

# Unmasking Mastitis

David Whyte<sup>1</sup>, Murray Woolford<sup>2</sup>, Graeme Mein<sup>1</sup>, Rod Claycomb<sup>1</sup>

<sup>1</sup>Sensortec Ltd, Hamilton, New Zealand

<sup>2</sup>Dexcel Ltd, Hamilton, New Zealand

Most farmers, consultants, veterinarians and milk processing companies around the world have listed “mastitis detection” as the primary need for development of on-line sensing technology.

However, when these groups of people were asked what exactly they wanted to detect and what they thought “mastitis” referred to, it became obvious that there exists a large amount of confusion regarding mastitis and mastitis detection.

This is because the true definition of mastitis is quite specific, while the term is often used to refer to a broad and complex sequence of events. “Mastitis” is defined by Webster and the International Dairy Federation as an “inflammation of the...udder.” If this is “true mastitis,” two interesting questions become obvious.

- (1) How can you build a sensor that detects “inflammation?”
- (2) Is “true mastitis” really what everyone wants to detect?

Each person has formulated their own personalised definition of what they really want to detect when they use the phrase, “detecting mastitis.” Some define “detecting mastitis” as when a test of bacterial pathogens is positive, others when SCC reaches a particular level, others when clinical signs such as clots or swelling occur.

Hillerton (2002) reported a summary of physiological effects following introduction of an organism to a teat. Table 1 shows how many milkings on average were required after introduction of the organism for the bacteria to be present in the milk, for SCC levels to rise ten-fold, for electrical conductivity to show a measurable rise and for clots to appear in the foremilk.

Table 1. Sequence of development of easily detectable events (given as the average number of milkings after introduction of the organism) in mastitis caused by streptococci and staphylococci (adapted from Hillerton, 2002).

Pathogen Used for Challenge	Bacterial presence in milk	Ten-fold increase in SCC	Rise in electrical conductivity	Clots in foremilk
Strep. uberis	2.3	3.1	3.5	5.2
Staph. aureus	1.1	2.3	2.7	4.2
Sensortec cause-effect sequence	(2)	(5-7)	(9-10)	(11)

All of these definitions contain some truth, give some information about udder health or milk quality and, in fact, are quite useful in herd health and milk quality management decision-making.

A cause-effect spectrum has been proposed and developed in conjunction with animal health experts from around the world (Whyte et al., 2002; Claycomb et al., 2002; Hillerton, 2002). This cause-effect spectrum (depicted in Figure 1) gives a clearer perspective about the process commonly referred to as “mastitis.” It outlines the upfront biological causes and the downstream physiological and behavioural effects that occur as a bacterial infection progresses. From this information, sensors can be developed that measure components at different stages of the spectrum, depending on the management decision that is being sought. The cause-effect spectrum is a generalisation of a “typical” bacterial infection episode (see Table 1). Its intent is to paint a picture of how various causes lead to their associated effects and how the various cause-effect relationships fit with each other along the spectrum.

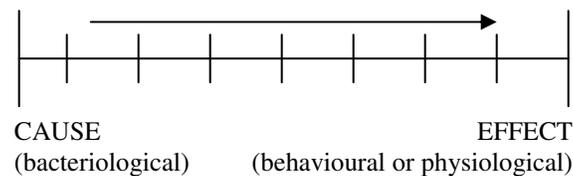


Figure 1. Diagram of a cause-effect spectrum (Claycomb et al., 2002).

### 1. Bacterial infection

The first step in the cause-effect spectrum is the contamination of the teat end with bacteria, followed by the bacteria entering the teat and gland.

### 2. Bacteria replication

As the bacteria multiply in the wonderfully rich nutrient environment of the milk, they produce many different metabolic by-products. One of the most significant by-products is lactic acid or lactate (Davis et al., 2002). Aside from measurement of the bacteria themselves, the measurement of a bacterial metabolite, such as lactate, would be about the earliest indicator that an infection has occurred. What is done about it at this point, of course, is a management decision that would need to be considered.

### 3. Glandular response

Once there is a non-bovine cell or a foreign substance in the system of a healthy normal animal, her natural defence system will detect the cell or substance and react. The first physiological trigger is for the gland to release so-called “acute phase proteins (APP),” which act as the signal to the immune system to do something. One such APP is called milk amyloid A (MAA) (Tridelta Ltd).

### 4. Initial immune system response

The increase in MAA leads directly to the immune system response of sending white blood cells or leukocytes to the udder. This is the first instance in the cause-effect spectrum when somatic cell count (SCC) rises. “Somatic cell” simply means “body cell” and includes any cell that is of bovine origin. This includes mostly white blood cells and mammary epithelial cells, the cells that actually synthesise milk. The initial leukocyte response leads to an increase in SCC levels. However, due to high baseline variation in SCC from cows due to factors such as breed, parity, stress, milking interval and other diseases, this initial rise in SCC is usually too small and too variable to be measured reliably.

## **5. Initial tissue damage**

If the infection has not been cured, bacterial levels eventually rise to the stage that they begin to damage the mammary epithelium. As this occurs, the SCC continues to rise, still due mostly to a further influx of leukocytes but now also due somewhat to dying and sloughing mammary epithelial cells. Somewhere at this stage in the spectrum, SCC becomes measurable over and above the baseline variation. Also, at this stage, initial tissue damage leads to release of “healing enzymes,” such as NAGase (Kitchen, date?).

## **6. Internal mammary swelling (“inflammation” or “true sub-clinical mastitis”)**

If the infection progresses, the mammary epithelium starts to swell. This swelling is internal and cannot be seen or felt by the observer.

## **7. Increasing tissue damage**

Again, if the infection has not been cured, damage to the mammary epithelium becomes worse. This may lead to extreme SCC increases as the damaged epithelial cells slough off into the milk, perhaps taking SCC levels into the millions of cells per millilitre. Obviously, once epithelial cells start to become significantly damaged, the milk yield would be affected. Whether or not this translates into a decline in milk yield from the udder as a whole probably depends on what the major rate-limiting factor is for the cow’s milk production, either the milk producing capacity of the udder or the level of nutrition. Research has suggested (Woolford et al., date?) that if nutrition level is rate-limiting, the equivalent of 3.5 quarters can convert all the food nutrients that are available for milk production equally as well as 4 healthy quarters. So, drops in milk yield at this stage are unlikely to solely identify the stage of infection.

## **8. Blood-milk barrier break down**

If epithelial swelling worsens, the alveoli in the gland start to break-down. As this happens, the so-called blood-milk barrier is breached, triggering leakage into the gland. While an “effect,” this key step is, in itself, a “cause” that triggers significant effects.

## **9. Influx of extracellular fluid into the milk**

Break-down of the blood-milk barrier permits extracellular fluid to enter the gland and mix with the milk. Extracellular fluid components, such as chloride, sodium, hydrogen, potassium and hydroxide ions enter the milk. If the damage to the blood-milk barrier is bad enough, even red blood cell levels in milk may rise at this stage.

## **10. Ionic effects**

The influx of ions into the milk leads to a decrease in the complex impedance of the milk and an increase in milk pH. The most common way of measuring the complex impedance is by electrical conductivity. There are now systems on the market that can do this by inductance as well. Due to biological variations in the complex impedance, the most effective way to diagnose udder tissue damage is to measure the complex impedance of individual quarters and then compare the values between the four quarters.

## **11. Clots, external swelling, redness**

Once the blood-milk barrier is breached, visible changes in the milk and the udder start to occur. This can include clotting, external swelling and redness of the gland and wateriness of the milk. By definition, this is the start of “clinical” symptoms.

### **12. Milk yield, milk temperature, activity**

Once “clinical” symptoms start occurring, the cow has progressed to a stage of visible illness. So much of the udder tissue is now damaged that there is often a significant drop in milk yield. The severity of the drop in milk yield and other clinical symptoms varies according to whether the infection is mild, severe, acute or per-acute. The cow may run a fever so the body and, thus, the milk temperature rises. If the cow is really sick, her activity level drops.

### **13. Death of animal**

An acute or per-acute infection may eventually reach its final conclusion with the death of the animal.

So, if this spectrum doesn't seem complex enough, note that the cow can self-cure or cure with treatment at any time along the cause-effect spectrum. Scientists are still debating some of the finer details of this cause-effect spectrum. However, there are many conclusions that can be drawn:

- “Mastitis” is an amazingly complex sequence of events.
- There are still many unknown variables and reasons. Each cow has a highly individual response and a specific baseline of measurable indicators.
- To develop a “mastitis sensor” could be likened to developing a “personality” sensor. Some objective tests are available, but no two experts will agree on exactly the same classification of a particular individual.
- The further along the cause-effect spectrum away from the cause, the higher the probability that the physiological or behavioural effect can be caused by something other than bacterial infection. For example, a rise in conductivity can be caused by a longer milking interval, or a drop in milk yield can be caused by changing the feed.
- Following from the above point, the closer the sensor measures toward the cause end of the cause-effect spectrum, the quicker and more effective the management response can be.
- The further along the cause-effect spectrum, the more the infection becomes established, the sicker the cow is and the less likely she will be to self-cure.
- Items on the spectrum that have different biological causes, such as conductivity and SCC, can be correlated but will never be direct indicators of each other. There will always be false positives and false negatives when using one to predict the other. However, remembering what the true cause is of what is being measured brings to light the real management value of evaluating that particular piece of data.

“True mastitis” would be difficult to measure and, in fact, is not really the information that most farmers require. However, many technologies are being developed that will help farmers to effectively and efficiently diagnose udder health and milk quality on-farm. Part of the successful development and application of this technology will be education of the dairy industry about tools such as the mastitis cause-effect spectrum. This education will lead to farmers, their support team and farm consultants being

better informed and able to purchase and recommend technology that is best suited to the needs.

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