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Intelligent Packaging: "A New Era in Food Protection and Preservation"

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SUMMARY

Packaging is a blend of science, art, and technology designed to protect products during distribution, storage, and sale. It plays a crucial role in keeping products safe, preserving their quality, providing information, and making them easy to use. Intelligent packaging, as described by Robertson (2006), goes a step further by including smart elements like sensors, recorders, tracers, and communicators. These elements, placed inside or outside the package, give insights into the history and quality of the food inside. This type of packaging can detect changes, sense environmental conditions, record data, trace the product's journey, communicate information, and apply scientific logic to extend shelf life, enhance safety, improve quality, and warn about potential issues. There are different types of intelligent packaging technologies. Sensors, which include receptors and transducers, convert and measure physical and chemical information from the food. Indicators, which often change color, show the presence or degree of certain reactions. RFID tags use radio waves to track and capture data about the package. Gas indicators are a specific type of sensor that monitors changes in the gas composition inside the packaging, which can be crucial for products stored in modified atmospheres. For example, an oxygen indicator changes color based on the oxygen levels inside the package. Time temperature indicators (TTIs) are another smart technology that track how long and at what temperatures the food has been stored, helping ensure its safety and quality. Some TTIs only react when the temperature exceeds a certain threshold, while others provide a complete history of the product's temperature exposure. RFID tags offer real-time tracking and data transmission, making it easier to trace products and ensure their quality. However, they can face issues like signal loss, high costs, and limited recycling options. Freshness and spoilage indicators detect microbial growth by reacting to byproducts like carbon dioxide or ethanol, often using color changes to show the freshness level of perishable foods. Biosensors and nanosensors go even further by detecting specific pathogens like E. coli or Salmonella through biological reactions and nanotechnology, providing critical safety information. Intelligent packaging is an exciting advancement in food technology, with the potential to greatly improve food preservation and safety. Despite some challenges such as regulatory compliance, production costs, and consumer trust, it is likely that future developments will integrate active and intelligent packaging to create truly interactive systems that meet the specific needs of food products.

INTRODUCTION

Packaging is the Science, art and technology of enclosing or protecting products for distribution, storage, sale and use. Functions of packaging includes containment, protection, preservation, communication, utility and performance.

Fig.1 Intelligent packaging

Definition:

"Intelligent packaging can be defined as "packaging that contains an external or internal indicator to provide information about aspects of history of package and/or the quality of the food" (Bahl & Bird, 2015). Intelligent packaging is a type of packaging in which the elements of Intelligence like sensor, recorder, tracer and communicator are added either inside or outside of the food package."

Intelligent packaging is capable of carrying out intelligent functions like:

- Detecting
- Sensing
- Recording
- Tracing
- Communicating and applying scientific logic
- Extending shelf life
- Enhance safety
- Improve quality
- Provide information
- Warn about possible problems, etc

Intelligent packaging with sensor technologies includes extended functions and uses digital systems to package food, cosmetics, medicaments, and other kinds of products. It is also adopted by brands in healthcare, logistics, transport, consumer electronics, and home care industries. Intelligent packaging provides information on the product quality during shipping and storage. It monitors the state of food and the surrounding environment and notifies the producer, retailer, or consumer of the condition of the food. Such smart, and interactive packaging enables tracing, and monitoring functions to ensure the quality and safety of a product, and hence, can help increase the expiration date of foodstuffs. Therefore, the demand for intelligent packaging is growing in the food segment (Palazzo et al., 2023).

Digital technologies are enabling the packaging to move from its core passive functions to more enhanced features such as prolonged preservation, traceability, communication, sustainable supply chain, life-cycle evaluation, and extended shelf-life of a product. Intelligent packaging can provide information about the conditions inside and outside of the packaging preventing contamination of the product. Monitoring of food products allows consumers, producers, and retailers to avert potential spoilage and unnecessary waste (Gigauri & Palazzo, 2023). Intelligent packaging is beneficial to communicate the content and status of packaged food to the consumer. This has the potential to be one of the greatest achievements in the field of food science and technology as this system can work efficiently to reduce the waste and shortage of the food supply (Solanki et al., 2023)

Intelligent packaging can be classified as :

1. Sensors usually contain receptor and transducer. Receptor is the one which converts physical and chemical information obtained from food into the form of energy, where was transducers will measure the energy.

2. Indicators will indicate the presence and absence of substance or the degree of reaction between two or more substances by means of a characteristic change, especially in color.

3. RFID (radio frequency identification tags) is the use of radio waves to read and capture information stored on a tag attached to an object.

Gas indicators and sensors:

Gas indicators will monitor the changes that are occurring in the gas composition inside the modified and controlled atmosphere food packaging. Metabolism and reaction of food products results in absorbing and releasing of certain type of gases which can be detected by the color change technology. It can also be used to indicate gas leak from active food packaging system.

Most commonly used gas indicator is Oxygen indicator; however, carbon dioxide indicator is also available. Color of the oxygen indicator will be pink, if the amount of oxygen present in package is 0.1% or less, if it increases to 0.5% or more the color changes to blue. In oxygen indicator color change maybe the result of redox reaction or oxygen binding reaction.

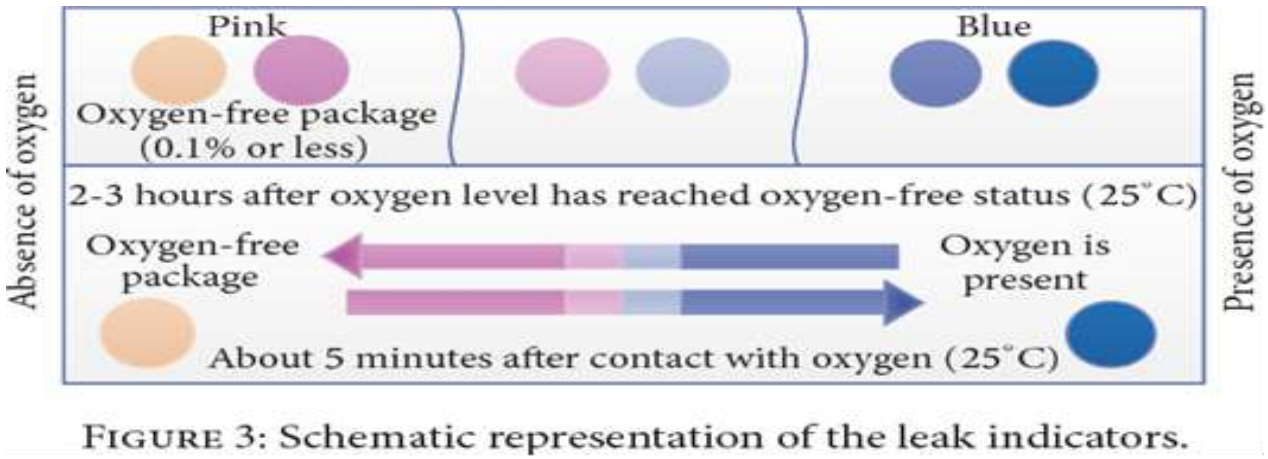

FIGURE 3: Schematic representation of the leak indicators.

Fig.4 Time temperature indicator:

Gas chromatography and gas chromatography mass spectroscopy (GCMS) are the destructive gas monitoring techniques which requires the package to be tampered before monitoring, this destructive gas monitoring techniques can be replaced by non-destructive on-Pack sensor for monitoring the gas composition.

Time temperature indicator:

Temperature influences the determination process directly that is at high temperature determination of food is relative lehigh does food safety and quality can be ensured by maintaining the correct storage temperature time temperature indicators. TTI works based on enzymatic reaction, polymerization and diffusion. Based on the time temperature indicators response it can be classified as partial or full history indicator. Partial history time temperature indicator the sperms only when temperature exceeds over the threshold level there is the full history indicators gives the response to out the product history.

Radio frequency identification:

Radio frequency identification tags are advanced form of data information carrier that can identify and trace a product, provide security and promotion of quality and safety. RFID's are affixed to container, pallet, package etc to obtain the real time information and transmit it to the user's information system. Radio frequency identification uses radio waves to track the items wirelessly. The information provided by RFID can be stored and read by appliances. Few drawbacks of radio frequency identification tags are loss of signal due to absorption by water, high price and limited recycling ability.

Fig.5 Radio Frequency Identification Tags

Freshness/Spoilage indicator:

Freshness/spoilage indicator detect the growth of microorganisms by reacting to the metabolites produced during growth of microorganisms such as carbon dioxide, ethanol, diacetyl, hydrogen sulfide and gives direct information about product quality.

Color indicating tags are attached as small adhesive label to outside of packaging film to monitor freshness of perishable food products such as fruits, vegetables and seafoods. Metabolism also produces a few acids like lactic acid and acetic acid which can be detected by a pH indicator, thus color-based pH indicator can be used as freshness/spoilage indicator. Different color indicates different stage of ripening.

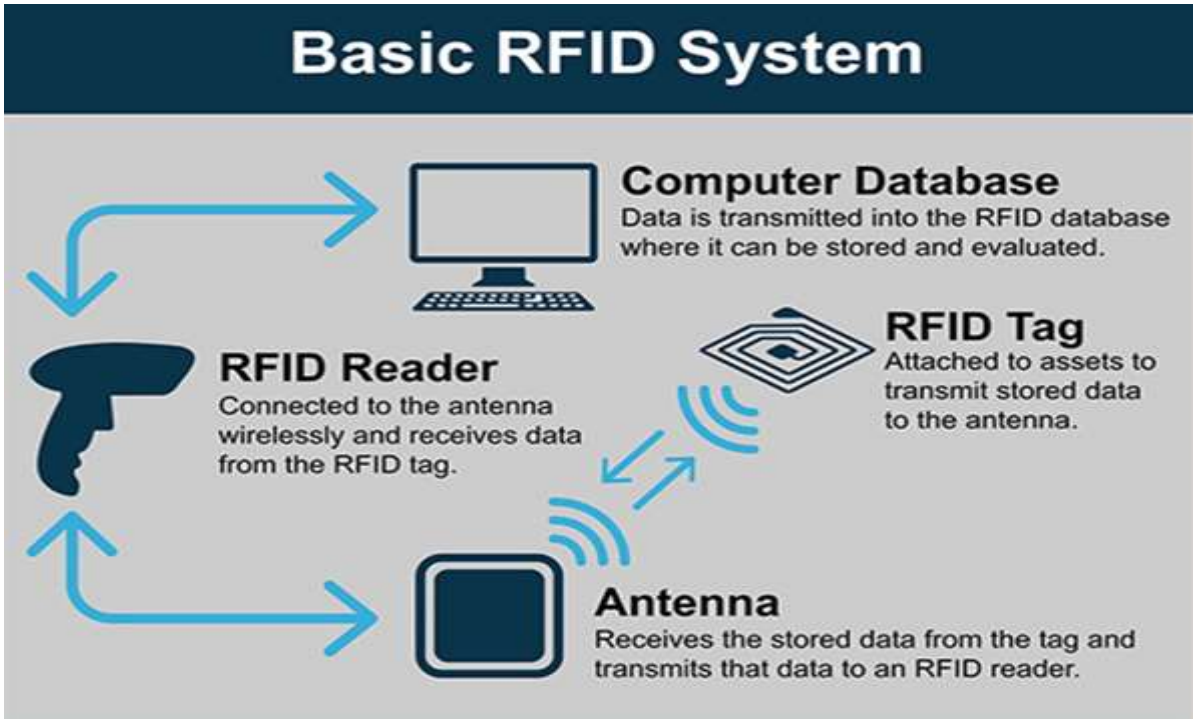

Fig.6 Freshness/Spoilage indicator:

Biosensors/Nanosensors:

These are the sensors which senses, records and transmit the information obtained from biological reactions. It consists of bioreceptors which are specific to target analyte and a transducer to convert biological signals to quantifiable electric response. Bioreceptors are the organic material such as enzymes, microbes, antigens, hormones, nucleic acids. Transducers maybe optical, electrochemical or calorimetric, and are system dependent. Biosensors are made to detect the pathogen present in the food like Escherichia coli, Salmonella typhimurium, listeria monocytogenes, shigella flexneri, Salmonella species, staphylococcus etc. Few biosensors are called nanosensors which contain nanoparticles which get attached to pathogens or other contaminants and detects its presence through fluorescence or magnetic devices. The detection is mostly based on conductance or bioluminescence.

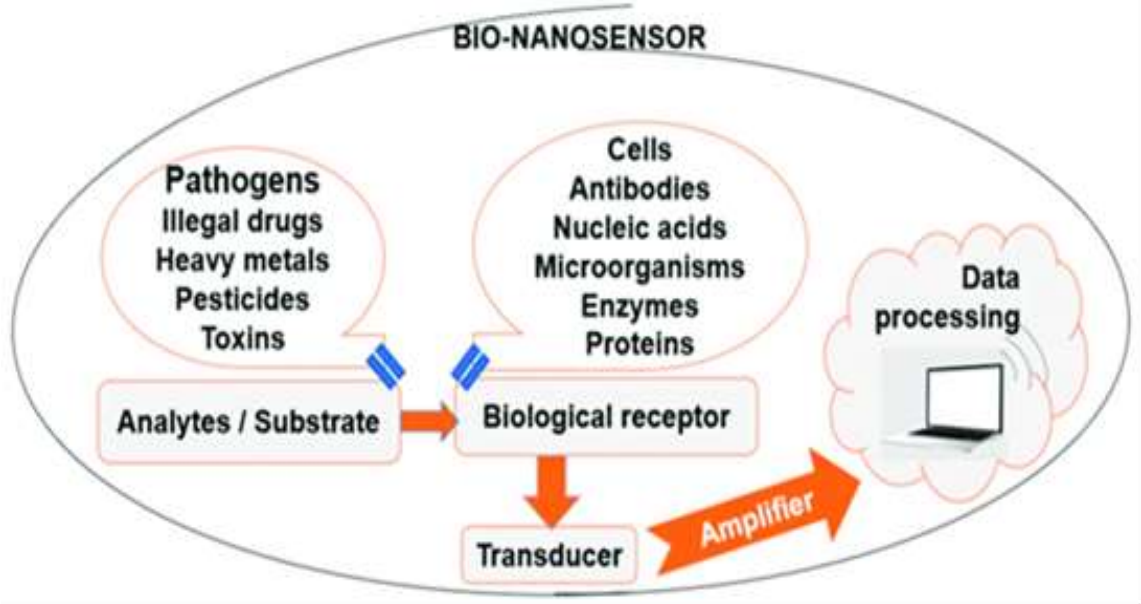

Fig.7 Bio-Nanosensors

CONCLUSION:

Intelligent packaging is an emerging area in food technology which provide enhanced food preservation interest in this area and the number of food related applications is expected to increase significantly in the near future. Although Intelligent packaging may provide many benefits to shelf-life extension and food. In contrast with safety, there are several issues to consider before implementing such packaging systems. Compliance with food-safety regulations, high production costs and consumer mistrust have been found to be potential challenges. it seems very likely that future development will combine the benefits of active packaging with intelligent packaging system and will eventually end up in development of truly interactive packaging that responds directly to the needs of the food. Intelligent packaging can play an important role in reducing the role of pathogen contamination and extending the shelf life of food as well as improving convenience and traceability.

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