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Infrared thermography: history, fundamentals and use in veterinary medicine and livestock

Animal health, diagnostic method, livestock, noninvasive technic, thermogram.

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ABSTRACT

The infrared thermography (IRT) is a technic of obtaining the superficial temperature of body and objects, that is being used in diverse sectors. This tools does not require physical contact with the surface of interest, therefore it is used as an evaluation method for the temperature of equipment in industries, humans and animals. The technic consists of a fast procedure, noninvasive and relatively easy to perform. In the Veterinary Medicine it can be used as a tool to infer and diagnose diseases, physiological conditions and pain in domestic and wild animals. In livestock, the IRT has been associated with feed efficiency studies, in the pursuit of identifying efficient animals. The results in these studies are controversial, but demonstrate the potential of utilization of this technology for that matter. Beyond the use for obtaining data in live animals and machines, the IRT has been studied for the determining the quality of food produced for bovines. The IRT is a versatile technic, applicable in many situations, and must continue to be studied as a tool to improve the routine of professionals and researches from different areas of knowledge.

Key words: Animal health, diagnostic method, livestock, noninvasive technic, thermogram.

INTRODUÇÃO

The infrared thermography (IRT) is an instrument of analysis noninvasive and non-radioactive, capable of analyzing physiological functions. The technic detects the infrared radiation emitted by a body with a temperature different than zero degrees and translates it into a thermographic image (thermogram) or a map of the temperature of the region analyzed. Hence, it allows the visualization of the body temperature changes due to regional alterations. The thermogram works as an amplificatory of our vision, assuring that we can observe the infrared spectrum created by the image.

In resume, it can capture the frequency of radiation that is naturally emitted by bodies, process and translates this information, in a way to make a visible image and passible of interpretation. In the industry or in any kind of business where preventive inspections are required, the IRT can be used to certify the conditions of mechanical and electronical equipment, for example, to infer about the circuit conditions and of energy panels (of low or medium tension) and other productive environments (SANTOS, 2010).

Therefore, the IRT can also be used in the human medicine to through heat analysis, identify neurological and muscle disorders, vascular diseases, pain and athletes (BRIOSCHI et al., 2009; CÔRTE & HERNANDEZ, 2016).

Beyond the application in the mentioned areas, the utilization of IRT expanded to diverse specialties of the Veterinary Medicine. The technic is helpful in the diagnose of inflammatory processes in different species, as well in the early detection of disorders in animals of difficult management, and the identification of efficient individuals.

Considering the all the use and application possibilities for IRT, the subject must be discussed. This review has the objective to reunite information on the matter of the history, functionality and application of the technic in the areas of livestock and health, focusing on animal applications.

History and production of the thermographic image

The use of images for identification, diagnostics, research and storage of data is historical. The technical for obtaining the images of a body are diverse and capable of providing a range of information. Among these we can quote: photography, radiography, ultrasound and most recently used in veterinary, the IRT. The last one is a noninvasive and indirect method that has many applications (LUZI et al., 2013).

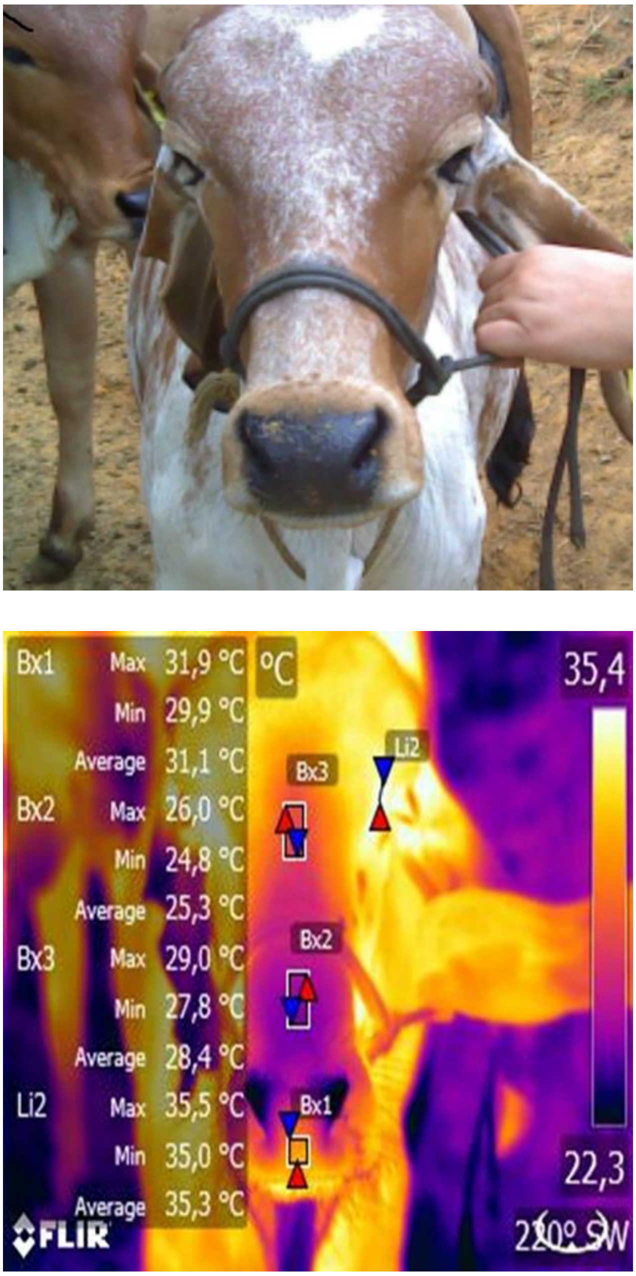
The first citations about the use IRT are dated from the experiments conducted in the era of Hippocrates. Even though rudimentary, he was the first on the report the existence of something in the surface of the human skin, capable of drying a material attached to it with different speeds according to where it was placed in the body. After that finding, a lot of studies worked to develop methods and equipment to detect and measure the component, the heat emitted in form of radiation, capable of causing the temperature difference between different points in the same body or object (ROBERTO & SOUZA, 2014).

The antique thermographic models furnished images of low quality and that took long periods to be processed. The technology of IRT as we know today, was only achieved and produced in major scale during the Second World War. From this point, the technology began to be used in evaluations of humans and animals, initially focusing in health and diagnostics (ROBERTO & SOUZA, 2014).

The principle of IRT have as fundamental groundwork the knowledge that all bodies are made of matter or mass, which emits infrared radiation that can be measured and correlated to the body temperature (KNIZKOVA et al., 2007). The functioning and the production of the thermographic image occur by the capture of the frequency of the infrared radiation emitted by a body that has an absolute temperature different from zero degrees. The image obtained from a surface (object, living being, environment) is engendered in an specific equipment able to capture those signals.

The thermic radiation can be defined as the portion of the electromagnetic spectrum that extends for approximately 0,1 to 100 mm (INCROPERA & DEWITT, 2008). The thermic cameras collect the infrared radiation coming from the surface, convert this radiation into radiometric signs and create a thermic image that represents the distribution of the body's surface temperature, the thermogram (INCROPERA & DEWITT, 2008; DIGIACOMO et al., 2014). In this system, each color captured on the thermogram expresses a specific range of temperature (EDDY et al., 2001; LUDWING, 2013) (FIGURE 1).

Figure 1. Photography (A) and thermogram with analysis of temperature (B) of a Gyr female calve at 173 days of age (**Source**: personal archive, 2017. Processed by FLIR Tools 5.x software).



For the temperature scales to be exhibited, the images are uploaded in the computer, processed and interpreted by a software that can translate each point of the image into a thermographic map. In this map, the points of radiation emission correspond to the coordinates of the x and y axis, and are represented by pixel units (HARRISON et al., 2007; GODYN et al., 2013; MCMANUS et al., 2016). The reading of the map is performed in Celsius or Fahrenheit degree and are demonstrated by color gradients, available in the software being used (color palette). The region selected in the map by the user for the verification of temperature, provide the maximum, minimum and the average temperature of the area of interest.

To produce a thermographic image is necessary to be between 0,5 m and 1,0 m close to the target, according to the origin of the body, without the need for constraining, sedation or analgesia (MCMANUS et al., 2016). Hence, it is considered a noninvasive technic of easy execution, that allows to be conducted in diverse environments, conditions, equipment, humans and animals.

Nevertheless, some factors need to be controlled when choosing the IRT, in order to guarantee the quality and the correct processing and interpretation of the images. Given its mechanism of capturing images, the temperature, humidity, direct incidence of sun light, rain, dirt, calibration and regulation of the thermographic camera can interfere in the result (REKANT et al., 2016; STEWART et al., 2016).

Utilization of infrared thermography in different knowledge áreas

The IRT is employed in sectors of the chemistry industry, automobilist, maritime, aeronautic, steel mill and construction, focusing on the preventive inspection of equipment (SANTOS, 2010). The thermographic image can be obtained from equipment during their functioning and during the inspection of systems and productive processes. Professionals and companies from the public security field and security of work also use this technology on construction and services (TAKEDA et al., 2017; TIRLONI et al., 2018).

Infrared thermography on animal health

Similar to the technological advances in the different areas of knowledge, in the agriculture and livestock sciences the development, application and use more refined equipment from the technology point of view, also occurred. That being so, we might say that as in the human Medicine, the Veterinary went through important advances in the last decades, even though in different speeds and scale.

The implementation of advanced tools is of great value for areas applicable to the human and animal health. Throughout these technics is possible to improve the knowledge into deeper levels, connect them to biological, physiological and microbiological processes, that way constantly increasing the comprehension about the natural an pathological events related to living organisms. With the increase in the application of the livestock precision, the IRT deserves highlighting in science and in the animal production, since it allows the collection of data directly from the animal's surface ou from specific anatomic regions.

Veterinary and animal science professionals and researchers obliged to the use of IRT in researches working with wild animals, birds, bovines, canids, caprine, equines, ovine and swine (NOGUEIRA et al., 2013; TORQUATO et al., 2015; CAMERINI et al., 2016; FERREIRA et al., 2016; PULIDO-RODRÍGUEZ et al., 2017). Its versatility in being applied to different species, objects and environments made the use of this technic popular in the scientific community and in the field. In practice, there are limitations regarding the utilization, which must respect conditions described previously to assure the quality of the image.

The IRT was used as a tool for evaluating clinical parameters in studies, to allow the researchers to infer about the circulatory system in the region of interest in the animal's body. In conditions of balance, when there is no disease, the heat production by the body can be originated from the cellular metabolic reactions, digestion and blood flow (HARRISON et al., 2007). The thermography of the skin is an evaluation method of the vascular system and the microcirculation, in which the radiation emissions are directly related to the perfusion and metabolism of the tissues. Variations in the tissue surface temperature, generally, are a result of changes in the vascularization of the selected area, what incites alterations in the emission of infrared radiation (STELLETTA et al., 2012). Hence, the IRT has been useful to evaluate the presence of disturbs, sickness and stress in animals (CHIU et al., 2005; BOUZIDA et al., 2009).

The world scientific literature has paid attention to the use of IRT in livestock for the purpose of diagnosing diseases before the clinical signs appearance (Schaefer et al., 2004). The application of the technic has proven to helpful in the identification of calves facing respiratory diseases (SCHAEFER et al., 2007; SCHAEFER et al., 2011). Schaefer et al. (2007) have shown that animals there are truly positive for diseases, based on a gold standard that includes rectal temperature, clinical score, number of leucocytes and the relation neutrophil / lymphocyte, exhibited higher thermic values of infrared pic, of 35,7 ± 0,35 ° C, when compared with animals truly negative for diseases 34,9 ± 0,22 ° C ($P < 0,01$). Poikalainen et al. (2012) demonstrated that thermic images can be used with success for detection of skin lesions as well. Alterations in the locomotor system, as lameness (ALSAAOD & BÜSCHER, 2012) and digital dermatitis (ALSAAOD et al., 2014) can also be evaluated by using the IRT.

Stewart et al. (2017) demonstrated that the IRT was a useful to determine the respiratory frequency of bovines. Corroborating this affirmative, Daltro et al. (2017), evaluating the tolerance of bovines for heat stress, found moderated to high correlations ($P < 0,05$) between the humidity of the eye globe, the tolerance to heat, the rectal temperature, the cardiac and respiratory frequency, with the IRT of some regions of the body (Table 1).

able 1. Correlation between IRT and parameters collected from the environment and the animal

	Evaluated area IRT[1]		
Parameter	Eye	Front udder	Posterior udder
Humidity	0,25	-	-
HT[2]	0,44	0,58	0,49
RT[3]	0,57	0,74	0,69
CF[4]	0,31	0,47	0,37
RF[5]	0,43	0,57	0,50
PS[6]	0,37	0,54	0,41

IRT[1]: Infrared thermography; HT[2]: Heat tolerance; RT[3]: Rectal temperature; CF[4]: Cardiac frequency; RF[5]: Respiratory frequency, and PS[6]: Panting score. **Source**: Adapted from Daltro et al. (2017).

Vaccination is a procedure adopted by the veterinary medicine for most domestic species but until the present moment the use of IRT for evaluating the effects of it are not described in some species, as it is not for bovines. A study conducted by Cook et al. (2015) observed the results of using the IRT on the detection of fever and behavior of swine in response to vaccination, finding a pic of radiation ten hours after. The thermographic evaluation was performed in a single interval of 24 hours.

Infrared thermograohy on animal performance

Another important application of the IRT is on feed efficiency researches, frequently conducted with production animals. One of the forms in which the animal can express its efficiency and metabolic activity is through heat production. The production of heat comes majorly from physical activities, metabolism and feed ingestion, and can be expressed, among others forms, by the thermic radiation emitted by the body surface.

The same way the dissipation of the heat produced by the animal can be a result of the factors. The loss of heat by the animal occur by evaporation, conduction, convection and radiation. Animals more or less efficient emit different radiation patterns, in different anatomic regions (SILANIKOVE, 2000; HARRISON et al., 2007).

The production of heat is commonly recorded by indirect or direct calorimetric methods, as in respiratory chambers (requires a specific environment and equipment for the measurement of production, emission and exchanges of CO_2, O_2 e CH_4 gases) and determination of the cardiac and respiratory frequencies. However, these methods are laborious because demand the permanence of the animal in place for long periods of time and equipment of difficult maintenance (MCMANUS et al., 2016). The measurement by cardiac and pulmonary debt requires less equipment, but manipulates the animal just as much, what can compromise the quality of the data, due to the stress (HARRISON et al., 2007).

The IRT presents itself hence as an alternative tool to gauge the heat production and can be applied to diverse anatomic regions of the body surface in these animals. The IRT was employed in the studies of feed efficiency with the objective of bring information for the discussion about the results of animals more or less effective.

Harrison et al. (2007) used the IRT to stablish predictive models of efficiency and growth (GE) in ruminants and birds. For growing animals, that does not transform the energy coming from the feed in product, the growth efficiency is a synonym of feed efficiency, translated as weight gain. The methods correlate IRT with average daily gain (ADG) and dry matter consumption (DMC). The equation defined b the authors is:

$$\boldsymbol{EC \text{ ou } GMD = fn(1/TIVn)},$$

in which the *TIVn* is the reason between the average temperature obtained on the thermogram and the metabolic weight (live weight ^{0,75}).

This equation can be applied to groups of similar animals, so for each group there must be a proper model of comparison. The same model cannot be used for any animal inside a population.

Works that focused on residual feed intake tested the IRT as an alternative for identifying efficient animals and registered images from their anatomic regions such as the eye, nose, rib, flank and member. The objective was to verify the existence of a correlation between the production of heat in these regions with parameters used for classifying animals according to its efficiency.

Is possible to suppose that animals more efficient for converting feed into metabolic energy would dissipate less heat, which means that they would require less maintenance energy due to its thermoregulatory capacity, among other genetic and phenotypic characteristics related to their metabolism. Many studies started from this principle to investigate through the IRT if there was a correlation between heat production and dissipation, with the feed efficiency of the phenotypic groups used (MONTANHOLI et al., 2010; DIGIACOMO et al., 2014; MARTELLO et al., 2016; LEÃO et al., 2018).

Leão et al. (2018) used the IRT to research the phenotypic differences between crossbred calves (Holstein x Gyr) during the suckling phase regarding the residual feed consumption, residual weight gain and heat production. Calves classified as efficient for residual weight gain presented a bigger temperature of the anatomic region of the eye then the less efficient ones. On the other hand, Montanholi et al. (2010), observed that the more efficient animals presented smaller temperatures then the less efficient ones in the region of the cheek (28,1º C vs. 29,2º C) and nose (30,0º C vs. 31,2º C).

Montanholi el al. (2010) also found a correlation of 0,37 and 0,41 between the IRT and the feed efficiency index used, for cheek and nose, respectively. The same way, Martello et al. (2016) described a positive relation of the IRT of the cheek, eye, bevel, rib, back and anterior members.

Other applications of the infrared thermography in agriculture sciences

A more recent way of using the IRT is the evaluation of the temperature of ensiled matter. The IRT has been analyzed for its capacity to determine the fermentative standard of feed and for the presence of mycotoxins. Correlations were not found yet, even though the IRT can be useful to verify the temperature of more exposed parts of the silo (SCHIMIDT et al., 2015).

FINALS CONSIDERATIONS

The IRT has demonstrated good results in the evaluations it was used for. However, the technic must continue to be explored so that the understanding of its relation to parameters commonly evaluated in the Veterinary Medicine and common areas can increase the comprehension, prevention and diagnose of the health condition and comfort of animals.

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