International Journal of Research in Engineering, Science and Management
Volume 4, Issue 2, February 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

Intelligent Packaging Using Sensor – An Overview

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***Abstract*: Intelligent packaging is a technique used to sense and detect the food materials. It increases the life time of the food materials to maintain the freshness in food some sensors are used to detect. It is a challenge to the food packaging industry and it also acts as a driving force for the developing a new and improved concepts of packaging technology. It is in order to meet the needs that intelligent packaging can be applied. This article refers to various kinds of sensors that are used in the packaging.**

***Keywords*: Intelligent packaging, sensor, biosensor, chemical sensor, IoT, gas sensor.**

1. Introduction

(Czech J. Food Sci., 35, 2017) Packaging production is a vast industry which is identified by its internal diversity and each of its sectors separately affects the condition in the market. The demand for packaging material has come into and articles contact with food are systematically growing. Due to the growing consumer rate in consumption of fresh products with prolonged shelf-life and regulate the quality, producer shave to provide novel and safe packaging. It is a risk factor for the food packaging industry and it also acts as a driving force for the improved new concepts of packaging technology (Farmer 2013; Cierpiszewski 2016; Zalewski & Skawińska 2016). Packaging separate through the external environment with the four basic function protection, communication, convenience, and containment. It related with the consumer by handling the packed products with practical features such as reclose- or microwave-ability. Furthermore, it offers various shape and size containers and adapts to the customer's lifestyle. In addition to improve the marketing and distribution, packaging also slows quality decay. That is why they contribute significantly to safe delivery and protection of packaged food (Yam, K.L.; Lee). The safety of food products is one of the main objectives of food law. Quality control in food manufacturing is closely related to technology, physical and sensory attributes of the product, the microbiological safety, the chemical composition, and nutritional value (Sawston, UK, 2012).

According to (Log Forum Sci. J. Logist. 2013). the global market for active and intelligent packaging will double between 2011 and 2021, growing at an annual rate of 8% until 2016, reaching US $17,230 million, and later at an annual rate of 7, 7%, reaching US $24,650million in 2021. The global demand for electronic smart packaging will grow to over $1.45 billion in the next decade [6]. Several relevant markets are forecasted for this type of packaging over the next decade; the most important is United States, with an annual growth of 7.4%, reaching US $3,600 million, followed by Japan, the second largest market, reaching a size of US $2,360million; Australia, US $1,690million; UK, US $1,270 million; and finally Germany, US $1,400 million.

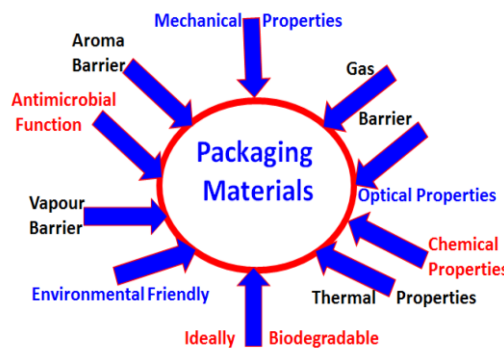

Fig. 1. Packaging material using intelligent packaging

2. Sensors and its Application

A. Bio Sensor

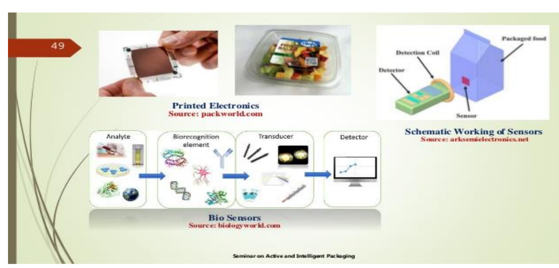

Fig. 2. Biosensor in food industry

One of the most import step by step monitoring the performance of food as intelligent packaging material appears to be electrochemical biosensors. Metabolites based on principle of indicator bio sensors. Some of the Metabolites Food products which indicate sensors glucose/lactic acid fermented food, Meat Colorimeter based on pH electrochemical sensor by redox reaction Carbon dioxide Meat, Fermented food

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Colorimeter based on PH Electrochemical sensor by Silicon-based Polymers Oxygen Meat, Vegetable Optical sensor by fluorescence, Colorimeter based on pH-indicator dye Electrochemical sensor by Zirconia, laser Biogenic amines By using electrochemical sensors the product can changes the pH of the food product fish, Meat Color-changing pH-sensitive dyes Electrochemical sensor by enzyme redox reaction Mol Cell Toxicol (2015) produce an electrical signal based on the concentration of the analyte68. There are two different types of electrochemical biosensors that depend on the nature of biological recognition processes: biocatalytic devices and affinity sensors. Agrimundo 7,2013.

Ronkainen, N. J., Halsall, H. B. & Heineman, (2010). Elements are usually redox enzymes, whole cells, or tissue slices that can recognize target molecules and produce electrical signals with bio catalytic devices. Antibodies, antibody fragments, these elements are used affinity. Among the different types of electrochemical biosensors, the most simplistic approach is the use of enzymes as recognition elements. sensors are relatively easy to use, small in size and shape, inexpensive, and it does not need any additional instrumentation, so that it can be easily be accepted to packaging materials. In addition, due to the innate nature of the enzymes, these biosensors are highly specific and selective to the substrate so that pretreatment and separation steps are not necessary [8], [9]. One of the challenges in designing biocatalytic sensors is the lack of selective enzymes for the analytes.

Advantages:

1) It does not require extensive clarification processes like enzymes,
2) It may have a better activity than separated enzymes,
3) Some enzymes may not be commercially or physically available in pure state, and finally
4) Isolated enzymes may have specific stability and shelf life compared with those in native forms.

At the same time,

Disadvantages:

1) Due to the presence of other contaminating enzymes losses may take place in selectivity and specificity, and a slow reaction take place.
2) Ideal electrochemical biosensors to analyse metabolites for meat freshness are highly to accept the amperometric technique as the method of electrochemical analysis for the transducer.
3) The amperometric technique directly monitors changes in recent generated by redox reactions with specific time.

Fig. 3. Process of biosensor

B. Gas Sensor

In the beginning of the spoiling process gas sensors are used for monitoring of spoiled foods. It a gas-sensitive material which is activated by an operator. working temperature- of the gas-sensitive material starts a chemical reaction and causes a change in electric resistance by using sensors. Studying sensors' performance in conditions with various temperature and humidity conditions on a decomposition of food gives us the movement to choose a meticulous and applicable type of sensors among all. The necessity of choosing a particular sensor for monitoring the spoilage of food in order to develop the food reliability is to main since it enhances food storage conditions and preserve the food from spoilage.

Recent problem solving methods for recognition of food spoilage caused formulating of new technologies that are typically mixed within a multidisciplinary like engineering, computer science and analytical science. The interdisciplinary approaches for the recognize of food testimonial, contamination and spoilage (Ellis et al., 2012) In the first section, procedures of food quality control are introduced, and types of gas given off the spoilage food are determined. In section two characteristic of intelligent device used in food packaging is introduced. In the third section, gas-sensors' performances are explained, compared and the most appropriate sensor in food industry is introduced. (Chinese University of Hong Kong At 04:49 23 February 2016).

Application of gas sensor in food industry:

- Detect the bacterial growth on food such as meat and fresh vegetables.
- Test the freshness of fish.
- The process control of cheese, sausage, beer, and bread manufacture.
- Detect off-flavors in milk and dairy products.
- Identification of spilled chemicals.
- Quality classification of stored grain for aroma (also aroma of toxin or spores like aspergillus).
- Identification of source and quality of coffee, monitoring of roasting process, and so on.
- Rapidity, objectivity, versatility, non-requirement for the sample to be pretreatment, easy to use Most applications of commercial and laboratory made sensors in food have been focused on rapid methods for detecting spoilage by bacterial contamination; some work has also been conducted to determine the presence of off-flavors in food.

These foods are in a wide range meat, fish, grains, alcoholic drinks, non-alcoholic drinks, fruits, milk and dairy products, olive oils, nuts, fresh vegetables and eggs.

C. Nano Sensor

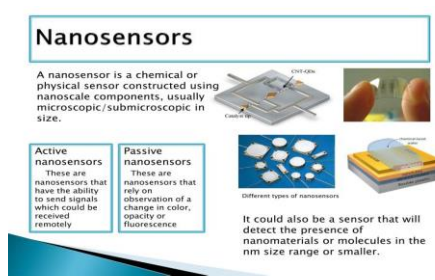

Fig. 4. Nano sensor
(Chinese University of Hong Kong at 04:49 23 February 2016)

1) Nano Coatings

Coating in food can be explained as thin film of edible material positioned between food components to provide a barrier to mass transfer. Edible coatings are recently used on a different form of foods, including vegetables, fruits, chocolate, meats, cheese, bakery products, candies and French fries. (S. A. H. Lim, J. Antony, and S. Albliwi, "2014). Up to now number of researches has been achieved in order to develop the physical properties of these edible films by the combination of Nano-particles. In order to lower the movement of oxygen, clay MMT has been inculded into pectin. Anoticeableraise in stability of chitosan layered Nano composites was obtained (Honarvar Z, Hadrian Z, Mashayekh M. 2016). The incorporation of inorganic Nano fillers such as, TiO_2, ZnO and ZnS, and carbon nanotubes has enlarge the retention of flavor, acids, sugars, color and texture, increased stability during shipping and storage, improved appearance and reduced spoilage. Jochenweiss, Takhistov Julianmcclements, 71.107–115.

2) Nano Laminates

A Nano laminate is made of two or more layers of material with nanometer dimensions that are physically or chemically mixed to each other. Nanolaminates gives some advantages over standrad technologies for the preparation of edible coatings and films and therefore have a number of vital applications within the food. A range of different adsorbing substances can be used to develop the different layers, such as; natural poly electrolytes (proteins, polysaccharides), charged lipids (phospholipids, surfactants), and colloidal particles (micelles, vesicles, droplets) Z, Hadrian Z, Mashayekh M. 2016). It would be useful to develop active functional agents such as antioxidants, antimicrobials, enzymes, anti-browning agents, flavors, and colors into the nano films. These functional agents would prolong the shelf life and quality of coated foods. These Nano laminates could be organized fully from food-grade ingredients (proteins, polysaccharides, lipids) by using easy processing operations such as dipping and washing (Z, Hadrian Z, Mashayekh M. 2016).

3) Nano Clays

Nano clays are very minute thickness (1 nm) with bi-dimensional platelets and several micrometer lengths Those are high performance, highly available and reasonable cost of materials. Thus compelling number of scientific researches has been done about nanoclays. Interaction between the Nano clays and polymers are examined as the initial theory for Nano based packaging material. According to the current scientific researches; two types of Nano scale composites are made by the interactions between Nano clays and polymers, named as intercalated Nanocomposites and exfoliated Nano composites. Beer packaging gives actual examples on Nano clay applications in food packaging sector. Due to some of the oxidation and unsatisfactory flavor improvement. In olden days, plastic was not used as a packaging material in beer industry. To overcome the problem some of the solution have been practically used in nano composite material. This led to employment of plastic materials in beer bottling and this material gives 6-month shelf life for beer. Soft drinks are one of the applied in packaging technology. In addition to beverages, certain food items such as processed meat, cheese, confectionary, and boil-in-bag foods can also be packaged according to this technology. Other than the prolonged shelf life, there are numerous other advantages in Nano clays and Nano-crystals based packaging material that are used in food. As an example, the weight of the Nano-based packaging is considerably less and it reduced cost for transportation. Significant increase in film strength is also can be achieved in these types of materials and this leads to ensure the protection of the food stuff which is inside the packaging material. The Nano clays on polymers reduce the transparency of the packaging with some limitation. Intelligent/Smart Packaging Intelligent packaging helps in detection the properties of the enclosed food and its existing environment and aids in providing (Mylvaganam M, et al. 3 J Food Technol Pres 2020 Volume 4 Issue 4) basic design for the retailer, customer and manufacturer about the condition of these properties. The most relevant function of intelligent packaging is to monitor both inside and outside condition. Another function is check the quality of the food product directly within package. Food spoilage during its market chain is essential to prevent any food borne diseases and to provide quality and safety product to the consumers from the identification of freshness. Recently polymer Nano composites are used to detect microbial gas emissions with regard to food spoilage. Such packaging can be monitor the spoilage through display it by changing the color. Spoilage indicators can also be installed at the packaging plant, so that they can detect the microorganisms that regularly infest the food.

D. Chemical Sensor

Chemical selective coatings which can take in a particular chemical on the surface and observation in presence, composition, activity or concentration have been employed as chemical sensors. These nano-based sensors are used for the observation of chemical contaminants, pathogens and spoilage, as well as tracking of products or ingredients through the processing chain.

which take full advantage of CNTs aspect ratio, mechanical strength, electrical and thermal conductivity with numerous carbon nano tubes properties and its application. (Carbon Nanotubes Properties and Applications, Cheap Tubes)

Types of Carbon Nanotubes:

The types of carbon nanotubes are typically referred to as Single Walled Carbon Nanotubes and Multi Walled Carbon Nanotubes. There are many variations of both types. They vary by purity, length, and functionality.

Fig. 5. Single walled double walled carbon nanotubes molecular structure (Carbon Nanotubes Properties and Applications, Cheap Tubes)

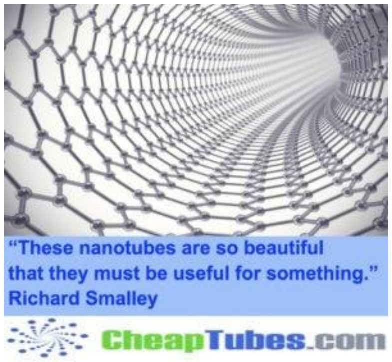

Fig. 6. An interior representation of a carbon nanotube
(Carbon Nanotubes Properties and Applications, Cheap Tubes)

Electrical Conductivity:

There has been considerable practical interest in the conductivity of CNTs. CNTs with particular combinations of N and M (structural parameters indicating how much the nanotube is twisted) can be highly conducting, and hence can be said to be metallic. CNTs can be either metallic or semi-conducting in their electrical behavior.

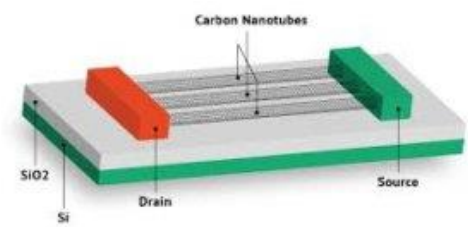

Fig. 7. Carbon nanotube electronics
(Carbon Nanotubes Properties and Applications, Cheap Tubes)

Conductivity in MWNTs is little complex. Some types of “armchair”-structured CNTs appear to conduct better than other metallic CNTs. Furthermore, interwall reactions within MWNTs have been found to redistribute the current over individual tubes non-uniformly. Single-walled CNTs no change in current with different parts of metallic. However, the behavior of ropes of semi-conducting SWNTs is different, in that the transport current changes abruptly at various positions on the CNTs.

The conductivity and resistivity of ropes of SWNTs has been measured by placing electrodes at different parts of the CNTs. The resistivity of the SWNT ropes was in the order of 10–4 ohm-cm at 27°C. This means that SWNT ropes are the most conductive carbon fibers known. The current density was approximately to achieve 107 A/cm^2, however in theory the SWNT ropes are able to sustain much higher stable current densities, as high as 1013 A/cm^2.

E. Carbon Nano Fiber

Carbon nanofibers can be fabricated with various commercially available options like electrospinning and other standard methods for nanofiber production, i.e. catalytic synthesis, VGCFNs or arc discharge. Although these techniques account for nearly all the ongoing CNF production, researchers are designed towards the modification of these techniques in order to obtain nanofibers with an enhanced surface and material properties for specific applications in different fields. A recent study declared by Jeong et al. it explains about the PAN based fabrication electrospun carbon nanofibers combine with melamine resulting in an overall chemically modified surface and pore structure in order to attain preferential adsorption of CO2 Carbon Nanotubes Properties and Applications | Cheap Tubes. Some other related studies declare to control the overall porosity of carbon nanofiber mats with alterations in the blend ratio or additionally information on chemical substance in difference ratios to the polymeric solutions (Journal of Cleaner Production, Volume 172, 20 January 2018).

Preparation of carbon nanofibers based on triblock copolymers combine with Zirconia oxide over its surface to protect and strengthen, chemically modified and controlled microstructure. Besides, all these characteristics help in prolong the membrane life of these Nano fibers.

(accessed on 4 November 2018). Development for various commercial applications in the industry bio- derived polymer are mixed. Conductivity, mesoporosity and surface area at a much lower cost when compared to recently used conventional techniques. Controlling the overall mechanical strength of these CNFs is another important objective for which a currently study developed CNFs from mixture of co-PAN and polyamic acid (PAA) in a specific molar ratio of 6/4 replace by its carbonization at 1400 °C, henceforth observing a three-fold development in the tensile strength. Magnetic carbon nanofibers Another possible technique of CNF fabrication involves the incorporation of magnetic nanoparticles or other magnetic films, followed by electrospinning. Most of the obtainable studies gives the detailed information electrospinning of PAN polymeric solution has been obtained by their calcination to obtain pure carbonized nanofibers. cellulose, lignin and other essential materials can be used as messenger. However, in this review paper, we are particularly discussed the current developments in this technique for producing CNFs. In a current study, Chen et al. have developed bead-free and uniform electrospun nanofibers from the homogeneous esterification of sugarcane bagasse (SCB) with different anhydrides, followed by carbonize them to obtain carbon nanofiber composites. (Realini, C.E.; Marcos, B. 2014).

F. IoT Based Sensor

The main function of food traceability and safety monitoring system is to provide information and record keeping procedures that indicate the path of a product unit, a group of products or ingredients from a provider, through all intermediate steps along the food chain to the final consumer (Zhang et al., 2011; Ene, 2013). For the achievement of the set functionalities, together with quick technology advancements, a several key requirements which depend on global principles can be defined (Zhang et al., 2011; Ene, 2013)

Advantages:

- Wireless, light weight, small size, low cost solution equipped with accurate and stable sensors for an essential variable.
- Ruggedness and transportability.

- Less invasive
- Compatible and standardized information.
- Defining the information and identification of lots of products.
- Step by step monitoring functions and real time food safety data gathering at each decision point.
- Recording information on the production process and establishing links between the information.
- Sending the result to the cloud automatically.
- Food safety emergency response system: immediate recall and preventive elimination of potential hazards. Aforementioned requirements represent a main guideline for building a custom monitoring system which can be applied on global scale issue. Application of internet of things in food packaging and transportation. In this paper, the creation of an economical, sensor-based remote monitoring system using cost-saving technology based on cheap computer board and wireless communication modules is proposed. For rapid monitoring, sensor unit represents a main building element which can be combined based on user needs and monitor different elements and parameters of products and its environment. Thus, different parameters as indicators of contamination of foodstuff could be evaluated by such miniaturized device. Temperature, humidity, chemical contaminants, microbial contaminants, etc. are some of the parameters. Increase of temperature and humidity cannot give information about the type of contamination which will happen, but it is a sign of contamination in many types of foodstuff (milk, meat, plants, etc.). Hence, temperature and humidity can be taken as parameters to follow in sensor design in order to have universal sensors for many different foodstuffs. The proposed solution is based on two elements: a traceability (which provides information about a product which is tracked and monitored) and monitoring (which provides a state of the product, package and its environment). Relying on new architecture and technologies in the field of nanotechnology, an extension of the system which will provide support for data collection from smart packaging is also proposed. Hardware implementation of proposed system is based on low cost computer board Raspberry Pi (RPi) which is used as a central processing unit and offers a lot of services for accessing sensor data, and communicates with end users, while different types of sensors (depending of target parameters) can make the detection module. A RPi is a credit card sized, powerful and lightweight ARM-based computer board which has support for a large number of input and output peripherals, and network communication what makes it as a right platform for interfacing with other devices and enables an almost limitless choice of its uses. RPi is running on Linux (version A, A+, B, B+, B2) or Windows 10 (version B2) operating systems, and the whole unit is powered with 5 V and 200–800 mA current, what implies a low-level consumption of 1–4 W (depends on version). Internet connectivity may be via an Ethernet/LAN cable or via a USB WiFi, WiFi Shields, Bluetooth, WiFi/Bluetooth USB Combos, RF Add-ons and cellular solutions (3G/4G USB modem or GSM/GPRS shields). RPi usage as a hardware for building an IoT solution with in detail presented analysis of its performance and constraints is presented in Vujović and Maksimović (2014). A complete solution for RPi in home automation process in Vujović and Maksimović (2015), while proposition of communication over GSM/GPRS is given in Vujović et al. (2015). Akyildiz and Jornet (2010) have introduced the use of nanotechnologies in various domains of applications as well as new technologies and architecture in the field of nanotechnologies like nano-nodes, nano-routers, nano-micro interface devices and gateways which enables the remote control of the nanosensor networks over the internet. Relying on proposed approaches a smart packaging technology can be connected to RPi system and thus provide a detailed information of foodstuff products [17].

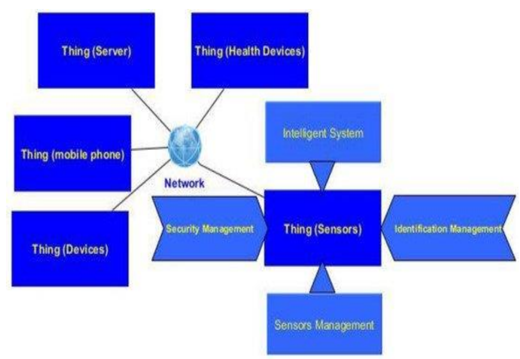

Fig. 8. IoT based sensor

3. Recent Advances On Intelligent Packaging

Advanced packaging is useful to develop the efficacy of the information conveyed during the product distribution process and in the hands of the consumer through innovative communication methods such as radiofrequency identity tags, time temperature indicators, integrity sensors, and freshness indicators. Although there are several expansion of electrochemical sensors, e-tongues and enoses for monitoring the fresh of food (Zou et al., 2015), in general this type of systems are costly with instrumentation and are usually not suitable to be incorporated in packaging. Among the techniques to develop easy handling disposable systems, the use of chromogenic chemo sensors is, perhaps, one of the most promising, since they are usually cheap, versatile, can be printed on the package, colour changes can be easily measured using cameras or other image capturing systems, or they may allow the naked eye detection of colour changes through transparent films. Few technologies are as advanced or as inexpensive as visual imaging. The use of single chromogenic indicators has the advantage of their simplicity but have some limitations such as lack of specificity (offering false positives or false negatives). Additionally, the presence of certain target metabolites is not necessarily an indication of poor quality and careful correlations among concentration of metabolites and organoleptic quality and safety are necessary.

TTIs is based usually on a visible response to mechanical, chemical, electrochemical, enzymatic or microbiological changes. The visible response to temperature is cumulative and although some correlations can be established between temperature and freshness, it does not really provide information about biochemical processes occurring in food. Another approach is the use of optoelectronic noses, built by an array of dyes able to offer information through suitable colour changes. Indeed, in the last few years, the use of arrays of non-specific colorimetric probes has proved a suitable approach to analyze complex systems. The issue of intelligent packaging is of great relevance and some compilations can be found in the literature. In general, the topic has been discussed based on the other related review article about packaging and it is focused on different form of packaging material are explained in this review paper (Advances in food packaging technology, review, December 2018, Nura Abdullahi).

4. Discussion and Conclusion

Thus the recent technologies have been used in intelligent packaging and sensor are widely used Even though we have focused in this review on sensors for detecting freshness, the development of sensors/indicators for packaging material. For example, the concentrations of contaminants leached out in plastic bottled water may be very low initially, and a gradual increase may occur depending on the storage duration and conditions. This paper gives a detailed information food safety requirement, existing systems, standards and regulations but also it identified novel techniques in food packaging and transportation. It is shown that the traceability information can be accessed through the internet relying on existing standards, and therefore it can be concluded that IoT concepts and technologies enable efficient methods for data gathering, communication and sharing from different resources automatically. IoT, as the wave for technology that combines mobile devices, smart tags and sensors and the cloud to yield real-time value, provides unprecedented opportunities for product tracking. In such way, a food traceability system can make consumers understand the production and circulation process, and increase consumers' faith to the food itself. In addition, this paper presents appliance of novel techniques and the proposition of low cost solution based on IoT.

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