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Use of infrared ocular thermography to assess physiological conditions of pigs prior to slaughter and predict pork quality variation

Angela V. Weschenfelder [a,b,c], Linda Saucier [b,c], Xavier Maldague [d], Luiene M. Rocha [a,b,c], Allan L. Schaefer [e], Luigi Faucitano [a,*]

[a] Agriculture and Agri-Food Canada, Dairy and Swine Research and Development Centre, Sherbrooke, QC J1M 0C8, Canada
[b] Département des sciences animales, Faculté des sciences de l'agriculture et de l'alimentation, Université Laval, Pavillon Paul-Comtois, Quebec City, QC G1V A06, Canada
[c] Institute of Nutraceuticals and Functional Foods, Université Laval, Pavillon des services, Quebec City, QC G1V A06, Canada
[d] Département de génie électrique et de génie électrique, Université Laval, Quebec City, QC G1V A06, Canada
[e] Agriculture and Agri-Food Canada, Lacombe Research Centre, Lacombe, AB T4L 1W1, Canada

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ABSTRACT

Infrared thermography (IRT) body temperature readings were taken in the ocular region of 258 pigs immediately before slaughter. Levels of lactate were measured in blood taken in the restrainer. Meat quality was assessed in the longissimus dorsi (LD), semimembranosus (SM), and adductor muscles. Ocular IRT (IROT) temperature was correlated with blood lactate levels ($r = 0.20$; $P = 0.001$), with pH taken 1 hour postmortem (pH1: $r = -0.18$; $P = 0.03$) and drip loss ($r = 0.20$; $P = 0.02$) in the LD muscle, and with pH1 in the SM muscle ($r = -0.20$; $P = 0.02$). Potentially, IROT may be a useful tool to assess the physiological conditions of pigs at slaughter and predict the variation of important meat quality traits. However, the magnitude of the correlations is rather low, so a further development of image capture technique and further studies under more variable preslaughter conditions ensuring a larger pork quality variation are needed.

1. Introduction

The stimulation of the sympathoadrenal axis due to physical stress response increases metabolic activity and heat production, resulting in higher core body temperature (Sawka, Wenger, & Pandolf, 1996; Terrien, Perret, & Aujard, 2011), with clear consequences on body metabolism and meat quality variation (Hambrecht et al., 2004; Ritter et al., 2009).

Infrared thermography (IRT) represents a non-invasive technique allowing the recording of body temperature without touching the animal (Stewart, Webster, Schaefer, Cook, & Scott, 2005; Warriss, Pope, Brown, Wilkings, & Knowles, 2006). By converting the infrared radiation emitted by a heat source into pixel intensity, the IRT provides an image map of temperatures (also called "thermogram") of the skin surface (Griffith, Türler, & Goudey, 2002). In past studies, IRT has been used to assess the welfare status of livestock under routine management practices, i.e. dehorning or health status control in calves (Schaefer et al., 2012; Stewart, Stafford, Dowling, Schaefer, & Webster, 2008). Based on the close association between muscle temperature rise and early postmortem pH fall rate (Klont & Lambooij, 1995), IRT has also been applied to detect the temperature rise in pigs in response to pre-slaughter handling with the ultimate objective to predict meat quality variation (Gariépy, Amiot, & Nadai, 1989; Schaefer, Jones, Murray, Sather, & Tong, 1989). However, the findings of these studies were not conclusive. The reasons for this conclusion can be two-fold as it may be either related to the less accuracy of the IRT equipment available at that time or to the choice of the fore-back as the anatomical location for the IRT scan. As for the latter hypothesis, Banhazi, Kitchen, and Tivey (2009) reported that, when the IRT measurement is taken at this location, its accuracy in detecting temperature differences may be reduced by the presence of dirt, hair, or water on the skin, which may influence the level of emitted radiation and bias the values. Preliminary trials run by our group also confirmed the lack of relationship between IRT scans on the fore-back skin and meat quality in 133 pigs lining up in the stunning chute (Weschenfelder, 2012).

The brain is the major source of metabolic-produced heat and houses the central nervous system regulating temperature of the body, i.e. temperature of the brain is recognized as the core temperature (McCafferty, 2007). Ocular temperature, due to its close proximity to the brain, is considered a good indicator of core temperature ($r \geq 0.80$; Tan, Ng, Acharya, & Chee, 2009; Kessel, Johnson, Arvidsson, & Larsen, 2010; Johnson, Rao, Hussey, Morley, & Traub-Dargatz, 2011). As the eye blood flow is tightly related to the sympathetic activity (Stewart et al., 2008), even mild stress responses can be detected as changes in the ocular temperature. Changes in ocular IRT (IROT) have been reported in response to acute stress, such as physical pain and

* Corresponding author. Tel.: +1 819 780 7237; fax: +1 819 564 5507.
E-mail address: luigi.faucitano@agr.gc.ca (L. Faucitano).

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inflammatory process in cattle (Johnson et al., 2011; Schaefer et al., 2012; Stewart et al., 2008), and were associated with increased salivary and plasma cortisol concentrations in rabbits and horses (Cook et al., 2001; De Lima et al., in press).

Differently from other real-time assessment techniques, such as the use of I-button data loggers for the recording of gastro-intestinal tract temperature (Carr, Newman, Rentfrow, Keisler, & Berg, 2008; Weschenfelder et al., 2012) or of the Lactate Scout Analyzer for the measurement of blood lactate concentration in the ear vein (Edwards, Engle, Correa, et al., 2010; Edwards, Engle, Grandin, et al., 2010), IROT represents a restraint-free and non-invasive method for the assessment of stress-related physiological response variation in live pigs just prior to slaughter. Its measurement may allow the early postmortem segregation of carcasses based on body temperature and may help processors minimize the meat quality losses associated to higher muscle temperature resulting in faster pH fall by modified postmortem carcass handling (i.e. faster carcass cooling; Bressan, Culau, Ourique, & Nicolaiewski, 1992).

However, the reliability of IROT for monitoring the physiological conditions at slaughter and early prediction of meat quality variation in pigs was never assessed as yet. The objective of the experiment was thus to determine whether the IR body temperature estimates, as measured in the orbital region immediately before slaughter, reliably reflect the preslaughter physiological conditions of pigs (as measured by blood lactate levels) and can be used to explain the variation in pork quality.

2. Materials and methods

2.1. Animals

This study was conducted at a federally inspected swine slaughter plant in Eastern Canada, where 258 market weight pigs (approximately 115 kg liveweight) were randomly selected over a 3-week period for the infrared thermography assessment of the ocular temperature while lining up at the entrance into the restrainer feeding the electrical stunner. In all these animals blood lactate was also assessed. However, meat quality traits were only assessed in a sub-sample (139 carcasses) of this population. At the end of the lairage period (approximately 5 h), pigs were electrically stunned (head-to-chest electrical stunning) and exsanguinated in the prone position.

All experimental procedures performed in the experiment were approved by the AAFC Animal Care Committee at Sherbrooke (QC) based on the current guidelines of the Canadian Council on Animal Care (2009).

2.2. Capture of infrared thermography images

A handheld infrared camera (ThermaCan i60, Flir Systems USA, Boston, MA), operated by a trained technician, was used to collect eye images of each pig just prior to slaughter. An ocular thermography image taken on a pig used in this study is shown in Fig. 1. The images were taken on the right side of each pig while the pig flow in the restrainer was stopped for a few seconds to allow the IROT image capture. Technical parameters, such as the camera emissivity setting of pig ocular surface (0.98) and distance between the IRT camera and the ocular surface (0.25 m), were under control during the IROT scan.

To avoid the confounding effect of ambient conditions on ocular temperature variation, an iButton data logger (DS1923 Hygrochron Temperature/Relative Humidity Logger, Maxim Integrated Products, Inc., Sunnyvale, CA) registering ambient temperature and relative humidity was attached to the camera while images were captured.

IROT images were analysed with the Flir Quickreport program (version 1.2, Flir Systems USA, Boston, MA) for the determination of the maximum temperature (°C) within the area of the medial posterior palpebral border of the lower eyelid and the lacrimal caruncle.

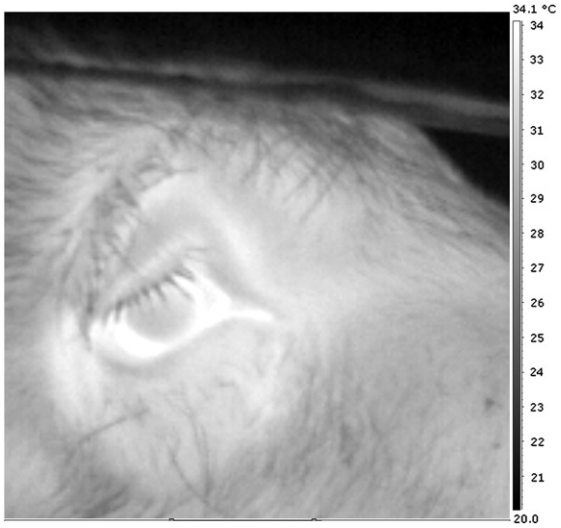

Fig. 1. Infrared thermographic ocular image of a pig in the restrainer.

2.3. Blood lactate measurements

Blood samples were collected from each pig at the same time as the IROT scan by picking one of the animal's distal ear veins with a retractable gauge needle. A drop of blood from the animal's ear was immediately dripped onto a sample strip (two strips or replicate/animal) and inserted into a handheld Lactate Scout Analyzer (EKF Diagnostic GmbH, Magdeburg, Germany) for the real-time assessment of blood lactate level.

2.4. Meat quality measurements

Muscle pH were measured in the longissimus dorsi (LD; at the 3rd/4th last rib level) and semimembranosus (SM; in the middle region) muscles at 1 h and 24 h postmortem (pH1 and pH24, respectively) with a temperature-compensating, spear-type probe (Cole-Palmer Instrument Co., Vernon Hills, IL) attached to a pH meter (pH 100 series; Oakton Instruments, Vernon Hills, IL). In addition, colour data were collected in the LD and SM muscles at the same anatomical locations after a 30-min blooming period. Instrumental colour (L*, a* and b* values) was measured with a Minolta Chromameter (CR-300; Minolta Canada Inc., Mississauga, Canada) equipped with a 25-mm aperture, 0º viewing angle, and D65 illuminant. Drip loss was measured in the LD and SM muscle using the modified EZ-dripLoss method described by Correa, Méthot, and Faucitano (2007). Three 25-mm-diameter cores were removed from the centre of 2.5-cm thick LD (removed at 3rd/4th last rib level) and SM chops, weighed, and placed into plastic drip loss containers (Christensen Aps Industrivaengetand, Hilleroed, Denmark), before being stored for 48 h at 4 °C. At the end of the 48 h storage period, muscle cores were removed from their containers, surface moisture was carefully dabbed, cores were reweighed, and drip loss percentage was calculated by dividing the difference between initial and final core weights by the initial core weight.

2.5. Statistical analysis

Data were analysed using the mixed model procedure of SAS (version 2.0.3; SAS Inst., Inc., Cary, NC). The CORR procedure of SAS was used for calculating the Pearson correlation coefficients to relate