Sujet thèse / PhD subject 2026

Titre Thèse	Technologies de détection hybrides pour l'évaluation de la qualité des grains de café : impédancemétrie et spectrométrie de masse en phase gazeuse	
PhD Title	**O**lfactory **R**esponse of coffee **B**eans based **I**mpedance sensing and **T**andem Mass spectrometry: Hybrid sensing technologies (ORBIT)	
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Projet phare principal	IOT	
Financement acquis Oui ☐ Non ☐ Partiel ☒	Si acquis (total ou partiel), préciser : (contrat, organisme, Université étrangère…) : demi-financement ICAM	
Financement demandé	Contrat Doctoral Etablissement	ULille ☒ Centrale Lille ☐ JUNIA ☐
	Région ou Autre ☐ Préciser :	Co financement (Préciser l'origine, demande en cours, et si acquis ou pas) : Co-financement ICAM Lille, Acquis

Abstract

Coffee quality assessment is a major scientific, economic, and societal challenge, as coffee is one of the most widely traded agricultural commodities worldwide. The quality of green and roasted coffee has a direct influence on market value, consumer perception, and the overall sustainability of the coffee supply chain. Quality variability arises from a complex interplay of factors, including plant physiology, storage conditions, microbial contamination, and environmental stress conditions. The global coffee industry represents a market of several hundred billion euros annually, with quality grading playing a central role in price determination. Producing regions are increasingly exposed to climate variability, which affects bean composition and aroma profiles, while consumers demand higher and more **consistent sensory quality**. Consequently, there is a growing need for rapid, objective, and valuable **intelligent tools** capable of assessing coffee quality throughout the production chain, **from farm to cup**.

Conventional methods for coffee quality evaluation rely primarily on sensory analysis (cupping), **gas chromatography–mass spectrometry** techniques (GC–MS), and **physicochemical measurements**. While cupping remains the industry's gold standard, it is inherently subjective, requires trained experts, and is not easily scalable. Chromatographic approaches provide precise and reproducible fingerprints but require expensive instrumentation, complex sample preparation, and laboratory conditions, limiting their deployment in field or industrial environments.

In this context, rapid profiling of volatile organic compounds (VOCs) has emerged as a promising **non-destructive approach** for assessing food quality [1]. Coffee beans emit complex mixtures of VOCs that reflect their botanical origin, processing methods, roasting degree, freshness, and the presence of defects. For instance, if we consider botanical origin and roasting degree, both factors significantly influence the volatile profile of coffee samples. Botanical origin determines the intrinsic metabolic composition of the beans [2], leading to characteristic precursor compounds that generate specific aroma markers. Processing methods modify fermentation dynamics and microbial activity, thereby altering the formation of alcohols, esters, acids, and other fermentation-derived volatiles. Roasting degree drives thermally induced reactions such as Maillard reactions, caramelization, and pyrolysis, which significantly reshape the VOC spectrum by generating furans, pyrazines, aldehydes, and ketones [3]. These volatile signatures constitute a rich chemical fingerprint that can be exploited to **discriminate quality grades** and **detect early degradation**.

However, the high dimensionality and complexity of these VOC mixtures require advanced sensing strategies combined with data-driven analysis. Throw the *ORBIT* project, we aim to design and develop an **intelligent**, **portable**, and **multifunctional detection tool** based on a miniaturized **multi-sensor platform** [4]. The device will integrate embedded algorithms for real-time analysis and processing of data acquired from an array of organic sensors. The objective is to identify specific chemical markers associated with coffee quality and purity, including early indicators that may be detectable at very early stages, before human sensory defects become perceptible. This approach is intended to **complement existing analytical technologies** by providing a non-destructive, rapid, and field-deployable solution adapted to real-world conditions.

The work will be carried out within this project builds upon the collaboration between the Institut Catholique d'Arts et Métiers (**ICAM**), the Institute of Electronics, Microelectronics and Nanotechnology (**IEMN**), and Hanoi University of Science and Technology (**HUST**), Vietnam. This collaboration combines complementary expertise in electronic sensor design, micro- and nano-fabrication, materials science, and data analysis, with strong experience in the development of innovative sensing platforms. By leveraging shared infrastructures, **interdisciplinary** know-how, and previous research activities, the project provides a robust framework for the development, validation of advanced sensing technologies.

[1] C. Taiti, G. Vivaldo, S. Mancuso, D. Comparini, et C. Pandolfi, « Volatile organic compounds (VOCs) fingerprinting combined with complex network analysis as a forecasting tool for tracing the origin and genetic lineage of Arabica specialty coffees », *Scientific Reports*, vol. 15, nº 1, p. 13709, avr. 2025, doi: 10.1038/s41598-025-97162-5.

[2] Yang, Si et al. "Determination of the Geographical Origin of Coffee Beans Using Terahertz Spectroscopy Combined With Machine Learning Methods." Frontiers in nutrition vol. 8 680627. 17 Jun. 2021, doi:10.3389/fnut.2021.680627 ».

[3] Moon JK, Shibamoto T. Role of roasting conditions in the profile of volatile flavor chemicals formed from coffee beans. J Agric Food Chem. 2009 Jul 8;57(13):5823-31. doi: 10.1021/jf901136e. PMID: 19579294 »

[4] L. Routier *et al.*, « Single-point calibration process based integrated electrical impedance analyzer for multi-selective gas detection », *Discov Appl Sci*, vol. 6, nº 8, p. 403, juill. 2024, doi: 10.1007/s42452-024-06102-x.