Non-invasive Core Temperature Transponders as a Problem Alert in Sheep Farming Management

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Abstract. Current farming management is evolving towards systems that require minimal human:animal interaction. However, there is still a need to monitor their condition. The use of transponders to track body temperature fluctuations within the animals may offer a solution. Using a sheep-parasitic nematode (Haemonchus) model we have demonstrated that body temperature is linked to the infection, to pain and stress. We suggest that temperature transponders are a good candidate for use in alert system in extensive farming.

1 Introduction

Labour costs, consumer attitudes and agricultural support regimes are moulding the management systems used in sheep farming [7]. Farmers are challenged with the prospect of achieving both high levels of animal welfare and sustained levels of profitability [7]. The integration of new technologies such as remote alert systems offer the possibility of saving time, energy and money while promoting animal welfare.

The well-being of herbivores on pasture is subject to numerous external disturbances including the threat of disease, pain and human-induced stress. Herbivores have evolved to present minimal indications of weakness to potential predators [5] a strategy which complicates attempts to evaluate potential suffering. However, previous studies have linked the afore mentioned threats of disease, pain and stress to fluctuations in body temperature. Increases in body temperature in response to infectious diseases, particularly bacterial or viral infections [2], and stress [14] have been well documented. Conversely, studies have shown that animals experiencing external pain treatments undergo a drop in body temperature [13]. The aim of this study was to determine if monitoring the body temperature of animals with remote technology can provide insight into their physiological well-being and thereby represent a potential tool in alert systems farming.

Traditional methods of assessing body temperature rely upon taking rectal temperatures with a thermometer. Besides being a laborious task, the required human contact is likely to stimulate a stress response in the animal resulting in a false measure. This inaccuracy is further exaggerated as the measure represents but a single moment in time. In reality, the body temperature of mammals is subject to numerous physiological variables which fluctuate throughout the day [10], [11]. Recent

Chylinski C., Cortet J., Crochet D., Sarradin P. and Cabaret J..
Non-invasive Core Temperature Transponders as a Problem Alert in Sheep Farming Management.
DOI: 10.5220/0003878500850091
In *Proceedings of the International Workshop on Veterinary Biosignals and Biodevices* (VBB-2012), pages 85-91
ISBN: 978-989-8425-94-2

technological advances to measure temperature have been based on surface temperature [9], thermal imaging [8] and sub-cutaneous transponders [16]. However, the effects of ambient temperature, the need for expensive hi-tech equipment and their required proximity to the animals to detect an information signal significantly limits their use. The prototype Medria ® thermobolus transponder technology used in this study overcame these drawbacks enabling us to track the body temperature of individual animals in real-time and from a distance.

The model system used to evaluate this technology included Martinik Blackbelly rams infected with the gastro-intestinal nematode, *Haemonchus contortus*. These blood-sucking worms greatly reduce the productivity of their hosts and currently present the greatest threat to ruminant farming worldwide [15]. Infection by *H. contortus* is known to cause substantial pathophysiological damage to the host specifically at two developmental time points, 1-2 days post-infection (p.i.) and 10-12 days p.i. At both these time points, the developing larval stages penetrate the mucosa of the host abomasum (glandular stomach) consequently destroying tissue and inducing lesions [3]. These two time points represent excellent periods in which to monitor for a pain temperature response. This would provide the first evidence that infection by *H. contortus* is painful to the sheep host. The evaluation of the *H. contortus* infection necessitated taking samples directly from the ram host. These intervals of intense human interference provided a focus on which to evaluate stress temperature responses. We hypothesize pain responses will be observed with a decrease in temperature corresponding to the two tissue penetration events and that human induced stress will be evident with rises in body temperature. It is necessary to understand how these two potentially conflicting effects on temperature interact before we establish the efficacy of using temperature as an alert system in the field.

2 Materials and Methods

The body temperature of 12 two-year old Blackbelly rams with no previous experience of nematode infection was tracked using prototype Medria ® thermobolus tansponders. These were installed in the rumen of each ram after having been swallowed. The transponders transmitted a signal to a corresponding Medria ® GSM radio base which recorded the temperature to an internet based file at 5-minute time intervals. Transponders were inserted on day 0, the same day in which all rams were inoculated with 10, 000 infective L3 larvae by oral administration. This study was part of a wider investigation in which the host response to four different lines of *H. contortus* were compared against each other, three rams per line.

The rams were penned in groups of 6 and maintained indoors throughout the experiment. They had open access to water and fed hay, feed concentrate and cereals *ad lib*. The infection was evaluated by taking rectal fecal samples from each of the rams. Nematode faecal egg counts (FEC) were then carried out using the McMaster flotation technique with sodium chloride as a flotation solution (specific gravity 1.18). This measured the nematode eggs per gram (EPG) of faeces sensitive to 50 EPG. Levels of EPG are universal indicators that should reliably detect the presence of infection and indicate its' intensity (Stafford, Morgan and Coles, 2008). All human interference to collect samples took place between 09:00 – 12:00. This provided the time frame in which all stress response evaluations were focused. Pain response evaluations focused around the days in which gross pathophysiology occurs.

All rams were slaughtered on day 53 post-infection by electronarcoses and exsanguination. All transponders were successfully recovered from the rumens.

Statistical analyses were performed with SPSS for ANOVA. The Zeitun software (version 0.2.1, 2009) was used to analyse time series of temperature. The trend option with cubic regression was chosen and the adjusted coefficient of correlation R^2 were calculated on a daily basis on records not related to major parasitism infection or sampling manipulations.

This experiment was approved by the regional ethical committee (Comité d'Ethique du Val de Loire) in 2011.

3 Results

3.1 Infection Evaluation

The average EPG of faces observed within all rams during the experiment was 500 EPG which corresponds to a medium-heavy infection intensity. The average EPG per individual however ranged from a few eggs to 1200.

3.2 Variability in Ram Temperature: "Hot" vs. "Cold" Individuals

The results show the average temperature of the individual rams throughout the experiment varied significantly between each other (ANOVA $p = 0.05$) ranging within 0.7°C, from 39.1 – 39.8°C (Fig. 1). Additionally, there was a significant variation in temperature within each individual (ANOVA $p = 0.001$)

The confidence intervals of the "hot" rams were demonstrably smaller than those of the "cold" rams (Fig. 1). This may be due to variation within a day or between several days. Investigations of the daily temperature dynamics from one of the "cold" and one of the "hot" rams demonstrated the "cold" ram to have much greater variability in temperature fluctuations. The computation was based on time points in which the rams were not exposed to external stress factors such as handling and a time after which the most severe pathophysiological effects of infection were likely to occur (from day 20 p.i.). It should be noted that the daily evolution of temperature (adjusted with a cubic regression) was more repeatable from one day to another in the "hot" than in "cold" ram (data not shown).

3.3 Modifications of Temperature Relative to Infection

On day 0, the same day in which rams were inoculated and the transponders were in serted, the rams exhibited temperatures which were significantly higher (ANOVA $p = 0.05$) than the average (Fig. 2). This was followed by a continual decrease in temperature until day 3 post infection (p.i.) when the temperature was significantly

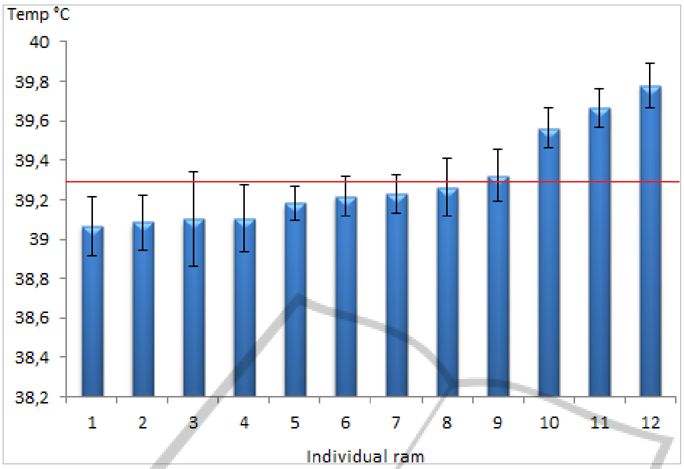

Fig. 1. Average temperature of individual rams throughout experiment. Data based on temperature observations from a full 24 hour period over 5 non-manipulation days (days 40, 41, 43, 46, 47 p.i.). Error bars represent 95% confidence intervals. The red line indicates the average temperature (39.3°C) of the rams throughout the experiment (n = 12).

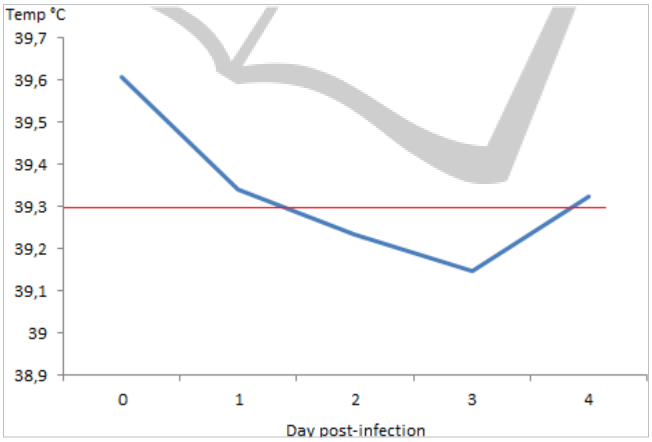

Fig. 2. Temperature of rams (average; n = 12) over days 0 – 3 p.i. Data based on temperature observations from a full 24 hour period. The red line indicates the average ram temperature (n = 12)(39.3°C) throughout the experiment.

lower (ANOVA $p = 0.01$) than average. This time period (day 1 – 3 p.i.) corresponds to the time in which larvae penetrate the abomasal mucosa as part of their developmental process. By day 4 p.i. the ram temperature returns to average.

The rams experience a significant drop in temperature over days 12 – 14 (ANOVA $p \leq 0.05$) (Fig. 3) corresponding the exit of the larvae from the abomasal mucosa and the development of lesions of the secretion glands. This is followed by a sharp increase in temperature significantly higher than average (ANOVA $p = 0.02$).

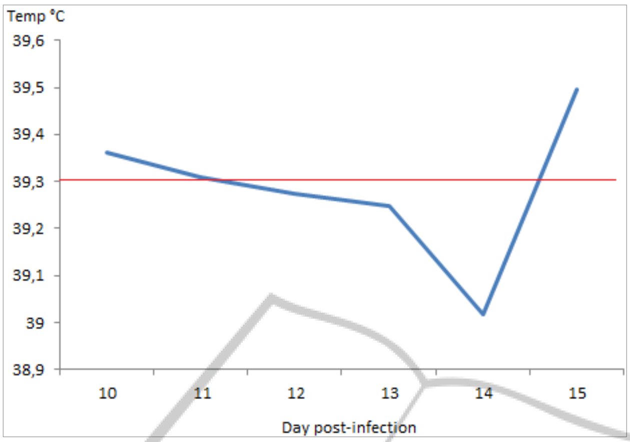

Fig. 3. Temperature of rams (average; n = 12) over days 10 – 15 p.i. Data based on temperature observations from 24 hour period. The red line indicates the average ram temperature (n = 12; 39.3°C) throughout the experiment.

3.4 Modifications of Temperature Relative to Manipulation

The handling of the rams caused a significant increase in temperature on each of the three sampling days (ANOVA $p \leq 0.05$) day compared to their average temperature in the absence of handling (Fig. 4). However, this increase reduced (ANOVA $p = 0.08$) with the repetition of sampling.

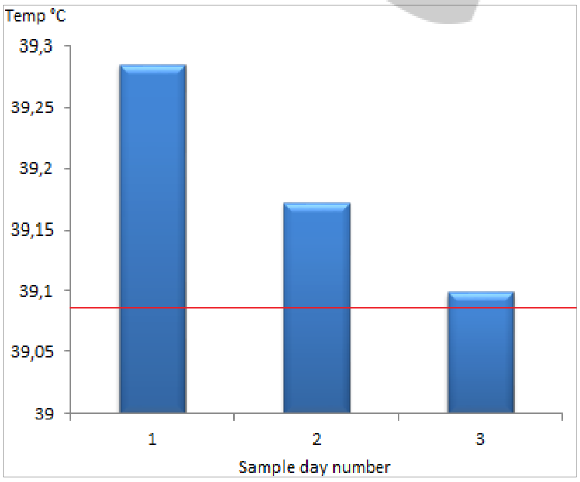

Fig. 4. Average ram temperature on sample days (days 32, 42, 53 p.i). Data based on temperature observations between 09:00 – 12:00.The red line indicates the average ram temperature (n = 12) (39.09°C) within this time period calculated from 5 non-handling days.

4 Discussion

The transponders were sensitive enough to detect significant variations between individual rams. Identifying the natural physiological limits of an individual is essential if they are to be used effectively as indicators of suffering. Previous studies based on rectal temperatures also recorded individual temperature variations [1] however, the temperature range observed in the present study (39.1 – 39.8°C) appears to be higher than theirs (38.8 – 39.3°C). It is possible that these differences result from differences between sexes or breeds of sheep or their infections status, but the remote temperatures recorded in real-time by the transponders are likely to provide a more accurate picture.

Pain responses (temperature decreases) were recorded at the two time periods in which host tissue destruction occurred. Tissue destruction is closely followed by inflammation [4] a known trigger for temperature increases [6]. This may explain the sharp rise in temperature to a level significantly greater than average observed on day 15. This provides the first evidence that infection by *H. contortus* causes pain in their hosts and carries with it important welfare implications. Ideally, the physiological indication of pain would be substantiated with behavioural criterion. However the nature of the infection and its consequent pathophysiology infer the pain would induce a chronic (lasting over several days) opposed to an acute pain. Preliminary studies (not presented) detected minimal changes in behavior even at peak temperature pain response time points.

Stress responses (temperature increases) were observed during animal handling events. Although the response lessened with frequency as observed in previous studies [13], they remained significantly above average temperature levels. As well as being a negative welfare state, the physiological effects of stress have a negative impact on meat quality. The use of remote monitoring systems would minimize the potential for human induced stress.

5 Conclusions

MEDRIA© thermobolus transponders were successfully used to track the body temperature of the rams and identify pain, stress and possible inflammation responses within their host. We suggests they present a strong candidate for alert systems in precision farming. The technology is restricted by the 400 meter limit in which the temperature signal can be received, extensive farms cover far greater ranges. Additionally, their cost at 60 euros each means there aren't likely to be adapted for use in entire flocks. The use of sentinel sheep to act as representatives of the flocks' condition may however provide a solution.

Acknowledgements

C. Chylinski is a grateful recipient of a PhD grant from the Pierre and Marie Curie EU program "NematodeSystemHealth".

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