Original Article

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EARLY PREDICTION OF NEONATAL CALF DIARRHOEA IN MURRAH BUFFALO THROUGH DAILY INFRARED TEMPERATURE MONITORING

Selvaraj Ragulraj[1], Mukesh Bhakat[2,*], Tushar Kumar Mohanty[2], Sanjit Maity[2], Goutham Mondal[2], Surender Lathwal[6], Abhijeet Fernandes[1], Palaniyappan Balasubramaniam Nandhini[1] and Rohit Kumar[2]

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ABSTRACT

The present study aimed for an early prediction of Neonatal calf diarrhoea (NCD) based on Infrared thermography (IRT) measured orbital temperature, in the naturally occurring NCD under organized farm conditions. Twenty, day-old Murrah buffalo calves were monitored for orbital temperature by IRT and rectal temperature by clinical thermometer consecutively for 30 days. Significant ($P<0.05$) increase in orbital and rectal temperature was recorded one day before, on the day and one day after diarrhoea in case of calves affected with diarrhoea (n=4) as compared to healthy calves (n=16). Significant ($P<0.05$) increase of 0.47°C and 0.70°C in Orbital and 0.92°C and 1.12°C in rectal temperature was recorded on the day of diarrhoea compared to two days before diarrhoea as well as previous seven days average temperature before diarrhoea in affected calves. Significantly ($P<0.05$) higher white blood cells count, lymphocyte and neutrophils percentage, and symptoms of shooting diarrhoea confirmed the NCD cases. IRT scanning of the eye can be a useful tool in early identification of NCD even before the actual clinical signs appear.

Keywords: *Bubalus bubalis*, buffaloes, Neonatal calf diarrhoea, infrared orbital temperature, rectal temperature, Murrah buffalo

INTRODUCTION

Calf survival is critical for dairy herd profitability and germplasm conservation (Sreedhar and Sreenivas, 2015). The calf is the future replacement stock of the dairy herd; therefore, the dairy farm's success depends on the proper management of calves to achieve the least calf mortality (Shakya *et al*., 2017) and optimum growth of calf to attain early sexual maturity. Once calf gets affected with calf hood diseases in the initial stage of life, it has a significant effect on future performance and further economic viability of the dairy farm. Calf mortality varies from 12.5 to 81% under organized farms and field conditions and depends on the day-to-day management of the farm (Tiwari *et al*., 2007; Shakya *et al*., 2017; Patbandha *et al*., 2017; Panmei *et al*., 2016; Sreedhar and Sreenivas, 2015). The percentage of calf mortality would certainly be reduced in efficient day-to-day maintenance and optimum herd health

[1]Indian Council of Agricultural Research, National Dairy Research Institute, Haryana, India
[2]Artificial Breeding Research Center (ABRC), Indian Council of Agricultural Research, National Dairy Research Institute, Haryana, India, *E-mail: bhakat.mukesh@gmail.com

measures. A maximum calf mortality rate of 5% is acceptable with standard management practices. Nevertheless, during the last few decades, one of the major worrisome factors in dairy farms and under field conditions is higher calf mortality. It is well documented that 20% of calf mortality can decrease farm profitability by up to 38 to 40% (Singh *et al*., 2009). One of the major reasons for calf mortality is diarrhoea (Tiwari *et al*., 2007; Shakya *et al*., 2017; Sreedhar and Sreenivas, 2015). The rate of occurrence of calf diarrhoea in buffalo calves (54.37%) was nearly equal to that of cattle calves (52.51%) (Malik *et al*., 2013). In dairy farms, diarrhoea alone causes 80% neonatal calf mortality in cattle (Sreedhar and Sreenivas, 2015) and 82.2% in buffalo (Tiwari *et al*., 2007). Calves are most commonly affected by gastroenteritis in 80% of commercial dairy farms (Balakrishna *et al*., 1996; Tiwari *et al*., 2007; Sreedhar *et al*., 2010; Shrivastava *et al*., 2013; Sreedhar and Sreenivas, 2015). Manjari *et al.* (2015) reported the prevalence of calf diarrhoea in neonatal buffalo calves between 0 and 45 days of age.

Mortality due to diarrhoea in neonatal calves was mainly linked to infectious agents such as *Coronavirus, Rotovirus, Escherchia coli*, species of salmonella and endoparasites (Snodgrass *et al*., 1986). The most common calf diarrhoea symptoms are high body temperature (over 39.5°C), dry muzzle, thick mucus appearing from the nostrils, reluctant to feed, dehydration, weight loss and sometimes death in severe cases (Schroeder *et al*., 2012). Pathogens are responsible for inflammation of the submucosa of the intestine and atrophy of the villous, so the nutrients and fluid cannot be absorbed by the intestinal lining which resulted in severe diarrhoea (Cho and Yoon, 2014).

Infection with the bacteria and virus together during calf diarrhoea causes septicemia and viremia, which is associated with core body temperature increase and emission of infrared rays, which can be captured by an Infrared camera. Infrared photographs taken over one cm around the eyeball region are useful in identifying temperature variations, since lacrimal glands serve as markers for changes in body temperature (Schaefer *et al*., 2007). The increase in temperature of orbital region captured by IRT in case of bovine viral diarrhoea (BVD) (Schaefer *et al*., 2004), bovine respiratory disease complex (BRD) (Schaefer *et al*., 2007; Schaefer *et al*., 2012) and side temperature in case of NCD (Lowe *et al*., 2019) was well documented even before the appearance of actual clinical signs. Conventional scouring or even other biological tests are often incapable of early detection of infection. Some of the pathogens in faeces causing NCD may also found in the healthy calves, further limiting the diagnostic for effective treatment (Abuelo and Alves-Nores 2016). IRT has been successfully used to monitor temperature change in case of mastitis (Polat *et al*., 2010), subclinical mastitis (Porcionato *et al*., 2009), lameness (Alsaaod *et al*., 2014), foot and mouth disease (Gloster *et al*., 2011) and bluetongue disease (Perez de Diego *et al*., 2013). Therefore, IRT may be a promising screening method for early detection of calf diarrhoea based on assessing the increase in temperature of the Orbital region, which is closely associated with rectal temperature (Schaefer *et al*., 2007). Therefore, the present study was designed to identify the neonatal calf diarrhoea in buffaloes using infrared thermography under the natural course of infection encountered in an organized farm.

MATERIALS AND METHODS

Animals care/ Ethical approval

The care and management of neonatal claves during the study period was approved by the Institutional Animal Ethics Committee (IAEC) at ICAR-National Dairy Research Institute (45-IAEC-19-3).

Study location

The buffalo claves maintained in Livestock Research Centre (LRC), ICAR-National Dairy Research Institute (ICAR-NDRI), Karnal, Haryana and the farm located at 29^{o}43" North latitude and 77^{o}20" East longitude with an elevation of 250 meters above the mean sea level. The region's climatic condition is tropical, and the animals face extreme climatic conditions with annual minimum-maximum temperature ranging from 4 to 45^{o}C and rainfall of 70 cm, which is mostly received in July and August.

Infrared thermography camera and Analysis software

In the present experiment, infrared thermal images were captured by a hand-held digital infrared thermal camera (Darvi DTL007 camera, TAK Technologies Pvt. Ltd) having high image resolution (384 x 288 pixels) with a temperature range of -20^{o}C to + 650°C, thermal sensitivity of <20^{o}C with an accuracy of ±2%. The camera was adjusted and calibrated to ambient temperature and humidity before the capture of IRT image. As per the manufacturer's recommendation for biological tissue analysis 0.96 emissivity and 20^{o}C reflected apparent temperature was kept constants for all the images. The unclear thermal images not included in the analysis. Darvi TI analysis software provided with the camera was used to record the surface temperature of each photographic episode. The maximum temperature of the eye, perianal, para lumbar fossa and cheek region of the images was recorded, and the data was used for statistical analysis.

Animals, diet and handling

Calves were kept in individual calf pen for ten days; after that, they were kept in an open paddock in daytime and closed pen in the nighttime. The calf pens were cleaned regularly. The average birth weight of the calves was 29.95±0.98 kg (22 to 35 kg). Calves were fed colostrum two times for five days and then milk feeding (10% of the bodyweight) was done in the morning and evening. In addition to that, green fodder and calf starter with 24% CP and 75% TDN were also provided.

Twenty healthy newborn buffalo calves were selected on the day of birth for the experiment. The calves were monitored for thirty days continuously. Infrared images were captured in various anatomical sites i.e. around the eye, perianal, para lumbar fossa and cheek region every day for thirty consecutive days in the morning from 8.00 to 10.00 A.M. under calf shed during feeding time without disturbing the animal. The infrared images were captured without restraining the animal until the observer was able to capture the image. In case of capturing infrared images of perianal region, calves were restrained properly and images were captured when no sign of struggle was evident. In similar way, the rectal temperature was recorded using clinical thermometer for thirty consecutive days. The infected calves were considered Experimental groups, and healthy animals were considered as Control group besides that same animal's pre-infection data was also considered as control for further analysis. The calf suffering from diarrhoea was confirmed by a veterinarian based on the rectal temperature of 39.5°C or higher, typical shooting diarrhoea (Figure 1) and higher WBC (10^3 /cmm), neutrophils (%) and lymphocytes (%) count (Figure 4). The affected calves were treated immediately after onset of clinical symptoms by qualified veterinarians as per standard procedure until their recovery.

Blood parameters

Blood samples were taken to estimate haematological parameters from the calves that showed calf diarrhoea symptoms and similar representative blood samples were taken from healthy animals. The calves were individually restrained for blood collection. Two to three ml blood was collected using EDTA vacutainer from each animal and immediately subjected to blood profile by using automatic blood analyser (Nihon kodhencelltaca, Tokoyo, Japan).

Statistical analysis

Statistical analysis was performed by using the SPSS 20.0 software (IBM Corporation, Armonk, New York, USA). The data of orbital, perianal, para lumbar fossa and cheek region temperature, rectal temperature and blood profile of healthy calves and calves affected with diarrhoea were analysed using independent t-test. In case of calves affected with diarrhoea temperature data of perianal, para lumbar fossa, cheek and rectum on the day of diarrhoea, two days before and previous seven days were used, and the average was analysed using independent t-test.

RESULTS AND DISCUSSIONS

The calves affected with diarrhoea on the day were taken as 0 day and the previous five days and after five days, data was taken for further analysis. The corresponding day's data of healthy calves were taken as control. The results of orbital temperature (°C) and rectal temperature (°C) of 5 days before and 5 days after diarrhoea between healthy calves and calves affected with diarrhoea have been presented in Table 1. Orbital and rectal temperature was significantly ($P<0.05$) higher, one day before (0.66°C and 0.45°C), on the day (0.55°C and 0.91°C) and one day after (0.45°C and 0.57°C) diarrhea in case of calves affected with diarrhoea compared to healthy calves. No significant change in orbital and rectal temperature was observed on other days. Significant ($P<0.05$) increase in orbital (0.47°C and 0.70°C) and rectal temperature (0.92°C and 1.12°C) was recorded on the day of diarrhoea in comparison to the temperature recorded two days before diarrhoea and seven days average temperature before diarrhoea in affected calves (Figure 2).

The temperature (°C) of perianal, para lumbar fossa and cheek of 5 days before and 5 days after diarrhoea between healthy calves and calves affected with diarrhoea has been presented in Table 2. The subtle change in the perianal, para lumbar fossa and cheek temperature (°C) was observed one day before (0.29°C, 0.22°C and 0.08°C), on the day (0.20°C, 0.32°C and 0.11°C) and one day after (0.03°C,0.04°C and 0.03°C) diarrhoea in case of calves affected with diarrhoea compared to healthy calves. No significant difference was observed in temperature (°C) of perianal, para lumbar fossa and cheek between diarrhoea and healthy calves. An increase in temperature of perianal (0.16 and 0.12), para lumbar fossa (0.75°C and 0.05°C) and cheek (0.14°C and 0.28°C) was recorded on the day of diarrhoea in comparison to the temperature recorded two days before diarrhoea and seven days average temperature before diarrhoea in affected calves (Figure 3).

The WBC (10^3 /cmm), neutrophils (%) and lymphocytes (%) count was 24.54±3.53, 49.75±3.15, 57.95±2.88 and 11.78±1.32, 32.88±5.29, 50.30±2.73 in diarrheic calves and healthy calves, respectively. The WBC, neutrophils and lymphocytes were significantly ($P<0.05$) higher in diarrheic calves compared to healthy calves (Figure 4).

Huge calf mortality due to NCD is a real challenge for both organised farm and under field conditions. Meganck *et al.* (2015) reported that worldwide in the front of the dairy and beef industry, NCD incidence rate is alarming. The economic loss in the case of NCD related to calf mortality and the associated loss in the long run in terms of calf growth and production is enormous. In the case of NCD, when the animal exhibits clinical signs, the internal damage to the digestive system and immune function has already been done; therefore, measures need to be developed to identify NCD at an early stage. Early detection of calf diarrhoea or any other disease condition using IRT, where surface and body temperature increase is one of the major phenomena, can help in deciding timely start of the targeted treatment; reduce the use of antibiotics, timely isolation of the animal, prevent spread of infection, decrease animal suffering and improve the welfare of the animal. In the early identification of Bovine respiratory disease (BRD) complex, revaccination can also be a possibility stated by Schaefer *et al.* (2007). Early disease diagnosis helps the dairy farmer in quick decision making and reduces the economic loss associated with veterinary treatment, death and labour. Till now, researchers have used infrared thermography as an early indicator to understand the change in temperature of various anatomical sites in case of bovine viral diarrhoea (Schaefer *et al.*, 2004) and NCD (Lowe *et al.*, 2019) in case of calves using infection induction model under controlled condition. The applicability of such induced models in case of early identification of naturally occurring similar infection under field conditions is still debatable. Therefore, the present study was planned to use IRT as an early indicator to predict neonatal calf diarrhoea in naturally occurring infection.

The change in the orbital temperature of an individual animal was mimicking the change in rectal temperature pattern, supported by the findings of Schaefer *et al.* (2004 and 2007) and reported that eye temperature is closely associated with rectal temperature in dairy animals. The lacrimal glands act as markers for change of body temperature as eyeball areas have more blood vessels and innervations (Schaefer *et al.*, 2007). Maximum temperature of orbital area was considered in the present investigation, which is supported by the observation of Lowe *et al.* (2020) who reported that image analyzed manually by software provided by manufacturer and auto analysis based on the algorithm for a maximum temperature of the designated orbital area showed close agreement. The normal physiological range of the orbital and rectal temperature recorded in neonatal healthy buffalo calves during the study period was 34.5 to 36.5°C and 37.5°C to 39.5°C, respectively. The overall higher orbital temperature in diarrheic calves compared to healthy calves was supported by the observation of Schaefer *et al.* (2012). They also reported an overall average (3-week period) higher orbital temperature in case of BRD true positive (TP) cases compared to true negative (TN) cases. Similar to our observation regarding peak orbital temperature of diarrheic calves, Schaefer *et al.* (2012) also recorded a significantly higher peak thermal response for the BRD TP cases compared to TN cases. The increase in temperature on the day of calf diarrhoea was also reported by various authors (Schaefer *et al*., 2004; Snodgrass *et al*., 1986; Mansoor *et al*., 2018). Calf diarrhoea occurs mostly due to infection with bacteria, viruses, and parasites (Mansoor *et al*., 2018). Infection with the bacteria and virus was associated with septicemia and viremia, which could be a possible reason for an increase in orbital and rectal temperature.

In the present experiment, out of twenty calves, four calves were affected with diarrhoea within one month after birth, with calf diarrhoea incidence rate of 20%, which was less compared to the calf diarrhoea incidence reported by various authors (79.50%, Ahmed *et al*., 2009; 73.41%, Shivarudrappa *et al*., 2013; 78.9%, Asmare and Kiros, 2016; 81.25%, Shakya *et al*., 2017 and 75%, Mansoor *et al*., 2018) might be due to management differences involved in rearing the calves.

An increase in the temperature of orbital, perianal, para lumbar fossa and cheek assessed by IRT and rectal temperature assessed by a clinical thermometer in calves was recorded around days of diarrhoea. In a similar line, Schaefer *et al.* (2004) observed an increase in orbital, ear, nose, dorsal and side temperature in calves affected with bovine viral diarrhoea. Similarly, Schaefer *et al.* (2007) also reported an increase in temperature of various anatomical locations in the case of calves affected with "bovine respiratory disease complex". On the contrary, the non-significant eye temperature change in the case of induced neonatal calf diarrhoea (NCD) was reported by Lowe *et al.* (2019). The significant increase in IRT side temperature and decreased shoulder temperature was recorded even before the disease's clinical identification (Lowe *et al*., 2019). Schaefer *et al.* (2004) documented that the different anatomical locations of calf regarding temperature change differ with disease conditions. Lowe *et al.* (2019) explained the temperature change of various anatomical location might act as an indicator for specific conditions as the change in temperature of extremities was reported to be a better indicator of feeding efficiency (Montanholi *et al*., 2010; Martello *et al*., 2016), whereas Lowe *et al.* (2019) found temperature change of core body area was useful indicators of NCD. The Inconsistencies in results may be associated with organisms involved in calf diarrhoea, their pathogenesis pattern and difference in anatomical location as well as variation in environmental conditions (temperature and humidity) in which the study was conducted.

In the present study it has been observed that IRT was able to detect increase in orbital temperature two days before the actual clinical sign appearance of diarrhoea. An increase in 0.47°C orbital and 0.92°C rectal temperature was recorded on the day of diarrhoea in comparison to the temperature recorded two days before diarrhoea in diarrheic calves. The results corroborate with findings of Schaefer *et al.* (2004), who documented that less than 1°C temperature change was clinically significant. In a similar line, Schaefer *et al.* (2012) reported more than 1°C increase in orbital temperature in case BRD TP cases compared to TN cases. Lowe *et al.* (2019) reported NCD could be predicted significantly ($P<0.001$) even before the appearance of clinical signs in case of a change in <0.3°C IRT temperature. Similar to our results, Schaefer *et al.* (2004) reported that the orbital temperature measured by IRT was more effective in detecting bovine viral diarrhoea where temperature change occurred as early as one day in case of eye (2.6°C or 0.26°C per day) compared to 5 to 6 days for other areas such as the ear (3.9°Cor 0.4°C per day), nose (3.5°C or 0.35°C per day), dorsal (1.8°C or 0.18°C per day) and side (1.9°C or

0.19°C per day).

In contrast, clinical signs appeared 8 to 9 days after BVDV inoculation. The temperature change was more stable in the eye than in other anatomical areas (Schaefer *et al*., 2004). Similarly, Schaefer *et al.* (2007) detected bovine respiratory disease complex 4 to 6 days earlier than the onset of clinical symptoms using infrared thermography. Similar to the present findings, researchers identified the onset of diseases by monitoring temperature change using infrared thermography (Schaefer *et al*., 2004; Schaefer *et al*., 2007; Schaefer *et al*., 2012; Polat *et al*., 2010; Hovinen *et al*., 2009; Rainwater-Lovett *et al*., 2009). Schaefer *et al.* (2007) showed that infrared values were as good as or even more efficient than clinical ratings, core temperatures, or hematology in detecting diseased animals before BRD's clinical presentation. HPA axis activity is the first physiological response in case of disease or distress condition, and it is not efficient for energy use, so 40 to 60% energy is mostly lost as heat within the infrared range (Schaefer *et al*., 2004). Considering that up to 60% of an animal's heat loss occurred within the infrared spectrum, the finding of radiated heat loss acted as an early predictor of fever. Similar to the present study regarding an increase in temperature of the para lumbar fossa, Lowe *et al.* (2019) reported early detection of neonatal calf diarrhoea (NCD) based on a significant ($P<0.001$) increase inside temperature (0.27°C) using IRT.

Similarly, an increase inside temperature was also reported by Schaefer *et al.* (2004) in the case of BVD. The temperature change in the para lumbar fossa area may be, the site of infection is closer to the area as it is situated over rumen fossa and the occurrence of inflammation in the intestines. A combination of IRT temperature with feeding and drinking behaviour further can improve the prediction of diseases in calves (Lowe *et al*., 2020).

Higher WBC, neutrophils and lymphocytes count in diarrhoea were also reported by various researchers (Malik *et al*., 2013; Schaefer *et al*., 2007). The increase might be associated with the infection and toxins produced by the micro-organism during diarrhoea, leading to stress and inflammatory changes and as a defensive mechanism increase in WBC, neutrophils and lymphocytes count were observed (Mansoor *et al*., 2018).

The disease prediction using such temperature data generated in the present study can be made in several ways, as stated by Schaefer *et al.* (2004). In the present study, the disease was predicted based on the temperature difference of a particular anatomical site of the affected animal from its own two days before and seven days average before the onset of temperature increase and unaffected control animal. Such models for early prediction of the disease have also been reported in Angus-Hereford cross heifers (Schaefer *et al*., 2004). The better approach is developing individual animal-specific thresholds to declare the animal healthy so that any deviation from the threshold would be the sign of an early indicator of disease (Lowe *et al*., 2020). The results depicted a significant increase in eye and rectal temperature in affected animals from its pre-infection temperature and the unaffected control animals of the same breed. Cook *et al.* (2002) reported that even though IRT's sensitivity is higher, the precise use of IRT for early detection of diseases is less. Standard clinical scores as an indicator of infection sometimes showed inconsistency (Wittum *et al*., 1996). The exciting fact besides non-invasiveness that IRT can provide real-time information contrasts to confirmatory laboratory-

Table 1. Mean ± S.E of Orbital temperature (°C) and rectal temperature (°C) of 5 days before and 5 days after diarrhoea between healthy calves (n=16) and calves affected with diarrhoea (n=4).

Days	Orbital temperature (°C)		Rectal temperature (°C)	
	Healthy	Calf diarrhoea	Healthy	Calf diarrhea
-5 day	35.73±0.18	35.48±0.25	38.75±0.14	38.30±0.18
-4 day	35.95±0.10	36.15±0.42	38.82±0.08	38.95±0.35
-3 day	36.02±0.10	36.00±0.16	38.91±0.07	38.83±0.17
-2 day	36.04±0.13	35.98±0.05	38.94±0.12	38.73±0.09
-1 day	35.69^{A}±0.19	36.35^{B}±0.15	38.55^{a}±0.15	39.00^{b}±0.10
0 day	35.90^{A}±0.14	36.45^{B}±0.06	38.74^{A}±0.11	39.65^{B}±0.03
1 day	36.00^{a}±0.12	36.45^{b}±0.06	38.78^{a}±0.11	39.35^{b}±0.09
2 day	36.02±0.12	36.08±0.16	38.70±0.10	38.78±0.10
3 day	35.96±0.13	36.00±0.39	38.78±0.10	38.63±0.21
4 day	35.97±0.14	36.10±0.20	38.88±0.10	38.85±0.15
5 day	36.03±0.13	35.83±0.28	38.78±0.11	38.60±0.19

Means bearing different superscripts within a row differ significantly ^{AB}(P<0.01); ^{ab}(P<0.05).

Table 2. Mean ± S.E of Perianal, Para lumbar fossa and cheek temperature (°C) of 5 days before and 5 days after diarrhoea between healthy calves (n=16) and calves affected with diarrhoea (n=4).

Days	Perianal temperature (°C)		Para lumbar fossa temperature (°C)		Cheek temperature (°C)	
	Healthy	Calf diarrhoea	Healthy	Calf diarrhoea	Healthy	Calf diarrhoea
-5 day	37.42±0.43	37.52±0.15	34.28±0.83	34.56±0.18	33.80±0.92	33.51±0.34
-4 day	37.56±0.55	37.64±0.21	34.48±0.80	34.32±0.24	33.93±0.81	33.12±0.16
-3 day	36.80±0.48	37.21±0.14	34.75±0.81	34.20±0.31	34.25±0.65	33.84±0.19
-2 day	37.12±0.83	37.28±0.18	33.98±0.94	33.51±0.16	33.60±0.74	34.00±0.05
-1 day	37.16±0.28	37.45±0.12	34.23±0.80	34.45±0.12	33.33±0.71	33.41±0.16
0 day	36.92±0.24	37.12±0.08	33.93±0.68	34.25±0.34	33.75±0.70	33.86±0.24
1 day	37.45±0.66	37.48±0.12	34.08±0.92	34.12±0.23	33.38±0.72	33.35±0.35
2 day	37.12±0.38	37.35±0.17	34.85±0.38	34.38±0.16	33.65±0.95	33.58±0.46
3 day	36.70±0.76	37.45±0.14	34.53±0.71	34.13±0.23	33.73±0.26	33.46±0.21
4 day	37.81±0.22	37.86±0.07	34.53±0.55	34.17±0.12	33.65±0.64	33.32±0.34
5 day	37.25±0.42	37.45±0.21	34.12±0.61	33.98±0.34	34.48±0.21	33.98±0.18

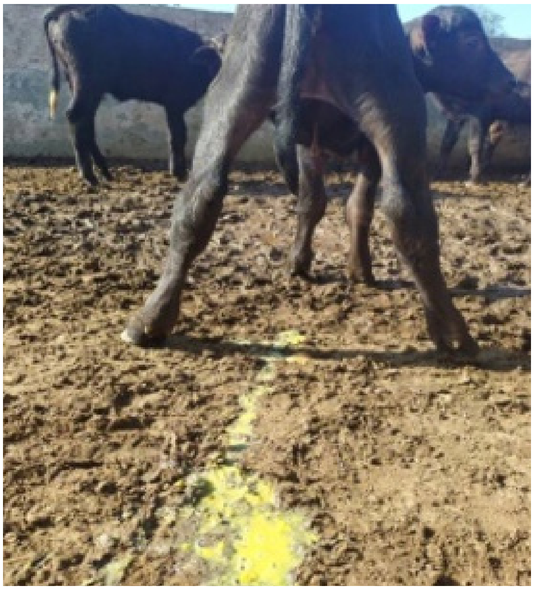

Figure 1. Calf affected with diarrhoea.

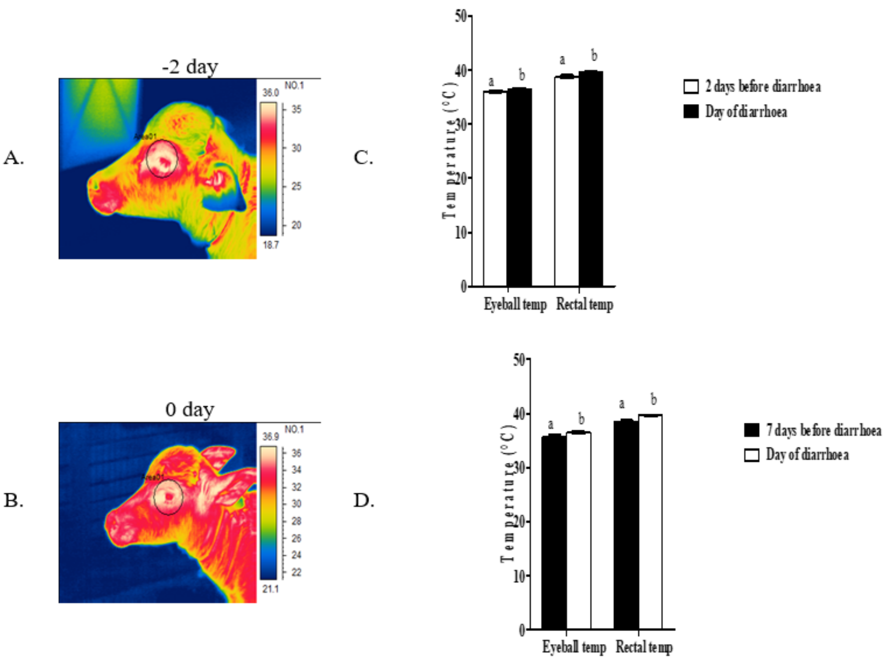

Figure 2. The figure represents A. IRT image of Orbital temperature of calf 2 days before infection; B. IRT image of Orbital temperature on the day of diarrhoea; C. Eye ball and rectal temperature (°C) of two days before and on the day of diarrhoea D. Eye ball and rectal temperature (°C) of seven days average before diarrhoea and on the day in diarrhoea affected calves, Bars with different superscripts differ significantly [ab](P<0.05).

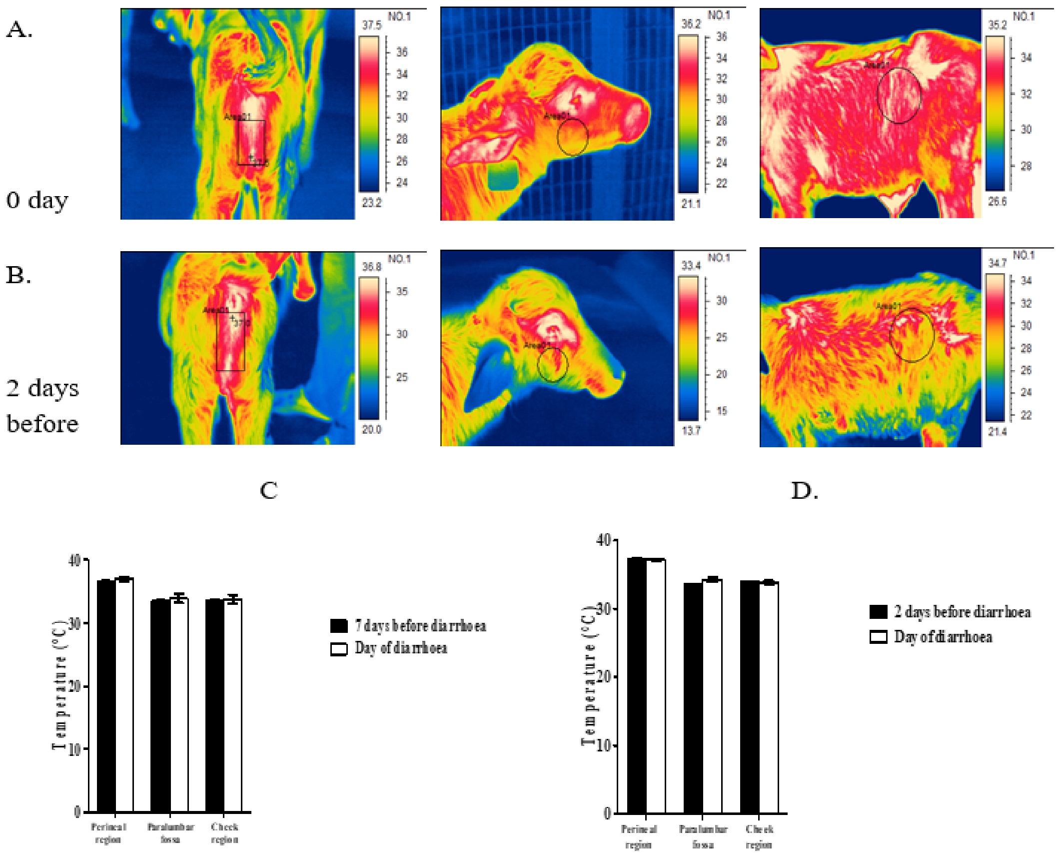

Figure 3. The figure represents A. IRT image of perianal, cheek and para lumbar fossa on the day of diarrhoea; B. IRT image of perianal, cheek and para lumbar fossa 2 days before diarrhoea C. Perianal, cheek and Para lumbar fossa temperature (°C) of two days before and on the day of diarrhoea D. Perianal, cheek and Para lumbar fossa temperature (°C) of seven days average before diarrhoea and on the day in diarrhoea affected calves.

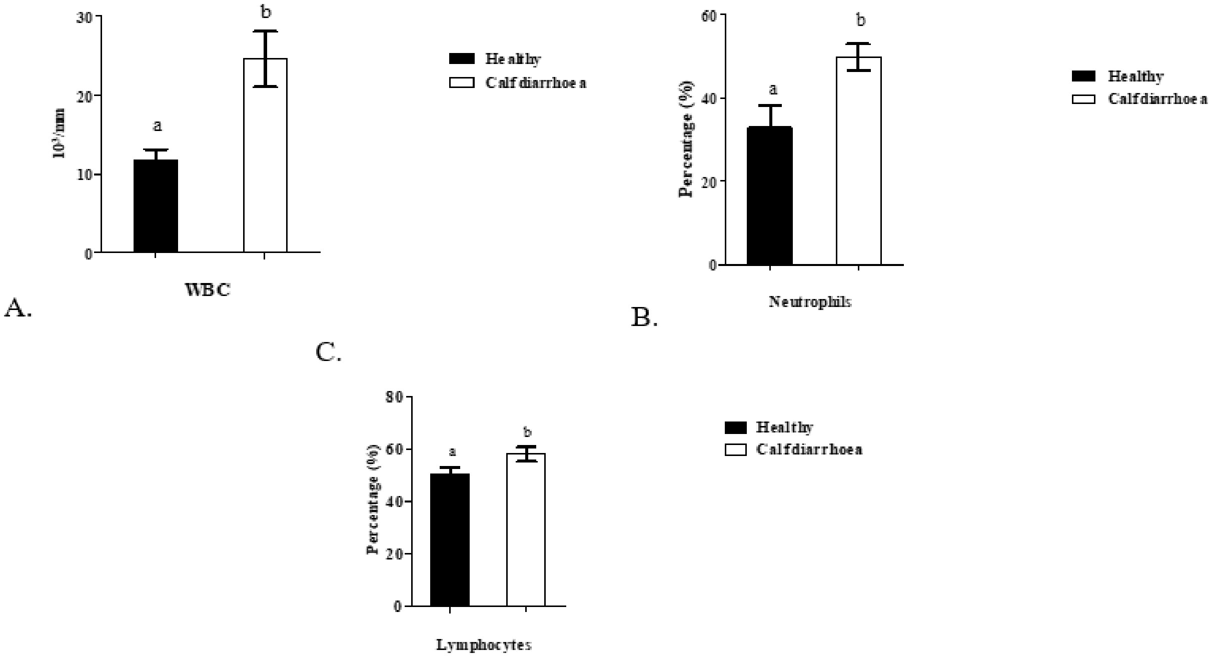

Figure 4. The fig depicts A. WBC (10^3 /cmm) count; B. Neutrophils (%) and C. Lymphocytes (%) of healthy calves and calves affected with diarrhoea Bars with different superscripts differs significantly ^{ab}(P<0.05).

based disease diagnosis (Schaefer *et al*., 2007). The added advantage of non-contact IRT in comparison to invasive monitoring of core body temperature and laboratory diagnostics was demonstrated in the study of Schaefer *et al.* (2007) that individual identification of the calves by RFID and auto capturing of IRT image during water drinking is more effective. Therefore, the IRT monitoring of orbital temperature in case of temperature change related to calf health can be used as a supportive tool in routine farm management to enhance the clinical score's efficiency. Better eye temperature efficiency may be due to close association with core body temperature as it is closure to blood flow surface (Cook and Schaefer, 2013). To increase the accuracy level, sex, weight, diurnal variation of temperature, season, clinical score and physiological indicators should also be considered (Cook *et al*., 2002). Further, the capturing infrared data without disturbing the animal's natural behavior, visible under manual handling while capturing IRT image, should be given importance as followed in the study of Schaefer *et al.* (2012), who used RFID enabled IRT scan windows in water trough level. In future, it is a step towards the development of automation to become part of precision farming based on image processing as supported by the recent development of an automated system based monitoring of eye and check the temperature using the algorithm to integrate the IRT image into the system for monitoring health and welfare of the animal (Lowe *et al*., 2020). Integration of IRT in automatic feed station, water station and machine milking system has enormous opportunity.

CONCLUSION

The present study concludes that Infrared thermography is sensitive enough to monitor the increase in ocular temperature two days before onset of the clinical sign of calf diarrhoea in Murrah buffalo. In the future, study a large data set is required to develop a cutoff value for the individual animal to declare whether the animal is healthy or not. The noninvasive, easy and efficient nature of the technology compared to time-consuming and skill-oriented laboratory-based disease diagnosis further emphasizes the worth of using IRT in routine farm operations. Further, the mobile based application using IRT can open a whole new dimension for efficient use of technology by the end-users at an affordable price in time to come.

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