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Enhanced Biosensor for Pesticide Residue Detection in Fruits and Vegetables

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A biosensor is a small analytical device that combines a biological or biologically derived sensing element with a physicochemical transducer either integrated within or closely associated with it. It employs a biological sensing element that is intimately linked or integrated with a transducer. The recognition process relies on the affinity between complementary structures such as enzyme-substrate, antibody-antigen and receptor-hormone complexes. The biosensor's selectivity and specificity are determined by the biological recognition systems connected to an appropriate transducer.

Introduction

India, recognized as the world's second-largest horticulture producer contributes approximately 12 per cent to the global fruit and vegetable production. In the 2020-21 period, the horticulture production reached an estimated 329.86 million metric tonnes. The prominent fruit-producing states include Andhra Pradesh, Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Karnataka and Tamil Nadu. On the other hand, Uttar Pradesh, West Bengal, Madhya Pradesh, Bihar, Gujarat, Maharashtra and Odisha stand out as the primary vegetable-producing states within the country. Haryana has production of 1010488.5 MT of fruits and 5350763 MT of vegetables during 2022-23(Anonymous, 2023). In order to meet the growing demand for fruits and vegetables and achieve increased productivity, the agricultural industry employs a diverse range of intentionally toxic substances known as pesticides. These pesticides are utilized for pest control purposes but have significant environmental implications when released into the surroundings (Bucur *et al*. 2018).

Principle of Biosensor

The fundamental concept underlying biosensors encompasses three essential elements:

1. A bioreceptor also known as a biological recognition system.
2. A Transducer.
3. Microelectronics.

The primary objective of the recognition system is to ensure the sensor exhibits a strong preference for the specific analyte being targeted for measurement. Through the interaction between the analyte and the bioreceptor an effect is generated and subsequently detected by the transducer. The transducer then translates this information into a quantifiable outcome such as an electrical or optical signal. In this process the biological element or bio element engages with the analyte under examination and the resulting biological response is converted into an electrical signal by the transducer.

Pesticide Detection using Biosensor

Bucur *et al*. (2018) explored that a range of biorecognition elements can be employed in biosensors to enable precise and sensitive identification of target pesticides within complex mixtures. These elements include whole cells or subcellular fragments of microorganisms, enzymes, antibodies, DNA sequences, aptamers or enzymes. Nonetheless, there exists a research void in terms of refining the conditions for electrode immobilization and devising methodologies for effectively detecting pesticides found in fruits and vegetables whereas, in their study Vamvakaki *et al*. (2007) successfully demonstrated the monitoring of organophosphorus pesticides specifically dichlorvos and paraoxon, using nanobiosensors based on liposomes. They achieved this monitoring even at extremely low levels of these pesticides. The researchers effectively stabilized the enzyme acetylcholinesterase within the internal nano-environment of the liposomes. They discovered that the reduction in the signal of the liposome biosensors was directly proportional to the concentration of dichlorvos and paraoxon even at concentrations as low as 10^{-10} M however, in their study Zheng *et al*. (2015) aimed to enhance the electrochemical detection of carbaryl and monocrotophos by modifying the electrode with a biocompatible matrix to facilitate the adsorption of AChE (acetylcholinesterase). The researchers optimized the conditions to develop a biosensor capable of detecting carbaryl and monocrotophos within specific concentration ranges further, the developed biosensor exhibited detection capabilities for carbaryl and monocrotophos in the concentration range of 1.0×10^{-14} to 1.0×10^{-8} M and 1.0×10^{-13} to 5.0×10^{-8} M respectively, under the established optimal conditions. Notably, the detection limits for carbaryl and monocrotophos were determined to be 5.3×10^{-15} M and 4.6×10^{-14} M respectively.

Conclusion

Researchers are currently working on the development of biosensors, specifically electrochemical biosensors to detect pesticide residues. These biosensors offer several advantages over traditional methods making them more convenient and advanced. They enable rapid, specific and highly sensitive detection for making field tests more efficient. Additionally, these biosensors are compatible with microfabrication technology and are cost-effective compared to conventional detection methods.

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