A Potential Application of Infrared Thermography (IRT) in Mediterranean Lactating Buffalo

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Authors’ contributions

This work was carried out in collaboration among all authors. Author FS designed the study, performed the statistical analysis, wrote the protocol and wrote the article. Author GG performed the analysis. Author GA performed the analysis and analyzed the data. Author RP designed the study and wrote the article. All authors read and approved the final manuscript.

ABSTRACT

Skin temperature is an important indicator of the physical and healthy status of animals. Infrared thermography (IRT) leads itself to countless applications in biology thanks to its characteristics of versatility and high sensitivity. Contactless surface temperature measurement using infrared thermography is a modern, noninvasive and safe technique of thermal profile visualization. IRT has also been used on humans and animals as a non-invasive diagnostic method for measuring physiological or pathological changes in skin temperature. The aim of this study was to investigate the possibilities of using IRT to assess the temperatures of the udder in order to a possible early diagnosis of mastitis in lactating buffalo. For the achievement of broached objectives, the measurements were carried out in a zootechnical farm located in Southern Italy. The number of lactating buffalo cows engaged in the udder experiment was 192. A FLIR i7 thermal imaging scanner was used for obtaining thermal images. Milk samples were taken on the same day as thermographic measurements after capturing thermal images. The PROCMEANS procedure was used to obtain the descriptive statistics for SCC and temperature in all category. The correlation between temperature and different categories of SCC was significantly positive. The relationship between SCC and temperature was indicated by an exponential equation \[y = 35.77 \times 0.00024 \times x\]; \(R^2 = 0.640; <0.001\). The results suggested that thermography can be used for early detection of subclinical mastitis in buffalo.

Keywords: Infrared thermography; buffalo cows; mastitis; somatic cell count; milk; healthcare.

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1. INTRODUCTION

All substance emits radiant energy due to their absolute temperature.

Skin emissivity is an important factor in determining the skin temperature, and through the assessment of surface temperature, it is possible to acquire knowledge regarding the physical and healthy status of animals [1,2,3].

There are many methods to measure the surface temperature, for example contact method (e.g. thermocouples) and non-contact (pyrometry, thermal imaging) [4].

IRT is a non-invasive testing technology that can be used to detect the surface temperature of objects. Thermal cameras collect infrared radiation emitted by the surface, convert it into electrical signals, and create a thermal image showing body’s surface temperature distribution [5]. In this process, each color expresses a specific temperature range, related to a defined scale. Thermoregulatory abilities are strongly correlated to energy balance and animals often try to limit the energy costs of normothermia [6]. In case of thermal changes, physiological mechanisms are enhanced, increasing the expenditure of energy [7,8].

In bovine medicine, IRT is primarily used for diagnostic purposes, but also for the assessment of animal welfare and even feed utilization efficiency [9]. Uses of IRT in the dairy industry include early detection of oestrus, mastitis and lameness. Previous studies have focused on the use of infrared thermography to detect mastitis much earlier than previously possible [10].

Previous studies used IRT analysis as a method for early detection of animals infected with bovine viral diarrhea virus or bovine respiratory disease using facial scans [11]. IRT has been also identified as a possible detection method for laminitis in lactating dairy cattle [12]. These studies have concluded that while IRT provides an additional perspective on disease and injury, it should complement traditional diagnostics methods [2,7].

Schaefer et al. [7] examined the possibility that changes in eye temperature, measured using IRT, can detect stress in dairy cattle. However, despite the findings using IRT, the increases in eye temperature following catheterization might need a cognitive component for assessing an appropriate animal response.

Mammary gland inflammation affects milk yield and quality and can lead to great economic losses for dairy farmers and cheese makers. Only from a healthy udder is milk of a physiologically normal composition produced [13]. The effects of mastitis on milk yield and milk quality have been observed for buffalo milk [14,15].

This study aimed to investigate the possibilities of using IRT to assess the temperatures of the udder as a possible early diagnosis of mastitis in lactating buffalo.

2. MATERIALS AND METHODS

2.1 Study Area and Experimental Lactating Buffalo

To achieve the set goals, the measurements were made in a zootechnical farm located in Southern Italy. The experiment was conducted for three months (May to July) at weekly intervals, for two weeks per month. The air average temperature of the experimental area was +34°C, with a relative humidity of 68%. The number of lactating buffalo cows engaged in the experiment was 192. The thermogram of the udders was registered after milking.

Poikalainen et al. [16] reported that there are no significant differences between the temperature of left and right udder quarters before and after milking.

Milk samples were taken on the same day as thermographic measurements after thermal imaging was acquired.

The animals were fed a total mixed ration of 22 kg of dry matter/day/head consisting of (% of dry matter): Corn silage (37.5%), concentrate (43.9%) and barley straws (18.6%).

Milk chemical-nutritional composition was determined using a Milk-Lab PRO (Milklab – United Kingdom), which is based on mid-infrared spectroscopy. The considered parameters were density, content of fat, proteins, and lactose. Somatic Cell Count (SCC) was determined by the fluoro optometric method (Fossomatic). Somatic cell count was log10-transformed before analysis because the SCC was not normally distributed. The chemical characteristics of the different samples are reported in Table 1.
Table 1. Chemical/nutritional characteristics of milk (% on dry matter) per sampling

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td><strong>Milk production Kg</strong></td>
<td>10.55±3.58</td>
<td>11.70±3.39</td>
<td>11.01±2.95</td>
<td>10.99±3.24</td>
<td>10.27±3.34</td>
<td>10.29±4.83</td>
</tr>
<tr>
<td><strong>Fat %</strong></td>
<td>10.34±1.65</td>
<td>9.89±1.81</td>
<td>9.20±1.42</td>
<td>9.07±1.42</td>
<td>8.59±1.04</td>
<td>8.86±0.99</td>
</tr>
<tr>
<td><strong>Lactose %</strong></td>
<td>5.22±0.26</td>
<td>5.36±0.27</td>
<td>5.23±0.35</td>
<td>5.30±0.25</td>
<td>4.71±0.47</td>
<td>4.82±0.27</td>
</tr>
<tr>
<td><strong>Protein %</strong></td>
<td>4.43±0.41</td>
<td>4.63±0.32</td>
<td>4.39±0.58</td>
<td>4.47±0.37</td>
<td>3.95±1.41</td>
<td>4.61±0.72</td>
</tr>
<tr>
<td>*<em>SCC log10 n°<em>1000/ml</em></em></td>
<td>2.18±0.33</td>
<td>1.90±0.60</td>
<td>2.06±0.32</td>
<td>2.28±0.31</td>
<td>2.50±0.15</td>
<td>2.47±0.14</td>
</tr>
</tbody>
</table>

2.2 Thermal Imaging

In the current study, the FLIR i7 thermal imaging scanner (FLIR Systems, Inc. 27700 SW Parkway Ave. Wilsonville, OR 97070, USA) with calibrated temperature range from −25.0°C to 105.0°C was used. This camera allows registering the object radiation temperature from distances of 0.7 – 2 m with a resolution of 0.1°C. The digital thermal image is produced on a 640 x 480 display. The sensing system of the camera is based on a 120 x 120 Focal Plane Array uncooled microbolometer. For image analysis the FLIR R&T software package was used.

During calibration of the camera an emissivity (Ɛ) of 0.95 was applied.

In our experiment, after different tests, the best place for registration of breast thermogram was found to be the milking parlor.

Thermographic images were captured from the lateral side for the forequarters and posterior or lateral side for hindquarters of the udder. The thermographic images were analyzed by FLIR Quick Report 1.2 software.

The temperature of the inner canthus and the maximum temperature of the udder surface in a particular image was recorded and used in the analysis.

2.3 Statistical Analysis

The ProcMeans procedure was used to obtain the descriptive statistics for SCC and temperature in all category. Somatic cell count was categorized (1 to 5) before analysis (1 = 0–100; 2 = 101–200; 3 = 201–300; 4 = 301–400; 5 = over 400). The categories 1 to 3 are considered to be without mastitis, while categories 4 to 5 are considered with subclinical mastitis.

3. RESULTS AND DISCUSSION

Mastitis is the most common and important economic disease of the dairy industry, and has a significant effect on the quality of milk [17] and on udder health. Early detection of mastitis is important for effective and successful treatment of intramammary infection. There are several techniques and biomarkers available for early detection of changes in milk; however, these diagnostic methods are laboratory oriented, lack full accuracy, and need a considerable time from the farm staff or milker [18,19]. Therefore, a cost-effective, rapid, non-invasive buffalo diagnostic technique with potential application in the open field is essential for monitoring udder health.

Skin temperature reflects the status of tissue metabolism, blood circulation and abnormal thermal patterns that can indicate areas of surface inflammation or circulatory impairments. Clinically, inflammation is characterized by five cardinal signs, namely rubor (redness), calor (increased heat), tumor (swelling), dolor (pain), and functio laesa (loss of function). The inflammatory response in mastitis is initially associated with the rise in the temperature of the udder. IRT detects surface heat emitted as infrared radiation; a thermal camera absorbs infrared radiation and generates pictorial images based on the amount of heat generated, without causing radiation exposure [19]. In general, on a thermograph, the warmest areas appear white or red whereas the coolest regions appear blue or black (Fig. 1).

By analyzing thermal maps, [17] found that the temperature of an unhealthy udder tissue was 2.3°C higher than that of a healthy one. Their results showed that udder surface temperature had correlations with SCC (r = 0.73) and with CMT (r = 0.86).
Kunc et al. [20] studied the thermographic methodology for the primary detection of subclinical mastitis. They reported that temperature differences between different udder regions were significant. That is, the temperature in the upper region of the udder was reported to be higher than the middle and lower regions. This indicates that the method can be used for diagnosing clinical mastitis, but not sub-clinical cases. Thermal image analysis used for clinical mastitis detection showed that the temperature difference between healthy and unhealthy tissues was between 1 and 1.5°C. At the same time, temperatures in lateral images of udder tissue were approximately 0.6°C higher than in medial ones.

The ProcMeans procedure was used to obtain the descriptive statistics for SCC and temperature per category (1 to 5). The results are reported in Table 2.

Table 2 shows that in the first three categories the temperature is between 31.7 and 40.4°C. In the last two categories the temperature varies from 35.2 to 41.9°C.

The correlation between temperature and different category of SCC show a positive significant correlation ($R^2 = 0.635$, $p < 0.001$). This represents substantial evidence that the measure of thermography may be a useful tool for subclinical mastitis screening in buffalo. Similar results have been obtained in other ruminants [18,21,22].

Later, the authors studied the relationships between the variable Temperature and the values of SCC (Fig. 2).

The relationship between SCC and temperature was fitted to an exponential equation [$y = 35.77(0.00024^x)$]; $R^2 = 0.640; p < 0.001]$. These results show that thermography can be used for early detection of subclinical mastitis in buffalo. This implies that IRT, as an indirect measure, is a sensitive screening measure for detecting subclinical mastitis.

### Table 2. Descriptive analysis by thermography

<table>
<thead>
<tr>
<th>SCC categories</th>
<th>Means</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard deviation</th>
<th>Standard error</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (n. 43)</td>
<td>36.19</td>
<td>31.70</td>
<td>39.30</td>
<td>1.61</td>
<td>0.25</td>
<td>2.61</td>
</tr>
<tr>
<td>2 (n. 35)</td>
<td>37.94</td>
<td>35.10</td>
<td>40.40</td>
<td>1.28</td>
<td>0.22</td>
<td>1.65</td>
</tr>
<tr>
<td>3 (n. 68)</td>
<td>37.51</td>
<td>34.20</td>
<td>39.80</td>
<td>1.17</td>
<td>0.14</td>
<td>1.38</td>
</tr>
<tr>
<td>4 (n. 21)</td>
<td>38.53</td>
<td>36.20</td>
<td>40.90</td>
<td>1.23</td>
<td>0.27</td>
<td>1.53</td>
</tr>
<tr>
<td>5 (n. 25)</td>
<td>40.62</td>
<td>35.20</td>
<td>41.90</td>
<td>1.39</td>
<td>0.28</td>
<td>1.94</td>
</tr>
</tbody>
</table>

![Fig. 1. Infrared thermography thermogram](image-url)
4. CONCLUSION

Surface temperature is an important indicator of animal diseases and for estimation of their physiological status; therefore, surface temperature estimation should be fast and accurate. In practice, several methods can be used to record skin temperature; however, using IRT, image analysis for estimating animal body temperature and forecasting its implication is becoming increasingly popular.

However, further study is necessary to determine the sensitivity predictive values of thermography detection of subclinical mastitis in buffalo, utilizing IRT as an indirect non-invasive screening measure.

ETHICAL APPROVAL

The experiment has been examined and approved by the appropriate ethics committee.

COMPETING INTERESTS

Authors have declare that no any financial and personal relationship with other people or organizations that could inappropriately influence their work.

REFERENCES

7. Schaefer AL, Cook N, Tessaro SV, Deregt D, Desroches G, Dubeski PL, Tong AKW,


