Small Ruminant Research 144 (2016) 135–139

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Real-time monitoring of peripheral body temperature using non-invasive, self-powered, sensor based radio-frequency device in goats (*capra hircus*)

Tridib Debnath[a,b], Santanu Bera[b], Suman Deb[c], Prasenjit Pal[d], Nibash Debbarma[a,b], Dhiman Das Choudhury[a], Avijit Haldar[a,*]

[a] *ICAR Research Complex for North Eastern Hill Region, Tripura Centre, Agartala, Lembucherra, 799210, West Tripura, India, India*
[b] *Department of Livestock Production Management, West Bengal University of Animal and Fishery Sciences, 37, K. B. Sarani, Kolkata, 700037, West Bengal, India*
[c] *Computer Science and Engineering Department, National Institute of Technology, Agartala, Tripura, India*
[d] *College of Fisheries, Central Agricultural University, Lembucherra, 799210, West Tripura, India*

ARTICLE INFO

Article history:
Received 2 August 2016
Received in revised form
16 September 2016
Accepted 18 September 2016
Available online 19 September 2016

Keywords:
Radio-frequency device
Thermometer
Body temperature
Goat
Black Bengal

ABSTRACT

The livestock health monitoring programme becomes central not only for preventing outbreak of the animal diseases, but also for ensuring the fitness of the animals that directly affecting the health of the consumers. Thus, the aim of the current study was to validate the real-time rectal temperature (RT) data of radio frequency based digital (RFD) thermometer with RT data of mercury bulb (MB) thermometer by conducting three experiments in Black Bengal goats. In experiment I, six non-pregnant Black Bengal does with a mean (±SEM) body weight of 10.93 ± 1.33 at the age of 2.25 ± 0.11 years were used to record RT for 2 h on empty stomach and 2 h after feeding at 0, 30, 60, 90 and 120 min using RFD thermometer as well as MB thermometer. In experiment II, previously selected six does were further used to record RT for 2 h before exercise and 2 h after exercise at 0, 30, 60, 90 and 120 min. In experiment III, twelve non-pregnant Black Bengal does with mean (±SEM) body weight of 15.83 ± 2.16 kg at the age of 3.61 ± 0.43 years were challenged with lipopolysaccharide (LPS) μg/kg body weight and RT was recorded at 15 min interval for 1 h prior to the administration of LPS at −60, −45, −30, 15 and 0 min (0 being the time of LPS administration) and then every 15 min interval for 5 h post LPS administration up to 300 min. Two way repeated measures analysis of variance (ANOVA) with post hoc comparisons by Bonferroni test depicted that there was no significant difference ($P > 0.05$) between real-time RT data recorded by RFD thermometer as well as MB thermometer before and after feeding/exercise/LPS administration. Both RFD thermometer and MB thermometer recorded increased ($P < 0.05$ or $P < 0.001$) RT due to the effect of feeding/exercise/LPS administration in experimental goats. Hence, the body temperature recordings from RFD thermometer would be acceptable and thus RFD thermometer could be used for monitoring real-time RT in goats.

1. Introduction

An animal health monitoring program to protect animal and human health has become a priority due to the incidence of bovine spongiform encephalopathy (BSE) or mad cow disease in the USA on December 2003 (Mathews et al., 2006). The frequent epidemic outbreaks in domestic animals such as foot and mouth disease (FMD) seriously threaten the national economy in many countries (Joo et al., 2002; McLaws et al., 2009). The outbreak of peste des petits ruminants (PPR), an acute, contagious, febrile, viral and frequently fatal disease of sheep and goats, caused a loss of US $ 7.7 per animal in 2008–2009 in India (Thombare and Sinha, 2009) and a loss of US $ 33 per animal in 2013–14 in Pakistan (Abubakar and Munir, 2014). In a case study of a simulated outbreak of FMD in California, $565 million of additional economic loss was forecast for every hour delay of detection indicating the critical importance of early detection methods, including body temperature monitoring system which could alert farm workers to deal properly and promptly with the situation (Carpenter et al., 2011). The body temperature is an excellent indicator of animal's general health for assessing ani-

* Corresponding author. Present address: ICAR-Agricultural Technology Application Research Institute (ATARI), Indian Council of Agricultural Research, Bhumi Vihar Complex, Block- GB, Sector- III, Salt Lake, Kolkata, 700097, West Bengal, India.
E-mail address: avijit_vet@rediffmail.com (A. Haldar).

http://dx.doi.org/10.1016/j.smallrumres.2016.09.007
0921-4488/

mal stress (Silanikove, 2000; Brown-Brandt et al., 2003), shearing effect (Piccione et al., 2002), warning for illness and diseases (Dalal and Zhukovsky, 2006). Rectal temperature also changes according to different ages in goats (Arfuso et al., 2016). The shifts in body temperature are useful not only for identifying an animal experiencing disease events (Benzaquen et al., 2007), but also identifying an animal with particular physiological conditions like oestrus state (Bewley, 2006), approaching parturition (Bewley and Schutz, 2010) etc.

The rectal temperature (RT) is used to show the body's peripheral temperature. RT is used almost exclusively and most likely because relatively simple, durable, and inexpensive equipment like mercury bulb (MB) thermometer can be used to measure RT with a reasonable degree of accuracy. Dairy farmers and veterinarians use body temperatures, most commonly rectal temperatures, in the detection and management of febrile conditions and changes in different states of animals (oestrus, heat stress and the onset of calving) for many years (Bewley and Schutz, 2010). However, the variation in body temperature requires frequent sampling and thus obtaining data in a continuous manner at farm and field is time and labour intensive and also costly. There is a need for solutions that provide continuous and automatic acquisition of this parameter. The internal temperature may be sampled using surgically implanted integrated transponder tags or skin surface-mounted radio transmitters, data loggers (Suthar et al., 2013; Piccione et al., 2013, 2014) and infrared thermography (Hoffmann et al., 2013; Martello et al., 2016). Considering animal welfare issue, external sensors such as, neck collar, ankle ribbon, accelerometer, pedometer and vibration sensor have been developed (Futagawa et al., 2010). In recent times, the development of Radio Frequency Identification Device (RFID) has opened a new scope for real-time body temperature monitoring in human as well as livestock animals. RFID is a system that wirelessly transmits the identity of an object, in the form of a unique sequence of numbers or letters, using radio waves. Various researchers (Zhang et al., 2004; Sikka et al., 2006; Maselyne et al., 2015) have used wireless, RFID technology to automatically determine the physiological and behavioral activity and to monitor the health condition of an individual animal.

Livestock animals are in a constant demand for supplying livestock products, leading to the need of continuous monitoring of their health to ensure their fitness as it directly affects the health of the consumers. Thus, the objectives of the present study were: (1) to examine whether RT recordings from radio frequency based digital (RFD) thermometer were similar to the recordings of MB thermometer and (2) to investigate the trend of changes in RT recordings from RFD thermometer as well as MB thermometer under different management conditions and endotoxin challenge situation.

2. Materials and methods

2.1. Experimental animals

Three experiments were conducted in female Black Bengal goats to validate real-time RT data of RFD thermometer with RT data of MB thermometer at Livestock Farm of Indian Council of Agricultural Research (ICAR) Complex for North Eastern Hill (NEH) region, Lembucherra; Tripura, India located 12.8 m above mean sea level at a 22°56′N latitude and 90°09′E longitude. The agro-climatic situation is humid, sub-tropical. Fig. 1 shows temperature humidity index (THI) during the experimental period from 17th March to 10th June 2016. THI remained below 60 during the first few days of the experiment and then varied between 70 and 80 indicating that the experimental animals were free from any severe environmental stress.

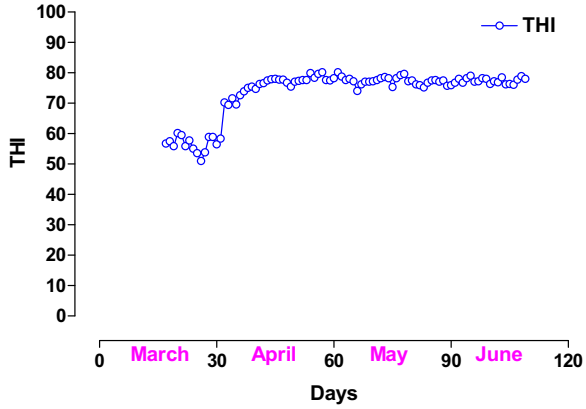

Fig. 1. Temperature Humidity Index (THI) during the experimental period from 17th March to 10th June 2016.

2.2. Farm management

The experimental goats were housed in well-ventilated individual pen with brick flooring and asbestos roofing and maintained in a sheltered paddock under natural daylight and environmental conditions. The experimental sheds were cleaned and washed every day with an antiseptic agent to keep the animals free from infection. They were fed according to the recommendations of the NRC (2007) with an access to green grass/cut green leaves like mulberry leaves, jack fruit leaves and commercially available pelleted concentrate feed. Clean drinking water was made available *ad libitum*. Deworming and vaccination against goat pox and peste des petits ruminants (PPR) were done as per standard schedule.

2.3. Experimental devices

RT was recorded by RFD thermometer as well as MB thermometer. DS18S20 Programmable Resolution1-Wire® Digital Thermometer, Arduino Uno Model was used for real-time monitoring of RT in goats. This RFD thermometer was developed and provided by Computer Science and Engineering Department, National Institute of Technology (NIT), Agartala, Tripura, India. This RFD thermometer provided 9 to 12-bit (configurable) temperature readings which indicated the temperature of the device. It converted 12-bit temperature to digital word in 750 ms (max.). Information was sent to/from the device over a 1-Wire interface, so that only one wire was connected from a central microprocessor to the device. The power of reading, writing, and performing temperature conversions was derived from the data line itself without an external power source. It measured temperatures from −55 °C to +125 °C with an accuracy of 0.5 °C from −10 °C to +85 °C.

2.4. Chemical

Lipopolysaccharide (*E. coli* 055:B5; reconstituted with 0.9% saline solution, Calbiochem, San Diego, CA, USA) was used to elicit body temperature in goats in the present study.

2.5. Experimental design

The experimental protocol and animal care were met in accordance with the National guidelines for care and use of Agricultural Animals in Agricultural Research and Teaching as approved by the Ethical Committee for Animal Experiments (ECAE) of ICAR Research Complex for NEH Region, Barapani, Meghalaya, India.