

A Low-Cost Modular System for Real-Time Wireless Monitoring of Coffee Fermentation Temperature

¹BERTARINI, Pedro Luiz Lima; ¹FERREIRA, Daniel de Oliveira; ¹MOTA, Alfredo Francisco Amâncio; ¹BORGES, João Victor Fernandes; ¹FREITAS, Otávio Ferreira; ¹BARBOSA, ¹Paulo Ricardo Pazetto; ²GOMES, Matheus de Souza; ³AMARAL, Laurence Rodrigues do; ⁴SANTOS, Líbia Diniz; ¹ARAÚJO, Luis Henrique Silva; ²JÚNIOR, Milton Thomaz Franco.

¹Universidade Faculty of Electrical Engineering, Federal University of Uberlândia, Patos de Minas, MG, Brazil;
²Biotechnology Institute, Federal University of Uberlândia, Patos de Minas, MG, Brazil ;
³Faculty of Computation, Federal University of Uberlândia, Patos de Minas, MG, Brazil ;
⁴Faculty of Chemical Engineering, Federal University of Uberlândia, Patos de Minas, MG, Brazil

Introduction

Temperature control during coffee fermentation is essential to ensure consistent sensory quality, yet many producers lack access to reliable and affordable monitoring technologies [1]. Manual measurements are often imprecise or infrequent, and most systems lack real-time data visibility [2]. To address this gap, we developed a low-cost and modular electronic system capable of monitoring fermentation temperature in real time, offering scalability and flexibility to coffee producers.

Materials/Methods

The system consists of a central unit based on Arduino Nano and DS18B20 waterproof sensors. Each device supports up to five simultaneous temperature inputs, allowing either multi-point readings in a single fermentation bioreactor or coverage of multiple bioreactors placed in close proximity. The data are transmitted via Wi-Fi using an ESP-01 module to a concentrator. Multiple such devices can connect to the same concentrator simultaneously, forming a star topology. The concentrator, built with a Heltec ESP32 LoRa WiFi device, aggregates incoming data and transmits it using the LoRa protocol to a gateway [3]. This gateway, also based on the same Heltec board, is placed near the farm’s Wi-Fi area and forwards the information to a remote web server. A dedicated webpage provides real-time access to the fermentation temperature data [4].

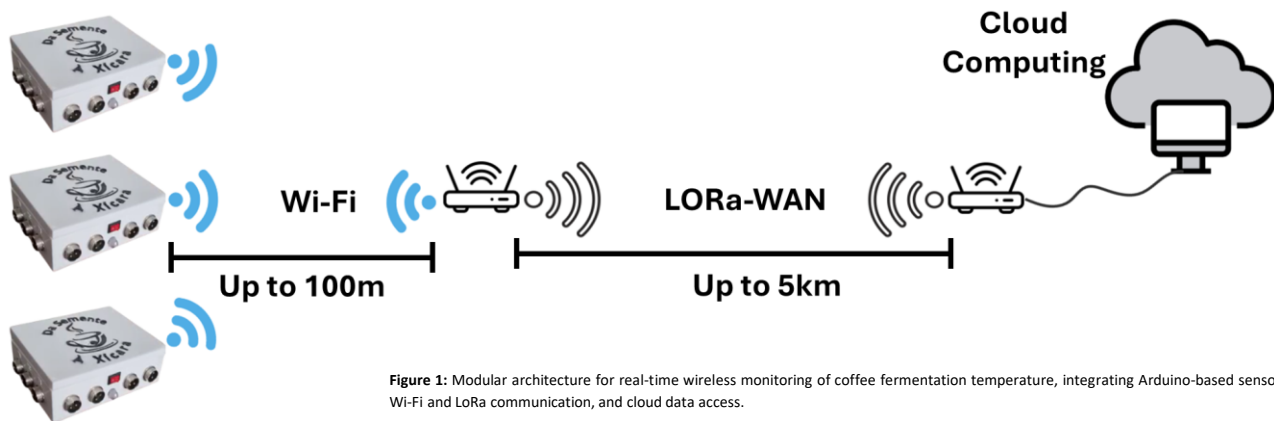


Figure 1: Modular architecture for real-time wireless monitoring of coffee fermentation temperature, integrating Arduino-based sensors, Wi-Fi and LoRa communication, and cloud data access.

Results/Discussion

In-farm evaluations were conducted with different bioreactor’s setups with temperatures ranging from 12°C to 34°C under innumeros fermentation conditions. The system demonstrated accurate and stable performance, supporting continuous and simultaneous temperature readings from multiple probes. Connectivity across all components—including Wi-Fi, LoRa, and server integration—performed reliably under all conditions.

Conclusion/Perspectives

This solution enables affordable, scalable, and real-time temperature monitoring during coffee fermentation. Its modular architecture supports flexible deployment, making it suitable for various farm sizes and layouts. The availability of real-time data empowers producers to make informed and timely decisions, improving process consistency and final coffee quality [5]. Future work will focus on field deployment in operational farm settings and long-term validation under commercial fermentation conditions. Future work will focus on extended field validation during full harvest cycles, as well as integration with data analytics and fermentation decision-support tools.

References: 1. Lee, L.W., Cheong, M.W., Curran, P., Yu, B., & Liu, S.Q. (2015). Coffee fermentation and flavor – An intricate and delicate relationship. *Food Chemistry*, 185, 182–191. 2. Elhalis, H., Cox, J., & Zhao, J. (2020). Ecological diversity, evolution and metabolism of microbial communities in the wet fermentation of Australian coffee beans. *International Journal of Food Microbiology*, 321, 108544. 3. Pagano, A., Croce, D., Tinnirello, I., & Vitale, G. (2022). A survey on LoRa for smart agriculture: Current trends and future perspectives. *IEEE Internet of Things Journal*, 10(4), 3664-3679. 4. Centenaro, M., Vangelista, L., Zanello, A., & Zorzi, M. (2016). Long-range communications in unlicensed bands: the rising stars in the IoT and smart city scenarios. *IEEE Wireless Communications*, 23(5), 60–67. 5. Bastian, F., et al. (2021). From Plantation to Cup: Changes in Bioactive Compounds during Coffee Processing. *Foods*, 10(11), 2827

Acknowledgements

