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Development of Adaptive Biosensor system approach for food products in storage (A Review)

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***Abstract:* - In recent years, the development of adaptive biosensor systems for food products in storage has been an increasingly vital topic of study. Designed to identify and monitor changes in food quality, safety, and freshness during storage, these biosensors can detect and track alterations in these factors. The strategy involves combining machine learning algorithms with the biosensor system to enable real-time data analysis and decision-making. This abstract provides an overview of the approach to the creation of an adaptive biosensor system for storing food products. The biosensor system consists of a variety of sensors and measuring devices, including as temperature sensors, humidity sensors, gas sensors, and microbial sensors, in order to offer a comprehensive picture of food quality during storage. The system employs algorithms for machine learning to assess sensor data and develop prediction models that may be used to optimise storage conditions and avoid food deterioration. These models may also be used to detect and identify particular pollutants in food products, such as bacteria or poisons. By offering real-time monitoring and management of food quality and safety, the development of adaptive biosensor systems for food items in storage has the potential to transform the food business. It is anticipated that these technologies will aid in decreasing waste from food, enhancing food safety, and extending the shelf life of food products**.

Indexed Terms: **Algorithms, Biosensor, Contamination Safety, quality,**

I. INTRODUCTION

Biosensing systems are devices or platforms that utilise biological molecules or live cells to detect and quantify analytes such as biomolecules, infections, poisons, or chemicals. Biosensing systems are utilised in several domains, including healthcare, environmental monitoring, food safety, and biodefense (Figure 1).

There are several types of biosensing systems (Figure 2), such as: Optical biosensors: These biosensors detect variations in the concentration of target molecules using light. They can detect both tiny molecules, like glucose, and big molecules, like proteins. Electrochemical biosensors: These biosensors detect changes in the concentration of target molecules using an electrode. Typically, they are used to detect glucose, cholesterol, and other macromolecules [1]. These biosensors utilise a piezoelectric crystal to detect mass changes on the crystal's surface. They can detect infections including bacteria and viruses [2]. Microfluidic biosensors: These biosensors detect and quantify target molecules using microfluidic channels. Common applications include point-of-care diagnostics and drug development. In healthcare, biosensing devices are being utilised for the detection and treatment of diseases such as diabetes, cancer, and infectious diseases. In addition, they are utilised for environmental monitoring, food safety, and biodefense. [3],[5],[6]

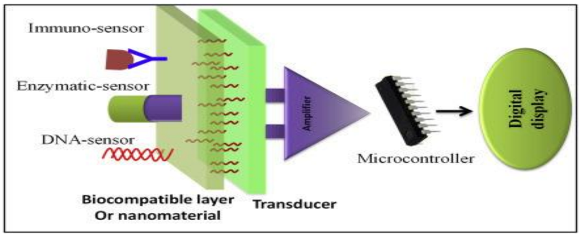

Figure 1: A schematic illustration of the major components of a typical biosensor.
Source: [4]

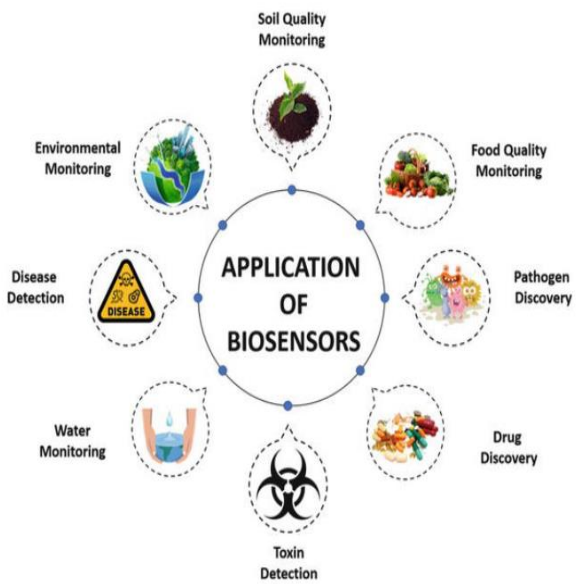

Figure 2: Applications of Biosensors in Agricultural produces
Source: [5][6].

1.1 Examples of Biosensing Devices Used in the Food Industry

The following are many examples of biosensing systems: Glucose biosensors: These biosensors utilise an enzyme to assess if glucose is present in blood or other physiological fluids. They are commonly utilised by diabetics in order to measure the glucose levels in their blood. The Freestyle Libre Rapid Glucose Monitoring System is an example of a system that might be termed a glucose biosensor [7], [8], [9].

DNA biosensors: These biosensors use DNA probes as the sensing element to identify specific DNA sequences in a sample. Among its many applications are the detection of infectious pathogens and genetic analyses. The DNA biosensor Verigene System [10], [11] can simultaneously detect several illnesses and genetic markers.

Electrochemical immunosensors: These types of biosensors utilise an electrode and an antibody to detect certain antigens or antibodies in a sample (Figure 3). They are commonly utilised in the diagnosis and monitoring of disease. The i-STAT System is an excellent example of an electrochemical immunosensor since it can detect a wide range of biomarkers in whole blood [12], [13].

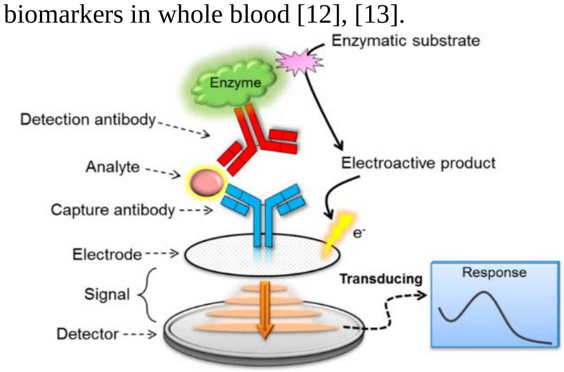

Figure 3: Electrochemical immunosensors
Source: [14]

Optical biosensors: These biosensors use light to detect changes in the concentration of target molecules. They can be used for applications such as protein detection and drug discovery (Figure 4). An example of an optical biosensor is the Octet System , which can measure protein-protein interactions in real-time [3], [15].

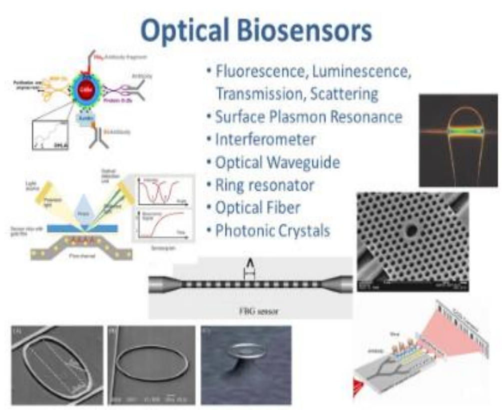

Figure4: Optical biosensors
Source: [16].

II. Integrating Biosensors with Existing Food Storage Infrastructure

It is possible to alter biosensing systems so that they can monitor the quality and safety of food goods while they are being stored (like food lipid, processed foods,). A few examples of how biosensing systems might be used to food storage systems are as follows:

A. Monitoring the temperature: biosensors are a useful tool for keeping track of the temperature inside of food storage facilities. For instance, a biosensor may be put to use to monitor the temperature inside of a refrigerator or freezer, and it may then sound an alarm to notify the user if the temperature exceeds a certain limit. This can help inhibit the formation of germs, which in turn helps food goods retain their freshness for a longer period of time [17], [18}.

B. Oxygen monitoring: Biosensors may also be utilised for the purpose of monitoring the amounts of oxygen present in food storage facilities. This can be especially helpful for preserving fresh food, as certain types of fruits and vegetables require less oxygen than others do during the storage process. The shelf life of food goods may be increased by the use of a biosensor in order to keep the proper oxygen levels in the storage system and maintain the suitable levels [19], [20]. Gas sensors: (Figure 5). These biosensors detect changes in the gas composition of the food packaging, such as oxygen or carbon dioxide levels. By monitoring these changes, the biosensors can provide an indication of the freshness of the food product and the potential for spoilage.

Figure 5: Gas sensor

Source: [15, 21]

C. Detection of pathogens Biosensors may be ut ilised for this purpose in order to detect pathogens such as bacteria and viruses that may be present in food storage facilities. For instance, a biosensor may be utilised in order to determine whether or not food goods that have been kept have Escherichia coli or Salmonella [21], [22]. This can assist in the prevention of foodborne diseases and ensuring that the food items are safe to consume.

Quality monitoring: Biosensors can also be used to monitor the quality of food products in storage systems. For example, a biosensor can be used to detect changes in pH, colour, or texture of stored food products. This can help identify spoilage or degradation of the food products and ensure their quality [23], [24].

By adapting biosensing systems to food storage systems, it is possible to ensure the safety and quality of food products while minimizing waste and improving efficiency.

III. Advanced Method of Adapting Biosensing Systems to Food Storage

Advanced methods of adapting biosensing systems to food storage involve the integration of different types of biosensors and the use of advanced data analytics and artificial intelligence techniques to improve the accuracy and reliability of the biosensors. Here are some examples of advanced methods of adapting biosensing systems to food storage. One advanced method of adapting biosensing systems to food storage is by using smart packaging. Smart packaging refers to packaging that has been designed to actively monitor and interact with the food products it contains. Here are some examples of how biosensing systems can be incorporated into smart packaging:

A. Multi-sensor integration: By integrating multiple biosensors, it is possible to improve the accuracy and reliability of the biosensing system. For example, a biosensor that detects changes in temperature can be combined with a biosensor that detects changes in gas composition to provide a more comprehensive picture of the food storage environment. By combining the outputs of multiple sensors, it is possible to reduce the number of false alarms and improve the overall accuracy of the system [6],[25]. Time-temperature indicators: These are biosensors that change colour or provide a signal when the temperature of the food product exceeds a certain threshold or when the product has been stored for too long. These indicators can be incorporated into the packaging material and provide a visual indication to the user that the food product may not be safe for consumption.

B. Artificial intelligence (AI) techniques: AI techniques such as machine learning and neural networks can be used to analyse the data from the biosensors and improve the accuracy and reliability of the system. For example, machine learning can be used to identify patterns in the data that are indicative of spoilage or contamination. Neural networks can be used to classify the data into different categories, such as safe or unsafe for consumption. By using AI techniques, it is possible to automate the analysis of the biosensor data and improve the efficiency and accuracy of the system [26].

C. Wireless Power Transfer (WPT): WPT is a method of transferring power wirelessly between the biosensors and the data processing unit. By eliminating the need for batteries or wired connections, WPT can simplify the installation and maintenance of the biosensing system. For example, a biosensor that detects changes in gas composition can be powered wirelessly and transmit data to the data processing unit in real-time. By using WPT, it is possible to reduce the cost and complexity of the biosensing system [16], [4], [27]. Biosensors for pathogen detection: These biosensors can be incorporated into the packaging material to detect the presence of bacteria, viruses, or other pathogens in the food product. The biosensor can then provide an alert to the user, indicating that the food product may not be safe for consumption.

D. Biosensors for quality monitoring: These biosensors can be used to monitor changes in the pH, colour, or texture of the food product. The biosensor can then provide an indication of the quality of the food product and whether it is still safe for consumption [16].

By using advanced methods of adapting biosensing systems to food storage, it is possible to improve the accuracy, reliability, and efficiency of the system. This can help ensure the safety and quality of food products while reducing waste and improving sustainability. Overall, the use of biosensing systems in smart packaging can provide real-time information on the safety and quality of food products. This can help reduce food waste and improve efficiency in the food industry.

IV. The Biosensing Systems Adaptation Protocol to Food Storage Infrastructure

Concerns about food safety and quality have increased the significance of biosensing systems ability to adapt to different food storage environments. Some ways in which biosensing technologies (Figure 6) are being applied to food storage infrastructure include the following:

A.WSN (Wireless Sensor Networks): WSN is a biosensing system that keeps tabs on the conditions of food storage through the use of a distributed network of sensors. Temperature, humidity, and gas composition are only few of the variables that may be tracked by the system. When environmental conditions become dangerously extreme, the WSN may provide immediate warnings. In one use case, the WSN can keep tabs on perishable goods as they're being stored or transported. The WSN may notify the management immediately if the temperature increases beyond the set point, allowing them to take immediate action to prevent the food from spoiling [28].

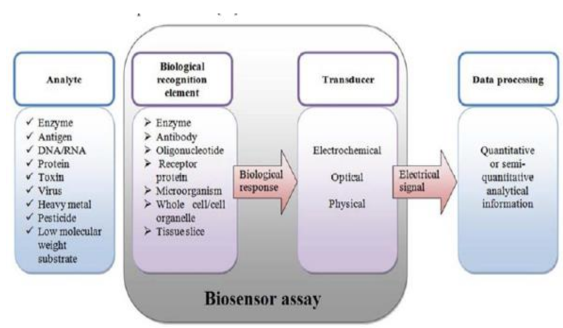

Figure 6: Biosensor Technologies Operational Process Source: [29].

B. Biosensing devices that utilise microchannels and microvalves to modify fluids are referred to as microfluidic biosensors. These biosensors are useful for identifying harmful microorganisms and other pollutants in food. You may use a microfluidic biosensor, for instance, to check for the presence of Salmonella in food samples. Quick and reliable detection of Salmonella in the sample is made possible by the biosensor, which may be used to curb the disease's further dissemination [29], [15], [30].

C. Optical biosensors are sensors that utilise light to detect alterations in either the food itself or the surrounding environment. These biosensors have the potential to identify problems with food quality such as rotting, contamination, and more. A meat rotting colour shift can be detected, for instance, with the use of an optical biosensor. The biosensor can measure the colour shift rapidly and precisely, providing a reliable indicator of the meat's freshness [30], [31].

D. Nano-biosensors: Nano-biosensors are biosensing devices that employ nanoparticles to detect changes in the food product or the environment. These biosensors may identify pollutants, infections, and other quality concerns. The presence of E. coli, for instance, may be determined by using a nano-biosensor on food samples. With the biosensor's fast and precise identification of E. coli in the sample, the potentially deadly disease may be contained before it has a chance to spread [28], [32], [33].

Biosensing systems may be used to food storage systems to assure the quality and safety of stored foods, reduce food waste, and boost productivity.

CONCLUSION

In conclusion, the development of adaptive biosensor systems for food products in storage is a sector that is quickly developing and has enormous potential to raise food quality and safety standards. These biosensors offer in-the-moment monitoring and analysis of a number of variables, including as temperature, humidity, gas concentration, and microbiological content, allowing the identification of changes that can point to contamination or spoiling.

The creation of prediction models that may optimise storage conditions and stop food deterioration is made possible by the combination of machine learning algorithms with biosensor systems. Specific pollutants in food products can also be found and identified using these models. Reducing food waste, enhancing food safety, and extending the shelf life of food items are all possible with the deployment of adaptive biosensor systems. The creation of inexpensive biosensors and the standardisation of testing procedures for biosensors are two issues that still need to be resolved. The creation of adaptive biosensor systems for food items in storage is a fascinating field of study, and despite these difficulties, it is anticipated to have a big influence on the food business. The accuracy and dependability of these systems will continue to be improved by ongoing developments in machine learning algorithms and biosensor technology, allowing for greater management of food quality and safety throughout the whole food supply chain.

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