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A review of infrared thermography: Boon in early detection of mastitis

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Abstract
Mastitis is the most frequent disease of dairy cows and has well-recognized detrimental effects on animal wellbeing and dairy farm profitability. Since the beginning of modern dairy farming, producers have sought effective methods to minimize the occurrence of mastitis in their herds. The objective of this paper is to review and highlight important advances in detection of mastitis. Reduction or complete loss in milk production affects farmer's income. Milk has to be discarded for 3 days during treatment and 3 days post treatment for withholding period. Several traditional methods used to detect mastitis are somatic cell count, microbial culture techniques, electrical conductivity, ultrasonography etc. SSC is more important to diagnose subclinical mastitis. Infrared thermography is a relatively new tool for diagnostics in animal health. It can perceive inflammation induced skin temperature changes and therefore can be employed for screening subclinical mastitis via measuring USST. It has highly predictive diagnostic ability similar to CMT.

Keywords: Somatic cell count, microbial culture techniques, electrical conductivity, ultrasonography, infrared thermography

Introduction
Animal husbandry is an integral component of agriculture sector and plays a multifaceted role in uplifting Indian economy. Livestock provides sustained income to small and landless farmers throughout the year, thus contributing in their socio-economic development. Livestock sector contributes 4.4 percent to GDP and 25.6 percent of total agricultural GDP (*National Accounts Statistics-2016; Central Statistical Organisation; GoI*). India possesses world's largest livestock population and largest producer of milk but still not self-sufficient in milk. Milk production during 2017-18 and 2018-19 is 176.3 million tonnes and 187.7 million tonnes respectively showing an annual growth of 6.47%. (Annual report 2019-20, DAHD & F, GOI). This growth is mostly the result of an increase in numbers of producing animals rather than a rise in productivity per head. Low productivity is due to poor animal health, inferior management practices and ineffective diagnostic techniques. Contagious disease affects animal health and productivity. Worldwide most frequently occurring calamitous disease of dairy herd is mastitis (Ojo *et al.* 2009) [20] causing major economic losses to the farmers. Disease causes inflammation of affected mammary gland. The major pathogens of both contagious and environmental mastitis are; *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus uberis*, *E. coli*, and *Klebsiella*, causes fever, inflammation, swelling, milk composition and color changes, and presence of somatic cells etc. Intensity of the inflammation can be classified into sub-clinical, clinical and chronic forms. Inflammation might differ in severity due to many factors such as pathogen type, animal health status, age and lactation cycle of the animal. In addition, mastitis being a potent zoonotic disease, poses serious hazard to human health (Blum *et al.* 2008) [3].

2. Materials and Methods
A cross-bred buff reducible hernias are suitable for conservative therapies. The hernial ring can be closed using conservative treatments such as belly bandages/ abdomi

Table 1: Mastitis Detection Methods

General Mastitis indicators	Automatic Digita Diagnostic tools	Specific Tests
Physiochemical markers-Electrical Conductivity (Khatun *et al.* 2018) [16], Lactose (Pyorala, 2003) [26], Protein (Hussein *et al.* 2018) [15], Enzymes (Patil *et al.*2015) [22]	Draminski mastitis detector (Steele *et al.* 2018) [30]	Microbial culture (Lam *et al.* 2009) [17]
Somatic cell count (Patil *et al.* 2015) [22]	Fossomatic meter (Steele *et al.* 2018) [30]	Polymerase chain reaction, RT-PCR (Behera *et al.* 2018) [1]
California Mastitis Test (Persson and Olofsson 2011) [23]	DeLaval Cell Counter (Steele *et al.* 2018) [30] Infrared thermography (Polat *et al.* 2010) [24]	Molecular methods-Amplified fragment length polymorphism (Mohajeri *et al.*2016) [19], Ribotyping (Choudhary *et al.* 2018) [4], pulsed-field gel electrophoresis (Pumipuntu *et al.* 2019) [25], RAPD-random amplified polymorphic DNA (Tomazi *et al.* 2018) [32]

Impacts of mastitis

Reduction or complete loss in milk production affects farmer's income. Milk has to be discarded for 3 days during treatment and 3 days post treatment for withholding period (Huijps, Lam and Hogeveen, 2008) [14]. The quality of milk is deteriorated due to elevated somatic cell count and decreased milk fat. Antibiotic treatment and veterinary care impose additional financial burden on livestock holders. The minimised organoleptic properties affect the selling price of milk and milk products. The meat of mastitis affected animals fetches lower prices due to reduced quality and carcass yield. Mastitis affected animals are culled and replaced with healthy stock. The premature replacement of stock largely contributes to economic losses (Halasa *et al*., 2007; de Graves and Featrow, 1993; Hortet and Seegers, 1998) [8, 6, 12]. Many mastitis cases remain unnoticeable and its effect on milk production remains unquantified due to poor diagnosis of disease.

Several traditional methods used to detect mastitis are somatic cell count, microbial culture techniques, electrical conductivity, ultrasonography etc. SSC is more important to diagnose subclinical mastitis. Quarter milk samples having SSCs < 1 lakh cells/ml are considered as normal, provided that the animal is not recently infected and no microorganism have been isolated from the milk samples (Harmon 2001; Smith *et al*. 2001) [10, 29] however, samples with SCC > 2 lakh cells/ml indicate subclinical mastitis (Smith *et al*. 2001, Harmon 1994 and Hillerton 1999) [29]. In subclinical mastitis milk is secreted with leucocytes and epithelial cells but SSC not always correlate with udder infection, season, stress, species, lactation number, stage of lactation affects SSC. These techniques are not sufficient in early detection of disease. So, there is need for alternative, fast, accurate methods for early disease diagnosis.

Use of Infrared thermography in Udder Health detection

Infrared thermography is a relatively new tool for diagnostics in animal health. It can perceive inflammation induced skin temperature changes and therefore can be employed for screening subclinical mastitis via measuring USST. It has highly predictive diagnostic ability similar to CMT. The udder skin surface temperature (SST) was positively correlated with the CMT score (r=0.86) and SCC (r=0.73). Exponential increase in SCC as the CMT score increased. Strong correlation between SST and CMT score (r = 0.92). (Polat *et al.* 2010; Colak *et al.* 2008) [24]. Rectal temperature, milk somatic cell count and electrical conductivity increased 4 h Escherichia coli lipopolysaccharide (LPS) post challenge which were presented as changes in skin temperatures in the ranges of 1-1.5ºC (Hovinen *et al*., 2008) [13] Sathiyabarathi *et al.* 2018 [27] assessed that the mean (±SD) USST of the subclinical and clinical mastitis affected quarters were 37.9±0.09°C and 38.2±0.10°C, respectively which is 0.8 and 1.1°C higher than the body and non-mastitis quarter temperature. The increase in USST of subclinical mastitis quarters showed a positive correlation with the SCC. Udder temperatures were higher in subclinical mastitis sheep. The udder temperature data correctly classify the animals into the mastitis groups (Martins *et al.*, 2013) [18]. All methods of analyzing thermograms were highly correlated and correlations between thermograms and rectal temperatures were found significant (P < 0.01; r > 0.840) (Stumpf *et al.*, 2020) [31]. Also the data collected by Schaefer *et al.*, (2004) put forward that infrared thermal measurements can be used in developing an early prediction index for infection as temperature increased by 1.5°C to over 4°C (P< 0.01) several days to 1 week before clinical signs appear.

Berry *et al.*, (2003) [2] investigated magnitude and pattern of daily variation in the UST of Holstein-Friesian dairy cows in various stages of lactation using IRT technology and revealed that the values of USST and SCC rose to an indicative level in subclinical mastitis. In cases of mastitis, udder surface temperature as measured by IRT has shown also a strong correlation (r=0.92) with the CMT test. IRT is able to discover changes that have not yet caused clinical signs in apparently healthy dairy cows (Pampariene *et al.*, 2016) [21]. Bovine Mastitis diagnosis results obtained from processing thermal images showed that the average temperature difference between unhealthy and healthy tissues was 0.44 ˚C. The detection accuracy of infrared thermography was 57.3%. (Golzarian *et al.*, 2017) [7]

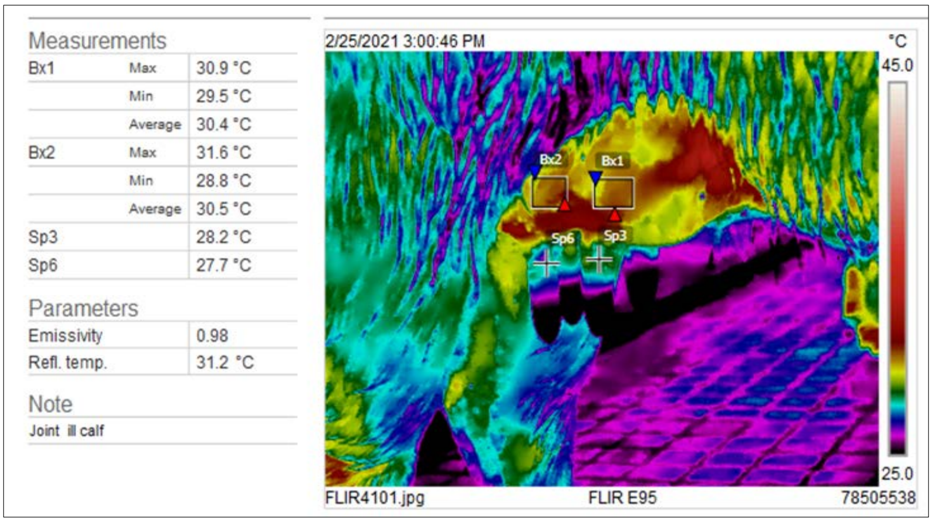

Fig 1: Thermogram of lateral view of right udder quarter of non-mastitis buffalo

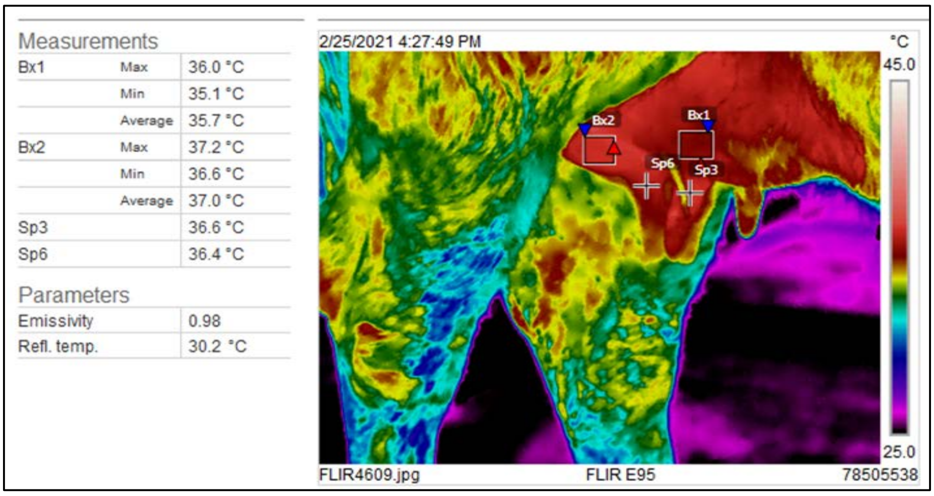

Fig 2: Thermogram of lateral view of right udder quarter of clinical mastitis affected Murrah buffalo

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