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Use of Biosensors to Combat with Emerging Challenges in Agriculture

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Abstract
Food security and food safety affects everyone worldwide and will remain a global challenge to human health in the foreseeable future requiring the rapid, sensitive, efficient and inexpensive detection of food contaminants. Thus, to improve consumer livelihood and optimum use of resources, rapid, real-time, portable, and cost-effective technologies such as biosensors are desired in the field of agriculture. Recent advancements in biosensors, such as an analysis tool in the fields of quality control and food safety, environmental pollution monitoring, medical and agricultural applications. The most major application of electrochemical sensors in agronomy is in the direct measurement of soil chemistry through tests such as pH or nutrient content. Soil experiment results are important to obtain optimal crop output yield and produce quality, tasty food. Nanotechnology and miniaturization of biosensors will lead to sustainable development in agriculture. However, there is need to direct our research towards improving the shelf life of a biosensor for increasing the acceptability among the end-users.

Keywords: Biosensor, Food Safety, Nanotechnology, Sustainable Development

Introduction
The growing population of world leading to increase in demands of food and being linked to the industrialization and intensification of agriculture and animal husbandry, results in both challenges and opportunities for safe food in the era of climate change and globalization. In developing countries, a major part of population is suffering from pesticide poisoning annually and it becomes an explosive fatal situation causing even deaths. Among the emerging novel trends and streams in agriculture biosensors are now gaining popularity. Presently in the modern biosensors, there is no need of any mediator. In these type of biosensors, the enzyme is directly reduced on the electrode surface (Zeinhom et al., 2018). The relevance of biosensors for ensuring food safety is shown by a projected market growth from 19.5 billion dollars in 2021 to 28.6 billion dollars in 2026 with a CAGR of 7.9% (Food

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Safety Testing Market, 2021). Agricultural biosensors are now dealing with the in-situ analysis of crop pollutants, pathogens and eventually contributing to decision control system in precision agriculture. In general, the development of a biosensor device involves a set of steps including, synthesis of sensing of material, selection of bio-receptor material, complex medium containing target analyte, signal processing unit, analysis, software development and final sensing unit as shown in Fig. 1.

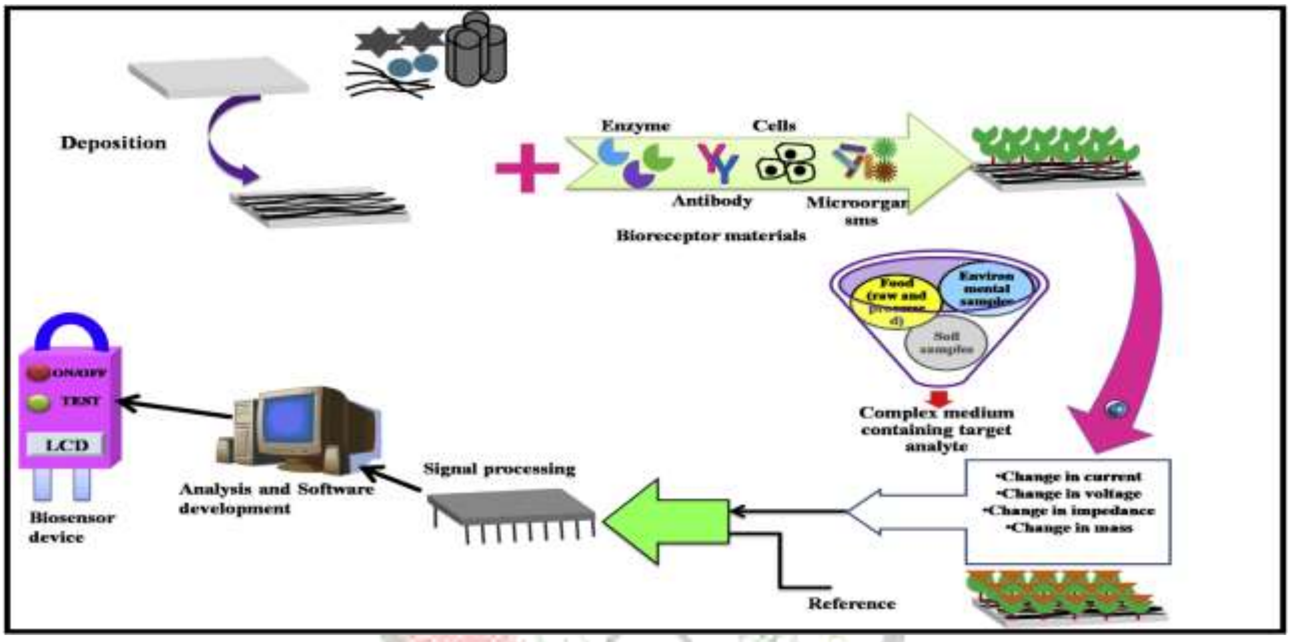

Fig. 1: Schematic of biosensor development for agricultural applications (Kundu, 2019)

Biosensors

Biosensors are the tools that have broad applications in biological detection or identification of biological processes usually follow a biological parameter that exists in the environment, Concentration and the like are used. The International Union of Pure and Applied Chemistry (IUPAC) can be defined as a device that uses specific biochemical reactions mediated by isolated enzymes, immune systems, tissues, organelles, or whole cells to detect chemical compounds usually by electrical, thermal or optical signals. Sensors are classified based on the use of sensors, signal inputs, processing mechanisms, materials, production technology, or the accuracy of the measurement is performed (Joes et al., 2003). Analysis tool is described as dense biosensors, bio or mimic the biological sensing element with a company that is close to, or in contact with the transducer mounted on it. In near future, biosensors will emerge as most powerful technology in modern precision agriculture to assist decision support systems for forecasting the disasters and assessing the losses

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smartly and quickly, ensuring sustainable agriculture with increased crop productivity. The biosensors have a huge market due to broad perspectives for crops, raw as well as processed food, environment monitoring and quality control system.

Measurement of Biosensors

The most common element in the living biosensors, including enzymes, antibodies, receptors, nucleic acids and are contexts. Exchangers are used in various biotechnology optical sensors, electrochemical, piezoelectric, thermometry. Biosensors can be the kind of living components, how they operate and their application categorized Converter (Jianrong et al., 2004). It is also reported with high specificity, low manufacturing cost, fast response time and ease of use as compared to other methods such as HPLC, optical emission spectroscopy, atomic absorption spectrophotometry (AAS).

Biosensors Supporting Sustainable Agriculture

Currently, biosensors have now intervened and geared the agricultural development. Biosensors have most remarkably contributed to achieve the ever-existing goal of precision in agriculture. Recently developed biosensors supporting sustainable agriculture are summarized in Table 1. A biosensor for the detection of the nitrate concentration in plants is developed by the group of Nicolas Plumere which only requires one droplet of plant juice and is designed to be user friendly enabling its use by the farmers themselves. Deficiency of nutrients and micronutrients like nitrogen, calcium, zinc, phosphorous etc. has been found to be related with lodging phenomenon observed in crops and in plants that are necessary to be detected so that the forecast associated with diseases can be real time and on regular basis (Barney et al., 2015). A label free colorimetric biosensor has been newly developed for identification of genetically modified food with fast and sensitive technique (Jung et al., 2015).

Table 1: Different biosensors with category and analytes, biorecognition element, detection method, assay time (Griesche and Baeumner, 2020)

Category	Analyte	Biorecognition element	Detection method	Assay time
Virus	Plum pox virus	Antibody	Electronical (Electrolyte Gated	15 min

			Organic Field Effect Transistor)	
	Citrus tristeza virus	DNA	Electrochemical	60 min
	Potato leafroll virus	Antibody	Colorimetric	15 min
	Rice tungro bacilliform virus	Antibody	Electrochemical	3 hr
Bacteria	*Xanthomonas arboricola* pv. *pruni*	Antibody	Colorimetric	<15 min
	Xanthomonas arboricola	Antibody	Electrochemical	>30 min
Fungi	*Pseuderocercospora fijiensis*	Antibody	surface plasmon resonance	10 min
	Botrytis cinera (DNA)	DNA	surface-enhanced Raman scattering	40 min
Oomycete	*Phytophthora infestans* (DNA)	DNA	Colorimetric	1.5 hr
Marker	Methyl salicylate	Enzyme (alcohol oxidase)	Electrochemical	1.05 hr
	Nitrate	Enzyme (nitrate oxidase)	Electrochemical	1 min

One of the most challenging aspects of food sustainability is the management of food excess. Biosensors have played crucial role in environment-controlled storage and intelligent food packaging. The packaging optimization techniques should be adopted to prevent contamination, loss of scent and moisture and thus finally decreases wastage of food. Among the various efforts in this direction of contamination of soil, a low cost, sensible and easy to operate enzyme based conductometric, colorimetric and potentiometric biosensor for copper, cadmium and lead have been reported (Tekaya et al., 2014). Water is important for photosynthesis as well as for flow of nutrients and many microelements which are necessary for healthy crop stand. That's why an amperometric biosensor has been developed for quantification of indole 3-acetic acid as a chemical indicator of water stress in corn plants (Subraya et al., 2013).

Role of Nanotechnology on Development of Agricultural Biosensors

As the natural agricultural inputs such as land, water and soil are finite; the requirement for precision technological inputs with minimal use of agricultural chemicals will be on upsurge for sustainable agricultural production. Since, nanotechnology is study of materials, process and phenomenon at nanometer scale and further exploration of matter for new applications in technical and societal challenges, conversion of macro material to nanoparticles causes generation of new characteristics of materials and as a result of which the material behaves differently. This difference in particular characteristic is suitably detected using nanobiosensors with enhanced sensitivity, accuracy, specificity and life as compared to conventional biosensors. Biosensors based on carbon nanotubes (CNTs), quantum dots (QDs), graphenes, gold (Au), silver (Ag), silica, nanocomposites and modified nanostructures with large surface to volume ratio has been synthesized in order to improve electrochemical parameters. Nanoparticles with ultra-small particles can better interact with microorganisms such as bacteria and viruses and hence provides a possible solution to related pathogenic agriculture problems (Ruttkay-Nedecky et al., 2017). In order to develop nanobiosensing devices, various nanobiosensing elements such as nanosurfaces, nanomaterials etc are needed. Nanocapsules are now being developed for effective delivery of various agricultural chemicals such as herbicides in order to boost their specific efficiency and effectiveness by slow and controlled release in the environment and get activated by the presence of the target (Khoobdel et al., 2017). More such advanced biosensors will come in near future as day to day research is bringing out novel materials, methods and techniques.

Conclusion

Biosensors are analysis tool in the field of quality control and food safety, environmental pollution monitoring, medical and agricultural applications. Remote spectral sensing has been successfully used to measure crop nutrition, crop disease, water deficiency or surplus, weed infestations, insect damage, plant populations, flood management, and many other field conditions. Moreover, the usage of modified nanostructures as matrix material and suitable biomolecule immobilization technique will significantly enhance the characteristic features of biosensors. Improvement in basic characteristics of biosensors will lead to widespread application in foremost challenging areas of agriculture. Besides this, lots of research studies have been carried in this field but the commercialized biosensor technology is still awaited. Thus, more devoted efforts are needed for bringing out the direct application of developed biosensor for use in real-time, in-field conditions by end users. Constraints and difficulties in the way of technological adoption and dissemination need to be addressed sincerely through research and development institutions and organizations.

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