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Validation of an intramuscularly-implanted microchip and a surface infrared thermometer to estimate core body temperature in broiler chickens exposed to heat stress

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ABSTRACT

Heat stress in poultry is associated with an increased core body temperature (CBT) which can be fatal. Methods of estimating CBT range from the minimally invasive method of inserting a digital thermometer into the cloaca of the bird, to the implantation of a temperature recording device (e.g. a data logger) in the peritoneal cavity, a method which gives the most accurate measure of CBT but may be considered invasive. To validate the use of less invasive alternatives to assess CBT in broiler (meat type) chickens using injectable devices, 12 birds were subject to surgery to implant a data logger deep in the body cavity and a microchip in the breast muscle. The birds were then placed in floor pens with an additional 36 birds and subsequently subjected to one of four simulated heat stress conditions over a 3-day period. Measurements of body temperature were collected at intervals from the data logger and microchip (CBT and IM-chip, respectively) along with taken under the wing, feet, comb and cloaca using an infrared thermometer. Changes in body temperature were calculated as the ΔT between pre heat stress and end of 3 h heat stress each day. There was no relationship between CBT and IM-chip, but there was a significant correlation between ΔCBT and ΔIM-chip ($R = 0.71$, $P < 0.05$) during the heat stress. SBT measured under the wing correlated with CBT ($R = 0.71$, $P < 0.05$). Collectively these data confirm the suitability of intramuscularly-implanted microchip and strategically-positioned infrared thermometers to monitor CBT in birds exposed to heat stress, thereby replacing the invasive surgery and associated side-effects of deep body-implanted data loggers for the benefit of animal welfare.

1. Introduction

A major factor influencing the performance, health and welfare of commercially-reared poultry is the thermal environment to which they are exposed. In the USA, the total annual economic loss due to heat stress in broiler chickens (meat-type birds), layers and turkeys was estimated to be $126.6 million (St-Pierre et al., 2003). Heat stress is also a major cause of the reduced efficiency of poultry production in the tropics (Ojano-Dirain and Waldroup, 2002). During the summer months, birds can be exposed to continuous thermal challenge during heat waves, defined as a period of high temperature and relative humidity (RH) that persists for a minimum of five days (Robinson, 2001). The risk of thermal stress in commercial poultry production is likely to increase with climate change (Skuce et al., 2013). Broiler chickens exposed to high temperature and relative humidity find it difficult to maintain their core body temperature (CBT) (Borges et al., 2007), since unfavourable gradients of temperature and water vapour reduce the opportunity for heat loss through sensible and evaporative means (Widowski, 2010). The resulting increase in CBT (Jensen and Toates, 1997) is a significant welfare issue (DEFRA, 2005). A simple and reliable method for the accurate routine measurement of CBT could therefore be a useful indicator of animal welfare during heat stress.

Measurement of CBT from the brain, viscera and deep skeletal musculature (Schwab and Schafer, 1972) or the hypothalamus, pulmonary artery or oesophagus (Brengelmann, 1987), although accurate (Blainey, 1974), requires a very invasive procedures. Thus, animals must be subjected to general anaesthesia and the placement of the temperature measuring and recording devices involves extensive surgery, Therefore, CBT has typically been measured by

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placing a digital thermometer into the rectum/cloaca (rectal temperature) of the animal (Quimby et al., 2009). This relatively less invasive procedure (Chen and White, 2006) still has some shortcomings, such as the need to restrain and handle the animal (Torrao et al., 2011), which could result in stress-induced hyperthermia (Dallmann et al., 2006). Although body temperature measured from a thermometer inserted into the colon and abdominally implanted telemetry were positively correlated (R = 0.824), temperature of the cloaca was 0.6 °C lower than CBT under heat stress conditions (De Basilio et al., 2003). This difference means that different benchmarks are required regarding assessment of the severity of the heat stress the birds are experiencing.

For continuous, reliable and accurate measurement of CBT, surgically implanted radio-telemetry data loggers (Dawson and Whittow, 2000) and telemetry devices (Lacey et al., 2000) have been developed. After suitable calibration against standard thermometers, a major advantage of loggers is that recordings of CBT can be made at pre-set intervals. However, disadvantages of data loggers are risk of infection after invasive surgery, recovery time for the animal prior to commencing any subsequent data collection, the fact that the logger gives only retrospective information about CBT since data can only be accessed after recovery of the logger post-mortem unless telemetric models are used, and finally the possibility of impairing welfare of the bird by obstructing the gastro-intestinal tract or respiratory system (Flecknell and Waterman-Pearson, 2000).

There is an increasing need for accurate measurement and recording of CBT in poultry in controlled studies addressing heat stress and strategies for its alleviation. Development of technologies and sensors that allow measurement and monitoring of CBT in conscious birds with minimal invasion, handling or modification of the animals' behaviour is therefore highly desirable to reduce suffering experienced by animals used in research. Progress has been made internationally in promoting the principles of Replacement, Reduction, and Refinement (the 3Rs) (Medina et al., 2015), i.e. where possible to use animal models rather than live animals, and/or reduce the number of animals used, and/or refine the procedures which animals undergo.

Temperature sensing microchips serve the dual purpose of measuring instantaneous body temperature and identification of the animals (Mrozek et al., 1995). Microchips require minimally invasive fitting (a simple injection), and typically result in minor tissue injury and discomfort to the birds (Chen and White, 2006), although both site and depth of injection are important considerations (Lohse et al., 2010). Identification microchips (RFID, radio frequency identification) with a temperature sensing element operate passively and have no capacity for data storage, but need to be activated by a reader to transmit a radio signal from the scanner to a receiver device (Chen and White, 2006).

Provided these microchips deliver an accurate estimate of CBT, they could serve as a replacement for data logger devices and, because this is a less invasive non-surgical technique, it offers a major refinement to estimating CBT in animals. Whilst the use of microchips to estimate CBT has been validated against other measures of core and rectal temperature in goats (Torrao et al., 2011), p i g s (Lohse et al., 2010) and rabbits (Chen and White, 2006), their use in chickens is yet to be validated.

Another method that might allow estimation of body temperature, and which is fully non-invasive, is by means of an infrared non-contact thermometer to measure surface body temperature (SBT). This approach is dependent on establishing whether a reliable predictive relationship exists between SBT and CBT. Infrared thermometers work by converting radiation emitted from the body into a temperature reading without the need for contact with the animal (Rextroat et al., 1999). During heat stress, vasodilation of blood vessels enhances blood flow to the body surface, causing an increase in skin temperature (Yahav et al., 2005). In poultry, the less feathered parts of the body (comb, legs, under the wings and the cloaca) (Gerken et al., 2006) are mainly involved in heat dissipation.

Given these promising reports of the potential to estimate CBT through implanted microchips and infrared thermometers, the aim of this study was to validate the use of an intramuscularly-injected microchip and a non-contact surface infrared thermometer as refinements of methodologies for the estimation of CBT in broiler chickens exposed to simulated episodic heat stress.

2. Materials and methods

2.1. Animals

A total of 48 female broiler chickens of a commercial genotype (Ross 308, Aviagen Ltd, Newbridge, UK; age 26 days, approx. 1100 g) were selected. Following commercial hatchery practices, the birds had previously received IB 4-91 and Hipragumboro vaccines at 7 and 18 days of age respectively. Upon arrival at the experimental facility, the birds were allowed an acclimation period of 7 days, during which temperature and RH of the facility were set at 20 °C and 50% respectively, according to recommendations for birds of this age (Aviagen, 1999).

The study was conducted in four identical climate chambers (4.1 × 2.4 × 2.2 m, L × *B* × *H*) equipped with computerized temperature and RH controllers. Birds were subsequently randomly allocated to one of four treatments, one treatment per climate chamber, with three replicate pen groups per treatment (4 birds per pen). Circular floor pens were made from plastic divisions (30 cm high, 93 cm diameter) with wood shavings (Goodwills Ltd, Ponteland, UK) spread 5 cm deep on the floor. Commercial feed (20% crude protein, 4% oil, 6% ash, 13.00 MJ ME/kg; W E Jamieson and Son Ltd, Masham, UK) and water were provided *ad libitum* with 6 and 10 cm of feeder and drinker space per bird respectively. Lighting conditions were 16L:8D with an intensity of 30 lx during the light period. At the start of the heat stress treatment, the birds were 46 days old with an average weight of 2423 ± 181.5 g.

2.2. Experimental design

This experiment was conducted under guidelines for animal welfare at both national and local levels. Procedures were approved by the Animal Welfare and Ethics Review Board of Newcastle University and carried out under Project License number PPL 60/4270 of the Animals (Scientific Procedures) Act 1986. To validate methods to estimate CBT in birds exposed to heat stress, it was necessary to simulate moderate episodic heat stress (MEHS) under controlled conditions in the laboratory. The aim was to induce a controlled and modest rise in CBT without resulting in mortality through hyperthermia. The experiment was arranged in a 2 × 2 factorial design, with two levels of temperature (normal = 20 °C and high = 30 °C) and two levels of RH (dry = 40% and humid = 70%) to create four different conditions. Each climate chamber contained one particular temperature-RH combination. Thus, depending on the particular treatment, the level of temperature/RH in each climate chamber was gradually increased from 'control' levels (i.e. 20 °C and 40% RH) over a period of 1 h (ST; step up in temperature by 2 °C every 12 min; while the RH was increased from 40% to 70%) and then held constant for a period of three hours. Once the 3 h had elapsed (3HS), temperature and RH were returned to control levels over a period of 1 h (SD; step down in temperature by 2 °C every 12 min; RH decreased from 70% to 40%).