

Remote Sensing for Monitoring Hydric Stress in Farm Animals

Elise Saoutieff¹, Sébastien Brulais¹, Ilaria Sorrentino¹, Marie Escudé¹, Mahfod Benessalah¹, Laura-belle Gauthier¹, Claire Verplanck¹, Romain Anciant¹, Isabelle Texier¹, Caroline Xavier², Lucile Hervé², Anne Boudon², Florence Gondret²

¹ Univ. Grenoble Alpes, CEA, Leti, Grenoble, France,

² INRAE, Institut Agro PEGASE, Saint Gilles, France
elise.saoutieff@cea.fr

Summary:

The rapid acceleration of global climate warming is presenting unprecedented challenges for agricultural systems worldwide. Particularly, enhancing livestock resilience to environmental stressors, notably represented by more frequent acute heat waves and feeds of poorer and inadequacy qualities, is one of the challenges.

In the Wait4 project, we aimed to quantify and characterize animal adaptation to heat and hydric stress. From this perspective, the development of new wearable sensors, based on microneedle patches to perform measurements of physiological parameters that are minimally invasive for animals were developed to monitor interstitial hydraulic conductivity which represents intrinsic permeability of the cells and saturation of the fluid, as a proxy of dehydration to inform about hydric stress.

Keywords: adaptation to heat stress, interstitial fluid, micro-needles, remote sensing, wearable

Background, Motivation and Objective

The consequences of global warming of 1.5 °C above pre-industrial levels and the resulting greenhouse gas emission trajectories require us to assess the impact of associated environmental changes on both humans and animals [1]. In France, a plan based on a Reference Warming Trajectory for Climate Change Adaptation (TRACC) [2] of +3°C by the end of the century was even launched in 2026 by the government to develop a climate change adaptation strategy. This includes planning water management and implementing vulnerability assessment of farm animals and resilience of farming systems as top priorities.

Farm animals are negatively affected by the climate change [3]. One of the biggest impacts is the temperature increase, especially more frequent and acute heat waves, that affects the hydration quality of feeds (especially forages), changes the feeding and drinking behaviors of the animals, and challenges thermoregulation mechanisms including sweating, respiratory hyperventilation, hyperthermia, and cellular responses in blood and tissues. Thus, moisture and heat were the most commonly perceived adverse factors in hot environment.

The WAIT4 project (Welfare: Artificial Intelligence and new Technologies for Tracking Key Indicator Traits in Animals Facing Challenges of the Agro-ecological Transition) aims to monitor animal physiology in response to climate change in controlled and harsh environments [4]. Indeed, IoT technologies offer new opportunities in precision livestock farming [5] to understand and improve animal's responses. However, sensor techniques are still barriers [6] for monitoring physiology of large farm animals.

Conductivity Sensor

A wearable sensor for dermal interstitial fluid (ISF) analysis, focusing on conductivity as an indicator of electrolyte balance, hydration, and metabolic changes was developed [7]. Based on poly(lactic-co-glycolic acid) (PLGA) microneedle arrays, sensors were fabricated via hot molding and coated with metallic layers to function as electrodes.

ISF, a biofluid similar to blood but more accessible, presents a promising non-invasive solution for health monitoring. During stress period, water quantity will decrease in the ISF and its conductivity increase.

System Architecture

The overall system architecture of the wearable device is shown schematically in Figure 1.

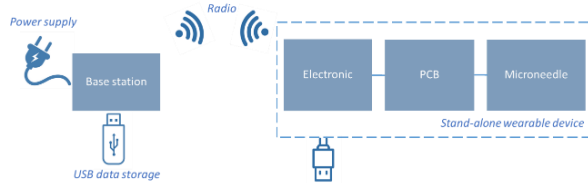


Fig. 1. Architecture of the autonomous wearable device

Each sensor (microneedle patch) is connected to a small circular printed circuit board (PCB) containing a temperature sensor and making contact with the patch via spring-loaded test pins. The sensor/PCB assembly is then connected via a ribbon cable to the data acquisition board (the mother board), which collects, processes and transmits the data to a base station with a radio signal (fig.2).



Fig. 2. Assembled patch connected to the mother board

The electronic mother board, embedded a AD5941 potentiostat to perform the impedance and so conductivity measurement.

Results

This study presents wearable sensors based on microneedle arrays, focusing on conductivity as an indicator of electrolyte balance, hydration, and metabolic changes. Their performance was first tested on skin models in labs. Then, sensors were inserted on living pigs and dairy cows under different conditions (from 24 hours until 1 week of implementation, followed by a period of thermal or hydric stress).

This minimally invasive solution supports sustainable, welfare-oriented livestock farming to address agro-ecological transition challenges.

Acknowledgements

This research was funded by Agence Nationale de la Recherche under the France 2030 program with the reference ANR-22-PEAE-0008.

References

- [1] GIEC report, 2023 Available: <https://www.ipcc.ch/report/ar6/syr/> (accessed: Ap. 27, 2026)
- [2] TRACC report, Available: https://www.ecologie.gouv.fr/sites/default/files/documents/27012026_DP_TRACC.pdf (accessed: Ap. 30, 2026)
- [3] A. Anuta, X. Wang, P. Kinay, The impacts of climate change on livestock: An interdisciplinary, scoping review of health, production, and adaptation strategies, *Climate Smart Agriculture*, Vol. 2, Issue 4, 2025, 100082, ISSN 2950-4090, doi: 10.1016/j.csag.2025.100082
- [4] I. Sorrentino, C. Verplanck and Y. R. J. Thomas, *Electrochemical Sensors for Animal Welfare*, *Proceedings 2024*, 97, 45. doi: 10.3390/proceedings2024097045
- [5] V. Choudhary, P. Guha, G. Pau, S. Mishra, An overview of smart agriculture using internet of things (IoT) and web services, *Environmental and Sustainability Indicators*, Volume 26, 2025, 100607, doi: 10.1016/j.indic.2025.100607
- [6] C.H. Knight, Review: Sensor techniques in ruminants: more than fitness trackers, *Animal*, Volume 14, Supplement 1, 2020, Pages s187-s195, doi: 10.1017/S1751731119003276
- [7] L. Gautier, S. Wiart-Letort, A. Massé, C. Xavier, L. Novais-Gameiro, A. Hoang, M. Escudé, I. Sorrentino, M. Bonnet, F. Gondret, C. Verplanck, I. Texier, *Micromachines* 16 (9), (2025), 1015, doi : 10.3390/mi16091015