Infrared thermography as non-invasive technique for early detection of mastitis in dairy animals - A review

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ABSTRACT

“Mastitis” is one of the major challenges for dairy industry, worldwide, as this is most common and costliest disease of dairy animals and contributes a substantial economical loss to dairy farmers. Subclinical stage of mastitis i.e. Sub-clinical mastitis (SCM) in dairy cow is matter of great concern for farmers as its incidence is more as compared to clinical form. In most of animal farms, monitoring of sub-clinical and clinical mastitis (CM) is usually performed through indirect test such as pH, electrical conductivity, somatic cell count (SCC), California mastitis test (CMT), culture test and biomarker tests. But, apart from these, there is a need of new rapid and sensitive technology to identify udder infections at early stages. Early detection of mastitis using non-invasive technology is need of the hour to reduce the economic loss of the dairy industry and farmers. It is well evident that, skin surface temperature is a critical indicator of bio-physiological health status of an organism. As a result of infection-induced inflammatory reactions, local blood circulation, metabolism and skin surface temperature increases. Thus, by monitoring the emitted heat from udder, can help in early detection of mastitis. Moreover, Infrared thermography (IRT) using highly sensitive thermal camera is able to monitor subtle change in skin surface temperature. IRT with mobile based application can further play an important role in the management of dairy farms on various aspects.

Key words: Dairy animals, Infrared thermography, Mastitis diagnosis.

IRT imaging: Sir William Herschel, a British astronomer, in year 1800, discovered Infrared radiation (IR) in sunlight.
IR is an electromagnetic radiation whose wavelength ranges from 700 nm (frequency 430 THz) to 1 mm (300GHz). IR thermography, works on principle that proportional to their temperature, all objects by means of conduction, convection, and radiation, following Stefan-Boltzmann law, emits infrared radiation (Poikalainen et al., 2012). Thus, Infrared thermography (IRT) can detect change in body surface temperature due to subtle changes in the blood flow. Skin temperature is a good indicator of organ health as animals dissipate their excess heat through skin. Moreover, exchange of heat occurs between core body and skin through blood circulation (Collier, 2006). Due to huge technological advancement in IRT, it can be used to measure the local and temporal changes of body surface temperature. IRT is a recent, simple and non-invasive tool that, without causing any radiation, detects surface temperature of body and gives pictorial images of animals (Soroko et al., 2014; Mazur and Eugeniusz-Herbut, 2006; Kunc et al., 2007). IRT has potential for disease diagnosis in bovine species (Stelletta et al., 2012). The potential of detecting mastitis by IRT is rapid, real-time and safe as IRT is able to measure increase in local temperature due to inflammatory reactions even before the symptoms of mastitis occurs (Colak et al., 2008). Researchers have also established the positive relationship of udder skin surface temperature with California mastitis test ($r = 0.86$) and Somatic cell count score ($r = 0.73$), they reported that, udder skin surface temperature and somatic cell count for healthy quarters ($33.45^\circ C \pm 0.09$; $>4$ lakh cells/ml) were different from subclinical ($35.80^\circ C \pm 0.08$; $>4$ lakh cells/ml) mastitis (Polat et al., 2010).

**Udder health status:** Good udder health is one of the important conditions for clean milk production. The adequate managemental steps help in reduction of udder infections to contribute in clean milk production. Therefore, for better management of udder health, researchers are trying to monitor the milking process using IRT (Paulrud et al., 2005; Végricht et al., 2007). Moreover, udder thermogram is able to assess the milking hygiene, as the cleanliness of udder surface influences the measurement results, mostly surface temperature (Poikalainen et al., 2012).

The major concern of udder health is related with occurrence of subclinical and clinical mastitis. Mastitis is the inflammation of the mammary gland causing physiological, biochemical and pathological changes in udder parenchyma, result in alteration of milk quality. Sub-clinical mastitis is defined as an infection without any signs of gross inflammation of udder which changes the milk composition which remains visually undetected (Radostits et al., 2007). Mastitis generally occurs as a consequence of interaction between a variety of microbial infections, host factors, environment and management which turn into a multi-factorial disease. Depending on the severity of the inflammation, it can be sub-clinical, clinical or chronic. The degree of inflammation is depends on the nature of the causative agent, age, breed, immunological health and lactation stage of the animal (Viguier et al., 2009).

Clinical and sub-clinical mastitis cause major economic losses to farmers and modern dairy industry in different forms viz., reduction in milk production, poor milk quality, increased culling rate, additional labour and expenses on treatment or control measures (Halasa et al., 2009; Hogeveen et al., 2011). Clinical mastitis is categorised as per-acute, acute and sub-acute mastitis on the basis of presence of gross inflammatory signs such as redness, swelling, pain, heat and loss of function.

**Subclinical and clinical mastitis:** IRT technology is able to detect clinical and subclinical mastitis. Subclinical mastitis is the major concern as it leads to more economic losses to the dairy farmers. In many cases, milk productivity and milk quality of the cow may reduce permanently (Halasa et al., 2007). To reduce the economic loss, early detection of sub-clinical mastitis can be helpful in diagnosis of the infection and causative agent and also help for implementation of effective managemental interventions. Sensitivity and specificity technique used for the detection of subclinical mastitis using IRT is similar to that of the California mastitis test (Polat et al., 2010). Colak et al. (2008) observed high correlation between the SCC and the udder skin surface temperature, where increase in temperature more than $1^\circ C$ was an indicator of mastitis and recommend IRT as a complementary tool in early diagnosis of subclinical mastitis in Holstein and Brown Swiss cows. But in Gir, IRT may be used for the identification of temperature variations of skin surface at different udder regions but this technique was not...
as effective in the detection of subclinical mastitis (Porcionato et al., 2009).

Diagnosis of clinical mastitis is easier and can be performed based on the visible abnormalities (Kurjogi and Kaliwal, 2014). Normally, there is increase in udder surface temperature during mastitis in dairy animals, which are affected mainly due to contagious pathogens and environmental factor, which further depends upon the affected quarter, mastitis pathogen, treatment, and management including environment related factors (Oliveira et al., 2013). Milk production is affected by both the forms of mastitis and it has been estimated that the average decrease in milk yield due to clinical and subclinical mastitis is 50 and 17.5 %, respectively (Singh and Singh, 1994). However, reports suggest that subclinical mastitis has a higher prevalence than clinical mastitis (Seegers et al., 2003; Mdegela et al., 2009). The brief findings of researchers have been documented in tabular form regarding use of Infrared Thermography for detection of subclinical and clinical mastitis.

Change in udder surface temperature and its measurement using Infrared thermography (IRT) in case of sub-clinical and clinical mastitis varies from the healthy quarter and wide range of difference was documented by various researchers, therefore IRT can be used as promising tool for assessment of udder health. But, contradictory results are available in case of sub-clinical mastitis detection using IRT (Polat et al., 2010), whereas mastitis can be detected efficiently using IRT (Scott et al., 2000; Metzner et al., 2014). Therefore, IRT can be explored to use in better management of udder health of dairy animals (Fig.1).

**Technique for diagnosis of mastitis: Benefits and limitation:** Mastitis in dairy animals can be detected by various methods viz., examination of udder, milk colour, and change in milk pH, electrical conductivity (EC) of milk, california mastitis test (CMT) and somatic cell counts (SCC). Recent studies has documented that EC, CMT and SCC are the better predictor of subclinical and clinical mastitis. The increased milk pH in the subclinical mastitis (SCM) may be related with high concentration of alkaline blood constituents such as sodium and bicarbonate ions which, due to inflammation of the mammary gland, increases permeability of the blood capillaries (Guha et al., 2010). Additionally, elevated milk pH during mastitis may be due to lower acidity which is associated with reduced lactose contents in mastitic milk (Ahmad et al., 2005). The electrical conductivity (EC) in normal milk varies between 4.0 and 5.0 mS/cm (Norberg et al., 2004), whereas EC in the milk of infected quarters varies between 5.63 vs. 6.71 mS/cm at 25°C (Syridion et al., 2013). The EC of mastitis milk remain comparatively higher as compared to normal milk (Bansal et al., 2005; Kamal et al., 2014). This may be due to change in ions concentration, particularly due to inflammatory changes of mammary tissue, increase in milk sodium and chloride concentrations. CMT is considered as the gold standard

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named cow side test for the identification of subclinical mastitis and is positively associated with SCC (Radostits et al., 2007). As per the findings of Skrzypek et al. (2004), milk SCC from healthy udders varies between 50,000 to 100,000 cells/ml. The threshold value of SCC is less than 200,000 cells/ml (Radostits et al., 2007; Sinha et al., 2014). The increase in SCC during infection might be due to the fact that bacterial invasion to mammary glands attract circulating polymorph nuclear neutrophils (PMNs) which in addition increases the dead and sloughed off mammary epithelial cells leading to higher somatic cell counts in the milk (Radostits et al., 2007). The SCC, EC and pH values are not only affected by mastitis but also by non-mastitic factors such as species, breed, parity and stage of lactation, may be the reason for variation in critical threshold value by different studies. Further, the reference test used to define SCM also varies from study to study, might be another contributing factor for variation of threshold values. The threshold values of milk also depend on the fraction of milk considered for identification of mastitis (Syridion et al., 2013). The diagnostic available for mastitis has been documented below (Fig 2).

Fig 2: Mastitis diagnosis of dairy cattle (Ahmad et al., 2005; Radostits et al., 2007).

CONCLUSION
Mastitis is one of the major concerns of dairy industry, which leads to huge economic loss and in addition to established laboratory methods available for its diagnosis, there is a need to address in the light of early mastitis detection by some highly sensitive non-invasive techniques as well. Infrared thermography (IRT) using highly sensitive thermal camera can be used as non-invasive technique. Due to physiological changes in udder during subclinical and clinical mastitis, IRT can measure the subtle change in udder temperature. Thus, infrared thermography may be a suitable tool for the early detection and screening of mastitic animals in dairy cattle. As there are some limitations adhered with IRT such as sunlight, moisture, dirt, weather conditions, etc. may influence the accuracy level of the IRT, there is need to explore IRT for diagnostic purpose in case of subclinical and clinical mastitis under Indian climatic conditions.

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Competing Interests
The authors declare that they have no competing interests.

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