PhD DISSERTATION PROJECTS

**Development of Sensing Solutions for Evaluation of Deposited Pesticides in Fruits**

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This PhD thesis research project is aimed to ensure environmental sustainability as well as the safety in fruits by developing sensing solutions for the evaluation of deposited pesticides in fruits. This is two-fold study, and the first step involves the development of better protocols and methods to evaluate pesticide deposition. Secondly, effective detection methods that provide easy, quick, economical, and environmental friendly on­-site detection of pesticides even at trace levels will also be developed. Furthermore, both methods will be validated, and their application will be carried out in the lab as well as in the field.

**Sviluppo di soluzioni di rilevamento per la valutazione dei pesticidi depositati nella frutta**

Questo progetto di ricerca di tesi di dottorato ha lo scopo di garantire la sostenibilità ambientale e la sicurezza nei frutti sviluppando soluzioni di rilevamento per la valutazione dei pesticidi depositati nei frutti. Questo è uno studio duplice e il primo passo prevede lo sviluppo di protocolli e metodi migliori per valutare la deposizione di pesticidi. In secondo luogo, saranno sviluppati anche metodi di rilevamento efficaci che forniscano un rilevamento in loco facile, rapido, economico e rispettoso dell'ambiente dei pesticidi anche a livello di tracce. Inoltre, entrambi i metodi saranno validati e la loro applicazione sarà effettuata sia in laboratorio che sul campo.

# **1. State-of-the-Art**

Fruits and vegetables are a substantial part of a healthy balanced diet providing vitamins, minerals, polyphenols, and dietary fibre to the consumers leading to a healthy lifestyle (He et al., 2023). The increased health awareness among consumers, rapid urbanization, and changed lifestyle patterns has dramatically skyrocketed the demand for fruits and vegetables globally. In order to meet the demand, farmers apply pesticides excessively to increase the yield (He et al., 2023; Philippe et al., 2021). Many systematic studies have also indicated that almost half of the pesticides applied to crops enter the environment by contaminated soil, water, and air from the site of application or field (Schleiffer and Speiser, 2022). Thus, Regulatory authorities are strictly monitoring pesticide deposition to evaluate the performance of agricultural sprayers and bring required changes to reduce the adverse impacts of spray drift on the environment and to lower pesticide waste (Munjanja et al., 2020). Pesticide deposition can be investigated by using various tracers solutions such as fluorescent tracers, colorimetric tracers, and metal ion tracers (Srinivasarao et al., 2021). Fluorescent tracers are extensively used because they are economical, less harmful, practical and highly sensitive in comparison to other tracers (Zhang et al., 2020). The deposition assessment by sensor provides benefits over direct sampling by reducing time and labor costs and providing information on the spray drift (Qin and Chen, 2023). The development of sensing solutions for assessing spray drift has become a popular trend due to advancements in sensor technology (Li et al., 2022). Thus, there is a need to find sensing solutions for the evaluation of pesticides deposited on fruits to ensure environmental sustainability and safety in fruits.

Right after the application of pesticides, their residues stay in the food, but the level is kept on decreasing due to their breakdown depending upon the type of food, type of pesticide used, application method, and post-harvest processing of food (Sindhu and Manickavasagan, 2023). Excessive exposure to chemical pesticides may cause diabetes mellitus, neurological disorders (Parkinson’s disease & Alzheimer’s disease), reproductive syndromes, respiratory issues, cancer, and oxidative stress (Umapathi et al., 2022). Keeping in view the associated health risk, Codex Alimentarius Commission has defined Maximum Residue Limits (MRLs) for all pesticides to protect human health and promote international fair trade (Sindhu and Manickavasagan, 2023). Thus, many attempts and investigations were carried out to reduce human exposure by restricting pesticide application and reducing the level of MRLs in food commodities. Conventionally, many methods such as atomic absorption spectrometry, High-Performance Liquid Chromatography, Liquid chromatography-mass spectrometry (LC-MS), Gas Chromatography, gas chromatography-mass spectrometry (GC-MS), Surface-enhanced Raman spectroscopy (SERS), capillary electrophoresis, and ELISA were employed for the detection of pesticides in various food commodities. However, high cost, greater time consumption, the requirement of expert personal, complicated pre-treatment of samples, and large instruments limit the application of these methods for on-site and quick detection despite being precise and highly sensitive methods (Schleiffer and Speiser, 2022). This highlights a dire need to develop effectual analytical methods that could provide easy, quick, economic, and environmental friendly detection of pesticides even at trace levels.

**2. PhD Thesis Objectives and Milestones**

The project aims to assess the correlation between the amount of deposited pesticides and residues on fruits. So, the amount of pesticide deposited during spray will be evaluated and correlated to the residues on the fruit. Within the overall objective mentioned above this PhD thesis project can be subdivided into the following activities according to the Gantt diagram given in Table 1:

A1) **Literature review**

A2) **Optimization and development of better protocols and methods to evaluate pesticide deposition:** The preliminary work starts with available instruments in the laboratory for the investigation of pesticide deposition. Moreover, the sensing methods to evaluate the pesticide deposition will be developed and tests will be conducted in the wind tunnel in the agroforestry and innovation lab by employing anti-drift nozzle and air-assisted spraying techniques.

A3) **Development of sensor-based solutions for the detection of pesticides in fruits:** The second year of the research will focus on the development of a sensing solution for pesticide detection in fruits. This work will be done in close collaboration with the Sensing technology lab. This second stage will be the next step toward the proposed study aim and will provide an alternative to a conventional method for pesticide detection in fruits.

A4) **Validation and application** of the sensing solutions developed during the first and second stages.

A5) **Writing and editing** of the PhD thesis, scientific papers and oral and/or poster communications.

***Table 2***Gantt diagram for this PhD thesis project.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity Months | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |  | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| A1) | ***Literature review*** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  A2) | ***Optimization and development of better protocols and methods to evaluate pesticide deposition*** |   |   |   |  |  |  |  |   |  |   |  |  |  |  |   |  |  |  |  |   |   |  |  |  |  |
| A3) | ***Development of sensor-based solutions for the detection of pesticides in fruits*** |   |   |   |  |  |  |  |   |  |   |  |  |  |  |   |   |   |  |   |   |   |  |  |  |  |
| A4) | ***Validation and Application of the sensing solutions***  |   |  |   |   |   |   |  |   |  |   |   |   |   |  |   |  |  |  |  |   |   |   |   |   |  |
| A5) | ***Thesis and Paper Preparation*** |   |   |   |   |   |   |   |   |  |   |   |   |   |   |   |   |   |  |   |   |   |   |   |   |   |

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