Infrared Thermography for Screening and Early Detection of Mastitis Infections in Working Dairy Herds

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ABSTRACT

Bovine mastitis infections cost the U.S. dairy industry at least $2 billion annually. This common affliction is difficult to treat and its impacts include reduced milk quality resulting in lower milk prices, as well as reduced output and increased veterinary costs for dairy managers. Redwood Infrared is working with the University of California Agricultural Extension Cooperative and research veterinarians across the country to develop a robust methodology for the use of infrared (IR) thermography as a tool for screening and early detection of mastitis in working dairies.

INTRODUCTION

If you're going to succeed as an independent infrared thermographer running your own consulting firm, odds are you're going to have to wear a lot of hats and figure out how to make your craft valuable to people in a lot of widely divergent environments. Aside from being as knowledgeable as you can with respect to operating your equipment and understanding the information it provides, perhaps the most important thing you can do is learn to understand what matters to your clientele. What are their biggest concerns? How is heat related to them? What can you as a thermographer do to alleviate their concerns, make their lives easier, and help their businesses be more profitable?

I recall a reference to using infrared for detection of mastitis in dairy cattle from the very first presentation I attended in the field of thermography. Before I decided to purchase a camera, I took ITC's 2-day Roofing Inspection course taught by Ron Lucier. Since several of us in attendance were uncertified at the time, Ron started with an overview of thermography principals and applications, among them showing us several slides of different animals in infrared. Ron's mastitis comment stuck with me, since my father-in-law has worked in the dairy industry his entire life, and while I've never been associated with that industry myself, I was aware that mastitis has long been the bane of the dairyman's existence. Coincidentally, the region of coastal northern California where I settled with my family is the home of the original California Happy Cows – wide open green spaces and temperate climate year round mean herds can be pastured the vast majority of the time.

From Ron's offhand remark about mastitis detection, I had mistakenly assumed that somebody somewhere was actually using infrared for that purpose. Nearly two years later, I was contacted by an Ag Extension Cooperative Dairy Agent after I'd published a couple of columns on predictive maintenance in the business section of our local newspaper. He was sponsoring a 'Dairy Days' workshop and asked me to give a short talk about the potential for condition monitoring of dairy equipment. Even small dairies do quite a bit of pumping, both in the milking parlor and for irrigation in their fields, so reliability is of paramount importance to them. Cows need milking twice a day whether your equipment is running or not. Failure to follow through can have catastrophic consequences. I was happy for the opportunity to speak to this potentially lucrative market in a collective setting, and as I prepared for the talk, decided it might be a good time to look into the mastitis application as well. I was surprised to learn that, while people have been talking about using IR thermal imaging for mastitis detection for some time, it didn't appear that anybody had actually proved that it would work, nor developed a robust methodology for its use.

A literature search accompanied by a flurry of phone calls and email contacts over the next couple of weeks appeared to verify that conclusion, but at the same time cemented in my mind the notion that here

is an application ripe for investigation, with the potential to deliver great cost benefits to the dairy industry at large.

MASTITIS AND ITS IMPACTS ON THE DAIRY INDUSTRY

Mastitis is a general term used to describe any inflammatory infection of the mammary gland of any mammalian species. More specifically, it is usually caused by a bacterial infection of the breast tissue in females during the postpartum period when milk is being produced. There are a number of different bacterial strains that dominate most mastitis infections in dairy cows, with notable trends toward increased incidence of one of the more troubling and difficult to treat strains over the course of the last decade.

Mastitis infections cause increased somatic cell counts (SCC), which both reduce milk output and dramatically impact milk quality. At the risk of being indelicate, it causes pus in the milk. At milking time, milk from many cows is pumped into central storage tanks before being loaded onto tanker trucks for transport to processing plants. This mixed milk is always tested prior to acceptance by the processing facility. Milk prices paid to farmers are dependent in large part on quality, with SCC along with butterfat content being the prime quality indicators.

Milk with high SCC from a single infected animal gone undetected can reduce bulk tank quality to the point where costs to the dairy can exceed $200 per cow for the entire herd – even uninfected cows – over the course of just a few short months. Consensus estimates are that mastitis infections cost the US dairy industry anywhere between $2 billion and $4 billion annually.

MASTITIS CONTROL

The three basic principals of mastitis control are:

1. Prevent new intramammary infections
2. Eliminate existing infections
3. Monitor udder health status

As with many infectious diseases, particularly where the use of antibiotic treatment is widespread, common bacteria that cause mastitis have evolved over time to become resistant to most antibiotics, making them much more difficult to treat. Consequently there has been a shift in the past five to eight years away from relying on treatment and toward implementation of aggressive prevention programs.

One important strategy for lowering SCC is diversion. Cows with the highest SCC have a disproportionate influence on the average cell count in the bulk tank, so identifying those problem cows and discarding their milk makes economic sense. In many cases, it proves more cost effective to cull infected cows from the herd than to attempt treatment and risk continued contamination of the bulk tank, or worse, spreading the infection to other cows.

Early detection of mastitis can improve profits by:

1. Increasing milk production
2. Decreasing milk dumped due to treatment
3. Reduced veterinary and drug costs
4. Reduced labor costs
5. Fewer culling and death losses
6. Improved quality premiums

Not all mastitis infections have equal impact on the bottom line. The highest producing cows are those most likely to fail to produce a protective keratin plug at dry off (the period immediately before calving when milk production ceases). This puts the most valuable cows at greatest risk for new mastitis infection during the highest risk period.

In addition to reduced milk production and milk quality, recent California studies have concluded that mastitis is associated with decreased reproductive performance. This is a factor affecting beef as well as dairy herds, and is a particular challenge for organic cattle operations that are restricted in their treatment options. New organic certification standards for milk and beef have spawned tremendous growth in those markets, since as commodities they command significantly higher prices than their conventional counterparts. This higher value coupled with greater risk presents a great motivation for organic herdsmen to adopt any means available in order to ensure herd health. Their very livelihoods depend on it.

There is a strong consensus among veterinary researchers that the use of thermography will be of great value in the early detection and prevention of the spread of mastitis, once a robust and affordable methodology for its application is developed.

EXISTING TEST METHODS

There are a number of existing methods of testing for mastitis, but they break down into essentially three categories:

1. Prestripping
2. Onsite chemical testing
3. Offsite sampling

Pre-stripping is the quickest and easiest means of monitoring for mastitis, and in well managed herds it is done every time a cow is milked. All it requires is simply pulling the first squirt or two of milk onto the floor, after the teat is cleaned and before attaching the automatic milking cups. If an infection is present, the milk will appear obviously contaminated. The downside of this method is that by the time you catch it, it's already too late, and odds are that particular cow's milk has already contaminated several bulk tank loads and cost the farm significant revenue.

There are a number of different onsite chemical tests of varying complexity that all take time from production and require training of dairy workers. These methods are generally not employed except to verify or quantify the magnitude of problems identified during pre-stripping.

Offsite testing that reports SCC costs anywhere from $5 to $12 per cow depending on herd size and sampling frequency. It requires a unique sterile test tube milk sample from each individual cow. Some milk buyers mandate their suppliers have this testing done at least once per month, but it is nowhere near a universal practice. Since it takes time and testing intervals can vary, it can often take months for infections to be detected.

It is therefore highly desirable to make available a simple, effective, onsite method to detect mastitis in its earliest stages while it is easiest to treat, and before it has a chance to spread through the herd. Since inflammation accompanied by increased temperature is indicated at the earliest stages of mastitis infection, infrared thermography could prove to be that tool.

CURRENT STATE OF THE ART

To date, no one has completed an exhaustive study into the use of infrared thermography for early detection of mastitis. A group in Canada has successfully demonstrated a correlation between daily variations in udder surface temperature such that it can be corrected to account for the influence of variations in ambient temperature conditions. That same group has gone on to test for and report on correlations between surface temperatures and induced diarrheal infections.

A group at Purdue in early 2000 did some preliminary testing with a very small sample of cows challenged with induced mastitis to positive effect, but concluded that while they could in fact detect mastitis using IR thermography, although they didn't believe at that time that it could necessarily detect it sooner or more cost effectively than existing methods. Advances in infrared technology coupled with

dramatic decreases in purchase price and increased availability since 2000 might lead one to believe that conclusion is worthy of reconsideration. Increased incidence of mastitis and increased cost of its impacts over the last five years would tend to corroborate that view.

Our own field research is preliminary and informal at best, but we were fortunate to gain access to a small sample herd at 'drying off,' a time during which risk for new infection in the most productive cows is very high. In an attempt to simulate a 'blind' study, we looked at the cows without knowing anything specific about their histories. Prior to capturing images we experimented with a variety of palettes, span settings, and alarm indicators, before settling on grayscale spanning from ambient up to 98°F with an isotherm alarm set at about 96°F, which appeared to represent a threshold temperature for the udders on most of the cows we were looking at.

Most of the cows crossed that alarm threshold only in the creases or under the tail where you would expect them to be warmer, but two of them had significant exposed areas above that temperature. When we pulled up the records from offsite testing that had been performed about three weeks prior, sure enough, we found that those two cows had SCC that were elevated to about twice the level of the rest of the sample population.

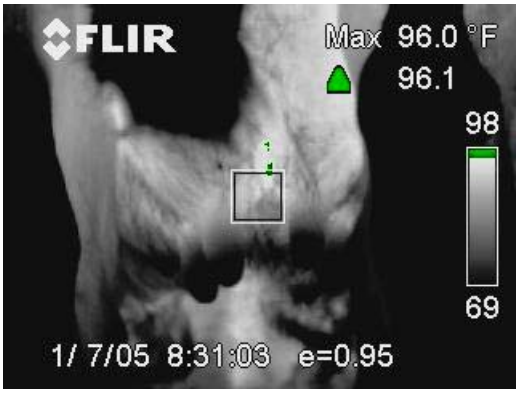

Figure 1. Normal udder heat signature with most recent SCC < 100,000

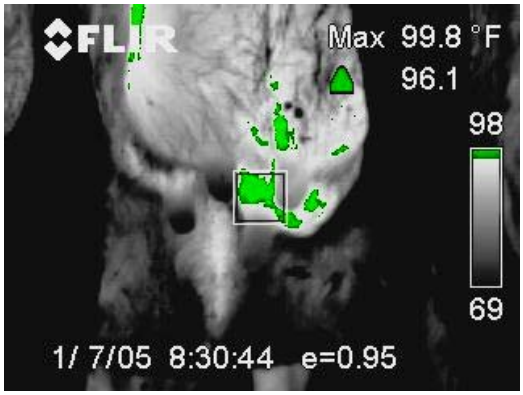

Figure 2. Anomalous udder heat signature with most recent SCC > 200,000

RESEARCH OBJECTIVES

Objectives of a successful infrared mastitis detection research program will revolve around development of a robust methodology whereby regular and frequent thermographic scanning procedures can be implemented by dairy farmers as a cost effective means of monitoring herd health.

Ultimately this will require development of a new, specialized, low cost, and easy to use or (even automated) infrared monitoring product designed specifically for installation in the milk parlor environment. Such a product will necessarily be subjected to rather extreme conditions on a continual basis. A reality of the dairy environment is that the closer you are to where the milk comes out, the closer you are to where other stuff comes out too. "Well I'll be dipped in s--t!" is not just an expression; it's something dairymen are resigned to when they get up in the morning, usually around 3:30 am, as if that alone weren't bad enough. An IR device situated so that it can monitor the udders of cow after cow throughout the twice daily milking routines will get plenty of that treatment too.

The first objective, however, will be proof of the concept that anomalous increases in udder surface temperature can be correlated to incidence of mastitis infection. This will be followed by development of a robust body of statistical data demonstrating that mastitis can reasonably be inferred where a unique set of thermal characteristics is identified by the heat signature of the udder surface.

As a methodology for practical implementation is developed, among the greatest challenges will be determining just exactly when and where the infrared monitoring of the bovine subjects should take place. Cows just entering the milking parlor are most likely to express various artifacts, including but not limited to moisture from inclement weather, mud, manure, urine, or recent exposure to direct sunlight.

Immediately prior to milking, teats are cleaned with wet towels and disinfectant. Immediately after milking, the teats and surrounding udder tissue are highly stimulated from the stress of the pumping they've just been subjected to. All of these factors can influence surface temperatures in ways that may either mask conditions we're concerned with or else provide false positive indicators.

PROPOSED SAMPLING METHODOLOGY

Development of a robust methodology will require accumulation of a great deal of data under a wide variety of circumstances. Our initial proposal involves sampling groups of several dozen specific cows from several different herds in different types of milking parlors over the course of several months in order to see what kind of patterns develop. Eventually, we will graduate to concentrated testing on a small dedicated research herd managed by the University of California Davis. This part of the study will include a control group and a group challenged with specific mastitic infectious agents. We expect the entire study to take about two years.

CONCLUSION

Ultimately, the goal of this initiative is development of a small, durable, foolproof infrared camera product that can be either portable or mounted in a fixed location. The performance feature set can be pretty constrained since it will only operate within a very limited range of temperatures, at set distances, and generally with a single optimized palette, with alarms set to notify the user of anomalies corrected to account for ambient conditions.

Getting the price down to where the device can be made cost effective and suitable for broad deployment is critical. Monthly SCC testing costs about $5 per cow, which means that most dairies should be spending about $6000 per year per 100 cows if they are screening monthly as is the recommended minimum. If thermal imaging can do the job, these testing costs can conceivably be dramatically reduced even while milk production and the premiums associated with improved milk quality are increased.

With costs for basic full featured thermal imagers coming down to between $10,000 and $15,000 already, is it likely that by limiting the features to those required for this task we could get a product under $5000 by 2007 or 2008? If so, even the smallest herds may have thermal imagers permanently installed in the barns by 2010.

SUMMARY

The IR community has long suggested that infrared thermography can be a suitable tool for early detection and screening for mastitis in dairy cattle. There is a consensus among dairy researchers that it is technically feasible, and preliminary investigation bears that out, indicating that a more exhaustive technical study is warranted. What's left is to collect comprehensive data to support development of a robust methodology for its implementation, resulting in a cost effective product that will allow for its wide scale deployment within the dairy industry.

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