Computers and Electronics in Agriculture 123 (2016) 10–16

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

Review

Infrared thermography in animal production: An overview

Concepta McManus [a,*], Candice B. Tanure [a], Vanessa Peripolli [a], Luiza Seixas [a], Vivian Fischer [b], Alexandre M. Gabbi [c], Silvio R.O. Menegassi [b], Marcelo T. Stumpf [d], Giovani J. Kolling [b], Eduardo Dias [b], João Batista G. Costa Jr. [e,*]

[a] *University of Brasilia, Faculdade de Agronomia e Medicina Veterinária, DF, Brazil*
[b] *Federal University of Rio Grande do Sul, Departamento de Zootecnia, RS, Brazil*
[c] *Eurotec Nutrition, Santiago do Chile RM, Chile*
[d] *Federal University of Rio Grande, RS, Brazil*
[e] *CNPq/Fundect/Embrapa Beef Cattle, MS, Brazil*

ARTICLE INFO

Article history:
Received 2 November 2015
Received in revised form 21 January 2016
Accepted 24 January 2016
Available online 18 February 2016

Keywords:
Disease
Ectoparasites
Mastitis
Reproduction
Pain
Stress

ABSTRACT

Infrared thermography technology is a noninvasive method that has been used to indicate thermal biometric changes in animal metabolism resulting from increased body temperature and changes in blood flow in response to environmental or physiological conditions. Thus, this technology can be a useful tool and general stress indicator as well as indicate inflammatory processes, pain and disease. Therefore, this manuscript aims to review the use of this technology in animal production, addressing aspects of heat and physiological stress, metabolism, nutrition, inflammatory processes, diseases, ectoparasite detection and reproduction.

Contents

1. Introduction

Invasive methods currently are commonly used to assess physiological and metabolic parameters in production animals (blood collection, rectal temperature, respiratory and heart rate measurements) (Stewart et al., 2008). Such invasive methods can produce unreliable results due to anxiogenic responses resulting from the procedure itself, thus making it difficult to interpret the results (Soerensen and Pedersen, 2015). These invasive methods can also require significant time and resources for determination of parameters.

All objects on Earth generate radiant heat in the infrared part of the electromagnetic spectrum. Bodies with temperatures above absolute zero emit radiation, forming an electromagnetic spectrum

* Corresponding authors.
E-mail addresses: concepta@unb.br (C. McManus), jbzootec@gmail.com (J.B.G. Costa Jr.).

http://dx.doi.org/10.1016/j.compag.2016.01.027
0168-1699/

that can be absorbed by other bodies around them (Roberto et al., 2014). Thus, with the use of digital thermography (thermographic camera), it is possible to detect this kind of radiation detecting even minimal temperature variations (Knížková et al., 2007).

Infrared thermography is a noninvasive remote sensing method used in measuring changes in heat transfer and blood flow, through the detection of small changes in body temperature (Nääs et al., 2014; Roberto et al., 2014). When an animal becomes stressed the hypothalamic–pituitary–adrenocortical axis is activated and heat is produced as a result of increases in catecholamines and cortisol concentration, in addition to blood blow responses, producing changes in heat production and heat loss from the animal (Schaefer et al., 2002). Thus, this technology may be useful as a general indicator of stress.

However, there are some limitations and factors that must be considered when using infrared thermography. Care must be exercised when taking images in sunlight or in high humidity conditions; also with convective heat loss due to wind or when surfaces imaged are dirty. Radiation measures by the camera do not only depend upon the temperature of the object, but is also a function of its emissivity and conductivity (Knížková et al., 2007).

Each region of the animal emits different amounts of infrared radiation. Such temperature variation can be interpreted by different computer generated colour palates. The images obtained allow direct observation of the temperature distribution over a surface (Knížková et al., 2007). Such information assists in the understanding of thermoregulation due to changes in surface temperature and the impact of environmental conditions on animal welfare (Kotrba et al., 2007). These temperatures are digitized and processed by computer and displayed in the form of a thermal map over the animal, which provide a detailed analysis of the temperature profile.

Infrared thermography has numerous applications, not only in industry, but also in human and veterinary medicine, for example in diagnostic purposes (Schaefer et al., 2012; Martins et al., 2013). The great advantage of the method is that physical contact with the monitored surface is not necessary, thus allowing the remote reading of temperature distribution (Speakmen and Ward, 1998).

This overview highlights studies and applications were infrared thermography has been used in animal production systems.

2. Infrared thermography information

Animal surfaces in the papers were measured by infrared thermograph cameras described in Table 1. The emissivity value was stated in only a few papers ranging from 0.98 to 0.86. These included 0.98 (Weschenfelder et al., 2013; Montanholi et al., 2008, 2009; Talukder et al., 2014), 0.97 (Abudabos et al., 2013; Martins et al., 2013), 0.95 (Alsaaod et al., 2014; Paim et al., 2012), 0.93 (Pezeshki et al., 2011) and 0.86 (Ferreira et al., 2011).

3. Heat and physiological stress

The evaluation of the adaptability and tolerance to heat are determined mainly by the physiological parameters measurement such as body temperature and respiratory rate (Costa et al., 2015). However, the animal often needs to be restrained to evaluate these parameters, which can cause stress due to handling (Mazieiro et al., 2012). Thus, thermography arises as a noninvasive and remote sampling tool that can aid in the identification of animal stress.

Thermographic images may indicate changes in the blood flow resulting from increased body temperature related to stressful environmental conditions. Thus, the temperature of the specific animal regions such as eye, neck, muzzle, rib, rump, flank, belly, thigh, shin, udder and foot, obtained with the use of infrared thermography have been used for predicting physiological parameters and stress in farm animals (Fig. 1) (Montanholi et al., 2008; Luzi et al., 2013; Soerensen et al., 2014; Weschenfelder et al., 2014).

Infrared thermography body temperature readings taken from the ocular region of pigs before slaughter showed to be a promising technique to predict the variation of important meat quality traits (Weschenfelder et al., 2013).

Paim et al. (2012) observed that the temperatures obtained by infrared thermograph of the muzzle, neck and rump were good indicators of environmental and thermal comfort conditions of lambs; therefore these points of the animal body were considered preferential to measure the animal thermal situation.

A study comparing the efficacy of the use of the maximum eye temperature, measured by thermography, with salivary cortisol levels to assess stress in horses during competitions suggested that

Table 1
Technical specifications of the infrared thermograph cameras used to collect data.

Author	Model	Infrared resolution (pixels)	Thermal precision	Thermal sensitivity	Minimum focus distance
Menegassi et al. (2015)	FLIR T300	320 × 240	+/−2 °C	<0.05 °C at 30 °C	0.4 m
Cruz Júnior et al. (2015)	FLIR T300	320 × 240	+/−2 °C	<0.05 °C at 30 °C	0.4 m
Cook et al. (2015)	FLIR A320	320 × 240	+/−2 °C	<0.05 °C at 30 °C	0.4 m
Talukder et al. (2014)	FLIR T620	640 × 480	+/−2 °C	<0.05 °C at 30 °C	0.25 m
Alsaaod et al. (2014)	FLUKE Ti25	640 × 480	+/−2 °C	⩽0.09 °C at 30 °C	0.15 m
Simões et al. (2014)	FLUKE Ti9	640 × 480	+/−2 °C	⩽0.09 °C at 30 °C	0.15 m
Soerensen et al. (2014)	FLIR SC660	640 × 480	+/−1 °C	<30 mK at 30 °C	0.2 m
Paim et al. (2012), Martins et al. (2013)	FLIR i3	60 × 60	+/−2 °C	<0.15 °C at 25 °C	0.6 m
Abudabos et al. (2013)	VisIR-Ti200	640 × 480	+/−2 °C	<65 mK at 30 °C	?
Valera et al. (2012)	FLIR i70	140 × 140	+/−2 °C	<0.08 °C at 25 °C	0.12 m
Weschenfelder et al. (2013)	FLIR i60	180 × 180	+/−0.1 °C	<0.1 °C at 25 °C	0.10 m
Ferreira et al. (2011)	Testo 880	320 × 240	+/−0.1 °C	<0.1 °C at 30 °C	0.10 m
Pezeshki et al. (2011)	FLIR E2	160 × 120	+/−2 °C	0.12 °C at 30 °C	0.3 m
Polat et al. (2010)	FlexCam S	?	+/−2 °C	<0.09 °C at 30 °C	?
Stubsjoen et al. (2009)	InfraCam SD	120 × 120	+/−2 °C	<0.1 °C at 25 °C	0.3 m
Rainwater-Lovett et al. (2009)	FLIR EX320	320 × 240	+/−2 °C	<0.08 °C at 25 °C	?
Montanholi et al. (2008, 2009)	FLIR SC2000	320 × 240	+/−2 °C	<0.05 °C at 30 °C	0.30 m
Fonseca et al. (2006), Van Hoogmoed and Snyder (2002)	DTIS 500	320 × 240	?	?	?
Stewart et al. (2007)	FLIR S60	320 × 240	+/−2 °C	<0.10 at 30 °C	?
Nikkhah et al. (2005), Schaefer et al. (2004), Berry et al. (2003)	FLIR 760	175 × 131	+/−2 °C	<0.10 °C at 30 °C	0.5 m
Holmes et al. (2003)	FLIR PM-280	256 × 256	+/−2 °C	<0.07 °C at 30 °C	?

[a]Variable are not available.