Thesis offer

Development of digital twin for contact cooking of minced meat

Context:

Approximately 20–25% of foodborne illness outbreaks can be attributed to the consumption of undercooked poultry or meat [1], [2], [3]. The World Health Organization highlights that *Salmonella*, *Campylobacter*, and enterohaemorrhagic *E. coli* are among the most common foodborne pathogens, with undercooked meat being a significant source. Undercooked beef is a leading cause of campylobacteriosis in some regions [4]. Minced meat has a higher risk of contamination compared to whole cuts. This is due to the grinding process, which can mix bacteria from the surface throughout the meat. Special populations, such as children, the elderly, pregnant women, and immunocompromised individuals, are more vulnerable to foodborne illnesses that can result from undercooked or contaminated minced meat. Judging the doneness of meat and poultry during cooking—particularly in contact cooking methods such as pan-frying—is a complex task. Despite being a common cooking process in both domestic and professional settings, contact cooking has received relatively little scientific attention compared to other methods. It presents a challenging trade-off between ensuring food safety (through sufficient heat treatment to eliminate pathogenic bacteria) and preserving organoleptic qualities (such as taste, texture, and appearance) by avoiding overcooking.

In addition to this problem, food preparation sector in general faced shortage of labour and high turnover rates[5], [6]. Even before the coronavirus pandemic, among Germany's top six most unpopular jobs were chef and sous-chef[7]. Hence, an adequate and affordable decision support system is the need of the hour and can address some of the challenges. We imagine an innovative solution designed to empower cooks in overcoming the challenges posed by high staff turnover and varying levels of kitchen experience. This tool will assist cooks in managing multiple pieces of meat, each with different starting times, ensuring that every item is cooked to perfection. By streamlining the cooking process and providing real-time guidance, our solution supports kitchen staff in delivering consistent, high-quality results, regardless of their experience level. The concept of the digital twin is integral to this dynamic: the aim is to develop a methodology and tools for integrating high throughput instrumentation, modelling, real time simulation, control, and decision support into a holistic approach.

Objective of the thesis:

The objective of this thesis is to develop a digital twin for the thermal contact cooking of minced meat. This involves the following sub-objectives

- Design and develop an experimental setup that accurately replicates real-life contact cooking conditions while ensuring system observability through sensor data acquisition.
- Optimal sensor placement and acquisition of experimental data of the contact cooking process, thus creating a database of the material properties of the meat evolution during the cooking process at various cooking conditions.

- Creation of physics-based simulation model which accurately depict the phenomena.
- Creation of low-latency reduced order models with meta-data from the mechanistic model simulations.
- Perform state-estimation. This can be with the use of a model-based approach or a surrogate model by machine learning methods such as neural networks[9] depending on the complexity.
- Develop real time monitoring systems and implement Model Predictive Control (MPC).

Competences required:

- Masters/Engineer in any related academic discipline with expertise in mathematical modelling and simulation – Mechanistic modelling and Data-driven modelling/Artificial intelligence, Control systems and instrumentation.
- Hands-on experience or strong motivation for experimental work, including: Design and construction of experimental setups, Sensor selection and placement, Implementation of computational models on physical systems.
- Good proficiency in English, proficiency in French is a plus.

Research environment and conditions of work:

This offer is funded from the start-up purse of a junior professor (Chaire de professeur junior - CPJ). The SPAB and MMIP departments of AgroParisTech are co-sponsors of this project: SPAB for aspects relating to the instrumentation, control and optimisation of food processes; MMIP for aspects relating to modelling, simulation, artificial intelligence and data processing. This position will be based in the ModIC (Modelling and Computer based Engineering) team at SayFood JRU (Paris-Saclay Food and Bioproduct Engineering Joint Research Unit), with strong interactions with MIA JRU Paris Saclay (Paris Saclay Applied Mathematics and Computer Science Joint Research Unit).

Food and bioproduct sciences and processes (SPAB, AgroParisTech) department positions its teaching and research activities in the general perspective of the challenges of the valorisation of agricultural resources through their transformation.

Mathematical, Computer and Physical Modelling (MMIP, AgroParisTech) department is interested in implementing methods for modelling, processing, and analyzing data to support decision-making in food and bio-product processes using approaches from mathematics, computer science, and physics.

SayFood JRU (INRAE-AgroParisTech-Univ. Paris-Saclay) is a research unit whose activities focus on the physical, biochemical and microbiological processes that govern food processing. Within this unit, the ModIC team focuses on the developing mechanistic models and applying the developed models for engineering applications.

SayFood MIA JRU (INRAE-AgroParisTech-Univ. Paris-Saclay) brings together statisticians and computer scientists specializing in statistical and computational modelling and learning for biology, ecology, the environment, agronomy, and the agri-food sector.

Each of the units has been in new premises since 2022, close to each other, on the Paris-Saclay site. The doctoral student will work at the AgroParistech - Palaiseau campus and will have open access to a wide range of leading experimental tools, modelling tools and associated expertise.

The PhD student will be affiliated with the ABIES doctoral school.

General information:

Duration: 3 years
Registration: Université Paris-Saclay, ABIES Doctoral School
Location: Palaiseau, Ile-de-France
Salary: gross 2200 € per month in 2025, 2300 € per month from 2026 onwards
Benefits: Reimbursed public transport (75%), flexible working hours, multidisciplinary scientific group
Starting date: October 2025
Secularism: The recruited person will be subject to the charter on secularism in public services (French law 2021-1109 of 24 August 2021). In particular, no religious symbols may be worn in the workplace.
Application deadline: 15 – July- 2025. Early applications welcome.

Candidature:

Applications (CV + motivation letter + last 3 years grades) and any requests for information can be sent to

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References:

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