalities is less than 8% (but a prevalence of 4% or 2% cannot be ruled out).

If the assessment has been conducted at a cow level:

Table 8 lists the number of cows with teat abnormalities at which it is likely that the prevalence of a cow having at least one teat with an abnormality is 20%, 10% or 5%. Figure 2 shows the relationship between these different levels of prevalence (cow-level).

If 6 or more cows are found to have at least 1 abnormal quarter, following examination of 50 cows, it is 95% likely that the prevalence is not different from 20%. But even if no abnormalities are found after examining 50 cows, the possibility that the prevalence of teat abnormalities is 5% cannot be ruled out. More quarters should be examined to rule out a prevalence of 5%. Conversely if 100 cows were examined and no teat abnormalities were found, it is 95% likely that the prevalence of cows with teat abnormalities is less than 5%.

Figure 2. Comparison of the cow trigger levels for different number of cows examined.



9.2

Minimise the build-up of mud on teats.

Reduce teat condition and hygiene problems caused by mud by maintaining clean, dry trough areas, farm tracks, laneways, feed pads and stand-off areas, and entrances and exits to the farm dairy.

If wet and muddy conditions cannot be avoided for lactating cows, and the rate of new clinical cases starts to increase, teats will need to be washed and dried before each milking.

Technote 26 discusses ways to fix areas that make udders muddy.

9.3

Minimise water on cows' udders.

Technote 5.3 discusses udder cleanliness and pre-milking preparation.

9.4

Check teat spray mix, particularly emollient concentrations.

Technote 7.5 discusses addition of emollients to teat sprays.

Technote 24 discusses servicing of the teat spray equipment.

9.5

Check important milking machine factors.

Call in a NZMPTA-certified milking machine tester if concerned that the operation of the milking machine is contributing to teat damage.

Technote 6.1 describes how to monitor and maintain milking machine function.

Technote 25 describes tests that can be carried out by certified milking machine testers.

9.6

Avoid the use of teat ointments, especially those that come in tubs or jars.

Ointments used to improve teat health and condition may have the opposite effect by:

- Increasing teatcup 'crawl'. In one study of the effects of greasing teats, the average strippings yield at the end of milking was trebled when all the regions of contact between the teat and liner were lubricated to reduce friction (Mein *et al.* 1973).
- Exposing the teat end to bacteria. Teat ointments that are dispensed by hands repeatedly dipping into a jar become easily contaminated with environmental bacteria.
- Prolonging the contact time of bacteria on the teat.

It is easier to avoid using teat ointments rather than to work around these issues. However if teat ointments are used:

- choose one of the varieties that use a base such as sorbylene or glycerol rather than the oily/grease type products;
- choose a dispensing container that maintains a clean reservoir of product, for example pump jars that dispense a single dose of product; and
- apply them only at the end of milking.

9.7

Seek advice from your veterinarian if problems persist.

Farmers are urged to seek advice from their veterinarian if problems are identified with teat condition.

Technote 13 and the SmartSAMM Mastitis Investigation Kit and provides a systematic approach to investigating problems.

Many farmers, especially those who have participated in training, use triggers to identify when their milking system is not operating properly – including assessment of teat condition.

Farmer assessment of teat condition covers the same range as described in this Technote, alerting them to changes in teat skin colour, swelling, hardness and teat ends. However, it is the adviser's role to investigate these alerts, including a thorough teat assessment, to better understand the situation.

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

Teat Club International papers

Hillerton JE, Middleton N, Shearn MFH. Evaluation of bovine teat condition in commercial dairy herds: 5 A portfolio of teat conditions. *Proc 2nd Int. Symp. Mastitis Milk Quality, NMC/AABP*, Vancouver, 2001; 472-473.

Hillerton JE, Morgan WF, Farnsworth R, Neijenhuis F, Baines JR, Mein GA, Ohnstad I, Reinemann DJ, Timms L. Evaluation of bovine teat condition in commercial dairy herds: 2. Infectious factors and infections *Proc 2nd Int. Symp. Mastitis Milk Quality, NMC/AABP,* Vancouver, 2001; 352-356.

Mein GA, Neijenhuis F, Morgan WF, Reinemann DJ, Hillerton JE, Baines JR, Ohnstad I, Rasmussen MD, Timms L, Britt JS, Farnsworth R, Cook N, Hemling T. Evaluation of bovine teat condition in commercial dairy herds: 1. Non-infectious factors. *Proc 2nd Int. Symp. Mastitis Milk Quality, NMC/AABP*, Vancouver, 2001; 347- 351.

Neijenhuis F, Mein GA, Britt JS, Reinemann DJ, Hillerton JE, Farnsworth R, Baines JR, Hemling T, Ohnstad I, Cook N, Morgan WF, Timms L. Evaluation of bovine teat condition in commercial dairy herds: 4. Relationship between teat-end callosity or hyperkeratosis and mastitis. *Proc 2nd Int. Symp. Mastitis Milk Quality, NMC/AABP*, Vancouver, 2001; 362-366.

Ohnstad I, Mein GA, Baines JR, Rasmussen MD, Farnsworth R, Pocknee BR, Hemling TC, Hillerton JE. Addressing teat condition problems. *Proc. 46th NMC Annual Meeting*, San Antonio, Texas, 2007; 188-199.

Reinemann DJ, Rasmussen MD, LeMire S, Neijenhuis F, Mein GA, Hillerton JE, Morgan WF, Timms L, Cook N, Farnsworth R, Baines JR, Hemling T. Evaluation of bovine teat condition in commercial dairy herds: 3. Getting the numbers right. *Proc 2nd Int. Symp. Mastitis Milk Quality, NMC/AABP,* Vancouver, 2001; 357-361.

Other papers

Agger JF, Willeberg P. Epidemiology of teat lesions in a dairy herd. Associations with sub-clinical mastitis. *Nord Vet Med*. 1986; 38:220-232.

Brightling, P, Mein GA, Hope AF, Malmo J, Ryan DP. *Countdown Downunder: Technotes for Mastitis Control.* Published by Dairy Research and Development Corporation, Australia 2000.

Britten A, Hansen N, Pradraza J. Effect of teat dips on hyperkeratosis, *Proc. 43rd NMC Annual Meeting*, Charlotte NC, 2004; 286-7.

Capuco AV, Bright SA, Pankey JW *et al*. Increased susceptibility to intramammary infection following removal of teat canal keratin. *J Dairy Sci,* 1992;75:2126-2130.

Capuco AV, Mein GA, Nickerson SC *et al*. Influence of pulsationless milking on teat canal keratin and mastitis. *J Dairy Sci,* 1994; 77:64-74.

Calvinho LF, Almeida RA, Oliver SP. Influence of Streptococcus dysgalactiae surface hydrophobicity on adherence to mammary epithelial cells and phagocytosis by mammary macrophages. *Zentralbl Veterinarmed B*. 1996; 43:257-66.

Dodd FH, Neave FK. Machine milking rate and mastitis. *J Dairy Res,* 1951; 18:240-245.

Dodd FH, Neave FK. Mastitis control. *Bienn. Rev,* National Institute for Research in Dairying, Shinfield, UK, 1970; 21-60.

Fox, LK. Colonisation by *Staphylococcus aureus* on chapped teat skin. *J Dairy Sci*. 1992; 75: 66-71.

Grindal RJ, Hillerton JE. Influence of milk flow rate on new intramammary infection in dairy cows. *J Dairy Res* 1991; 58:263-268.

Grindal RJ, Walton AW, Hillerton JE. Influence of milk flow rate and streak canal length on new intramammary infection in dairy cows. J Dairy Res. 1991; 58:383-8

Hemling TC. Teat condition – prevention and cure through teat dips. *Proc. British Mastitis Conference*, 2002; 1–14.

Hillerton JE, Ohnstad I, Baines JR, Leach KA. Performance differences and cow responses in new milking parlours. *J Dairy Res.* 2002; 69: 75-80.

Hillerton JE, Ohnstad I, Baines JR, Leach KA. Changes in cow teat tissue created by two types of milking cluster. *J Dairy Res.* 2000; 67:309-317.

Hillerton JE, Pankey JW, Pankey P. The effect of over milking on teat condition. *J Dairy Res.* 2002; 69: 81-84.

Kingwill RG, Neave FK, Dodd FH, Griffin TK, Westgarth DR, Wilson, CD. The effect of a mastitis control system on levels of clinical and sub-clinical mastitis in two years. *Vet Record,* 1970; 87:94-100.

Lacy-Hulbert J. Physical characteristics of the teat canal and relationship with infection. *Proc 37th NMC Annual Meeting*, St. Louis, Missouri, 1998:54- 61.

Lacy-Hulbert SJ, Hillerton JE. Physical characteristics of the bovine teat canal and their influence on susceptibility to streptococcal infection. *J Dairy Res*. 1995; 62:395-404.

Lacy-Hulbert SJ, Hillerton JE, Woolford MW. Influence of pulsationless milking on teat canal keratin growth and turnover. *J Dairy Res.* 1996; 63:517-24

Mamo W, Rozgonyi F, Brown A, Hjertén S, Wadström T. Cell surface hydrophobicity and charge of *Staphylococcus aureus* and coagulase-negative staphylococci from bovine mastitis. *J Appl Bacteriol.* 1987; 62:241-9.

Mein GA, Thiel CC, Westgarth DR, Fulford RJ Friction between the teat and teatcup liner during milking. *J Dairy Res*. 1973; 40:191-206.

Neijenhuis F, Barkema HW, Hogeveen H, Noordhuizen JPTM. Classification and longitudinal examination of callused teat ends in dairy cows. *J. Dairy Sci.* 2000; 83:2795-2804.

Neijenhuis F, Barkema HW, Hogeveen H, Noordhuizen JPTM. Relationship between teat-end callosity and occurrence of clinical mastitis. *J Dairy Sci.* 2001a; 84:2664-2672

Neijenhuis F, Klungel GH, Hogeveen H. Recovery of cow teats after milking as determined by ultrasonographic scanning. *J Dairy Sci.* 2001b; 84: 2599-2606.

Ohnstad IC The use of regular teat condition scoring as a milk quality management tool. *Mastitis Research into Practice: Proc of 5th IDF Mastitis Conference,* New Zealand. 2010; 106-109.

Parkinson TJ, Vermutt JJ, Malmo J. *Diseases of Cattle in Australasia*, VetLearn, Wellington, New Zealand. 2010.

Rasmussen MD. Influence of switch level of automatic cluster removers on milking performance and udder health. *J. Dairy Res.* 1993; 60:287 -297.

Rasmussen MD. Short term effect of transition from conventional to automated milking on teat skin condition. *J Dairy Sci*. 2003; 86:1646-1652.

Rasmussen MD, Frimer ES, Kaartinen L, Jensen NE. Milking performance and udder health of cows milked with two different liners. *J Dairy Res*, 1998; 65:353-363.

Rasmussen MD, Hemling TC. The influence of automatic teat spraying on teat condition. *Proc. 41st NMC Annual Meeting*, Orlando, Florida, 2002; 166-167.

Rasmussen MD, Larsen HD. The effect of post milking teat dip and suckling on teat skin condition, bacterial colonisation, and udder health. *Acta Vet Scan* 1998; 39:443-452.

Reinemann DJ Latest thoughts on methods for assessing teat condition. 2007 *Proc. 46th NMC Annual Meeting*, San Antonio, Texas, 2007; 173-180

Shearn MFH, Hillerton JE. Hyperkeratosis of the teat duct orifice in the dairy cow. *J Dairy Res.* 1996; 63: 525-532.

Sieber RL, Farnsworth RD. Prevalence of chronic teat end lesions and their relationship to intramammary infection in 22 herds of dairy cattle. *JAVMA.* 1981; 178:1263- 1267.

Timms L. Winter conditions and teat health. *Proc. 43rd NMC Annual Meeting*, Charlotte, North Carolina, 2004; 143-158.

Williams DMD. *A study of the epithelium of the bovine teat canal*. PhD thesis, The University of Melbourne, Australia, 1984.

Williams DMD, Mein GA. The role of machine milking in the invasion of mastitis organisms and implications for maintaining low infection rates. *Kiel Milch Forschungsberichte*, 1985; 37:415-425.

Williamson JH, Woolford MW, Day AM. The prophylactic effect of a dry-cow antibiotic against *Streptococcus uberis*. *NZ Veterinary Journal*, 1995; 48:228-234.