

Application of Nanosensors in Food Packaging

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ABSTRACT

The importance of quality along the agri-food chain has increased due to raised consumer concerns and demands of the stakeholders like government and other interested parties. Prolonging the shelf life and freshness as well as improving the quality of food are the targets in the food market. Intelligent/smart packaging makes use of the communication function of the package to aid in decision making, hence, enhancing food safety and quality. Nanotechnology is a newly emerging technique which has the potential to transform the food industry. This technology encompasses the assembly, characterization and handling of devices, structures or materials. A nano sensor is considered as a tool to measure physical quantities and change these into signals which can be detected and examined. This review narrates the concept of nano sensors and how they can help enhance the food packaging by detecting the presence of gases, chemical contaminants, pathogens, and even changes in environment, thus ensuring the food products to be fresh and safe for consumption. Several types of nano sensors being used in food packaging include nanoparticlebased sensors, array bio-sensors, electronic noses, Fluorescent based oxygen sensors etc. Indicators like time- temperature indicators, freshness- indicators and integrity-indicators help enhance the packaging properties by monitoring the change in pH, temperature, and gas compositions. The technology of Radio Frequency Identification and incorporation of Graphene-based nanomaterials are some of the latest developments in the area of food packaging nanotechnology. Besides the various advantages offered by the nano sensors, the safety issues associated with them need special attention, hence regulation on the food security of nano sensors application is quite necessary.

Keywords: Nano sensors, nanotechnology, food quality, shelf life, intelligent packaging, food packaging, freshness-indicators, food safety, contaminants

1. Introduction

Food safety is a prime concern for public health. In today's fast-paced world with reduced time for selection and cooking with fresh ingredients and the growing concern in safety has led to a huge demand for development of new and advanced packaging systems. So, the packaging unit is one of the most important amongst the other food manufacturing processes, as it protects the product against damage or contamination during storage and transportation activities. At the time of supply, the quality of food products can decay physically, chemically as well as biologically. (H. Han, 2005).

Active and intelligent packages come in two forms of smart packages. Active packaging uses techniques that intentionally release or absorb compounds from the food or food packaging head space. This prevents lipid oxidation, microbial growth, and decomposition reactions of water loss, and extends the shelf life of the product by recovering better than traditional food packaging. Smart packaging communicates with consumers and other people throughout the value chain. Two types of smart packaging advance the packaging industry. Oxygen,

ethylene and moisture scavengers continue to dominate active packaging, but the recent increase in active packaging emitters is dramatic. Hence, it is imperative to devise quick and efficient techniques to detect harmful contaminants. Many food-borne illnesses result in morbidity and mortality world-wide. Since the global population is rising, scientists with innovative and unique ideas are working on newer technologies to provide excellent quality products to consumers. Proper Packaging prevent the food from the deterioration due to the influence of both external and internal environment. (Mohan, 2022) Intelligent packaging provides an explicit functionality apart from the physical barrier between the food product and the neighboring environment. The rise of intelligent packaging has made it viable to monitor and provided details about the condition of food, package, and the environment.

This paper demonstrates the concepts of different types of intelligent packaging and nano-sensors. Extensive research shows that this nanotechnology has the potential to enhance food safety, progress pathogen detection time and regulate the quality of food and packaging through the

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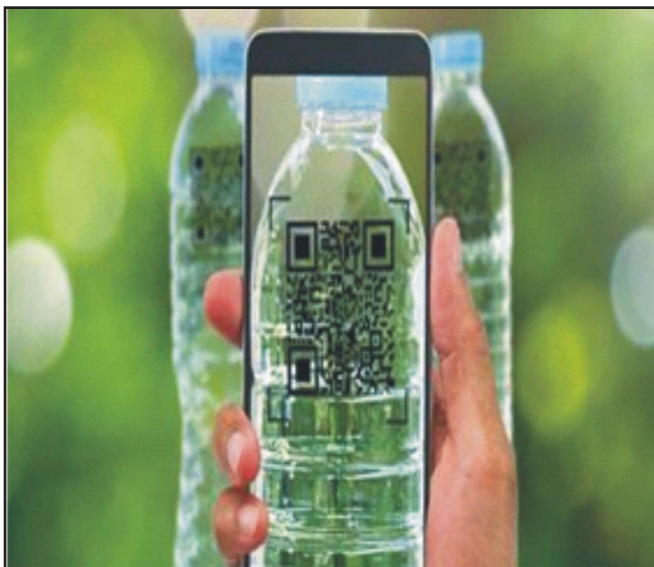
supply chain. (Fuertes, et. al., (2016) Apart from these methods, nano-technology offers a cutting-edge and powerful platform for exploiting unique properties of materials at nano level. The development of nano sensors has prospect to detect food contaminants in an easy and effective manner to ensure the safety of consumers. Overall, nano sensors with their distinctive properties are improving food security.

2. Concept of Intelligent Packaging

Intelligent packaging involves the technology which utilizes the communication function of the food package to improve decision making to gain the benefits of superior quality food products. (Yam, et. al., 2006) Intelligent packages contain compounds that monitor the condition of the packaged food or the environment surrounding the food. The aim is to analyse and monitor the state of the product inside the package and deliver information to the consumers. This can be information about the state of a package and its time of manufacture or storage conditions. The additional benefits of intelligent packaging contribute to improving Hazard Analysis and Critical Control Point (HACCP) and Quality Analysis and Critical Control Point (QACCP) systems, thereby detecting unsafe food in the field and potential health. Establishing a strategy to identify and mitigate damage. Their occurrence ultimately leads to improved food quality (Muller 2019).

3. An overview on Nano-sensors:

A nano-sensor can be stated as a tool that has the ability of conveying information about the behavior and characteristics of nanoparticles at the nanoscale level to the macroscopic level. Nano-sensors evaluate the physical quantities and convert them into signals which can be detected and examined. They present notable improvements in selectivity, precision, speed and



Source: Food Marketing and Technology India

sensitivity compared to the standard biological and chemical methods. Nano-sensors can be employed for detection of microbes, pathogenic contaminants, food freshness and overall quality. The nano-sensors used in the field of food and agriculture amalgamate the concepts of chemistry, biology and nanotechnology. (Malmiri, et. al., 2019) They provide real-time monitoring compared to conventional detection techniques including spectroscopy and chromatography. Application of nanotechnology in food industries is often used in detection of bacteria in packaging, or produce flavor, color quality, and safety to increase the barrier properties. Precautions also are needed to use nanotechnology in food packaging as very little knowledge is available at the moment on its impact on environment and human health. Nano materials can enhance mechanical strength; increase heat resistance; reduce weight and provide a better barrier against oxygen, carbon dioxide, UV radiation and moisture of food packaging materials. (Chaudhary, 2020)

4. Need for Nano Sensors

The nano-sensors play a very crucial role in food packaging and transportation. Regarding food safety, consumers must count on expiry dates provided by manufacturers based on a set of shelf-life studies carried out by the company. Any violation in the transport or storage conditions will lead to degradation of the food quality which the consumer might not know unless the package is opened or consumed. The unique chemical and electro-optical properties of nano-sensors can help enhance the food packaging. They can spot the presence of gasses, aromas, pathogens, chemical contaminants, and also changes in the surrounding environment of the packaged food. Nano-sensors make sure that consumers get fresh and fine quality products while also improving the safety of the food. (Omanović-Miklićanin, et. al., 2016).

5. Types of sensors used in food packaging

- Various types of nano-sensors being used in the food packaging industries comprise of nanoparticles-based sensors, electronic noses, array-biosensors, Fluorescent based oxygen sensors, nanocantilevers, solution-based nanoparticles, and nano-test strips.
- Nano-sensors in plastic packaging can detect gasses in spoiled food articles and alerting the consumers by changing the color of the packaging as an indicator.
- Moreover, packaging film laced with silicate nanoparticles can diminish the entry of atmospheric oxygen into the package and leakage of moisture out of the package, thus keeping the food fresh for a longer time for consumption. (Logrieco, et. al., 2006)
- Different types of sensors have been made to detect E. coli (bacteria) contamination in packaged foods. The

present technology can help detect the pathogenic microbes in food products in 2 to 7 days.



Source: Science Direct

5. Types of Indicators

1. Time and Temperature Indicators



Source: Timestripblog

2. Freshness Indicators



Source: Timestripblog

A freshness indicator examines and suggests the total originality of the food-product; mostly it is in the form of labels on the holder. Generally, for these indicators their center of attraction is on the observation of the initial form of change (gas composition, pH, etc.). As the developing differences are observed by the indicators and are represented into a reaction, mostly a color reaction which

can be resourcefully considered and associated with the freshness of foodstuffs. This indicator is established on circumventing connection of metabolites via color indicators (e.g., pH) or established on immediate connection of metabolites by biosensors. Label sensor is established on methyl red; red/methyl cellulose membrane that functions on the regulation of rising in pH, due to unstable amines spoilage. RipeSense™ is the foremost smart sensor label which alters the color to demonstrate the condition of ripeness of the fruit. (Fuentes et. al., 2016)

3. Integrity Indicators

Gas indicators help in maintaining the poisonous composition of the gases delivered from decomposing foodstuffs in a food receptacle that can menace the healthiness of consumers. Oxygen in the atmosphere can influence color difference, oxidative rancidity, and microbial decay. Many oxygen indicators are developed to indicate the differences in color due to meddled packages. Oxygen indicators are generally used to determine inappropriate sealing and rate weakening of modified atmosphere containers.

Carbon dioxide indicators consist of a carbon dioxide absorbent with a chemical dye in a polymeric film to estimate fermentation capacity in foodstuffs during allocation and storehouse. (Love et. al., 2020)



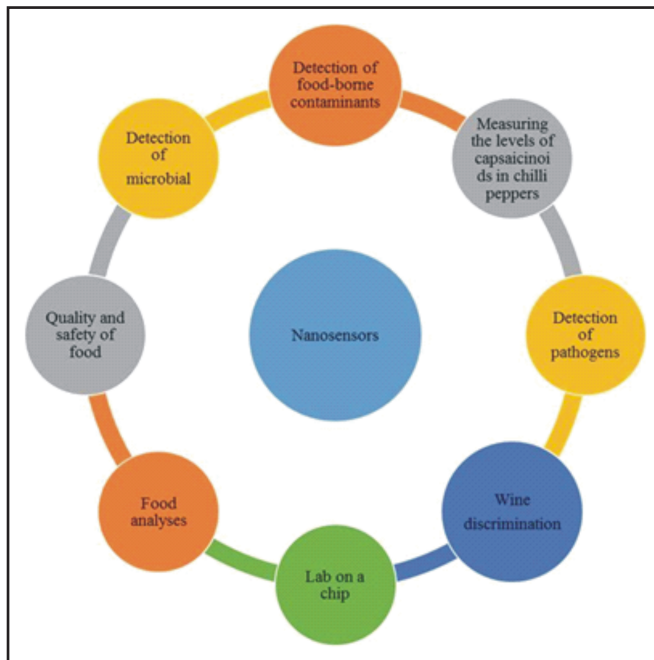
Source: WUR edepot

6. Benefits of using Nanosensors in Food Packaging

- The implementation of nano-sensors in the food packaging to maintain its grade in all its stages production, processing, supplying and consumption.
- Identification of organo-phosphate pesticide remains in food.
- Identification of humidity or temperature differences due to moistness.
- Electronic tongue addition in food packaging is made up of a collection of nano-sensors which are incredibly susceptible to gases emitted by spoiled

food, delivering a transparent and observable indication if the food is garden-fresh or not.

- Nanotechnology can help to decrease the packaging waste connected with processed foodstuffs and help the conserving of fresh foods.
- It preserves the freshness of food.
- Observe the contamination and control the atmosphere of food.
- They can also witness any nutrient insufficiency in edible plants. (Fuertes, et. al., 2016)



Source: Springer

7. Recent Developments

- Nowadays, the multiple common retail sensors are Radio Frequency Identifications (RFIDs), which are confidently served for supply chain quality assurance and for observing the exterior requirements. Smart radio-frequency labels with detectors can evaluate humidity, temperature, and the existence of volatile amine compounds. A primary RFID system consists of three essential parts: the identifier (a tamper-proof instrument that is permanently connected or embedded), a reading gadget and a software for recording, transferring and displaying of data.
- Radio frequency identification tags can be associated to yield packaging to deliver real-time data to the consumer. Radio Frequency Identification tags have the ability to evolve into one of the most advantageous technologies for the food packaging since it can fulfill all the necessities of a sensory food safety monitoring, package hunting, checklist control and much more. (Puffenberger et al., 2010)

- The Unique physical format, as well as its chemical and electrical effects, makes graphene an excellent choice for service in the sensor technologies. Graphene-based nanomaterials have abundant unique assets, which make them suitable for biosensors and other instruments and strategies used in the study and management of food quality.



Source: eeNews Europe

8. The Challenges of using Nano-sensors in Food Packaging

A major shortcoming is the slight power that can be reserved in a nano-sensor particle as correlated to the power desired by the instrument to convey. Despite nanotechnology delivering countless benefits to the food industry, the safety topics related to the nanomaterials cannot be ignored. Multiple researchers have discussed the safety emergencies associated with nanomaterials highlighting on the potential for migration of nanoparticles from the packaging material into the food and their effect on the user's health. In addition, the tiny size of these nanomaterials may raise the chance for bioaccumulation within body organs and tissues (Singh et al., 2017)

9. Safety Considerations

There are many worries for users of nanotechnology processed foods, one of which is the anticipation of the actions of nanoparticles in the body and the harmful consequences they could have (Fuertes et al 2016). Hence, it is important to determine a set of procedures and limitations on the food security of nano-sensors inferences. (Fuertes, et. al., 2016) There are increased chances of leaching of nanoparticles from the food packaging into the food product, which may lead to unfavorable health consequences on consumption. It is vital to study the effects of nanomaterials under natural conditions and with food products. A more suitable knowledge of the effects of such materials on human health and the environment is crucial before their complete application in the food sector.

Presently, there is restricted learning and awareness of the changes in the physicochemical properties and the life-cycle assessment (LCA) of nano compounds during the

unabridged food supply chain. The safety of nano-sensors poses a notable challenge to both the government and the industry. On an industrial scale, it is important to estimate the release of Nanomaterials into the atmosphere and evaluate the following exposure levels to these materials.

10. Concluding Remarks

The recent expansion of nanotechnology has a high credible lead for the food industry. The technology of combining nano-sensors in food packaging is an evolving domain that will focus on food security and increase exponentially in the upcoming years. This new packaging system can help in the recognition, observing, tracing, recording, communication through the supply chain. Be it spreading the shelf life, improving food safety, maintaining the food fresh and flavor is retained or lowering packaging waste, nano-sensors win it all. Because of the nano sensors present in the food packages, the user now can understand the quality of the food product they are consuming. Even though the advancements in nanotechnology are paving new paths day by day, there still endure many challenges and possibilities for the advancements in current technology. There is a strong requirement to regulate nanomaterials before their incorporation into food processing and packaging, demanding periodic risk assessments. Also,

many issues need to be addressed to resolve consumer's concerns.

11. References

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