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# Clinical assessment of infrared thermal technique for early detection of hoof disorders in cattle

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ABSTRACT

The clinical study was undertaken in 36 cattle suffering with various types of hoof lameness. All the cattle were subjected to infrared thermal screening to record the skin surface temperature of the affected hoof. The average age and weight of the cattle were 30.38±4.89 months and 389.66 ±19.56kg, respectively, with 24 males and 12 females. Prevalence of hoof disorders was found to be higher in hind limb as compared to forelimbs included arthritis, overgrown hoof, white line disease and foot rot. Highest incidence of hoof disorders was observed in Deoni male cattle reared on hard floor housing system. Tachycardia (76.13±2.53/min) was persistently observed in affected cattle. Radiographic findings of digital joints revealed loss of periosteal integrity, osteomyelitis and altered bone opacity. Phalangeal arthritis showed highest average lameness score of 3.25 as compared other hoof disorders. The mean average values of skin surface temperature of fetlock, interdigital claws and medial claws of affected hind limb was 33.69±0.35°C; 32.84±0.46°C and 30.62±0.49 °C as compared to healthy limb which were 30.63±0.18°C; 29.80±0.33°C and 28.57±0.42°C, respectively. The overall average mean value of skin surface temperature in healthy hooves and affected hooves were 28.54±0.45°C and 30.46±0.57 °C, respectively which was indicative of significant rise in skin temperature of affected hoof temperature. To conclude, the infrared thermography is a non-invasive and reliable technique in detecting early lameness due to hoof lesions.

**Keywords**: Cattle, Hoof, Infrared, Lameness, Osteomyelitis, Thermographic

Hoof disorders are highly important in terms of dairy economics and are the third most important musculoskeletal disorder, after infertility and mastitis in dairy cattle. Lameness poses a significant health challenge in Indian dairy animals and is globally characterized as a clinical disorder impacting the locomotor system and adversely affecting cow locomotion, posture, and overall mobility (Flower and Weary 2006). Hoof lameness causes gradual milk reduction prior to the onset of occurrence of lameness in dairy cattle (Green *et al.* 2014). Lameness, being influenced by a complex interplay of factors, involves a multifactorial etiology encompassing aspects related to housing, managemental practices, and specific characteristics of the animals.

Infrared thermography (IRT) is a non-invasive technique capable of detection thermal radiation from the surface of any object. In animals, the body surface temperature is a function of blood flow and metabolism rate of underlying cells or tissues could potentially be assessed by measuring skin surface temperature using IRT. IRT can also be used to diagnose various inflammatory conditions such as sole abscess, hoof abscess, laminitis, etc. in horses (Eddy *et al.* 2001). Thermographic imaging shows promise as a diagnostic tool for detection of hoof lesions in dairy cows. The ability to detect potential of pathology and associated inflammation from changes in the coronary band in a noninvasive manner is desirable. Evidence supports the hypothesis that coronary band temperature, measured by infrared thermography, increases the detection of abnormalities of the hoof before routine hoof trimming. A combination of thermography image analysis with clinical examination would be a helpful technique for preventing lameness. Therefore, IRT may be used in the future to help veterinarians and herd managers detect hoof lesions associated with lameness in dairy cows (Alsaaod and Buscher, 2012). Hence, the present clinical study was undertaken in smallholder dairy farms to evaluate the clinical utility of infrared thermal technique in early detection of hoof affections and correlate the affected site temperature and lameness score in cattle.

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## MATERIALS AND METHODS

Total 36 clinical cases of cattle were screened randomly

Table 1. Properties of IRT Camera used for detection of skin surface temperature (°C) of affected hoof in cattle

| S. No | Configuration/Properties of IR camera | Constant values |
|---|---|---|
| 1 | Ideal distance between the body parts to camera while measuring surface temperature | 0.5-1 Meter |
| 2 | Reflected temperature | 20 °C |
| 3 | Atmospheric temperature | 25 °C |
| 4 | Relative humidity | 50% |
| 5 | Ext. optics temperature | 20 °C |
| 6 | Ex. Optic Trans. | 1 |
| 7 | Red/white region | Heat source |
| 8 | Yellow/orange region | Warm Surfaces |
| 9 | Green region | Moderate or ambient temperature |
| 10 | Blue/purple region | Cold surfaces/ area losing heat |

for anamnesis includes duration of lameness, grazing system and type of flooring (kachha, rough, and slippery). Clinical evaluation included (HR, rectal temperature, etc.) and physical examinations to rule the assess severity of swelling, pain, enlargement, etc. In severe laminitis cases, medio-lateral (M-L) and anterior-posterior (A-P) radiographic view was taken to diagnose the underlying cause of lameness. Hematological examinations included hemoglobin (gm/dL), total leukocyte count (µL), total erythrocyte count (million/µmL), differential leukocyte count (%) and packed cell volume (%). Hoof lameness scoring was done as described by Sprecher *et al.* (1997). All the animals were subjected for recording of skin surface temperature recording of concern anatomical hoof area by using infrared camera (FLIR, E-76 Model). The emissivity value (ε) was set to 0.98, which refers to the objects ability to absorb and emit infrared radiation (Table 1). In cases of unilateral forelimb or hindlimb hoof lameness, the skin surface temperature was taken in contra-lateral limb for comparison purpose in same animal. As per instrument configuration, the camera was used in a fixed position and all images were captured at a distance of about 0.5 m-1m distance from the anatomical area of hoof. The surface temperature of affected hoof was taken at heel bulb, interdigital/lateral/medial claw; sole, white line, axial/abaxial wall and fetlock. The obtained data was analyzed by using one sample student t-test and complete randomized design one way analysis of variance (ANOVA) as described by Snedecor and Cochran (1994).

## RESULTS AND DISCUSSION

*Incidence of hoof lameness*: A total of 36 cattle with different breeds presented to teaching veterinary hospital during winter to late spring season having history of dark hoof lameness were included in the study. The average age of cattle was 30.38±4.89 months, weighing between 282kg to 500kg (389.66 ±19.56kg) comprised of 24 males (66.67%) and 12 females (33.33%). Out of 12 females, 5 were heifer followed by 4 lactating and 3 pregnant. Among 36 cases, hind limbs were affected in 69.44% animals (n=24) followed by forelimb (7 cases; 19.44%) and both limbs (4 cases; 11.11%) (Table 2). The incidence of hoof lameness was also affected by the number of lactations maximum in 3rd lactation (7.83%) followed 2nd lactation (5.25%), 1st lactation (2.58%) and before 1st lactation (1.10%) (Mishra *et al.* 2020). This might be due to gradual drainage of minerals due to imbalance in diet and production over lactation age.

In 25 cases of hind limb lameness, prevalence of digital arthritis was found to be maximum (40.00%), followed by overgrown hoof (28.00%), white line disease (20.00%) and foot rot (12.00%). However, in forelimbs, the highest prevalence was white line disease (3 cases; 42.85%) followed by overgrown hoof (2 cases; 28.57%) and foot rot (14.28%) and arthritis (14.28%). Out of 4 (mixed lameness), 3 cases showed arthritis and remaining one had foot rot.

The lameness-related hoof disorders in dairy cows can result from infectious diseases like foot rot (FR) and bovine digital dermatitis (BDD), as well as lesions caused by claw horn disruptions, such as sole ulcers (SU) and white line disease (WLD) (Von Keyserlingk *et al.* 2009). Cattle with light-colored hooves are more likely to suffer with sole hemorrhages and white line disease, than those with darker colored hooves (Sogstad *et al.* 2011). In the present, the higher incidence of hoof disorders were reported in Deoni having light colored hoof could be are less resistance to mechanical forces and moisture as compared to dark colored (pigmented) hooves. The lameness-related hoof Disorders (HDs) in dairy cows can result from infectious diseases like foot rot (FR) and bovine digital dermatitis (BDD), as well as lesions caused by claw horn disruptions, such as sole ulcers (SU) and white line disease (WLD) (Von Keyserlingk *et al.* 2009). A 877 cattle survey from 15 intensive dairy farms in Korea revealed various hoof

Table 2. Prevalence of various hoof disorders in relation to hindlimb, forelimb and both hindlimb lameness in cattle (n=36)

| Involved Limb | Various Hoof Disorders (No of cases with their percentage) | | | |
|---|---|---|---|---|
| | White Line Disease | Overgrown Hoof | Arthritis | Foot rot |
| Hindlimb (n=25) | 5 (20.00%) | 7(28.00%) | 10 (40.00%) | 3(12.00%) |
| Forelimb (n=7) | 3(42.85%) | 2(28.57%) | 1(14.28%) | 1(14.28%) |
| Both Hindlimb (n=4) | - | - | 3 (75.00%) | 1(25.00%) |

Table 3. Mean average (±S. E) values of physiological parameters recorded in cattle (n=36) affected with hoof disorders

| Sr. No | Physiological parameter | Mean±SE |
|---|---|---|
| 1 | HR/Min | 76.13±2.53 |
| 2 | RR/Min | 25.97±1.04 |
| 3 | Temp (̊F) | 102.2±0.23 |
| 4 | Degree of lameness (1-5) | 2.55±0.13 |
| 5 | Severity of pain (1-10) | 5.58±0.30 |
| 6 | Digital Artery Pulse (per Min) | 72.33±2.31 |

disorders in 31.5% of cattle, with hoof overgrowth (24.1%) being most common followed by Infectious hoof disorders in 6.2% and under noninfectious category, bovine digital dermatitis (3.2%) and laminitis/corium damage (3.1%) the most prevalent lesions in cattle (Espiritu *et al.* 2025).

Total 251 cattle were reported to the hospital with various disease condition, among only 36 cattle surveyed for hoof disorders and highest incidence was observed in Deoni (61.11%) followed by Red Kandhari (25.00%), non-descript (5.55%) and 3 crossbreds (8.33%). Highest incidence of hoof lameness in HF crossbred (14.96%), followed by Gir (14.5%) and Kankrej (14.35%) (Bagate *et al.* 2012)**.** In present study, the prevalence of hoof disorders was higher in Deoni cattle. However in another study, HF crossbred dairy cattle are more vulnerable to the incidence of hoof disorders could be due to increasing in age, more body weight and lighter colored hooves (Kumar *et al.* 2019). In our study, male animals were more vulnerable for hoof disorders which could be due to utility of Deoni bullock for draught purpose. Cattles reared on hard floor (57.14%) suffered hoof affections, by Kachha floor (28.57%) and mixed floor (14.28%). Flooring materials varied across both farm types, with stone slab floors being the most prevalent (51.21%, n=316), followed closely by concrete (46.35%, n=286), and a smaller proportion utilizing earth (Patoliya *et al.* 2024). Hoof disorders are most common in cows raised in intensive housing systems, with breed, age/parity, body weight, production stage, hoof color/ symmetry, behavior, farm hygiene, and diet being the most likely risk factors (Yadav *et al.* 2025). In present study the quality of fodder and concentrated was poor and deficient with nutrients. Hoof disorders have multi-factorial etiology and predisposing factors like imbalanced nutrition (Adams *et al.* 2017).

*Clinical findings*: The average duration of lameness in present study was 8.44±1.22days with altered gait, inappetence, jerky head movement and shortened strides. Behavioral indicators of limb pain, such as resting a limb, shifting weight between limbs, and bearing weight unevenly are associated with the presence of a hind limb hoof lesion (Jewell *et al.* 2021). Tachycardia (76.13±2.53/ min) was persistently observed in larger extent succeeded by mild to moderate tachypnea (25.97±1.045/min), fever (102.22±0.23$^0$F) and paler to congested mucous membrane (Table 3). There was increase in body temperature (39± 0.463), respiratory rate (42.38 ± 4.463) and heart rate (73.58 ± 4.366) in horses suffering from laminitis (Al-Derawie, 2012).

Table 4. Mean average (±S.E) values of hematological parameters recorded in cattle (n=36) affected with hoof disorders

| Sr.No | Hamtotological Parameter | Mean±SE |
|---|---|---|
| 1 | Haemoglobin (g/dL) | 9.04±0.31 |
| 2 | PCV% | 31.03±0.95 |
| 3 | WBC $10^3$ | 10.16±0.64 |
| 4 | RBC (million/cumm) | 6.80±0.21 |
| 5 | Platelets(L) | 3.05±0.27 |
| 6 | Neutrophils($10^3$) | 4.03±0.43 |
| 7 | Lymphocyte ($10^3$) | 4.84±0.39 |
| 8 | Monocyte($10^3$) | 0.12±0.04 |
| 9 | Eosinophils | 0.24±0.05 |
| 10 | Grannulocyte($10^3$) | 4.23±0.47 |

*Physical findings*: Overall physical findings hoof lameness revealed interdigital arthritis (14 cases) characterized by the fetlock swelling, walking narrow, camping forward and crossing either fore or hind feet followed by overgrown hoof (9 cases) like corkscrew scissor hoof; white line disease (8 cases) and foot rot (5 cases). Smallholder dairy farms predominantly tethered their animals, either within sheds, yards, or under trees, particularly during daytime hours and housed during night (Patoliya *et al.* 2024).

*Hematological findings*: There was significant ($p<0.05$) decrease in average values of Hb (9.04±0.31), PCV (31.03±0.95%) and TEC (6.80±0.21) recorded among animals suffering from various hoof disorders in present study (Table 4). Few cases in present study were recovering from lumpy skin disease showed neutropenia (4.03±0.43). Crossbred dairy cattle with claws disorders showed significant increase in neutrophils count and decrease in Hb, PCV, TEC and lymphocyte count (Dongra *et al.* 2020).

*Radiological findings*: Cases with chronic arthritis showed periosteal reactions on phalanges (Fig.1), radiolucency of bone marrow has been widened could be due to osteomyelitis. In another case there was a significant alteration in bone density of third phalanx, chip like fragment was noticed in second phalanx and one case there was deviation of second and third phalanx. Radiographically, hoof disorders characterized by osteomyelitis, exostosis, bone deformity, changes in bone density, soft tissue calcification, arthritis, degenerative joint diseases and rotation of phalanges (Parizi and Shakeri, 2007).

*Lameness score findings*: Four animals showed camping forward and walking narrow (score-1) followed by 11 cases (score-2) showed knuckling of the fetlock. In 18 cases, heel horn showed eroded and changes in the distribution of weight bearing result in overgrowth hoof (score-3).

In another three cases, heel erosions were present in the lateral claws of hind legs; leading to shifting of weight


Fig. 1. Significant change in the bone density of P3 bone (A); change in radiolucency indicative of Osteomyelitis (B); the periosteal reaction of Plalanx-1 and Plalanx-2 bone (C) and change/ deviation in the angle of P2 and P3 in relation to hoof digit angle (D).

Babu *et al.* 2018). Hoof pathologies in dairy cows can be demonstrated via IRT (Svejdova *et al.* 2013 and Alsaaod *et al.* 2014).

*Influence of forelimb hoof lameness on hoof skin temperature*: There were significant changes (p<0.01) in laminitic and healthy hoof in the present study and have been depicted in Table 8.

Hoof skin temperature could represent the status of the blood flow and metabolism rate of underlying tissues may prove useful for early detection of laminitis, sole ulcers, underlying various inflammatory conditions, etc. The 38 dairy cows affected by foot diseases showed higher foot temperature values compared to healthy cows (p<0.05) to medial claws gives typical appearance like cow hock stance (Score-4 and Table 5). The most effective method for identifying lameness in animals was inspecting the walking gait of the animal (Flower and Weary, 2006) and it required at least a week interval to ascertain the difference in the locomotion of the animal (Alawneh *et al.* 2012). In our study, cattle with phalangeal arthritis showed highest average lameness score of 3.25 might be the due to periosteal reaction on bone surface or change in bone density (Parizi and Shakeri, 2007).

*Breed wise hoof skin temperature of affected and healthy hoof*: Significant difference was observed both in affected and healthy hooves between Deoni vs. Red Kandhari (P < 0.001) and Non-descript vs. Cross breeds (P < 0.001). It was observed that the mean difference between affected and healthy hoof temperature of Deoni, Red Kandhari and crossbreeds were different, indicating existence of breed and species difference in thermographic profile (Table 6). The lower body temperature in Deoni could be attributed to the fact that Deoni and Red Kandhari cattle have higher thermoregulatory capability than crossbred. *Bos indicus* cattle produces less heat, have increased capacity to lose heat into the environment or due to contribution of both mechanisms. Further, it was suggested that properties of hair coat (light colour) in zebu cattle increase the conductive and convective heat loss and minimize the absorption of solar radiation (Hansen, 2004). Lower metabolic rate, body size, reduced growth rate and low to medium milk yield may contribute for better thermoregulatory mechanism in *Bos indicus cows* than *Bos taurus* (Finch,1985).

*Influence of ambient temperature on healthy and affected hoof skin surface temperature*: Out of 36, 32 cases were suffering with unilateral lameness (either forelimb or hindlimb) and the average mean values of skin surface temperature in healthy and affected hooves were 28.54±0.45°C and 30.46±0.57°C, respectively with difference of 1.92°C. In our study, the ambient temperature was not affected on the thermal images of skin surface of hoof in both healthy and affected hoof (Fig. 2). Maximum temperature of infected hooves was unaffected by ambient temperature (*P* > 0.05), whereas the temperature of healthy hooves was associated with ambient temperature (Byrne *et al.* 2018). The maximum temperature of affected hoof was significantly higher than that of non-affected hoof even in hot environments, suggests that IRT could be used as a hoof lesion detecting tool under subtropical climate conditions (Chiu and Hsu, 2022).

Table 5. Average lameness score of animals affected with different hoof affections

| Sr.No | Hoof affections | Lameness score | | | | | Total No. ofAnimals | Average lameness score |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | |
| 1 | Arthritis | 1 | 3 | 8 | 1 | - | 13 | 3.25 |
| 2 | Overgrown hoof | 1 | 4 | 5 | 1 | - | 11 | 2.75 |
| 3 | White line disease | 1 | 3 | 3 | 1 | - | 8 | 2 |
| 4 | Foot rot | 1 | 1 | 1 | 1 | - | 4 | 1 |

Table 6. The average mean (±SE) values of skin surface temperature recorded in Deoni/Red Kandhari/Non-Descript and Cross Bred jersey cattle in present study

| Anatomical area of Hoof | Deoni (n=22) | | Red Kandhari (n=9) | | Non-Descript (n=2) | | Cross-bred Jersey (n=3) | |
|---|---|---|---|---|---|---|---|---|
| | Affected Hoof | Healthy Hoof | Affected Hoof | Healthy Hoof | Affected Hoof | Healthy Hoof | Affected Hoof | Healthy Hoof |
| Heel bulb | 30.84±0.48 | 27.80±0.40 | 33.06±0.39 | 28.84±0.42 | 31.2±0.04 | 28.25±0.43 | 31.2±0.04 | 30.1±0.51 |
| Interdigital Claw | 34.05±0.31 | 29.83±0.36 | 33.33±0.44 | 30.31±0.44 | 32.85±0.17 | 29.5±0.32 | 32.85±0.17 | 30.06±0.49 |
| Medial claw | 30.90±0.53 | 29.37±0.44 | 32.47±0.57 | 29.44±0.47 | 31.4±0.77 | 28.6±0.70 | 31.83±0.74 | 28.6±0.70 |
| Lateral Claw | 30.8±0.48 | 29.28±0.44 | 33.5±0.55 | 28.44±0.36 | 31.75±0.78 | 28.9±0.65 | 31.46±0.68 | 28.9±0.65 |
| Sole | 29.69±0.34 | 28.08±0.28 | 29.52±0.43 | 27.08±0.39 | 27.95±0.27 | 26.95±0.27 | 28.26±0.28 | 26.95±0.27 |
| White Line | 28.21±0.38 | 27.11±0.42 | 28.38±0.61 | 26.91±0.38 | 26.65±0.10 | 26.95±0.43 | 27.76±0.27 | 26.95±0.43 |
| Axial wall | 27.22±0.36 | 26.77±0.38 | 28.07±0.55 | 26.97±0.40 | 27.25±0.29 | 26.95±0.31 | 26.9±0.18 | 26.95±0.31 |
| Abaxial Wall | 27.55±0.34 | 27.15±0.40 | 28.3±0.55 | 26.64±0.32 | 27.55±0.31 | 26.65±0.36 | 26.63±0.15 | 26.7±0.28 |
| Fetlock | 34.12±0.30 | 31.05±0.32 | 34.38±0.28 | 30.9±0.20 | 30.05±0.03 | 30.2±0.35 | 31.66±0.57 | 31.45±0.05 |

*Influence of hind limb lameness on hoof skin temperature*: Among 36 cases, 25 cases of hindlimb hoof (either right or left hind limb) lameness showed varying degree of pain at hoof skin area on deep palpation and showed average values of surface temperature of fetlock, interdigital claws and medial claws of affected hindlimb and Table 7 and Fig. 3 a and Fig.3 b). When a hoof has lesions, the affected limb shows an increase in surface temperature (Lokesh

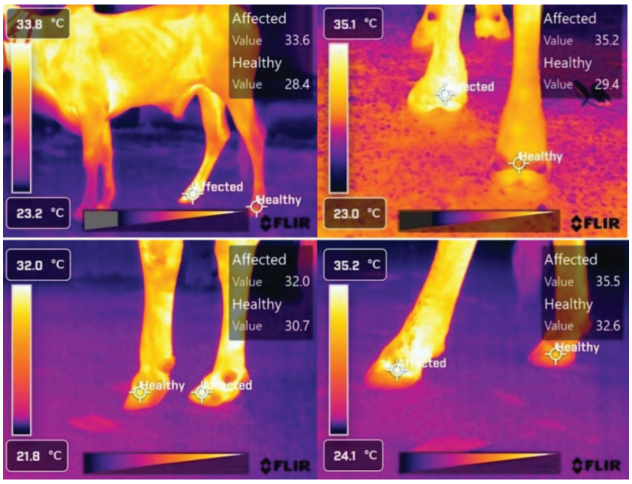


Fig. 2. Thermographic images of A) Left hind hoof (*Arthritis*), B) Right hoof (*WLD*); C) Right hind hoof (*Arthritis*) and D) Left hind hoof (foot rot) showing the skin surface temperature of affected forelimb hoof

Table 7. The mean average (±SE) values of skin surface temperature (ºC) of hind limb hoof (either right or left) and its associated structure in cattle (n=25)

| Anatomical area of Hoof | Affected Hoof (ºC) | Healthy Hoof (Contra lateral limb) (ºC) | t-value |
|---|---|---|---|
| Heel bulb | 30.97±0.49 | 27.93±0.32 | 8.35** |
| Interdigital Claw | 32.84±0.46 | 29.80±0.33 | 6.86** |
| Medial Claw | 30.62±0.49 | 28.57±0.42 | 8.07** |
| Lateral Claw | 31.10±0.51 | 28.42±0.38 | 8.42** |
| Sole | 29.11±0.35 | 27.30±0.31 | 8.38** |
| White Line | 27.92±0.37 | 26.67±0.27 | 5.92** |
| Axial Wall | 27.35±0.34 | 26.53±0.27 | 4.82** |
| Abaxial Wall | 27.58±0.36 | 26.77±0.27 | 3.82** |
| Fetlock | 33.69±0.35 | 30.63±0.18 | 10.77** |

Note: **Highly significant difference ($p<0.01$) between two means).

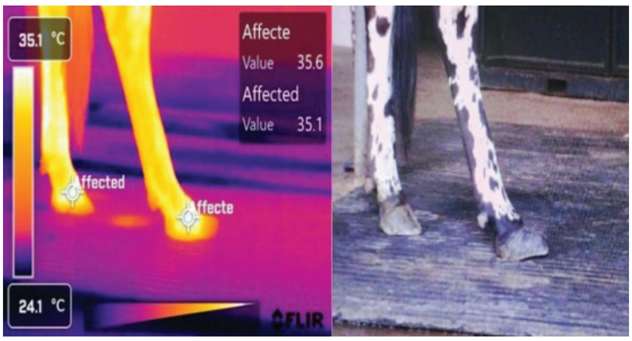


Fig. 3 a) Visual image and infrared thermogram of bilateral hoof hindlimb lameness due to overgrown hoof in cattle showing higher skin surface temperature of both hoof and associated area.

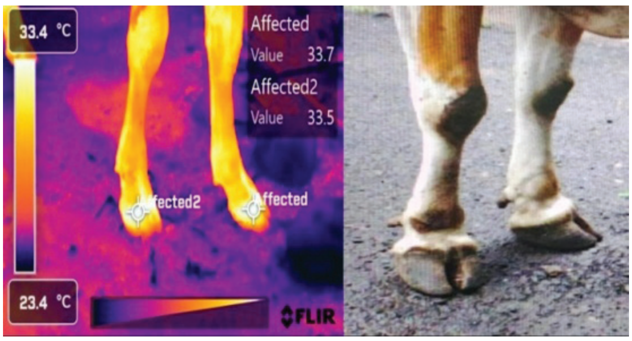


Fig. 3 b) Visual image and infrared thermogram of bilateral hoof hindlimb lameness due to white line disease in cattle showing higher skin surface temperature of both hoof and associated area.

Table 8. The mean average (±SE) values of skin surface temperature (ºC) of forelimb hoof (either right fore or left fore) and its associated structure in cattle (n=7)

| Anatomical area of Hoof | Affected Hoof (ºC) | Healthy Hoof (Contra lateral limb) (ºC) | t-value |
|---|---|---|---|
| Heel bulb | 31.31±0.49 | 27.97±0.44 | 3.94** |
| Interdigital Claw | 34.24±0.34 | 29.07±0.35 | 4.47** |
| Medial Claw | 34.14±0.36 | 30.41±0.25 | 10.23** |
| Lateral Claw | 33.45±0.34 | 30.22±0.33 | 6.28** |
| Sole | 30.61±0.36 | 28.58±0.32 | 3.79** |
| White Line | 27.88±0.43 | 26.78±0.35 | 3.10** |
| Axial Wall | 27.42±0.49 | 26.61±0.40 | 2.51** |
| Abaxial Wall | 27.88±0.37 | 26.95±0.43 | 3.13** |
| Fetlock | 34.17±0.37 | 30.8±0.35 | 4.27 |

in all considered regions (Gianessella *et al.* 2018). Our clinical study highlighted the potential application of IRT as a reliable, practical tool for detection of hoof lesions in dairy cows. The maximum temperature of affected hoof was significantly higher than that of non-affected hoof even in hot environments (Chiu and Hsu, 2022).

The white and red colors of the scale represent the highest and lowest surface temperature, respectively. In the present study, the prevalence of hindlimb hoof lameness in cattle was higher include digital arthritis followed by overgrown hoof, white line disease and foot rot due to faulty managemental practices such as imbalanced nutrition, hard and slippery floor and unhygienic hoof. It was found that, there was higher mean temperature difference was observed in affected hooves than healthy hooves detected via infrared thermal technique would serve as a potential non-invasive diagnostic/screening tool for monitoring hoof health.

In conclusion, thermographic sketch of affected hoof detected via IRT device might be a potential indicator for early forecasting of hoof disorders in precise manner to determine hoof health in dairy cattle and contribute in economic losses of dairy farmers or entrepreneur.

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