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PRODUCTION AND MANAGEMENT: *Technical Note*

Infrared thermography as an alternative technique for measuring body temperature in cattle*

A. A. Hoffman,[1] N. S. Long,[1] J. A. Carroll,[2] N. C. Burdick Sanchez,[2] P. R. Broadway,[2] J. T. Richeson,[3] PAS, T. C. Jackson,[3] and K. E. Hales,[1]† PAS

[1]Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409-2141; [2]USDA-ARS Livestock Issues Research Unit, Lubbock, TX 79403; and [3]Department of Agricultural Sciences, West Texas A&M University, Canyon, TX 79016

ABSTRACT

Objective: The objective of the current experiment was to evaluate the use of infrared thermography (INFRA) as an alternative to rectal temperature (RT) for monitoring body temperature in steers.

Materials and Methods: An *Escherichia coli* lipopolysaccharide (LPS) was administered to 31 steers (initial BW 295.8 ± 46.5 kg) via i.v. injection to produce a febrile response. Each steer was fitted with an indwelling rectal probe to monitor changes in RT in 30-min intervals. Thermal temperatures (INFRA) were collected in 30-min increments beginning at h 0.5 to 1.5, h 2.5 to 3.5, and h 4.5 to 5.5. Additionally, temperatures were collected in 60-min increments beginning at h −1.5 to −0.5 and h 6.5 to 12.5. Relative to LPS administration, thermal temperatures were subsequently recorded at h 18.5, 24.5, 36.5, and 47.5. Correlation analyses were conducted using PROC CORR where Pearson and Spearman correlation coefficients were evaluated between the RT and INFRA. Additionally, RT and INFRA were analyzed using PROC MIXED where the model included temperature measurement method (RT or INFRA), hour, and the interaction of method × hour. Steer within temperature measurement method was included as a random effect and was the subject of the repeated measures analysis.

Results and Discussion: Increases in RT and INFRA were evident within 1 h of the LPS administration, both methods confirming an induced febrile response. Rectal temperature and INFRA did not differ for 50% of the time points ($P \geq 0.16$); however, the 2 methods differed at h −0.5, 0.5, 1.5, 5.5, 9.5, 10.5, 11.5, 18.5, 24.5, 36.5, and 47.5 ($P < 0.01$). Temperatures between each method diverged 9.5 h after LPS was given. A Pearson correlation of 0.71 ($P < 0.01$) was noted between RT and temperature of the eye measured using INFRA. Likewise, a Spearman correlation of 0.66 ($P < 0.01$) was noted between RT and INFRA measurements. Infrared imaging is noninvasive, quick to perform, and decreases additional stressors caused by handling and restraint of the animal.

Implications and Applications: These data suggest that further research is necessary for INFRA to be a viable alternative to RT measurements in cattle.

Key words: body temperature, infrared thermography, rectal temperature

INTRODUCTION

Body temperature (**BT**) is often used to evaluate the health status of cattle and assist in the diagnosis and treatment of disease. The most common method for measuring BT in cattle production is rectal temperature (**RT**), as it is relatively simple and inexpensive (Reuter et al., 2010). Nonetheless, measuring RT can produce inaccurate results because of cattle handling that are difficult to interpret, and it is time consuming and invasive, thus creating additional stress on the animal (Soerensen and Pedersen, 2015). Likewise, RT can be affected because of handling stress and the procedure itself (Burfeind et al., 2010). Rectal probe insertion depth caused up to a 0.4°C difference when the probe was inserted deeper in the rectum of dairy cows (Burfeind et al., 2010). Automation of physiological measures in livestock is important for scientist and producers; when phenotypic data can be collected via automation in real time, it decreases the need for skilled labor. Infrared thermography (**INFRA**) is a noninvasive technology that can detect deviations in an animal's surface BT because of changes in blood flow and resulting heat distribution from the surface of the animal (Nääs et al., 2014). Changes in BT, detected as variations in surface temperature, could be related to several physiological or pathological states (Schaefer et al., 2004;

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†Corresponding author: kristin.hales@ttu.edu

Montanholi et al., 2008). The use of INFRA has applications in human and veterinary medicine as a diagnostic tool (Schaefer et al., 2012; Martins et al., 2013) and thus exists as an alternative technique available for measuring BT in livestock production systems. Therefore, the objective of the current experiment was to evaluate the use of INFRA as an alternative for monitoring BT in steers in a temperature-controlled environment.

MATERIALS AND METHODS

Camera Settings

The FLIR E95 hand-held thermal imaging camera with a 24° lens (FLIR Systems) was used throughout the experiment. Camera cost in April 2021 was $3,700. This camera was used because it was sturdy for field application and relatively inexpensive. The imaging camera contains settings for emissivity, reflected temperature, atmospheric temperature, relative humidity, distance, and measurement tool. Emissivity is the ability of an object to emit infrared energy. The correct emissivity setting is critical for collecting accurate temperatures, and emissivity was calculated by comparing the camera temperature to the measured RT within an animal for calibration (Schaefer et al., 2004). Before the start of the experiment, emissivity was calculated by adjusting the emissivity setting to ensure camera temperatures matched (within ±0.3°C) the reading from the rectal thermometer (GLA M900 Series; GLA Agricultural Electronics), and emissivity was set at 0.89 for black-faced cattle. Reflected temperature was measured by pointing the camera 180° from where temperatures were collected and recording the temperature. Atmospheric temperature and relative humidity were measured in real time with an environmental data logger (AG Livestock Drop; Kestrel) and used to adjust the respective camera settings before each collection point or at times of major atmospheric changes. Major atmospheric changes included noticeable shifts in atmospheric temperature (±5°C) or relative humidity (±10%). The measurement tool on the camera screen was set as a box with a hot spot locator within the box.

Schaefer et al. (2004) reported that changes in eye temperature were more consistent than other anatomical areas of the body. The box displayed on the camera screen was placed around the lacrimal region of the eye and searched for the highest temperature within the box until an image was captured. The camera was used approximately 1 m from the point of eye of the steer.

Operation Procedures

The camera was powered on for at least 5 min before any temperatures were collected; additionally, the camera was allowed to sit for at least 5 min after the battery was changed as recommended in the manual. An angle between 45° and 90° and distance of 1 m were maintained from the lacrimal region of the eye. The camera was focused using the focus trigger button or by manually adjusting the lens to ensure clear, unblurred image quality. The image was captured by pulling the capture button, and the saved image was viewed to record the temperature. If images were blurry or temperatures were outside the normal range for cattle (36.7 to 39.1°C), excluding a febrile response from the LPS, images were recaptured (Fielder, 2022).

Study Design

All live animal procedures were approved by the West Texas A&M University Institutional Animal Care and Use Committee before study initiation (IACUC #2021.03.001) and the USDA-ARS Livestock Issues Research Unit (IACUC # 2121F). Because environmental factors are known to affect the accuracy of infrared cameras (Kastelic et al., 1996), this study was conducted in a semi-temperature-controlled indoor facility at the USDA, ARS, Livestock Issues Research Unit, near Lubbock, Texas. Infrared and rectal temperatures were collected during an ongoing lipopolysaccharide (**LPS**) immune challenge experiment in which LPS was injected into a jugular catheter at 0.25 μg/kg of BW. For the study, crossbred black-faced steers (n = 31; 295.8 ± 46.5 kg) were housed in individual stanchions (length = 2.28 m; width = 0.76 m; and height = 1.67 m) where they had ad libitum access to feed and water. Temperatures were collected from each steer over a 48-h period where LPS was administered at h 0 to induce a febrile response. Rectal temperatures were collected every 5 min using an indwelling rectal thermometer, as described by Reuter et al. (2010). Convenient INFRA temperatures were collected when possible. Thermal images were collected every 30 to 60 min starting 1.5 h before LPS was given and continuing to 12.5 h after LPS was given (Figure 1). Furthermore, thermal images were collected at 18.5, 24.5, 36.5, and 47.5 h after LPS was administered. Time of day was recorded each time thermal images were captured. For the comparison of RT versus INFRA, the RT recorded nearest the time of INFRA measurement was used. For example, if the temperature of the eye was recorded at 1126 h and RT were collected at 1125 and 1130 h, the RT temperature collected at 1126 h was used for the comparison.

Statistical Analysis

Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc.). Steer was the experimental unit for all analyses. Correlation analyses were conducted using PROC CORR where Pearson and Spearman correlation coefficients were evaluated between the RT and INFRA. Additionally, RT and INFRA were analyzed using PROC MIXED in which the model included temperature measurement method (RT or INFRA), hour, and the interaction of method × hour. Steer within temperature measurement method was included as a random effect and was the subject of the repeated measures analysis. Multiple covariance structures were tested and autoregressive 1 (AR 1)

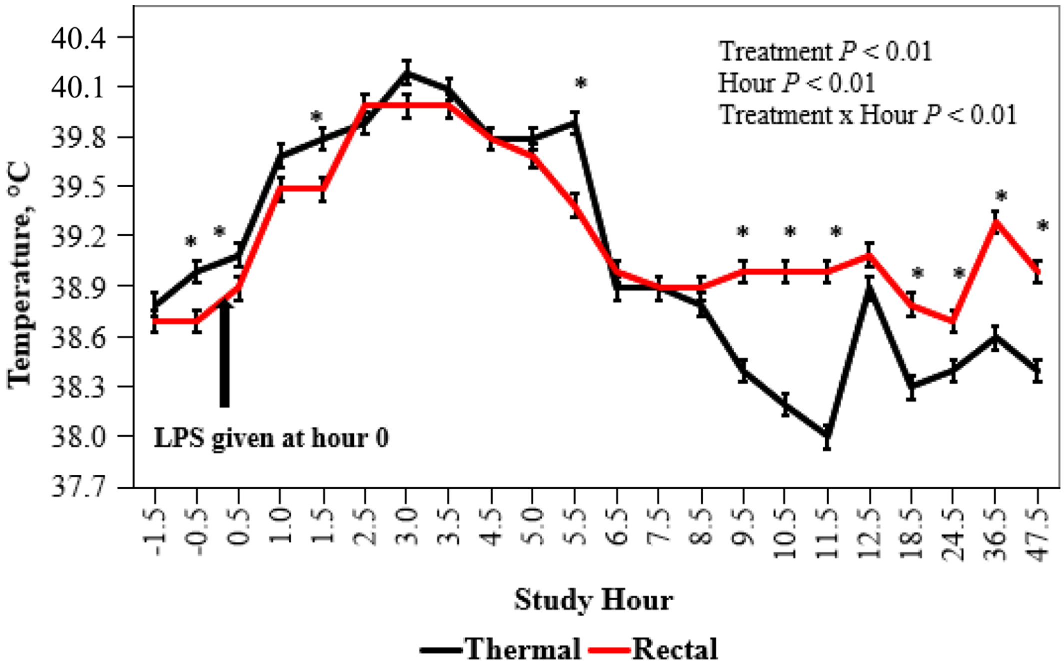

Figure 1. The effects of a lipopolysaccharide (LPS) immune challenge on rectal temperature (red line) and infrared thermography measured at the eye (black line) in 31 calves. Least squares means (±SEM) of temperature were measured at h −1.5, −0.5, 0.5, 1, 1.5, 2.5, 3, 3.5, 4.5, 5, 5.5, 6.5, 7.5, 8.5, 9.5, 10.5, 11.5, 12.5, 18.5, 24.5, 36.5, and 47.5. Eye temperature was measured using an infrared camera (FLIR E95; FLIR Systems) at a distance of 1 m with an angle between 45° and 90°. Rectal temperature was measured with indwelling rectal thermometers described by Reuter et al. (2010). *$P < 0.05$.

was used because it resulted in the smallest Akaike and Schwarz Bayesian criteria.

RESULTS AND DISCUSSION

Before the administration of LPS, BT ranged from 38.7 to 39.0°C (Figure 1); BT then peaked for 3 h after LPS was administered (between h 1 and 4). No difference in RT and INFRA was detected before the LPS was given at −1.5 h ($P = 0.29$). Conversely, BT differed between RT and INFRA at −0.5, 0.5, and 1.5 h relative to LPS ($P \leq 0.01$). Thereafter, temperatures between RT and INFRA did not differ between h 2.5 and 9.5 ($P \geq 0.19$), except that RT and INFRA differed 5.5 h after LPS administration ($P \leq 0.01$). For the remainder of the BT-collection time points, from h 9.5 to 47.5 RT and INFRA differed ($P < 0.01$). Rectal temperatures were greater than INFRA at h 9.5, 10.5, 11.5, 18.5, 24.5, 36.5, and 47.5 ($P < 0.01$), whereas they did not differ 12.5 h after LPS administration ($P = 0.05$).

If heat generated from inflammation is transmitted to the skin via increased capillary blood flow, it should be dissipated as energy and able to be detected by the infrared camera (Schaefer et al., 2004). Inflammatory diseases, including bovine respiratory disease complex, and bacterial infections are often characterized by an inflammatory response. In a research setting, the exogenous administration of LPS induces an inflammatory response mimicking the body's reaction to disease, characteristically noted by fever (Carroll et al., 2009). Increases in both RT and INFRA were evident 1 h after the i.v. administration of LPS, with both methods confirming an induced febrile response. These data are consistent with results reported by Carroll et al. (2009) that noted an increase in RT as early as 1 h after LPS was given to steers. Rectal temperature and INFRA measurements peaked at h 3.5 after LPS before declining toward prechallenge measurements.

The decrease in INFRA following the immune system challenge (h 9.5 to 47.5 after LPS was given) could be attributed to a sympathetically mediated vasoconstriction response. A sympathetic nervous system response can cause a decrease in blood flow to the ocular capillary beds and, subsequently, a decrease in measured lacrimal temperature (Stewart et al., 2007; Stewart et al., 2008, George et al., 2014) and vasoconstriction of the vessels that supply blood to the skin. Therefore, less heat is produced in the eye because of decreased blood flow. The infrared camera functions by detecting the thermal energy or heat emitted, which is used to produce an image (Schaefer et al., 2004). Plausibly, a decreased blood flow could explain the divergence in RT and INFRA temperatures for h 9.5, 10,5, 11,5, 18.5, 24.5, 36.5, and 47.5. Physiological factors that influence blood circulation and thermoregulation can affect readings obtained via INFRA (Rekant et al., 2016). When INFRA was used to evaluate the effects of sedation protocols on temperature regulation in dogs, those given medetomidine (an anesthetic and analgesic) had a decrease in peripheral skin temperatures (Vainionpaa et al., 2013).

A Pearson correlation of 0.71 ($P < 0.01$; Table 1) and Spearman correlation of 0.66 ($P < 0.01$) for the entire experiment were noted between RT and INFRA. At h −1.5 before LPS was given, a Pearson correlation of 0.93 ($P < 0.01$) and Spearman correlation of 0.89 ($P < 0.01$) were observed. Likewise, before potential blood flow changes at h 8.5, a Pearson correlation of 0.90 ($P < 0.01$) and Spearman correlation of 0.85 ($P < 0.01$) were noted. These correlations suggest that INFRA may be an advantageous alternative to measuring temperature at the rectum in cattle. The correlation coefficients were strong (>0.85) before LPS was given and before potential blood flow changes occurred.

Infrared imaging is noninvasive and quick to perform and decreases additional stress caused by handling and restraint of the animal. Correlations between RT and INFRA have been reported in noninfected (correlation of 0.80) and infected quarters (correlation of 0.82) of the udder in dairy cows that were inoculated with *Escherichia coli* (Metzner et al., 2014). Similarly, when INFRA was used to evaluate techniques to monitor BT of grazing cattle, weak correlations were detected between RT and INFRA measured at ear base (correlation of 0.26) and ocular eye (correlation of 0.39; Giro et al., 2019). Similar to our experiment, George et al. (2014) evaluated rectal, vaginal, ocular, and muzzle temperature in hair sheep and cows that were challenged with exogenous LPS and reported a 0.58 correlation coefficient of RT and INFRA measured at the eye.

The use of INFRA has been evaluated previously as an alternative BT measurement tool to detect bovine viral diarrhea virus (Schaefer et al., 2004), mastitis in dairy cows (Metzner et al., 2014), and bovine respiratory disease in growing steers (Schaefer et al., 2007; Schaefer et al., 2012). In calves inoculated with bovine viral diarrhea virus, the use of INFRA detected changes in BT consistent with disease (Schaefer et al., 2004). Furthermore, temperature did not differ when measured at the ocular of the eye, side, back, hooves, ears, and nose (Schaefer et al., 2004). The use of INFRA at the eye of cattle has identified cattle with bovine respiratory disease days before cattle showed clinical signs of illness at a rate comparable to that of measuring RT (Schaefer et al., 2007; Schaefer et al., 2012). George et al. (2014) reported that maximum ocular and muzzle temperatures were less than rectal and vaginal temperatures in hair sheep and cows; nonetheless, all methods detected the febrile response induced by LPS. Results from the current study and those previously reported in the literature indicate that INFRA can detect a febrile response.

It is noteworthy that some limitations and factors must be considered when using INFRA. The accuracy of images may be compromised when taken in conditions with direct exposure to sunlight, high relative humidity, high wind speeds, or when imaged surfaces are dirty or contain debris (McManus et al., 2016). For application in feedlot cattle, use of INFRA is likely best suited for enclosed cattle processing facilities to decrease the environmental interference of direct sunlight and wind. Furthermore, when calibrating the camera before use, if reflected background temperature is inaccurate, error will be introduced into the algorithm used by the camera (Tattersall, 2016).

Table 1. Pearson and Spearman correlation coefficients of rectal temperature and infrared thermography of the eye measured in 31 calves used in a lipopolysaccharide (LPS) immune challenge experiment to induce a febrile response[1]

Item	Coefficient	*P*-value
Entire experiment		
Pearson correlation	0.71	<0.01
Spearman correlation	0.66	<0.01
h −1.5		
Pearson correlation	0.93	<0.01
Spearman correlation	0.89	<0.01
h 8.5		
Pearson correlation	0.90	<0.01
Spearman correlation	0.85	<0.01

[1]Eye and rectal temperatures were measured at h 0.5, 1, 1.5, 2.5, 3, 3.5, 4.5, 5, 5.5, 6.5, 7.5, 8.5, 9.5, 10.5, 11.5, 12.5, 18.5, 24.5, 36.5, 47.5 after LPS administration. Eye temperature was measured using an infrared camera (FLIR E95; FLIR Systems) at a distance of 1 m or less with an angle between 45° and 90°. Rectal temperature was measured with indwelling rectal thermometers described by Reuter et al. (2010).

Overall, these results indicate a moderate relationship between INFRA of the lacrimal region of the eye and RT when measuring BT of cattle in a temperature-controlled environment. Infrared thermography can generate meaningful information on BT, but there are some limitations that should be considered. In conclusion, a greater understanding of factors that affect INFRA must be evaluated before this alternative technique can be widely adopted in livestock production systems.

APPLICATIONS

Body temperature is often used to evaluate the health status of cattle and assist in the diagnosis and treatment of disease. The most common method for measuring BT in cattle production is RT. Nonetheless, measuring RT can produce inaccurate results, and this technique is time consuming and invasive, thus creating additional stress on the animal. Infrared thermography is a noninvasive technology that can detect deviations in surface BT because of changes in blood flow and resulting heat distribution from the surface of the animal. Rectal temperature and infrared thermography were in agreement for 50% of the time points measured. Temperatures between each method diverged 9.5 h after lipopolysaccharide was given, potentially because of changes in blood flow. Physiological states that alter blood flow of the eye have the potential to cause infrared temperature to differ from RT. Moderate correlations were noted between RT and temperature of the eye measured using infrared thermography. Infrared imaging is noninvasive and quick to perform and decreases additional stressors caused by handling and restraint of the animal.

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LITERATURE CITED

Burfeind, O., M. A. G. von Keyserlingk, D. M. Weary, D. M. Veira, and W. Heuwiser. 2010. Short communication: Repeatability of measures of rectal temperature in dairy cows. J. Dairy Sci. 93:624–627. https://doi.org/10.3168/jds.2009-2689.

Carroll, J. A., R. R. Reuter, J. Chase Jr., S. W. Coleman, D. G. Riley, D. E. Spiers, J. D. Arthington, and M. L. Galyean. 2009. Profile of the bovine acute-phase response following an intravenous bolus-dose lipopolysaccharide challenge. Innate Immun. 15:81–89. https://doi.org/10.1177/1753425908099170.

Fielder, S. E. 2022. Normal rectal temperature ranges—Special subjects. Merck Veterinary Manual. Accessed Sep. 1, 2022. https://www.merckvetmanual.com/special-subjects/reference-guides/normal-rectal-temperature-ranges.

George, W. D., R. W. Godfrey, R. C. Ketring, M. C. Vinson, and S. T. Willard. 2014. Relationship among eye and muzzle temperatures measured using digital infrared thermal imaging and vaginal and rectal temperatures in hair sheep and cattle. J. Anim. Sci. 92:4949–4955. https://doi.org/10.2527/jas.2014-8087.

Giro, A., A. C. C. Bernardi, W. Barioni Junior, A. P. Lemes, D. Botta, N. Romanello, A. N. Barreto, and A. R. Garcia. 2019. Application of microchip and infrared thermography for monitoring body temperature of beef cattle kept on pasture. J. Therm. Biol. 84:121–128. https://doi.org/10.1016/j.jtherbio.2019.06.009.

Kastelic, J. P., R. B. Cook, G. H. Coulter, G. L. Wallins, and T. Entz. 1996. Environmental factors affecting measurement of bovine scrotal surface temperature with infrared thermography. Anim. Reprod. Sci. 41:153–159. https://doi.org/10.1016/0378-4320(95)01460-8.

Martins, R. F. S., T. do Prado Paim, C. de Abreu Cardoso, B. Stéfano Lima Dallago, C. B. de Melo, H. Louvandini, and C. McManus. 2013. Mastitis detection in sheep by infrared thermography. Res. Vet. Sci. 94:722–724. https://doi.org/10.1016/j.rvsc.2012.10.021.

McManus, C., C. B. Tanure, V. Peripolli, L. Seixas, V. Fischer, A. M. Gabbi, S. R. Menegassi, M. T. Stumpf, G. J. Kolling, E. Dias, and J. B. G. Costa Jr.. 2016. Infrared thermography in animal production: An overview. Comput. Electron. Agric. 123:10–16. https://doi.org/10.1016/j.compag.2016.01.027.

Metzner, M., C. Sauter-Louis, A. Seemueller, W. Petzl, and W. Klee. 2014. Infrared thermography of the udder surface of dairy cattle: Characteristics, methods, and correlation with rectal temperature. Vet. J. 199:57–62. https://doi.org/10.1016/j.tvjl.2013.10.030.

Montanholi, Y. R., N. E. Odongo, K. C. Swanson, F. S. Schenkel, B. W. McBride, and S. P. Miller. 2008. Application of infrared thermography as an indicator of heat and methane production and its use in the study of skin temperature in response to physiological events in dairy cattle (*Bos taurus*). J. Therm. Biol. 33:468–475. https://doi.org/10.1016/j.jtherbio.2008.09.001.

Nääs, I. A., R. G. Garcia, and F. R. Caldara. 2014. Infrared thermal image for assessing animal health and welfare. J. Anim. Behav. Biometeorol. 2:66–72. https://doi.org/10.14269/2318-1265/jabb.v2n3p66-72.

Rekant, S. I., M. A. Lyons, J. M. Pacheco, J. Arzt, and L. L. Rodriguez. 2016. Veterinary applications of infrared thermography. Am. J. Vet. Res. 77:98–107. https://doi.org/10.2460/ajvr.77.1.98.

Reuter, R. R., J. A. Carroll, L. E. Hulbert, J. W. Dailey, and M. L. Galyean. 2010. Technical note: Development of a self-contained, indwelling rectal temperature probe for cattle research. J. Anim. Sci. 88:3291–3295. https://doi.org/10.2527/jas.2010-3093.

Schaefer, A., N. Cook, S. Tessaro, D. Deregt, G. Desroches, P. Dubeski, A. Tong, and D. Godson. 2004. Early detection and prediction of infection using infrared thermography. Can. J. Anim. Sci. 84:73–80. https://doi.org/10.4141/A02-104.

Schaefer, A. L., N. J. Cook, C. Bench, J. B. Chabot, J. Colyn, T. Liu, E. K. Okine, M. Stewart, and J. R. Webster. 2012. The non-invasive and automated detection of bovine respiratory disease onset in receiver calves using infrared thermography. Res. Vet. Sci. 93:928–935. https://doi.org/10.1016/j.rvsc.2011.09.021.

Schaefer, A. L., N. J. Cook, J. S. Church, J. Basarab, B. Perry, C. Miller, and A. K. W. Tong. 2007. The use of infrared thermography as an early indicator of bovine respiratory disease complex in calves. Res. Vet. Sci. 83:376–384. https://doi.org/10.1016/j.rvsc.2007.01.008.

Soerensen, D. D., and L. J. Pedersen. 2015. Infrared skin temperature measurements for monitoring health in pigs: a review. Acta Vet. Scand. 57:5. https://doi.org/10.1186/s13028-015-0094-2.

Stewart, M., A. L. Schaefer, D. B. Haley, J. J. Colyn, N. J. Cook, K. J. Stafford, and J. R. Webster. 2008. Infrared thermography as a non-invasive method for detecting fear-related responses of cattle to handling procedures. Anim. Welf. 17:387–393. https://doi.org/10.1017/S0962728600027895.

Stewart, M., J. R. Webster, G. A. Verkerk, A. L. Schaefer, J. J. Colyn, and K. J. Stafford. 2007. Non-invasive measurement of stress in dairy cows using infrared thermography. Physiol. Behav. 92:520–525. https://doi.org/10.1016/j.physbeh.2007.04.034.

Tattersall, G. J. 2016. Infrared thermography: A non-invasive window into thermal physiology. Comp. Biochem. Physiol. A Mol. Integr. Physiol. 202:78–98. https://doi.org/10.1016/j.cbpa.2016.02.022.

Vainionpaa, M., K. Salla, F. Restitutti, M. Raekallio, J. Junnila, M. Snellman, and O. Vainio. 2013. Thermographic imaging of superficial temperature in dogs sedated with medetomidine and butorphanol with and without MK-467 (L-659–066). Vet. Anaesth. Analg. 40:142–148. https://doi.org/10.1111/j.1467-2995.2012.00768.x.